~~A STUDY OF~~ CONCEPTUAL AND PROCEDURAL UNDERSTANDING OF COUNTING BY PUPILS WITH SEVERE LEARNING DIFFICULTIES

by

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Abstract

This thesis concerns the ability of pupils with severe learning difficulties (SLD) to develop both the skills and an understanding of counting. To date, research in this area has been limited, one strong reason being the difficulties the researcher encounters in this field. For example, there is no single defining criteria of severe learning difficulties, the population is small and heterogeneous, and the nature of the children's learning difficulties provide a series of challenges to the collection of data first hand. The implications of these factors for the design of research are introduced in chapter one, together with a brief over-view of different approaches to understanding the nature of SLD.

In chapter two, a review of the literature on how typically developing preschool children learn to count is presented. For this, the work of Gelman and her colleagues is taken as a starting place. Her five principles of counting and the distinction she draws between conceptual and procedural understanding form the basis of the discussion. Within this framework, different views of the order in which conceptual and procedural understanding occur, are considered. These include Gelman's view that children are guided in acquiring the procedures by an implicit understanding of the principles of counting as well as the opposing view that the child has first to acquire the procedures for counting, before they are able to deduce the principles. From this analysis it is suggested that neither extreme position is viable. Instead, it is proposed that the process of acquisition should be viewed as interactive with the acquisition of procedures leading to understanding which in turn leads to refinements in performance.

Little research has taken place in the field of counting with pupils with SLD. In chapter three, a review of the existing literature considers studies which investigate overall performance levels, those which make comparisons between pupils with SLD and other children with a similar mental age, and studies which describe attempts to improve performance through intervention. Although the performance studies reveal

a variation of ability with overlap between pupils with severe and moderate learning difficulties they do suggest a probable ceiling on the attainments children and young people can reach. What predicts these levels of performance, however, is unclear. The comparison studies provide contradictory evidence concerning the equivalence of preschool children and those with SLD and the review of intervention studies reveal that improvements in performance are possible but are uninformative with respect to the processes which underlie learning. Overall the review revealed that the research with children with SLD has been limited, both in the questions which it addresses and in its theoretical orientation.

The primary aim of this thesis is to investigate the extent of pupils attainments in counting, both in relation to performance and understanding. An essential part of this objective is to first establish whether children with SLD are able to understand the principles of counting and second to investigate the temporal order to this. A third aspect is to explore selected factors which might contribute to differences between pupils' attainment.

A series of three studies are undertaken which examine the acquisition of procedures and conceptual understanding in counting in both children with severe learning difficulties and preschoolers. These are preceded by an exploratory study which sets out to establish a satisfactory way of studying counting in this particular group. Once this has been achieved the first proper study addresses the question of which comes first for children with SLD, the acquisition of counting skills or understanding. It reveals that some children are clearly able to demonstrate *understanding* and that this is followed (but was not solely dependent on) successful *performance* on counting tasks. The second study then compares the attainments of a group of pupils with SLD and a group of typically developing preschoolers. Performance on both counting and error detection tasks is found to be poor in these two groups but no overall differences are found. The study does, however, reveal some qualitative differences in the responses of the two groups, with children with SLD using fewer count words and using a smaller repertoire of responses to a cardinal question than the preschoolers.

The final study explores some of the reasons for these qualitative differences between the groups by comparing various of aspects of the number environment in which children with SLD and nursery children learn to count. The study has three parts and is carried out with children from two SLD schools matched on two different measures with children from two nurseries. Firstly, questionnaires are used to examine staff attitudes towards counting activities. Whilst staff in both settings are found to have a variety of different general aims, they share similar views of the importance of counting and acquiring the number word sequence. More precisely, they don't see either activity as very important.

The second part of this study is based on observations of children's experiences of number words in both nursery and SLD settings across curriculum areas/activities. Observations reveal considerable variation in the practices of the four settings with none providing all the characteristics identified as important by those investigating mother-child interactions. Conversely, no setting provides all the characteristics identified by those favouring mechanistic approaches. Additionally, no setting provides evidence of staff individualising childrens' experiences. The final part of the study into children's counting performance reveals (unsurprisingly) that overall the best predictor is mental age.

In chapter nine the data from all three studies is pooled for further analysis, revealing that children can be seen as falling within four groups of attainment, the largest being those who are in the process of acquiring the procedures and with an equal number falling in the two extreme groups of non-counters and error detectors. The remaining small group of children are described as being transitional, able to count proficiently but not able to demonstrate understanding. Throughout the studies all children who demonstrate understanding are proficient counters. Whilst no difference is found between typically developing and SLD children in the distribution of children across the four groups, the pattern of acquiring the procedures appears to be different with the SLD group acquiring competence in one:one correspondance first, followed by stable order (and then cardinality) and the preschoolers adhering to stable order and then one:one correspondance.

Chapter ten explores the theoretical and practical implications. The process of acquisition of skills and understanding is characterised as a gradual one with children's thinking developing from being based on a series of rules which operate largely independently in restricted contexts, to being based on an understanding of the principles enabling the generation of strategies for problem solving. It is suggested that a likely mechanism for change is the child's awareness of a mismatch between the expectation and the outcome of a particular action or sequences of action but that further investigation is needed focusing on particular transition times.

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1.1 Introduction

The ability to perform a variety of mathematical activities forms an integral part of everyday life. Without conscious effort we count and use numerical symbols. These abilities contribute to the successful execution of a range of every day living skills. For example visiting a friend may involve any or all of the following skills- making a telephone call, telling the time, catching the bus, using money, finding the correct house. Each component part typically involves the use of numerical skills. The essential nature of this area of skill and understanding is reflected in our education system with mathematics forming a core area of the National Curriculum.

This thesis concerns the ability of pupils with *severe learning difficulties* (SLD) to develop the skills and understanding of counting, an area in which little previous research exists. Counting forms an important early mathematical skill and one that can be used later as a tool for addition and subtraction (Carpenter & Moser, 1984; Fuson, 1986; Baroody, 1987). To the lay person the limited research interest in this area may be unsurprising given the nature of the childs learning difficulties, yet there is a growing body of research which suggests that an awareness of numerosity and changes in array size is present in very young infants and may not, therefore, require extensive experience or cognitive skill, (Strauss & Curtis, 1984; Moore, Benenson, Reznick, Peterson, & Kagan 1987; Starkey, Spelke & Gelman, 1990; Wynn, 1992). In the light of this data, one might expect that at least some of the basic elements of counting would be accessible to pupils with SLD. Yet, when this thesis was started in 1987 it was hard to find information on whether and how these pupils were being taught to count. Moreover, those curricular guidelines which did exist were almost entirely based on behavioural approaches which approached the teaching of counting through task analysis and shaping (e.g. Bender, Valletutti & Bender 1976, Popovich & Laham 1982) with little if any attention given to the development of understanding. It is hardly surprising, therefore, that teachers may lack the knowledge and confidence necessary to teach pupils with learning difficulties to count (McEvoy 1989/90). This thesis largely arose from a need to provide teachers with this confidence and expertise and the belief that the curriculum should be based on more than supposition. A detailed examination of the curricular area together with undertaking relevant research would provide a better foundation for practice. It was, however, recognised that there were a number of methodological challenges to be faced that would shape the design of the study and became an integral part of the research itself.

In the following section the first area of challenge, namely some of the characteristics of this population of children are explored together with discussion of how these features impinge on the type of methods available to the researcher. These characteristics include criteria for classification, the size of the population, and a number of the factors which contribute to the heterogeneity of this population. This discussion will be followed by the second challenge, finding an appropriate approach to the study.

1.2. Who are Children with Severe Learning Difficulties ?

1.2.1 *Characteristics of the population*

The population of children defined in this country as having SLD is small. An analysis of studies undertaken in the UK suggests that during the school years there is a prevalence of approximately 3-4 children with severe learning difficulties per thousand typically developing pupils (Craft, 1985; Richardson & Koller, 1985). Whilst some children may be located in integrated settings, the majority will attend SLD schools, the average size of which is around 76 pupils, ranging in age from 2-19 years (Evans & Ware, 1987). The overall target population is therefore restricted in number and grouped together in relatively small units. Access can be further limited due to the higher risk of chronic ill health (Beange & Bauman, 1990) which not only affects the performance of these pupils at school but will also reduce their attendance .

The population is not only small in size, it is also very heterogeneous. This results not only from the variation in etiology of severe learning difficulties but from the presence of additional impairments- physical, behavioural, sensory or a combination

(Kelleher & Mulcahy, 1986). Taking etiological factors first, severe learning difficulties usually occur as a result of organic damage to the CNS arising from a variety of different genetic disorders (chromosomal or single gene) prenatal infections and toxins (Fryers 1990). Additionally, a few children will have severe learning difficulties due to insult, injury or disease after birth. Normal development will therefore be disrupted at different stages, but for the majority this will occur before birth. Children with Down syndrome and Fragile X together probably account for about one third of the population (Bregman & Hodapp, 1992) but the presence of a specific diagnosis does not guarantee homogeneity as both have variable expression (Cunningham & Sloper, 1983; Simensen & Rogers, 1989). For example, biologically one can distinguish between three types of Down syndrome (trisomy, translocation and mosaic) but it is not yet certain whether each is associated with a particular profile of development.

A second, associated factor that leads to heterogeneity in the population is the presence of additional impairments. These may occur singly or multiply. Smith and Phillips (1992) in a survey of pupils in SLD schools in Birmingham found that only 14% of pupils had no additional impairments. The reported incidence of each type of impairment varies from study to study but it is likely that between 10% and 15% of children in an SLD school will have a significant hearing loss and some 30% a slight hearing loss (Kropka & Williams, 1986). Similarly approximately 15% will be partially sighted or blind (Ellis 1986) but again estimates vary. Between 17% and 35% are likely to have a physical disability (Kelleher & Mulcahy, 1986). Definitions of behaviour disorders are imprecise and existing surveys are infrequently restricted to children. However it is likely that about 8% of children with SLD will display extreme forms of disturbed behaviour and an additional 20% less acute but frequent forms of the same problems (Kiernan & Kiernan 1989; Krose & Fleming 1993). An additional characteristic is the relatively large number of pupils within the population who are either totally or largely non-verbal (Leeming, Swann, Coupe & Mittler, 1979) and who therefore use a range of modes of communication.

Both these characteristics, the low incidence and heterogeneity, pose particular difficulties for the researcher who wishes to collect data with any expectation that the findings will generalise to other portions of the same population. The criteria for forming a representative sample is uncertain. This is not aided by the lack of specific criteria for ascertaining that a child does indeed have severe learning difficulties.

1.2.2 *Problems of Defining Severe Learning Difficulties*

In this country definitions of severe learning difficulties are largely based on the services pupils require. The term severe learning difficulties was proposed in the Warnock report (DES 1978) and formally adopted in the 1981 Act (DES 1981). The change in term was used to make two important points. First, it was acknowledged that there is a continuum of need with no sharp distinction between the handicapped and the non-handicapped. Secondly, and just as important was the recognition that learning difficulties were the result of an interaction between the child and his environment. The emphasis was placed on special educational *needs*, with a distinction made between groups who needed access to the curriculum, those who required a modified or different curriculum, and those whose educational needs related to the type of climate of the school. Thus, children with severe learning difficulties were generally seen as those children who required a different curriculum - a developmental curriculum (DES 1985).

This kind of definition creates a number of difficulties for the researcher. For example, the basis for distinguishing between groups of children with different needs are imprecise and lend themselves to subjective judgements, especially for those individuals who fall on the margins. The lack of precision creates difficulties communicating with personnel outside education in this country as the terms and the basis for distinguishing between groups may well have little meaning for them. Additionally, the origins of the meaning are even less clear with the introduction of the National Curriculum (ERA 1988) where pupils with SLD are referred to as those children who are making small steps of progress towards, or within, level one of the National Curriculum (NCC 1989, 1992). Similar difficulties occur with regard to personnel from other countries - reference to educational need does not provide a useful international criteria.

For the purposes of research it is necessary to adopt a way of characterising the population which will enable comparisons to be made with studies carried out in other countries. Typically researchers adopt a classification based on either severity or etiology (Hodapp & Dykens, 1994) and one way of indicating the level of severity is to use a normative measure such as IQ or mental age (MA). Convention, rather than legislation suggests that pupils with SLD fall between IQ 20 and 50/55 in this country (British Psychological Society 1963; Kushlick & Blunden 1974). This cutoff point is used to distinguish between those who would be described in this country as having moderate learning difficulties (falling between IQ 50/55-70) and those with SLD. Those who fall below IQ 20 are described as having profound learning difficulties.

If we turn to look at the recent international definitions we see that reference to IQ continues to be made (World Health Organisation 1968, 1980, 1992) but that the cutoff points vary and there are important differences between countries in the descriptors used. These are set out in Table 1 below. For example, the World Health

Table 1 : Classifications based on IQ

	IQ Equivalence	Terminology
UK	Below 50	1959 Severely Subnormal 1971 Educationally Subnormal (Severe) 1981 Severe Learning Difficulties
	50 - 70	1959 Subnormal 1971 Educationally Subnormal (mild) 1981 Moderate Learning Difficulties
World Health Organisation (1968, 1980, 1992)	20 - 34	Severe mental retardation
	35 - 49	Moderate mental Retardation
American Psychiatric Association (1987)	20/25 - 35/40	Severe mental retardation (Trainable mentally retarded)
	35/40 - 50/55	Moderate mental Retardation (Educable mentally retarded)

Organisation classification system (1968, 1980, 1992) designates those with an IQ between 20 and 34 as falling into a severe "category", those with an IQ between 35 and 49 as falling into a moderate "category". The American Psychiatric Association (1987) follow the WHO classifications but with slightly raised upper limits and the use of additional terms, trainable and educable mentally retarded (Grossman 1983).

In general, definitions of learning difficulties based purely on the notion of intelligence as measured by an IQ test have been subject to immense criticism, not least because of the limitations of using instruments not standardised on the whole range of children (e.g. Berger & Yule, 1987; Norwich, 1990), the uncertain measures taken (e.g. Evans 1990) the rather "loose" theoretical underpinning (Garndner and Clarke 1992), and the use of differing cut-off points (Macmillan, Gresham & Siperstein 1993). Despite these criticisms, however IQ continues to be used and the use of IQ in recent definitions largely escapes comment in relation to people with *severe* learning difficulties (Macmillan, Gresham & Siperstein, 1993; Reiss, 1994). Criticisms are tempered by professionals acknowledgement of the purpose for which IQ tests were designed and that the scores do provide an almost universally recognised way of describing groups of individuals (Clarke & Clarke 1985). In sum, it is a concept that is internationally understood.

Although the use of mental age (MA) or developmental quotients provide alternative criteria to IQ (Hogg & Raynes, 1987), precise definitions based on MA are hard to find. For instance, Ysseldyke (1987) goes back to Goddard (1919) to find a reference to those who we would now refer to as having severe learning difficulties as having a mental age between three and seven years. Originally IQ was calculated by taking the ratio of MA to chronological age (CA) until Wechsler replaced it with reference to standard deviation scores (Clarke 1965). We can therefore infer that pupils with an IQ of 50 or less will have a MA of half, or less than half, of their CA. However, it must be noted that, as with measures of IQ, these developmental tests have not been standardised on pupils with severe learning difficulties and the additional presence of sensory or physical handicaps may again make measurement inaccurate. Such tests have also received criticism in relation to their poor predictive power (Cunningham, 1982; Berger & Yule, 1987).

The alternative "culture" of research is to classify individuals by etiology, an approach more characteristic of studies undertaken by geneticists and psychiatric researchers (Hodapp & Dykens 1994) who potentially have the skills to make such diagnoses accurately. It is not characteristic of research by special educators and for a number of very good pragmatic reasons it has not determined the methodology they use. Firstly, teachers are likely to find themselves with a class of individuals who have not been grouped on the basis of etiology but on the basis of need. Furthermore, it is likely that for over a third of the class there will be no specific diagnosis (Elliott, Jackson & Graves, 1981; Smith & Phillips, 1981, 1992). Secondly, since the total population is so small, looking at a sub-section of that population creates problems even if one does choose the most commonly represented etiology. Thirdly, there is a danger that the findings will be seen as specific to that group and that the group itself will be seen as homogeneous. Finally, in most cases special educators do not possess the skills to determine etiology and are reliant on the judgements of others. Access to these judgements may be limited as, in many cases, the records held in school provide inadequate information (Evans & Ware, 1987).

1.2.3 *Additional difficulties*

Pupils with SLD are not easy to work with, either as a teacher or researcher. A number of researchers have sought to catalogue the specific difficulties experienced by children and adults with SLD (e.g. Clements 1987). These include a difficulty with motivation and attention, with understanding and remembering instructions, and such learning to learn skills as imitation. These difficulties will be familiar to the teacher who faces the challenge daily and who may well as a consequence use a number of specific techniques. Faced with these difficulties many researchers have therefore sought to collect their data indirectly through asking teachers and parents (e.g. Leeming, Swann, Coupe, & Mittler, 1979; Buckley & Sacks, 1987; Hogg, Lambe, Cowrie & Coxon, 1987). These methods require extensive preparation and training to ensure that the data is generated by personnel interpreting the requirements consistently. In the present educational climate such commitment may be hard to find. It can also be strongly argued that, given the lack of previous research, this method of data collection does not provide the same insights to the ways in which children approach a task as the first hand collection of data. Therefore, despite the challenges presented, an experimental approach is adopted.

1.3 Approaches to Studying Children with SLD

Perhaps not surprisingly, the study of children with severe learning difficulties has paralleled the study of typically developing children. Just as the "either/or" aspect of the nature-nurture debate within child development generally has become one of degree, so too is it acknowledged that the progress of children with SLD is dependent on both intra- and extra- child factors. In addition to the similarities in approach however, there are a number of important differences.To a large extent these have emerged as a result of a desire to understand children with difficulties in their own right. This has led, for example, to important debates about how children with SLD differ from others rather than by how much.

In the past the debate has been dominated by two within-child approaches to the understanding of learning difficulties. As we can see from the following brief discussion, neither provide a totally satisfactory account. Recently more attention has been given to the role the environment plays and in particular to the interactive nature of its effect on the progress made by the child with severe learning difficulties. The following section includes an outline of these approaches and in so doing sets the second challenge for this study, finding an appropriate framework for the research.

1.3.1 *Within- Child Views*

In the past two views characterised theoretical approaches to understanding children with learning difficulties (Detterman 1987) and were portrayed as diametrically opposing. They were referred to as the *deficit* (or difference) and the *developmental* (or delay) approaches to the understanding of "mental retardation" and each espoused the use of different methodological designs.

In short, the defect theory adopted particularly by Ellis and colleagues (Ellis, 1969; Ellis, 1970; Ellis & Cavalier, 1982) strove to investigate how people of different IQs performed on particular learning tasks (Ellis 1969) with the result that many specific deficits were revealed, for example in attention and discrimination (Zeamon & House 1973, 1979; Whitley, Zaparniuk & Asmundson 1987) in memory (Ellis, 1963; Ellis & Woodridge, 1985; Marcell & Weeks 1988) and in generalisation (Zeamon & House 1984). The methodology proposed by Ellis (1969) was based on matching individuals on the basis of CA, although it is notable that others adopting this approach have used groups matched on both CA and MA (e.g. McDade & Adler, 1980) or just inferred MA (e.g. McKenzie & Hulme, 1987). Essentially, this approach seeks to explain performance differences in terms of particular difficulties and consequently adopting a deficit- based approach to the study of counting in children with SLD would place the main emphasis on the *processing skills* required to count.

The contrasting approach, the developmental/delay position, expressed by Zigler (Zigler, 1969, 1982) held that the mentally retarded passed through the same stages of development as non-retarded children, but with a slower rate of progression and a lower ceiling. This approach was originally limited to studying those individuals without organic damage and utilised an experimental design which matched children according to mental age in order to reveal that they performed equally on developmental tasks. The developmentalists have become increasingly differentiated as a group and the theories have widened along with the individuals investigated. Some researchers have adopted a "similar structure" approach arguing that not only do individuals pass through the same sequence but they reveal similar reasoning at each stage (Weisz, Yates & Zigler, 1982). These studies have traditionally used Piagetian tasks with individuals who have mild learning difficulties. Adopting a developmental approach to the study of counting would place greater emphasis on the understanding children have of the counting task. It would also have the philosophical advantage of establishing similarities between groups of children rather than differences.

Despite the vehemence of the controversy it is clear that the divide between the two approaches has narrowed. Instead of viewing the approaches as opposing it is now possible to see them as different aspects of the same theory rather than as mutually exclusive (Detterman 1987). Indeed it could be argued that the distinction between the two approaches is no longer clear as deficit studies take into account development and developmental studies point to areas of difference.

1.3.2. *More Recent Accounts of Defect and Developmental Theory*

A common feature of early research was the search for a single defect which would explain the performance of children with severe learning difficulties. More recently, the very success of many of these studies has led to a questioning of the findings. Since these defect studies are largely based on the idea of learning involving successive processes of attention, discrimination, memory etc, it has been argued that if the series of processes are seen as a linked chain, a defect in one link is likely to impair the quality of other links (O'Connor, 1987). This would account for the large number of studies of different areas of learning which demonstrate deficits and would explain why both basic level processes are implicated (such as the speed of information processing, Marcell & Cohen, 1992) as well as metaprocesses (such as the use of rehearsal or chunking strategies, Hulme and Mackenzie, 1992). It is clear therefore that the search for a single deficit or even multiple deficits which will account for the functioning of children with SLD in the any area, including counting is inappropriate.

More recently, some developmentalists have turned their attention to individuals with organic damage focusing on groups of individuals with a specific etiology most notably Down syndrome (e.g. Cicchetti & Pogge-Hesse, 1982; Cicchetti & Ganibar, 1990) and Fragile X (e.g. Dykens & Leckman, 1990). Within these groups, it has been argued that a number of specific disorders appear which have a distinct developmental and behavioural pattern (e.g. Bloom, Hersch, Podruch, Weisskopf, Topinka & Reese, 1986; Dykens, Hodapp, & Leckman, 1987; Dykens & Leckman, 1990; Hodapp, Dykens, Ort, Zelinsky & Leckman 1991; Tingey, Mortensen, Matheson & Doret, 1991; Bregman & Hodapp, 1992). Many of these studies seek to show that children with a particular etiology do follow the normal sequence of development in terms of the stages passed through but with different patterns of cognitive strengths and weaknesses. On this basis therefore, it is necessary to understand mental retardation not in terms of "same" or "different" but more as "experiments of nature" which will ultimately lead to a better understanding of typical development (Hodapp, & Burack 1990; Hodapp, Burack & Zigler, 1990).

There are a number of difficulties with an approach which seeks to distinguish between different etiological groups yet not distinguish between individuals within a group. A number of studies have failed to find confirmation of etiology specific differences. Smith and Phillips (1992), for example, found few significant differences in a longitudinal study of some 200 children with SLD when they corrected their sample for the presence of additional impairments. Hodapp, Leckman, Dykens, Sparrow, Zelinsky and Ort (1992) found similarities between children with Fragile X, nonspecific mental retardation and Down syndrome in the relative strength of simultaneous processing compared to sequential processing as measured by the Kaufman Assessment Battery for Children - although there were differences between the three groups on some subtests. This study, like many others which compare etiological groups, used a very small sample and it is notable that not all children with a given etiology portray the same profile. Finally, a recent study by Dykens, Hodapp & Evans (1994) suggests that the age of children may be linked to increased variability between children.

These studies raise questions concerning the extent to which they reveal developmental profiles which are specific to a single etiology. For example, children who have severe learning difficulties as a result of a variety of causes are deficient in language skills (Bloom, Hersch, Podruch, Weisskopf, Topinka, & Reese, 1986) which suggests that this may well be a general feature of central nervous system damage which results in severe learning difficulties. Equally, the high incidence of hearing impairment amongst children with severe learning difficulties (Kropka and Williams 1986) is likely to affect the development of language and communication skills.

These limitations are largely aimed at studies which seek to determine differences and similarities between individuals on the basis of etiology rather than arguments against the use of a developmental approach per se. A knowledge of ordinary child development would appear to be a fundamental starting place for understanding the way in which children with SLD may acquire the ability to perform and understand counting tasks. An additional advantage of taking a developmental approach is the opportunities it provides for considering the child within his/her environment.

1.3.2 *The Role of the Environment*

A number of early studies created optimism in those working with children with severe learning difficulties that the course of development could be altered by changing the environment. For example, the IQ gains made by children who were removed from adverse environmental conditions (reviewed by Clarke & Clarke, 1976; Skuse, 1984) and the early intervention studies carried out by Cunningham and others (reviewed by Farran, 1990) with children with Down syndrome and other disabilities suggested that changes in the environment would lead to a beneficial effect on development.

In evaluating this evidence, however, it is important to distinguish between studies involving pupils who may have been misdiagnosed as having severe learning difficulties because of the extremely adverse social conditions, and those involving children who are in an ordinary environment, diagnosed as having severe or moderate learning difficulties and consequently provided with optimum conditions for development. It is also important to differentiate between the ability of the environment to bring about changes in behaviour and its contribution to changes in IQ (O'Connor, 1987). Finally, it is important to note some of the difficulties with much of the research in this field, the lack of detail of samples, of intervention methods, home characteristics and most importantly the lack of controls (Cunningham, 1982, 1987).

In parallel with Head Start studies, children with severe learning difficulties have often made short-term gains but the long-term effectiveness is open to dispute. It has been suggested that one particular outcome may be the change in attitudes of caregivers who are effectively given a more positive set of expectations (Cunningham, 1987). Moreover, recent studies of children with Down syndrome have also suggested caution (Wishart, 1991, 1993) as new learning may not be consolidated and therefore gains may be subject to a wash-out effect. The environment may therefore have a less certain effect on this group of pupils (Sameroff, 1990).

1.3.3 *Interactive Accounts*

Developmentalists have more recently taken an interactive approach and not only examined the effect of the environment on children with learning difficulties but also the way in which their behaviour affects the environment they receive. Researchers adopting a Vygotskian perspective with mainstream children have demonstrated the mediating role that mothers and significant others have in negotiating meaning with their offspring (e.g. Wertsch, 1978; Wertsch, Minick & Arns, 1984; Brown & Ferrara, 1985), but studies of infants and children with learning difficulties suggest that the mode of interaction may be different. In particular, adults seem to adopt a more directive, controlling style of interaction towards young children with learning difficulties (Stoneman, Brody & Abbott, 1983; Marfo, 1984) despite our lack of knowledge about the effect this may have on encouraging or suppressing the development of understanding or general learning skills. These studies do however emphasize the importance of considering the nature of the responses made by both the child and others in their immediate environment.

Pupils with severe learning difficulties are likely to be developing numerical skills over a longer period of time and one of the important environmental influences in the development of such skills must be the school, especially as many pupils attend from the age of 2 years. The potential effect of different types of schooling on children with learning difficulties is suggested by the superior gains made in some areas by children with Down syndrome attending mainstream schools compared to those in special school (Casey, Jones, Kugler & Watkins, 1988; Sloper, Cunningham, Turner & Knussen, 1990). Interestingly it appears to be academic skills (including mathematics) which are more likely to be positively affected by a mainstream environment.

Over the past twenty years there have been many changes in the educational content and methods provided for children with SLD. Prior to 1971 children received training in junior training centres and it appears that many children were exposed to "academic" instruction as many of these centres adopted an infant school approach (Gunzburg 1965). It is paradoxical that whilst training was provided under the auspices of the department for Health children were receiving daily teaching of maths (Simpson 1967). This occurred despite clear warnings that some pupils would attain little (McDowall, 1964).

The change in responsibility from Health to Education occurred together with a move away from this rather academic approach and the development of new teaching techniques. This change, which was largely due to discontent with the approaches adopted from mainstream, resulted in the view that in the area of maths children were being taught a set of mechanical skills and that pages of sums was not matched by real understanding (Gunzburg 1965, Eden 1976). Pioneering work by Woodward (1959, 1961, 1962, 1972) however, suggested that children with severe learning difficulties passed through the same stages as ordinary children but that because of the lowered ceiling it was inappropriate to be teaching these children about number (Woodward 1962). Schools set about formulating new aims which stressed the development of independence skills and autonomy and these were largely retained for the next 15 years. (Hughes, 1975; Leeming et al 1979; De Souza & Bailey, 1981; Carden & Robson, 1985). During this time the emphasis was firmly placed on a functional approach so that the development of social and self-care skills were given a high priority and the development of academic skills such as number a low priority. Whereas maths had constituted a central activity for JTCs with some older children spending as much as one eighth of their time on it (Simpson 1967) teachers in schools for pupils with SLD saw it as relatively unimportant. They ranked "basic skills in number" as being least important in a study by De Souza and Bailey (1981) and 11th out of 13 stated aims by Carden and Robson (1985). It is currently unknown how teachers view the teaching of number now that it has a central place in the National

Curriculum.

Any attempt to understand the development of counting in pupils with SLD must therefore take heed of the fact that schools for children with SLD may not have taken a significant part in encouraging the development of counting skills *and* understanding. This can be contrasted to the growing evidence which suggests that both mothers and peers appear to play a significant role in providing contexts for teaching normally developing children about number (Saxe & Posner, 1983; Durkin, Shire, Riem, Crowther & Rutter, 1986; Saxe, Guberman & Gearhart, 1987; Durkin 1991; Munn & Stephen, 1993; Saxe, Gearhart, Note & Paduano, 1993).

1.4 Conclusion

Simple maths forms an important everyday living skill that provides access to some valuable activities. It is therefore important to determine how much pupils with SLD can learn and how best to teach them. Research with this population faces a number of difficulties, not least because of the restricted size of the population and its heterogeneity. It has been argued that limiting the study to groups of children with specific etiologies does not overcome this problem and creates a number of pragmatic difficulties. Instead it has been proposed that the population will be identified by reference to IQ or MA for, whilst both these measures have limitations, they do provide internationally recognised reference points.

Although various approaches to the study of counting skill in children with SLD are feasible, in the present state of our knowledge, direct observation seems most fruitful in that it is most likely to provide the investigator with insights into the acquisition process. Despite the previous polarisation of approaches to studying children with learning difficulties these are not viewed as totally distinct. However a developmental approach is taken as a starting place as without the framework of understanding the stages and strategies adopted by ordinary children one is unable to interpret the behaviour and understanding of children with SLD. This approach characteristically considers both skills and understanding and highlights similarities between pupils rather than searching only for differences.

Children with SLD by definition will be older than mainstream children developing similar skills. The effect of several years more experience is uncertain. Indeed it is unclear how the environment supports development and learning in pupils with SLD. Clearly an optimum environment leads to the development of new skills and understanding although one should be cautious about the extent of change it will bring about. The opportunities schools present children with severe learning difficulties forms an important area of study and this needs to take into account the interactive nature of the experiences. The next chapter starts the process of understanding by examining the literature on the typically developing child.

Chapter Two

The Development of Early Mathematical Skills in Preschool Children

2.1 Introduction

The focus of this thesis is on the pupils ability to count. As noted in chapter one, counting can be seen as an important mathematical tool for not only does it enable children to distinguish between groups of objects but it also provides them with a means to understanding more complex computations such as changes that occur as a result of addition and subtraction.

2.2 Principles, Procedures, and their Interaction.

An important distinction is made throughout this thesis between what children can "do" and what children understand, namely between the development of procedures and the development of conceptual understanding. Opinions on how children develop the skills and understanding of counting vary. At one extreme, there are those who take a "principles first " approach in which an implicit understanding of the principles of counting are seen as guiding the acquisition of procedures. At the other extreme, there are those who take a "procedures first" approach with the understanding of principles developing out of the acquisition of procedures and lastly there are those who see the two components as interactive. In this chapter these theories and the empirical studies which are relevant to our understanding of counting in children with SLD will be reviewed.

2.2.1. A brief overview of some current theories.

Over the years the work of Rochel Gelman and her colleagues (Gelman, 1978; Gelman & Gallistel, 1978; Gelman, 1982; Gelman & Meck, 1983; Gelman, Meck & Merkin, 1986; Gelman & Cohen, 1988; Gelman, 1990) has become increasingly influential in the way psychologists view the development of counting in young children. Right from the very beginning Gelman's theory differs from that of her opponents in the belief that even very young children have an implicit understanding of number. She accords the young child <u>innate</u> predispositions which guide learning in the domain of number. This can be labelled the "principles first" account.

To support this view Gelman consistently draws on the growing body of research which investigated the ability of very young child to discriminate between arrays of differing numerosity and to respond to changes in numerosity (e.g. Strauss & Curtis, 1984; Cooper, 1984; Starkey, 1992) albeit using small arrays of objects. Young infants are able to respond to numerically relevant information because, she contends, it is salient to them (Gelman & Meck, 1986). In her view, therefore,

> "it seems that the ability to count and do simple arithmetic problems may be as natural as the ability to speak a language." p 182, Gelman, (1982).

As a way of conceptualising the innate predispositions she believed the child to possess, Gelman formulated five principles which she saw as guiding and constraining the child's counting behaviour. Gelman (1990) has likened the principles to a skeleton in the sense that they provide the framework for the body of development in this domain. In the same way as a skeleton is not overt but implied so are the principles seen to be implicit in the counting behaviour of the child.

The child is guided in the acquisition of counting by five principles, three of the five being the 'how to count' principles, referring to stable order, one:one, and cardinality and the other two, the abstraction and order-irrelevance principles, refining these in presenting non-constraints to counting. Although principles inform the learner as to what is an acceptable count,

> "some of the principles may operate more or less in isolation in the counting behaviour of very young children", Gelman & Gallistel, (1978), p 73.

Gelman makes an important distinction between implicit and explicit understanding of principles (Gelman, 1982; Gelman & Meck, 1986). Implicit understanding of principles is viewed in much the same way as knowledge of the rules of language. In the same way as children are seen to deduce rules for grammar so implicit understanding of principles can be inferred from the childs incorrect performance on counting tasks (Gelman, 1982). This parallel is especially well exploited in the analysis of errors as a means of determining the child's understanding. Psycholinguists, for example, will view the production of "mouses" as evidence for the acquisition (and overgeneralisation) of a rule for plurals. In a similar way, the childs production of stable but idiosyncratic counts is viewed by Gelman as evidence of an implicit understanding of the need to produce the list of number words in a stable order. Explicit understanding however is demonstrated only when the child is able to say why it is necessary to adhere to the principles (Gelman & Meck, 1983).

In support of Gelman's theory, Wilkinson (1984) has argued that during the pre-school years the task for the child is not to learn the components of counting but to learn to co-ordinate them. Children know *what* to do but have trouble doing it and the more components to the task the more errors occur. Children's knowledge of counting is therefore in his view more adequately described as variable than restricted.

As a further development of their position, Gelman and colleagues put forward a model to account for development in counting (Greeno, Riley & Gelman, 1984; Gelman, Meck & Merkin, 1986) in which a distinction is made between conceptual, procedural and utilisation competence. Within this framework,

> "Conceptual competence represents understanding of principles in a form that enables their use in planning... By 'procedural competence' we refer to knowledge of general principles involving relations of goals, actions and requisite conditions for actions....[and] Utilization competence includes knowledge used by the theorem prover in its efforts to relate features of the task setting to goals of planning." p 99.

Utilization competence can be perceived as having a plan of action and procedural competence denotes the ability to execute this plan. The distinction between utilisation and procedural competence is typically called on to explain later developments in children's ability where problem solving is called for in relation to new tasks and contributes little to the discussion of the first four principles of counting.

In contrast to the "Principles First" approach, "Procedures First" explanations of counting do not accord the learner domain-specific processes or structures nor do they rely on innate capacities. Instead the learner acquires the procedures for counting through copying examples present in the environment (Briars & Siegler, 1984; Hersovics, Bergerson & Bergerson, 1986) rather than constructing the process for himself. This approach predicts that learning develops as a function of the opportunities to observe and practice counting behaviour, which should at least in part account for individual differences. The sequence of words for example, is learnt by building up associations between words in the list so that 'next' connections are formed (Siegler & Robinson, 1982).

In contrast to Gelman's approach, therefore, this approach places the emphasis on an analysis of the *performance* demands of the task. For example, with counting one can divide the process into constituent parts of attending to each object in turn, simultaneously producing a number word that is part of a string of learned words, discriminating between the "attended to", and "the still to be attended to" objects and being able to hold in mind the last number tag in order to be able to answer a 'how many' question. Practice enables the child's performance to become more fluent so that the attentional demands diminish and allow him to perform additional parts of the task. One can therefore view the development as being additive with performance dependent on the number of components to the counting process. Such an approach explains the gap in development between counting a set and making a set because, in the latter task, the additional load on memory as the child has to compare the number uttered whilst counting with the one held in memory as the requisite number. One might also expect that the larger the set, the greater the performance demands will be and the lower the child's subsequent performance.

When the child has acquired the procedures for counting, Baroody and Ginsburg (1986) propose that he is in a position to abstract the rules which govern them as certain features come to be viewed as common to more than one task. Thus, through discriminating the critical features of counting, the child is able to generalise to achieve correct performances across tasks. However, it is the rationale for these rules which would be viewed as the principles that govern counting and it would not be until the child is able to understand why these rules have to be adhered to that one could credit the child with understanding the principles. Strategies that the child develops whilst learning to count are not thought to occur as a result of constraints or principles (that the child understands) but as a function of the need to diminish the task demands, to minimize (for example) the demand on memory or attention.

A mid-point position between the 'principles first' and 'procedures first' accounts of the development of understanding which sees a mutual interaction between the development of procedures and conceptual knowledge in these pre-school years has been proposed by Resnick, (1983) and Hiebert and Lefevre, (1986). For these authors the development of *skill* in counting can precede understanding, and likewise the development of understanding can inform the child as to how to carry out procedures correctly. Consequently children gain insight at different times in the acquisition process and this insight is not necessarily of an all or nothing nature, but more of a dawning recognition. Moreover understanding and procedures might develop at differing rates in parallel with mutual interaction leading to spurts in learning. This approach neither denies the role of imitation nor seeks to see the child as entirely passive in the learning process.

Although there is clearly dissent over aspects of Gelman's theory she alone has attempted to provide the most complete account of the development of counting in very young children and her account will therefore be used as a basis for discussion throughout this thesis. The following sections will be organised using her five principles of counting as a framework.

2.2.2 *Testing the Theories*.

Whilst it is possible to differentiate between three processes of conceptual, procedural and utilization competence in a theoretical model, the linguistic limitations of the young child create the need for indirect accessing of these areas of competence. Three sources of evidence are provided by Gelman and her colleagues (Gelman, 1982; Greeno, Riley & Gelman, 1984; Gelman, Meck & Merkin, 1986):

* Children's own performance
* Children's ability to detect errors
* Children's ability to deal with novel tasks.

Children's own performance

This type of data is derived largely from two studies referred to in Gelman and Gallistel (1978) as the "Magic Experiment", and the "Videotaped Study". The first of these, the magic experiment, was originally designed to investigate children's understanding of conservation of number (Gelman 1972) and is reported by Gelman and Gallistel (1978). In this experiment 16 two-year-olds, 56 three-year-olds and 56 four-year-olds were presented with two plates holding different set sizes of small toys. One of these was named the 'winner' by the experimenter, the other the 'loser'. These plates were covered and shuffled until the child appeared to have lost track of the 'winner' which he was then asked to identify. On a few trials he was asked to justify his decision. During this phase of the experiment there was no need to make reference to number, nor to count. In the second phase however number was overtly introduced as the arrays were 'surreptitiously' changed either by adding or subtracting an item or by altering the spatial arrangement or identity of items in the set. The children were not only asked if there had been a change and the nature of it, but also how may objects had been on the plate. The important aspects of this study with reference to later discussions of evidence is that small set sizes were used, and that its design is such that counting was only elicited for part of the procedures. The child was able to use processes other than counting (such as perceptual) in his decision making.

The videotaped study, in contrast to the magic experiment, was designed to ensure that counting was eventually elicited. Nineteen two-year-olds, 21 three-year-olds, 19 four-year-olds and 15 five-year-olds were introduced to two puppets and presented with two plates, one of which was designated the child's plate. Children were initially asked how many items were on the plate and if this did not elicit counting behaviour, the subsequent trial included an instruction to count them. Parallel presentations were given of set sizes 2 and 3, 4 and 5, 7 and 9, and 11 and 19, in a mixture of linear and random arrays. Not all children received the larger set sizes, but this study was much more likely to ensure that children did count. Two of the two-year-olds were dropped from the study as they had no idea what was required of them and one two-year-old's data was lost.

Error-Detection Studies

In response to criticisms that too much competence is granted to subjects (Sternberg 1980) Gelman and colleagues further support their claims by the use of puppet studies (Gelman and Meck 1983, Gelman, Meck and Merkin 1986), in which they seek to provide evidence that children fail to count correctly not because of a lack of understanding but due to the performance demands. Consequently these experiments seek to lessen the demands on young children by the requirement that they detect errors in the performance of others. The ability to detect errors suggests that pupils are able to monitor performance and therefore presume an understanding of principles. Puppet studies are carried out with three and four year olds.

Novel Counting Tasks

The third line of evidence is provided through the presentation of a novel constrained counting task (Gelman, Meck and Merkin 1986; Gelman and Cohen 1988) and is used in this thesis to consider the evidence relating to the order-irrelevance principle. Children are required to count by making particular items in the array receive a specific number tag. For example children may be asked to make the second object in a line be given the number tag "four". Children are therefore required to count in a different way but their solution requires adherence to the principles of counting whilst meeting the task demands. They argue that children cannot do this task if they do not have implicit understanding of the principles of counting (Gelman, Meck and Merkin 1986). Constrained counting tasks are given to three, four and five year olds.

2.3 The Acquisition of Principles

The three types of evidence just described will be used to investigate how children acquire the skills and understanding of counting using Gelman and Gallistel's (1978) five principles to structure the discussion. Particular consideration will be given to the evidence that pre-school children understand the principles of counting before acquiring the skills.

2.3.1 *Production and Understanding of Stable Order*

Regardless of which theory/perspective we take one of the most significant aspects of counting is that children learn a list of number words. Gelman argues that children have an implicit understanding that:

* count words are a separate class of words
* they must be produced in a stable order. (Gelman 1982)

In her view count words are acquired because the child has a basic understanding that one needs to use a special list of unique words in a stable order. As Gelman (1982) has pointed out these number words appear very early in the child's vocabulary - even earlier than colour words. She uses evidence of children's errors to support her theory and refers to these incorrect counts as idiosyncratic. In her view, one can credit children with understanding stable order if they use their list of idiosyncratic tags in a fixed order (Gelman & Gallistel, 1978; Gelman, 1982). On this basis one might expect to see evidence of stable ordering even in children's earliest attempts to count and therefore it would be present in the youngest children, as well as in the idiosyncratic portions of the count lists of older children.

Children's Own Performance

Data from the "videotape study" (Gelman & Gallistel, 1978) suggests that less than one third of two-year-olds demonstrate clear adherence to a stable order . Out of 16 children, one did not use a list of number words at all, one appeared to produce only the number three, and only five used fixed idiosyncratic lists. One of these five recycled his conventional list which does not sit comfortably with an implicit understanding of stable order. Although the data for the older children does not differentiate between idiosyncratic counters and conventional counters, it does reveal that only two three-year-olds showed no tendency to honour this principle.

Evidence of a similar developmental trend is apparent in the data from the "magic experiment". If we examine the response to set size 2 and 3, 14 of the two-year-olds "counted" but 21% of these showed no stable order. This decreases to 4% of three-year-olds and no four-year-olds. In the same way, the number of children who showed evidence of stable-order on 60% of trials, referred to by Gelman and Gallistel (1978) as the "shaky" group, also decrease from 14% of two-year-olds, to no four-year-olds. Again the data does not differentiate between the idiosyncratic counters and those with a conventional count.

In sum it would appear from this data that not all children demonstrate implicit understanding of stable order but there is a developmental trend with older children adhering more closely than younger children. Alternative explanations of the process of acquisition account for why this might be so and will be discussed later.

Error Detection Studies

The second line of evidence from Gelman and colleagues is provided through a puppet study (Gelman & Meck, 1983) where children aged 3-5 years were required to judge puppet counts. Performance improved with age with 3 year olds detecting 76% of incorrect trials and 5 year olds, 97%. Random lists were the easiest to spot, followed by reversals, followed by skipped numbers. As further support for their hypothesis Gelman and Meck note the lack of reliable effect of set size despite using arrays up to 20 which exceeded many of the children's own count lists. [However an alternative explanation of children's success lies with the prediction that recognition of correct sequences is likely to be better than recall (Estes, 1984)].

Alternative Explanations of the Acquisition of the Number List

One alternative argument is that children simply imitate the counting that they hear around them and they learn the list as a serial recall task. The appearance of a stable sequence of incorrect numbers is a function of the way the sequence is acquired (Fuson, Richards & Briars, 1982; Siegler & Robinson, 1982) and of the demand to repeatedly count similar sized arrays (Wagners & Walters, 1982). Fuson et al (1982) collected counts on children aged 3-5 years and found the sequence produced by the child typically reveals three distinct portions - a stable conventional portion, a stable unconventional portion and, lastly, an unstable unconventional portion. The middle portion rather than revealing implicit understanding of stable order is in their view characteristic of learning a serial recall task. The criteria for this middle portion is the appearance of two or more number words which differ from the conventional sequence and appear in between 40-100% of trials within a single session. The criteria would therefore appear to include Gelman and Gallistel's "shaky group" as it is characterised by omissions (most frequently with a forward direction to the count) and includes repeated words in the non-stable portion.

In order to provide a more detailed explanation of this characteristic pattern of errors Siegler and Robinson (1982) highlight 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 they have no more 'next' connections and then either stop or randomly produce numbers. These "random" numbers may be produced singly or as a string, dependent on whether they have a next connection or not. Unlike productions of later strings where a knowledge of the structure may help the child, there are no clear regularities in children's stopping points and initial prompts do not greatly facilitate additions to the string. Children omit numbers either because they have no 'next' connection or an incorrect 'next' connection. In this way they produce counts which are idiosyncratic. Stability depends on the strength of the connection with repeated counting (without correction) of arrays serving to strengthen incorrect connections.

One can further develop this explanation by providing two reasons for why not all children produce this pattern of unconventional stable order counts. Firstly, it depends on the demand for repeated counting of items and secondly on the willingness of the child to count beyond his knowledge of the count list. It is notable that fewer children produce stable unconventional portions in longitudinal studies when comparisons are made between count sequences over time. Fuson et al's cross sectional study where children counted rows of increasing length found that 54% of children were willing to count past the production of accurate sequences and of these 88% produced a stable unconventional portion. However, in the longitudinal study only 33% produced these portions. Wagner and Walters (1982) in a longitudinal analysis of nine children's symbolic development from one to five years found no strong evidence in relation to unconventional counts. Only five instances are reported, all within a short time span of one another and all involving the omission of a single digit. They put forward the hypothesis that it is due to a primacy-recency effect and an artefact of demanding repeated counts of similar sized arrays. It was also not a uniform occurrence in the data provided by Baroody and Price (1983) in a similar small-scale longitudinal study.

In conclusion, it would appear that stable order is not apparent in all children's counts at any one point in time. In Gelman's own experiments not all children showed evidence of stable order, although it was increasingly evident with age. However there is no reason to assume, as Gelman does, that these changes represent increased understanding. The rote way in which the number string is acquired and the fact that children know increasing numbertags are more likely explanations for the appearance of the stable but unconventional portions of their counts. As the child attempts to hone his performance to the conventional list, some weak associations are formed and some inappropriate associations. This leads to a mixture of stable and unstable unconventional portions to the list.

The understanding that any list can be used to count with, provided that it is used in a stable way also appears to be abstracted with time and as a function of experience. Gelman's evidence for this is linked to the early appearance of count words in children's vocabulary, earlier than for example colour words (Gelman and Meck 1986). Other investigators provide evidence which suggests that although young children may use their own idiosyncratic stable list in counting they appear not to know that nonstandard or unconventional stable lists can be used to count with (Saxe, Becker, Sadeghpour & Sicilian, 1989). Saxe et al (1989) required children aged between three and twelve years to judge the counts of two puppets, one of whom used a nonstandard list correctly and one of whom used the standard list both correctly and incorrectly. When the nonstandard list was the alphabet, only eleven-year-olds viewed correct letter counts as adequate, although eight-year-olds view them as more adequate than using the standard list incorrectly. There is therefore evidence that this understanding develops quite late.

Further studies by Saxe et al (1989) suggest that prior experience is important in reaching this understanding. Six-year-old *bilingual* children performed at a level equivalent to the eleven-year-olds and when six year old monolingual children were given brief training in Chinese number words they accepted accurate counts using this non-conventional list. On the one hand this supports the premise of Gelman that count words are a special list of words, but suggests that the essential features of stable order are deduced following the acquisition of procedures.

Summary

If we return to Gelman's main arguments we can agree that children quickly come to see count words as forming a special list and the task for them is to acquire this list. The evidence does **not** suggest, however, that children are guided in their acquisition of this list by an implicit understanding of the principle of stable order. Children's idiosyncratic counts do not always contain a stable unconventional portion and when they do associationist explanations predict the pattern of errors. Children are able to detect errors in counting as they recognise the conventional order even when they can't always recall it.

2.3.2 *One: One Correspondence*

Gelman's second principle of counting is the one-one principle whereby children understand that each item in an array is assigned one, and only one tag and each tag must be unique. This involves partitioning, as the child has to separate the counted from the to-be-counted items (Gelman, 1978). This principle highlights the difficulty in separating procedural demands from conceptual understanding as children's ability to perform correctly has to be determined at least partially by the extent to which they can adhere to stable order. The child needs to know as many number tags as there are objects in the set in order to attempt one-to-one correspondence.

Children's Own Performance

Gelman first provides evidence of children's use of the one to one principle from data derived from the "videotape study" (Gelman & Gallistel, 1978; Gelman, 1982) and takes as a "crude index" whether or not children use as many tags as items. Data from the two-year-olds indicated that overall the greater the set size the more number tags were produced, although similar utterances were made for set size 4 compared with 5, and set size 7 compared with 9. However, whether this data supports the view that children have a clear understanding that the tags have to be assigned in a one-to-one fashion is debatable. It is more parsimonious to assume that the understanding that children acquire is restricted to the notion that more objects require more words to be said.

Performance improves with age, but deteriorates as a function of set size (this could be predicted on the basis of a change in procedural competence), however, because the number of children attempting each set size differed as older children did not count small sets and younger children did not attempt larger sets it is difficult to attain a clear profile from this source of data. In her 1982 study Gelman also reports on the tendency of children to self-correct but does not provide precise data. This would constitute perhaps the strongest evidence that children at least know the rules of counting which provides them with a standard for correct performance.

Error Detection

Using the more fruitful technique of error detection, Gelman and Meck (1983) found that 75% of three-year-olds spotted the puppets' errors of skipped objects and double counted objects in at least three out of four trials, and 83% of four-year-olds did likewise. They report little effect for set size (6 and 12).

In contrast, younger children were not so successful in a similar puppet study by Briars and Siegler (1984) where only 30% of three-year-olds displayed judgements consistent with knowing that word/object correspondence is essential compared to 90% of four-year-olds and 100% of five-year-olds. Moreover, in contrast to the Gelman and Meck (1983) study set size differences were found with errors more readily detected in small (3,4) than large (9,10) set sizes. Whereas in all groups skipped objects were most likely to be rejected suggesting that children know that it is important to give attention to each object, a high proportion of four-year-olds also thought it was essential to start at an end and to count adjacent objects. Since Briars and Siegler were unable to find a single child who was able to judge the counts correctly but not count correctly themselves they suggest that it is most likely that learning the procedures guides knowledge of the counting principles. This suggestion is further supported by the finding that some children did count correctly but were unable to detect errors.

There are three key areas of discrepancy between these two studies. Firstly, the three-year-olds performed so much worse in the Briars and Siegler study than in Gelman's study, secondly the effect of set size was significant in one but not in the other study and thirdly the finding that all children could count themselves before they were able to detect errors in Briars and Sieglers study. One possibility is that three-year-olds in Briars and Sieglers study failed to understand the task demands despite the fact that this part of the study was replicated with additional demonstrations and language modifications. It is an unlikely explanation as the replication was designed to ensure that the children knew that it was permissable to say that the puppet was incorrect, and therefore their failure to discriminate between counts was because they did not know the criterion on which to make judgements. Secondly to turn to the set size difference there is an obvious difference between the two studies as Briars and Siegler compare performance on set sizes 3 and 4 with set sizes 9 and 10 (compared to

Gelman and Mecks's 6 and 12). It may be that for some of the children the smaller set size was within counting range whereas the largest one wasn't, thus bringing about a set size difference. This however further supports the procedures first argument but does not explain the overall difference between samples.

Gelman and Meck's (1983) plexiglass study suggests that whereas approximately 90% of three-year-olds can count five objects this falls to approximately 70% for set size 7 and 40% for set size 11. The figures for four-year-olds are 100%, 95% and 70%. Clearly some children in their error detection sample are spotting errors in sets that they are unable to correctly count themselves. If we judge the Saxe et al (1989) study by the same criteria then the position is not so clear as children were failing to detect errors in very small set sizes that they would almost certainly have been able to count. This is further questioned by Briars and Siegler's findings.

Another major difference between the two studies was the number of trials required. Three-year-olds in the Gelman and Meck study only received 12 trials and the four-year-olds received 48 whereas all children in the Briars and Siegler study received four blocks of 18 trials, a total of 72 trials. It is clear that in attentional terms the Briars and Siegler study is demanding more of the child. Not only do they have to watch considerably more puppet counts but they are also being asked to count large sets themselves. It is possible that this could lead to depressed performance, whereby 'the game' is no longer motivating and their attention is no longer sharply focused on the task.

Clearly contextual variables and task demands are important in much the same way that has been found for conservation performance (Donaldson, 1982). Evidence from the study by Saxe et al (1989) contributes to our knowledge in this respect, as children appeared to experience considerable difficulty detecting skipped item and double counts on small sets but performed much better when they were required to settle an argument between two puppets.

The Interrelationship of Understanding and the Acquisition of Procedures

The question of how procedural and conceptual knowledge develop in this kind of task is clearly very complex and as yet is not clear. Children clearly don't judge puppet counts correctly until they can at least count small set sizes. Thus it is possible that knowledge of these procedures facilitates deductions of what aspects of the task are essential. However, whilst correct counting on at least some set sizes may be a necessary pre-requisite, it is not automatically the case that this leads to understanding. Children clearly improve with age in their ability to detect errors, and similarly their counting skills improve. Improved understanding may lead the child to improve their execution of procedures if they monitor their own performance.

The Development of Strategies

The interrelationship of the acquisition of procedures and understanding is further highlighted if we turn to consider the development of counting strategies. Children clearly show the development of procedures that are an aid in adhering to one:one principles, for example the use of gesture followed by touching objects and changes in strategy for counting random arrays . This suggests that there is a growing awareness of the need for one to one correspondence before totally accurate counting emerges. For example Saxe and Kaplan (1981) argue that two-year-olds use gesture in counting but not in a way that actually makes the count more accurate. It is used simply to refer words to objects just as they might do in other naming activities. However, the function of the gesture changes to enable them to align them in a one:one relationship and to separate the counted from the to-be-counted (Beckwith & Restle, 1966). Fuson and Hall (1983) refer to the internalization of tagging as three-year-olds actually touch the object and four- and five-year-olds point. Shannon (1978) found a characteristic shift from a sequence involving first touching objects based purely on proximity, to going round the outline before counting interior objects, to counting in lines or rows. However, although there were some shifts in strategy dependent on set size this did not always entail the adoption of a strategy that was likely to lead to fewer errors. Fuson (1988) reports that it is only when the child is 5-6 years do they regularly use the most efficient strategy of moving objects from the pile as they count. It is unlikely however that all these strategies are developed purely as a result of imitation, and they may reveal partial insight consistent with an interactive model of understanding.

Summary

Children would appear to deduce the idea of one-to-one correspondence over time. Gelman's evidence suggests that children quickly come to see that more objects require more words but it is likely that at this early stage their understanding is no more precise. The conflicting evidence provided by the error detection studies further questions the notion of implicit understanding. Briars and Sieglers (1984) study suggests that children think that it is important to count adjacent items and to start at an end. To some extent this is mirrored in the development of strategies outlined by Shannon (1978). Procedural changes of this sort suggest that the child is beginning to deduce the principles for counting prior to a flawless performance. A comparison of puppet studies suggest that the attentional demands and the meaningfulness of the context may be two important variables. It is likely that for one-to-one correspondence an interactional account best explains development with procedural competence informing conceptual competence which leads to a further improvement in procedures.

2.3.3 Cardinality

Gelman (1978) highlights two aspects of the cardinality principle. The first is that it gives special significance to the last tag used in a count. The second related aspect is that this last tag "represents a property of the set as a whole". It follows therefore that in order to understand fully the cardinal principle the child must acknowledge that the last tag refers to the number in the set *only* if stable order and one-one correspondence has not been violated. One would expect on this basis that there would be a decrease in cardinality response in relation to the child's fluency in counting, and consequently that there would be differences in performance dependent on set size.

Children's Own Performance

Although Gelman and Gallistel (1978) point out neither the magic study nor the videotaped study were designed specifically to test children's understanding of cardinality or to compare children's performance across set size they do use data from both of these sources to investigate the cardinality principle. Since the children were not consistently asked "how many" in the videotaped study, nor did they necessarily show overt counting this produced unequal samples of children who counted different set sizes at any one age level. In addition, Gelman and Gallistel (1978) use the criterion of producing the cardinal value on at least one trial and they also distinguish between direct and indirect criteria of cardinality. If we take the direct criteria this includes repetition of the last tag or emphasis on the last count word. Using these criteria 5/16 two year olds, 5/32 three year olds and 29/32 four year olds demonstrate cardinality on set sizes two and three. Clearly emphasis of the last word may in fact purely be seen as a feature of counting intonation- a procedural feature. However, bearing in mind these limitations there does appear to be evidence of decreasing application of the cardinal principle with set size.

Gelman and Gallistel (1978) further support their hypothesis that children understand cardinality by reporting the pattern of incorrect responding. As set sizes increase cardinality responses decrease first, then one:one shows increasing errors whilst stable order continues to be shown on larger set sizes. The data is consistent with the view that children recognise that in order to give a cardinality response they must be accurate in their execution of one:one and stable order. Gelman and Gallistel's own data, therefore, provides some support for the view that children do have an understanding of the cardinal principle.

In contrast to Gelman and Gallistel (1978) other researchers fail to provide evidence of differences in cardinality response associated with set size (Fuson, Pergamet, Lyons and Hall, 1985; Fuson, 1988; Wynn, 1990) and this has contributed to the view that children initially simply acquire the *rule* for cardinality. They learn for example that in order to answer a 'How many' question, one repeats the last tag. Adherence to this rule requires no understanding and should be quickly generalised from small to large sets. However some mistakes might occur if there were phonic similarities between the last word and the preceding or subsequent word (such as in the teen words). Wynn (1990) also argues that one might expect the child to occasionally give the correct answer, as it is most recent in memory having been the last count word uttered, but this would be prior to attaining the rule. Once learnt, the rule would be quickly generalized as the performance demands are fairly simple.

In contrast to the findings of Gelman and Gallistel (1978) Fuson, Pergamet, Lyons and Hall (1985) report considerable consistency of last word responding in preschool children. Over a series of three experiments testing 117 children between the ages of two and a half and four and a half years on set sizes 2 through to 19, between 85% and 100% of the sample were consistent. Either children gave the last tag word almost always or they very rarely did. There was also a consistent lack of difference between children's responses to large and small set sizes which of course contrasts with the effect of set size on accurate counting. Twenty out of 48 children in their first experiment were not accurate counters but were last word responders on small set sizes (4, 5, 6). Some were inaccurate counters but used the last tag; equally others counted accurately but did not use the last tag. For large set (9, 12, 14) sizes only two children were accurate counters yet 18 gave last tag responses. Clearly, from these studies of Fuson et al. (1985) accurate counting was not a necessary feature of the last tag responder. Thus Fuson (1988) concludes:

> "Not only does set size not seem to affect last word responding across a sample of children, but also individual children are quite consistent in such responses; They either almost always or instead almost never give last-word responses." p 225.

Fuson (1988) argues that the differences between set sizes found by Gelman and Gallistel (1978) are due to design artifacts. Children were not always asked 'how many' and therefore the data includes those who volunteered the last word response. As the task proceeded children may have stopped volunteering. Another important factor was that children were asked the 'how many' question before counting, with the implication that this increased the memory demands of the task as a function of the set size. Support for these criticisms also come from Wynn (1990) who found no set size differences in cardinality responses of children aged two-and-a half to three-and-a half, when they were asked 'how many' after counting.

Further proof of the effect of timing on last word responding is provided by Frye, Braisby, Lowe, Maroudas and Nicholls (1989). Different cardinality questions were asked before, after, and both before and after children counted set sizes 4, 5, 12 and 14. Performance was generally found to be better if the question was asked after the child had counted, and this was particularly marked for large set sizes. The set size differences found in the videotaped study by Gelman and Gallistel (1978) could, therefore, well be due to children forgetting the question. Given the variation of instructions given, 'How many', 'Go ahead', and 'Count them', children were not aided in remembering by the consistency of demands in previous trials.

The question of whether children who acquire the 'last tag rule' understand that this indicates the properties of the set has been further investigated by Frye et al (1989) who found children gave more correct answers to the 'How many' question than to either 'Are there X counters' or 'Please give me X', with this last instruction being the most difficult. A further study was carried out by Frye et al. (1989) where children aged three-and-a half and four-and-a half years were required to watch the experimenter counting small (4, 5) and large (12, 16) sets and either agree or disagree with count assertions and cardinal assertions. Children were more accurate at judging whether the counts had been correct than judging the accuracy of the cardinal statement which suggests that children do not necessarily link counting and cardinality and provides further support for the argument that it is a rule which has been acquired. Fuson (1988) similarly found that children performed better on the count reference question 'Show me the star where you said n' than the cardinal question 'Show me the n stars'.

Further evidence for the fact that it is a rule that is acquired is the readiness of children to given a small number response to large set sizes (Fuson, 1988). As children depart from stable order, they frequently recycle previous parts of the number string, consequently the last number tag uttered may not be related at all to set size. Children appear to pass through stages in their response to the 'How many' question. A two-and-a half year old child may well give a single digit response, but this appears random. This is replaced in three-year-olds by recounting the set. Fuson (1988) argues that this relates to increased modelling by the parents of counting, and children fail to distinguish between the 'How many' question and an instruction to count. Children show a mixed profile of single (incorrect) digits and recounting as a response before finally developing correct last word responses.

Alternative Explanations of How Children Acquire Cardinality

The evidence that children have an implicit understanding of cardinality is limited and a variety of alternative explanations have been put forward to how children acquire this understanding. Fuson (1988, 1991) suggests four possible ways in which the child may acquire the last tag rule. Firstly the last tag word used may be salient to the child because of some event. For example, it may be emphasized by another person in counting the set. Young children often show this emphasis in their own counting (Gelman and Gallistel, 1978), although they don't necessarily repeat this word in their own counting task, perhaps to indicate that they have come to the end. Fuson also argues that the last tag may be salient to the child if it was a large number, as it would be less common in the child's experience.

A second, and more plausible argument is that the recency bias in children together with positive feedback may account for its acquisition. A third alternative is that children are instructed and the acquisition by 60% of Fuson's sample following limited teaching suggests this may be a route for some children. A fourth explanation, one for which there has been some support is that children may form the rule through subitizing small set sizes and noticing that the number is the same as when they count. If children did achieve the last tag rule through subitizing, it could be argued that they may have greater understanding of cardinality as they, in Fuson's terms, had made the cardinal count transition and knew that the number given described the properties of the set. This presupposes that the child has a concept of two or three as indicating numerosity. Although Gelman and Gallistel (1978) deny the role of subitizing in children's understanding of cardinality the "automatic" perception of numerosity has been utilised by teachers (Doman 1979) and by researchers in the field of learning difficulties (Brown, Bellamy & Gadberry, 1971) and therefore warrants consideration.

The role of subitizing

The majority of research on the process of subitization has been carried out with adults rather than children. The term was coined by Kaufman, Lord, Reese and Volkmann (1949) and was used to distinguish processes based purely on visual perception and those of estimating and counting. The essential differences between them were in their view, report time and accuracy. Subitizing was seen as the process responsible for distinguishing arrays of up to six dots and estimating for arrays of more than six dots as demonstrated by discontinuities of the slope of reaction time. Although Svenson and Sjoberg (1983) also put the break in reaction time at five and six dots, Chi and Klahr (1975) put it at four dots. Differences in methodology may account for this, as for example Kaufman et al. required subjects to locate the array whereas Chi and Klahr presented the arrays within the central field of vision. Before considering the evidence of young children's reactions it is worth considering the argument put forward by Mandler and Shebo (1982) that counting is used for arrays of four to six where the pattern is held in consciousness, and that perception of canonical arrays is acquired for arrays of two and three based on doublets (straight lines) and triplets (triangles). With regard to adults therefore there is clear evidence of rapid identification of arrays up to 6 dots, based on perception for smaller arrays and perception and counting together for larger arrays.

Can children subitize ?

The evidence provided by two studies which included children of different ages support the idea that the ability to quantify patterns of dots develops with age (Chi and Klahr 1975, Svenson and Sjoberg 1983) with children performing more slowly than adults until the age of ten years (Svenson & Sjoberg, 1983). However, it would appear that the difference between counting and subitizing in terms of reaction time is not clearly discernible in children. Whereas adults were found to have a reciting rate four times that of subitizing, children's reciting rate is largely comparable to their subitizing rate (Chi & Klahr, 1975). This may reflect general differences in the speed of information processing or it may reflect that (like counting) the process of recognising patterns is far from automatic.

Whilst this process may be slow it may still provide a bridge to cardinality but only if children "subitize" before they are able to find out cardinality by counting. We therefore need to consider the response patterns of younger children. The main proponents for the primary role of subitizing are Schaeffer, Eggleston and Scott (1974) and Klahr and Wallace (1973, 1976) further outlined by Klahr (1984).

Klahr and Wallace (1973, 1976) put forward the view that subitizing occurs before counting and that the former 'plays an essential part' in the child's understanding of quantity. Klahr (1984) argues, from the evidence in infants, that at four months infants are able to encode cardinality for sets up to three or four objects - the point at which children's and adults' reaction times change in gradient. He posits the idea of a time line - a trace whereby the system can reflect on the result of actions. Thus, for example, an infant can encode a quantity together with the transformation that occurs as a result of action and the time line allows him to inspect the differences of the two encodings. Klein and Starkey (1987) however argue that this is not a truly *numerical* process, as it does not involve one:one correspondence but is probably based on differences in global features such as the surface area covered.

Schaeffer et al. (1974) also argue for the existence of detection of numerosity prior to counting but on the basis of the responses of young children rather than infants. They tested 65 children aged 2.0-5.11 years on a series of counting and cardinality tasks. On the basis of the children's responses they formulated four stages of development. At the earliest stage almost all children were able to state the number of men in a picture without counting when only two men were pictured but this success decreased to 38% on array sizes of four. Young children were able to put two or three sweets in a container on request and with less accuracy able to tap two or three times on a drum. In the experimenters' view this perception of small quantities apparent in Stage 1 children facilitates the child's later development of cardinality through noting that the same number is obtained by counting.

Two points are of interest here. Firstly stage 2 children appear from the data to perform less well than stage 1 children on pattern recognition. This could be due to a number of factors, either for example, the development of counting interferes with the previously acquired perceptual skills or it results from the way in which the experimenters allotted children to groups. Why, for example, was the one child who could count to four not included with stage 2 children ? Secondly, it is worth noting that children were tested for up to 90 minutes and Schaeffer et al. (1974) themselves question the possible learning outcomes for children.

Wynn's (1990) data support the findings of Schaeffer et al. (1974) that children are able to give one and two items well before they are able to use counting to give the correct number of items for larger set sizes. Her findings suggest that at approximately three-and-a-half years the child changes strategy to use counting to give the number of items asked for. Prior to this children are classified as 'grabbers' who may, without counting, give the appropriate number for small set sizes of 1-3 but who otherwise take a handful.

Considerable evidence therefore exists that children do have some knowledge of small numbers prior to being able to count accurately. In infancy they have an awareness of numerosity and changes in numerosity and at two and three years have acquired a label for these canonical patterns. Further evidence suggests however that either this is not true for all children or that counting interferes with this knowledge.

Gelman and Gallistel (1978) found that children in the "videotape study" were equally able to count and subitize. Fifty percent of their two-year-olds were able to give a cardinal value for set size two and all could count to this number and 25% could give a cardinal value for set size three and all could count to three. Likewise 3 year olds in a study by Silverman and Rose (1980) did not show a superior performance of subitizing compared to counting although they found that it was very difficult to inhibit counting. This difficulty may reflect the firm link the question "how many" has with an instruction to count.

Fuson (1988) in studies of 42 children aged two-and-a half to four years found that most children could subitize two (80%), about half sometimes subitized three (most likely in rows) and about a third sometimes subitized four (non-row arrangements only). She comes to the conclusion that subitizing is characteristic of particular children, but although many children can subitize small sets, it is not a pre-requisite to knowing the last tag rule.

It would appear from these studies that children as young as two-years-old are able to correctly label arrays of two. This may be evidence of an acquired canonical pattern such as that proposed by Mandler and Shebo (1982) learnt together with an accompanying label. Wagner and Walters (1982) found that in the transcripts of every child in their longitudinal study, the first appearance of words two and three are not accompanied by counting. For children from one-year onwards these number words appear only 15% of the time accompanied by counting. This compares to arrays of 4 or more when only 5% are <u>not</u> accompanied by counting. They argue that the child classifies groups of objects up to three in much the same way as they classify animals, furniture etc. However, they are granting the child an understanding that although two and three belong to the same class they are not viewed as being equal quantities. Wagner and Walters (1982) argue that the ability to estimate small magnitudes emerges quite early but the idea that counting is a procedure to use for this develops later.

The findings of Durkin, Shire, Reim, Crowther and Rutter (1986) in part support these conclusions. In a longitudinal language study of mothers and infants between the ages of nine months and three years, cardinal use of words and number strings appear together for the first time at the 15-month level, but mothers use cardinal expressions of number far more than they do number strings. The cardinal use of number words also appears first in the child's vocabulary, although they may alternate number strings with their mother prior to this.

A tentative theory could be put forward that children do subitize small sets and some describe them by using a cardinal term, but this is not connected at this point to a 'how many' question. The positive findings of Wynn (1990) do not run counter to this proposal, as her children were instructed to 'give' a small number, but they do appear contrary to the findings of Schaeffer et al.'s (1974) however methodological difficulties may account for this, in particular children may have learnt the label in the course of the study.

Summary

The evidence suggests that young children are exposed to and do use cardinal number words from a very young age. Many also acquire canonical patterns of two and three, although this may not be an automatic perception in the same way as subitizing has been portrayed in adults and will largely be a function of learning experience. In much the same way as Klein and Starkey (1987) argue that subitizing is not a truly numerical process, as it does not involve one:one correspondence, one can argue that this early ability to label sets of two and three is not a numerical process. It would appear that, at least for the majority of children, it is not a process which directly facilitates an understanding of cardinality. Given that some groups of very young children (Schaeffer et al. 1974; Gelman and Gallistel, 1978) out-perform older children or more competent counters, it would appear that this process is largely acquired independently of counting and cardinality. It would be interesting to see if the young child's propensity to give a single (albeit incorrect) response to the 'how many' question prior to the stage of recounting relates to the ability to subitize. Number might thus be viewed as a label rather than something which is related to counting.

The evidence for implicit understanding of the significance of the last tag is limited largely to set size differences found by Gelman and Gallistel (1978) and not replicated by other researchers. We can therefore conclude that counting is acquired and becomes linked to the 'how many' question, and the most likely mechanism for acquiring a last tag response would appear to be through observation and systematic reinforcement by a more competent counter. Cardinality appears at first to be limited to understanding a rule as it is quickly generalized and used willingly in the face of quite overtly inaccurate counting. Children still have some way to go in understanding cardinality as shown if we now turn to consider the order-irrelevance principle.

2.3.4. *Order Irrelevance*

This, in Gelman's view is the last principle to show functional maturity in the child (Gelman 1982). It involves an understanding that the order in which items are assigned a count word is arbitrary. That is to say that although the count words have to be produced in the standard order, objects can be processed in any order. Two fundamental aspects have been highlighted with regard to this principle. The first aspect concerns both children's willingness and ability to count by processing objects in different ways. The second concerns children's knowledge of the outcome of counting in different ways. All three lines of evidence, own counts, error detection and performance on novel tasks are used by Gelman and colleagues to support implicit understanding of this principle.

Children's Own Performance

The origins of this principle can be traced to Gelman's evidence that young children show an implicit understanding in their own counts. In the videotape experiments (Gelman & Gallistel, 1978) arrays were rotated between trials and children were reported as being happy to count starting with objects that had previously been counted last. They also report on pilot studies carried out with 3 and 4 year olds where set sizes of between 4 and 7 objects were repeatedly counted with the position of objects being changed between counts. It is difficult to be sure with this evidence however that children are guided by this "non-constraint" to counting. Therefore three further measures are taken, firstly a requirement to count in a way that demonstrates order irrelevance and adherence to the other principles of counting, error detection studies and lastly prediction studies.

Novel Counting Tasks

Early piloting of a constrained counting task by Gelman and Gallistel (1978) revealed that 3 year olds had difficulty on a constrained counting task when they were required to make a target object a specific number in the count using set sizes of 4 and 5. This was followed by a more systematic study which included five year olds as well. Performance clearly improves with age, with 12% of the 3 year olds, 44% of the 4 year olds and 75% of the 5 year olds able to count in this way. Although the children who succeeded were better counters, it was not the only determinant of success as not all good counters could count in this constrained manner. It would appear that this task is a stringent measure of how fluently the child can carry out the *procedures* for counting. (A similar comparative study is reviewed in chapter three.)

Error Detection Tasks

Conflicting evidence has emerged again as a result of these studies. Gelman and Meck (1983) included within their experiment on 3 and 4 year olds some one:one errors which they refer to as pseudoerrors. On these trials the puppet either started his count in the middle of the array and doubled back for the remaining items, or counted first the red chips and then the blue chips which were presented alternately in the array. The results indicate that taking a criterion of 75% of trials correctly judged, 11/12 three year olds and 10/12 four year olds made responses consistent with understanding that these were in fact pseudoerrors. Briars and Siegler (1984) presented 3, 4 and 5 year olds with a series of unusual counts, whereby the puppet counted either in the opposite direction or by starting in the middle or by alternate objects. In contrast to the success displayed by children in the Gelman and Meck study, only 35% of 3 year olds, 65% of 4 year olds and 53% of 5 year olds were successful. In addition they comment that:

> "a high proportion of 4 and 5 year olds knew that assigning one number word to each object was essential and that counting in the standard direction was unessential, but also thought that counting adjacent objects consecutively and starting at an end were essential" p 614.

One possible explanation of this finding is that children's understanding was influenced by their experiences of others counting. Not only is it unlikely that they observed such pseudoerrors as alternate object counting or starting to count with a middle object in the counting of others but also they would not be encouraged to count themselves in this way because of the additional demands it places on attention and the increased likelihood of inaccurate counting. It does not however explain why children performed better in the Gelman and Meck (1983) study.

The monitoring of a puppet's performance places quite considerable attentional demands on a child. In order to detect errors the child must be able to predict the correct response whilst attending to the puppet. Correct detection of errors relies on the child anticipating what the response should be and being aware when there is a mismatch between the expected and the actual. It might well be predicted that unusual counts place higher demands on the child because they run contrary to expectation. Alternatively, if set sizes are blocked and the child focuses on the last count word given the task is made easier, providing he understands that the cardinal value remains unchanged. Children would therefore be hindered by testing over long periods of time when the attentional demands are greater but would be aided by the presentation of errors blocked by set size and type of error. We have already noted the increased number of trials presented by Briars and Siegler (1984) might have hindered performance but also Gelman and Meck (1983) presented all types of one:one/pseudoerrors in a single block which may have further facilitated preschoolers performance.

In 1986, Gelman and Meck argued that the difference in findings between the two studies may be partially due to the instructions given to the child. In their experiment the children were told that "Mr Horse is just learning how to count" whereas the children in the Briars and Siegler experiment was told that the puppet "knows his numbers". However both groups were informed that they sometimes made mistakes. In their view children were primed in the latter study to look for the conventional. They also argue that as children were repeatedly asked to count a set before every block of testing children were reinforced with the idea of a set method of counting. However this experience of Briars and Sieglers children should have facilitated their knowledge of the correct cardinal value of the set from which to make judgements.

A more plausible explanation put forward for the discrepancy is the style of interaction between experimenter and child. Whereas Briars and Siegler (1984) appear to have adopted a style conducive to testing children, Gelman and Meck adopted a "very interactive mode" (Gelman & Meck, 1986), including asking children to explain their judgements:

> "As a consequence, without planning to, we may have given children a hint about how to approach the difference between conventional and unconventional trials." p43.

A follow-up is reported in Gelman and Meck (1986) using four and five year olds. Pseudoerror trials included starting counting in the middle of the array, skipping an item in the middle of the array and returning to count it last, and a compensation error trial whereby one error effectively cancelled out a previous error. Children were asked to explain their judgements. One:one errors were also included with skipped-object trials and double-count- object trials. Four year olds correctly judged an average of 9.3/12 trials, and five year olds 10.5/12 trials. In contrast to their previous experiment it would appear, taking the child's immediate response 4 year olds performed better on 1:1 errors than pseudoerrors and better on compensation trials than pseudo-errors. This difference largely disappears if one takes their best response. It would appear therefore that performance on error detection mirrors their likely experience of different types of counting but that during the course of testing performance improves. This may be due to the interactive style which encourages reflection.

A study by Frye, Braisby, Lowe, Maroudas and Nicholls (1989), provides some insight into how children make their judgements on error detection tasks. Four twenty minute sessions were carried out with children aged three-and-a half to four-and-a half years where the experimenter counted either correctly, made stable order, one:one or pseudo errors. Children were asked to respond to a counting assertion "I think I have counted right [or wrong]. Have I ?" or a cardinal assertion " I think there are [X]. Are there ?" In contrast to the 1:1 violation trials and stable order violation trials, children were more successful on the cardinality assertions for the pseudo-error trials and less successful on the counting assertions. The differences between the two assertions suggest that children have two distinct ways of treating a trial either one counts correctly or that one gives the correct cardinal response. If children understood the link between counting and cardinality these differences would not be evoked as it would not elicit greater attentional demand to keep in mind both aspects at once. Instead it suggests the least effort principle in operation. The attentional demands for detecting one-one errors when the counter does not follow a conventional count procedure perhaps encourages the child to concentrate solely on the outcome response of cardinality.

Frye et al (1989)'s study supports the findings of Briars and Siegler (1984) that correct counting precedes correct judgement of the principles on which an accurate performance is based;

> "the observed progression, from easiest to hardest, was: counting a small set, counting a large set, judging the experimenters counting of a small set, and judging the experimenters counting of a large set." p1167.

As with the Briars and Sieglers study they used randomised sets thus demanding that the child judged each set on its own performance merits.

Predicting Cardinality in Different ways

An alternative strategy for eliciting children's understanding of the order-irrelevance principle is to ask them to predict the outcome of counting a different way. Saxe, Guberman and Gearhart (1987) tested two and four year olds on an order-irrelevance task using set sizes 3 and 6. Children were asked to count a set starting with the left-hand item and tell the experimenter how many there were. They were then asked "You got X animals counting from this end to this end. How many animals do you think there would be if counted this way and made this animal number one ?" and the array was covered. The task was repeated indicating the middle item as the number

1. The task was found to be too difficult for both 2 and 4 year olds despite the inclusion of a very small set size.

Baroody (1984) argues that children have acquired an order-irrelevant rule rather than an understanding of the principle. In much the same way that children learn to add by taking either of the addendums first, as with order-irrelevance they don't have an understanding that the cardinal outcome is the same but they know that it is OK to count in opposite directions. Baroody presented five and six year olds with a set of 8 items to count and say how many. They were then asked if they could make the last item number 1 and count in the reverse direction. Following the child's response they were then told "We got "n "counting this way what do you think we would get counting this way?" The array was covered and when the child had responded he was asked to count in the opposite direction. All children gave a positive answer to being able to count in the opposite direction and all but one child was able to do so. However 36% of kindergartners made an incorrect prediction about the outcome of recounting and a further 8 were unsure and then made an incorrect prediction. A clear developmental trend is evident as 87% of first graders were able to correctly answer the question. Children were reminded by the question what their previous count had found and therefore the lack of success cannot be directly a result of forgetting.

One possible reason for the lack of success in Baroody's sample is that they were drawn from a rural area and this resulted in different educational experiences. When Gelman, Meck and Merkin (1986) attempted to replicate this experiment they found that their sample of five year old urban children made too few errors to form a comparison group, and used instead a group of four year old children drawn from an urban area. They set out to test the hypotheses that poor responding by the children was either due to the phrasing of the question which was seen by the pupil as a "challenge" or that children were unconfident of the accuracy of their own counting. An alternative question was given to one group of children which took the form "Could you start counting with N", N being the child's cardinal value, "How many will there be ?" or "What will you get ?" For one group the procedure used was the same as Baroody's and a third group was given the opportunity to count the array three times so that they could be sure about the outcome before being given the Baroody question. The response of the children support Gelman, Meck and Merkin's (1986) claim that the language used impeded children's judgements in the Baroody experiment. Only 8% of four year olds correctly answered the question in the "Baroody" condition compared to 83% in the "Alternate Question" condition. Some children did benefit from increased opportunity to count the set as 50% of this group correctly answered the Baroody question. Further error detection tasks reveal that the three groups were comparable in other respects. The same developmental trend was apparent in that 83% of five year olds could correctly respond to the Baroody question. Similar differences were also found by Gelman, Meck and Merkin (1986) in a follow-up study with three year olds. What is not clear is whether the children responded better because the alternate question was less challenging or because it gave them a better understanding of the task demands ?

Further support for Gelman's claim that catchment areas (and therefore experience) affect the success rate is provided by Hersovics and Bergeron (1989). They investigated five and six year old childrens understanding of the uniqueness of the cardinality of a set. Three groups of children (from Montreal, Paris and Cambridge) were given a set of 12 cubes and asked to count them and then told that when another child counted he had found there were 11 cubes. They were asked "Do you think you are right, or is he right, or are you both right?" There was a difference between the groups in that the Parisian children initially claimed that both children were correct, a finding that the experimenters hypothesize was due to the emphasis in the French system for "getting along".

Summary

The evidence suggests that understanding of order-irrelevance develops with age. Success on novel counting tasks improves with age as does the ability to predict the outcome of counting in different ways. Both depend on the child being a fluent counter and confident in his own counting ability. Although Gelman and Gallistel (1978) state that the young child has implicit understanding of this principle Gelman and Meck (1986) concede that the development of procedural competence in these task probably sets in train further conceptual competence.

These studies raise some very important design issues concerning sample selection, method of presentation and instructions. An important distinction needs to be made between studies in which an "interactive mode" is adopted and one which purely "tests" the child. Whilst asking the child to give reasons for his answers could be construed as challenging the child, on the other hand it may bring about new insights and understanding in that the child is being encouraged to reflect on the arbitrary nature of a feature of counting. This experience may well bring about changes in performance and provide the child with cues as to how he should approach the task. Such indirect feedback is unavailable to the child under pure testing conditions. Additionally the ability to reflect may be further hindered by prolonged testing and when a greater variety of "odd counts" are presented. Such conditions are likely to result in a lowered performance. Researchers must also examine how they select their samples as there may be cultural differences in the way preschoolers respond.

2.3.5 *Abstraction*

This principle states that any items, both real or imaginary, or collection of items can be counted (Gelman 1982) and unlike other principles it has received relatively little attention either from Gelman and her colleagues or other researchers. In fact it has been referred to as the "step-child" of the family (Fuson 1988). In part this is because it is an arbitrary principle for if the other principles provide the child with guidelines for counting, this principle (together with that of order-irrelevance) provides a non-constraint to counting.

Evidence for this principle is provided by Gelman and Gallistel (1978) in studies requiring children to count heterogeneous items which children were reported as happy to do. Fuson (1988) also reports a willingness to count heterogeneous arrays. In these circumstances children may well take their lead from the instructions given and a useful distinction can be made between spontaneous counting and responding to instructions to count when items are presented to the child. Gelman (1980) found three and four year olds willing to count everything in the room but she reports that they spontaneously counted either the people or the objects and only when asked about the other things did they proceeded to include other categories of items.

Shipley and Shepperson (1990) suggest that children are largely guided in what they will count by the discreteness of the entity. For example when children were asked to count the cars they counted each physically separate piece of car although the level of success was improved when they were tutored. One explanation for this is that it constituted a novel task (Wynn 1990) and that a more usually encountered routine was to count the "pieces". Wynn (1990) further explored children's ability to count different types of array including "jumps" and "sounds" and found that children were least accurate in the most "novel" conditions. Indeed three of the youngest children did not count in any of the non-object conditions. This does not support the idea of an implicit principle that anything can be counted. If such an understanding existed it appears it would be limited to any physically discrete separate object. Fuson (1988) in fact argues that the term principle is not really appropriate in this context as it simply conveys a description of what children will count without providing the cues or guidelines expected of the term.

2.4 Conclusion

Taking the theory of Rochel Gelman and her colleagues as a framework, the preceding chapter has considered the evidence that children have implicit knowledge of a set of principles which guide them in the acquisition of counting skills. Although clear data is often lacking the bulk of the evidence suggests that in the extreme form this theory is incorrect. Instead the evidence points to the importance of developing procedures for counting. However a simple explanation of procedures first is also unsatisfactory. It is likely that at least for some aspects of the task, the child's performance is improved by a parallel development of understanding. An intermediate or mid-point position is consistent with this evidence as this would suggest that there is a mutual interaction between procedures and understanding although it must be noted that in the early stages of counting the evidence is most clearly weighted to the child having limited understanding. Rather than taking a purely global stance it is necessary to consider each of the underlying principles in turn in order to view the role of understanding.

The acquisition of a stable order in the production of number tags is consistent with a rote method of associative learning (Siegler and Robinson 1982). Well learnt portions of the sequence are produced consistently and are dependent on the formation of 'next' connections. Stable but unconventional portions of the child's count contain omissions and occur most frequently when children are required to repeatedly produce strings over a short period of time (Fuson, Richards & Briars, 1982). However, there is less evidence that these portions are characteristic over time (Wagner & Walters, 1982; Baroody & Price, 1983). Children need to be exposed to correct models of counting in order to perfect their performance. Without these models, repeated practice leads to the formation of incorrect 'next' connections.

Thus for stable-order it would appear that children start to acquire the procedures and quite quickly come to see the list as special. This understanding ensures that only count words are included. Children don't yet appear to understand that it is a stably ordered list nor that any list will suffice. These appear to be abstracted with time and as a function of experience (Saxe, Becker, Sadeghpour & Sicilian, 1989).

The acquisition of the one:one correspondance principle further highlights the interactive nature of understanding and performance. Larger sets elicit more count words (Gelman & Gallistel, 1978) but so do sets of heterogeneous items (Fuson 1988). Children's early understanding may well be limited to the idea that the more objects there are, or the more dimensions, more words have to be said. With time it would appear that this understanding is refined in some way so that every item has a word assigned to it. At this stage children are then able to detect the errors puppets make in certain contexts (Gelman & Meck, 1983; Saxe et al, 1989). However there are contrast between children's understanding and performance as evidenced by Briars and Secada (1988) reverse pattern of own errors to judged puppet errors. The demands of counting large sets clearly lead to errors which decrease the effort needed as children omit objects . A parallel response can be seen in younger children who skim over a set of objects. The greater propensity to produce flurries of number words without allocating them to individual objects suggests that in young children both procedural and conceptual understanding is lacking.Again therefore we see the development of procedures and an increasingly refined understanding of the principle. It is likely that at some point understanding outstrips performance and that this leads to the development of strategies to improve performance on large sets.

Children's pattern of responses to the "How many" question similarly suggests that cardinality is a principle which the child deduces over a period of time. The developmental pattern of producing a single incorrect digit, followed by recounting, and finally giving a single correct digit reveals the child's growing understanding of what is required. However even at the stage of giving a single digit correct response the child may still be limited to having acquired a rule- repeat the last tag. Unlike the stable order and one:one principles, set size does not appear to influence cardinality performance (Fuson, Pergamet, Lyons & Hall, 1985; Wynn, 1990; Fuson, 1988) despite the fact that cardinality must follow correct counting to be meaningful. In sum accurate counting on its own is not a necessary pre-requisite to being a last tag responder (Fuson 1988).

A consideration of the order irrelevance principle also reveals the partial nature of the preschool child's understanding. Until children link correct counting with cardinality and can make predictions on this basis their understanding may be said to be incomplete. It is at this point that there can be a match between conceptual and procedural competence. The ability to count correctly and repeatedly arrive at the same cardinal value facilitates understanding. Finally the evidence of implicit understanding of the abstraction principle is limited but children's unwillingness or inability to count in novel situations suggests that this too is learnt.

Throughout this chapter emphasis has been placed on the acquisition of procedures as a means of acquiring conceptual understanding of what it means to count. Two points of particular relevance to this thesis emerge. Firstly the environment must play an important role in providing support and opportunity for developing counting procedures which in turn support the development of conceptual understanding of what it means to count. Secondly we can refute the statement that preschool children are intuitive in their understanding of counting whilst children with severe learning difficulties develop only rote skills. Instead we can firmly state that the development of these skills can be viewed as an essential part of learning about counting for any child. It is within this context that we now examine the literature on counting in pupils with SLD.

Chapter Three

The Development of Early Mathematical Skills and Understanding in Pupils with Severe Learning Difficulties

3.1 Introduction

The literature on the development of numerical skills in pupils with severe learning difficulties is limited both in terms of the total number of studies undertaken and in the extent to which guidance is offered to the researcher or teacher. For this review extensive literature searches were carried out using the computer search facilities of the British Education Index, Exceptional Child, Psychinfo and ERIC in both 1988 and 1992. The key words used were Counting, Numeracy, Number Concepts, and Severe Learning Difficulties, Trainable Mentally Retarded, Moderately Mentally Retarded and Moderate Learning Difficulties. These searches yielded a total of 57 articles, many of which did not include empirical data but gave descriptions of the curriculum and information relevant to teaching number concepts to SLD pupils and were therefore excluded from the review.

In addition to the requirement that they include empirical data a further three criteria were formulated for including studies in the review. Firstly, the study had to include some subjects with an IQ under 50 and with the *mean* IQ for the total sample falling below 50. In this country these children would be referred to as having severe learning difficulties whereas in other countries this group may be referred to as having moderate or severe mental retardation (American Psychiatric Association 1987) or as Trainable Mentally Retarded (TMR) or Educable Mentally Retarded (EMR). As stated in Chapter One, current educational definitions of this group of pupils tend to use "curricular needs" (DES, 1978, 1981; NCC, 1989, 1992) as a defining criterion but this was not considered to be adequate for the present purposes. Secondly, the studies had to include school-aged subjects. Whilst the studies might not be confined to subjects aged two to nineteen years the sample would include pupils within this age range. Thirdly, the studies had to describe children's responses to specifically designed numerical tasks. In some instances these data was included in broader studies that extended into other developmental areas but the additional information is not included in this review.

Once these criteria had been applied, the remaining studies could be divided into three types:

* those concerned with investigating attainments in the area of number referred to here as *Performance Studies.*
* those which made comparisons between the performance of mainstream pupils and those with severe learning difficulties on number tasks referred to here as *Comparison Studies.*
* those which systematically tested the efficacy of intervention procedures referred to here as *Intervention Studies.*

These three types of study will be discussed in turn.

3.2 Performance Studies

Potentially, studies of attainment provide three types of useful information. First, they provide data on the range of achievements possible within a particular group of pupils. Second, they provide data on possible ceilings to development and some indication of the sequence by which tasks are achieved. Third, they identify factors such as mental or chronological age which influence the attainments achieved. Finally they have the potential to indicate at what ages or stages most learning is achieved and thereby indicate to the teacher the most profitable ages at which to teach number concepts and skills.

Nine studies in this category meet the above criteria. Table 3.1 provides summary details of their samples, investigation tasks and findings. Interestingly none of them were carried out in this country and therefore did not involve samples directly equivalent to the SLD population in the U.K.

3.2.1. The Findings

The earliest study in this group is rather different from the other eight as it investigates the discrimination of numerosity, a topic which has received relatively little attention among SLD populations. By documenting the responses of residents with severe and moderate learning difficulties to instructions to take out "a few", "a lot" or "most" beads from a tray, Silverstein, Auger, and Krudis (1964) showed that pupils were clearly discriminating between these descriptors by varying the number of beads selected from the tray. Interestingly, the children consistently demonstrated a (mis)understanding that "a lot" was more than "most" suggesting that at least some children with SLD are susceptible to the language used for instruction. As we shall see later the development of perceptions of numerosity have also been the subject of a small number of intervention studies.

Sequence and Ceiling

Seven of the nine studies provide data relevant to understanding the sequence and limits of attainment that one might expect from children performing in the SLD range. Spradlin, Cotter, Stevens, & Friedman 's (1974) study specifically set out to investigate the order in which the children acquired a range of "pre-arithmetic" tasks, including counting, numerical recognition, and numerical use. They found that children with PPVT scores in the range 12-50 succeeded on numerical use but failed on counting tasks. In this respect they behaved quite differently from typically developing pre-school children participating in a similar study by Wang, Resnick and Boozer (1971). Whereas Spradlin et al's study found that 62% of pupils could select a stated written numeral and 52% could read numerals, fewer than 45% could count or make sets of objects. In contrast, pre-school children in the study by Wang et al (1971) typically learnt to count before they use numerals. It is possible that this difference is accounted for by the school experiences of those with learning difficulties since older pupils in a study by McEvoy and McConkey (1991) showed similar levels of proficiency in recognising and naming numerals. Pre-school children therefore do not learn them first simply because the use of symbols is taught at school. The

Table 3.1 Performance Studies

Citation	*Sample*	*Tasks*	*Findings*
Silverstein, Auger & Krudis 1964	45 "resident patients" CA mean 14.7 years IQ mean 49.5	To take out from a tray of beads "a few" a lot" or "most" and put them in a bag. Trays contained either 25, 50, 100 or 200 beads.	Sample divided into 3 groups on the basis of their arithmetic age: 2.6-4.5, 4.6-6.5, & 6.6-8.5. The number of beads taken did not vary significantly with arithmetic age. The number of beads taken increased with the number in the tray although the percentage taken decreased. In order of the quantity taken- "a few" had least and "a lot" had the greatest number, with "most" falling between them.
Cornwell 1974	38 Children with Down Syndrome MA.10-5.10 years CA 5-19 years	Set sizes 1-7: Make sets Cardinality Count sets "name the correct number of objects"	No difference between tasks using blocks and keys, 1. Making sets gradually improved with age but never reached 100% 2. Lowest MA group could not count sets whereas those with the highest MA were 100% correct.
Spradlin, Cotter, Stevens & Friedman 1974	48 children PPVT scores 12-50, CA 8 years-15 years	Set Sizes 1-5: rote count to specific numeral, count sets, make sets, state, select, and match numeral, match numerals with sets, match sets with numerals, match sets with sets, match objects	Order of easy to difficult: match objects, use numerals, count subsets, count total sets, select numeral to show set size, count to specific numeral. Little difference in ability related to presentation of ordered and disordered arrays or if used pictures or real moveable objects. Memory appeared to play a significant factor in ease with which performed skills.
Baroody & Snyder 1983	15 TMR pupils MA 4.6-6.4 years CA 17-21 years IQ 30-47	Set sizes 1- 10 : rote count count sets cardinality abstraction make sets order-irrelevance N+1>N rule N after Addition Commutativity	80-100% Rote count to ten, enumerate sets to 7, has cardinality rule, abstraction principle, and order irrelevance. 20% or less could make sets up to 6, answer N after verbally, N+1>N rule, invent procedures other than count all for addition, use commutativity
Baroody 1986a	11 subjects IQ 33-49 CA 6.0-12.10 years, 2 subjects IQ 51 & 60 CA 5.10 & 6.9 years.	Set sizes 1-5: rote count, cardinality make sets 2-5, order-irrelevance finger representation	2/13 showed stable-order, rote count 1-3 to 1-24, 9/13 demonstrated understanding of cardinality 5/13 demonstrated understanding of order-irrelevance 2/13 largely successful in making sets 1-5, 6/13 largely successful in making sets with fingers.

Citation	*Sample*	*Tasks*	*Findings*
Baroody 1986b	36 moderately retarded 13 CA 6.0-10.10 23 CA 11.0-14.2 IQ 33-50 (plus mildly retarded sample)	Set Sizes 1- 10: rote count count by 10's count sets 2-10, make sets 2-10, cardinality rule 1-10, subitizing die patterns, finger representation 2-10, match sets 3-10.	For sets 1-5 77% could count sets 69% could represent sets with their fingers 62% knew cardinality rule for sets 1-5 and 54% demonstrated understanding of cardinality for sets 6-10, 23% counted to 29 38% could make sets 1-5, 31% able to subitize 38% demonstrated understanding of order-irrelevance with small sets and 31% with large sets. 23% matched sets 1-5 9% count by 10's.
Marx 1989	37 adults CA 19-70 years IQ 20-79 42 children CA 5 years +	Set Sizes 1-5: Cardinality tasks: answer how many sets 1-5, make sets 1-5. Ordinality tasks: indicate 1st, 2nd, 3rd etc out of a set of 5 both orally and by written symbol.	Adults: 86% of cardinal responses correct 39% of ordinal responses correct Children: CA 5-8 years : 47% on cardinality & 16% on ordinality. CA mean 11.8 years: 95% on cardinality & 44% on ordinality. CA mean 17.1 years: 94% on cardinality & 46% on ordinality tasks.
McEvoy & McConkey 1990	20 pupils with moderate mental handicap MA mean 4.1 years CA 12-17.5 years	Set sizes 1-20: count sets 2,3,5,9,12,14,20 Make sets 2,3,5,9,12,14, 20.	80% able to count sets 2 & 3 70% able to make sets 2 & 3. 0% able to count set of 20 5% able to make a set of 20. More accurate if counted aloud. Most frequent errors: in count sets - word-point,in make sets- too many number words
McEvoy & McConkey 1991	51 pupils with moderate mental handicaps MA mean 4.7 years (Leiter) 4.3 years (PPVT) CA 11.75 years- 18.25 years	Sets sizes 1-20, Numerals 1-85. Rote count, count on, count backwards, count in tens. Count sets, cardinality, make sets. numeral recognition reading, & matching to sets.	**Mean rote count** 1-32. Group A: counts up to 19- 15/51 Group B: counts up to 99- 28/51 Group C: counts to 100 + - 8/51 **Counting on** 2 digits from 8,9,10 : Group A: 40% Group B: 82% Group C: 100% **Counting Backwards**: knowing next digit 7,6,5,.. Group A: 60% Group B: 61% Group C: 88% **Counting in tens**: know next decade- Group A: 13% Group B: 22% Group C: 50% **Count sets**: 86-90% correct for small sets (2,3,5) 33-48% correct for large sets (9-20) **Make sets**: 85% correct for small sets 44% correct for large sets. **Make equivalent set**: 83% correct for small sets 27% correct for large sets

difference between the two groups would therefore be accounted for by the variation in experiences. Equally however the difference between the two groups could that pupils with learning difficulties learn more readily those number aspects which are essentially rote.

In addition to documenting the sequence of skill acquisition, Spradlin et al's (1974) main contribution was to draw attention to the possible role of memory in the performance of these tasks. Since their performance was poor when required to count to a specific number or to make a set of a designated number, pupils with SLD appeared to experience difficulty holding in mind a number whilst simultaneously either reciting numbers or counting a set . From these findings it could be suggested that the sequence of attainment is determined by the demands placed on memory and therefore explains why counting a set was found to be easier than making a set. This order of difficulty is also apparent in the studies of Baroody and Snyder (1983) and Baroody (1986a, 1986b) but it is not a uniform finding as the data provided by Cornwell (1974), Marx (1989), and McEvoy and McConkey (1991) does not show a similar superior performance of counting a set to making a set. One possible reason for this discrepancy may be the suggestion made by McEvoy and McConkey (1991) that the way children are taught to carry out the task may affect the child's level of accuracy. Children for example who are taught to move the object as they count a set may find the task of making a set very similar to counting a set and therefore achieve similar levels of accuracy. This again points to the importance of experience in determining a pupils achievements.

An examination of the achievements of the top 20% provides an indication of the likely ceiling for the majority of pupils in SLD schools. The data from three different studies by Baroody and his colleagues suggest that only a few children will be able to count in 10's (Baroody 1986b), make sets beyond 6, answer verbally what number comes after N, invent ways of adding (other than count all) and know the N+1 >N rule (Baroody & Snyder, 1983). Similarly data provided by McEvoy and McConkey (1990) supports the claim that pupils have difficulty in counting in tens and in making larger sets. These aspects have quite important implications for the development of money skills. Being able to count in 10's, being able to count on and knowing which amount is larger are fundamental to any shopping activity.

Looking at the same data a different way we can examine the attainments of the top 80% of pupils which provides an indication of what the *majority* of pupils (as opposed to those who excel) are capable of achieving before leaving school. Data from the study by Baroody & Snyder (1983) suggest that this includes the ability to rote count to 10, count sets up to 7, and to demonstrate understanding of the cardinality rule, abstraction principle and order-irrelevance principle. It would seem therefore that pupils with severe learning difficulties attain a mixture of skills *and* understanding by the time they leave school. At this point there appears to be no simple explanation for determining what children acquire before leaving school.

Before turning to examine the nature of the child's understanding of mathematical concepts it is interesting to consider the limitations in the attainment of skills. Why for example, are the majority of children only able to count to 10 ? Equally why are so few children able to count in 10's or to give the next digit in the sequence ? Fuson, Richards and Briars, (1982), suggest that being able to move freely up and down the number string is an important skill in its own right. It enables the child to develop such procedures for addition as being able to count on- a strategy that few SLD children would seem to use. Whilst it appears that these are all acquired skills the relationship between the count sequence and other higher-order skills has only been explored with reference to pre-schoolers (Siegler & Robinson, 1982). Thus the SLD child's failure to develop further may be because of specific difficulties in some aspect of learning this skill or it may be due to limited opportunities for practice, or a combination of both.

Pupils Errors

Pupil errors in counting, as shown in Chapter Two have provided a rich source of data from which to understand the way children progress in this domain. Analysis of this type can be problematic however, as the presence of errors may be taken both as evidence of procedural difficulties and as indicative of limited conceptual understanding. If, however, children with SLD experience particular difficulties one might expect that the profile of errors might differ from mainstream.

Only one of the nine studies systematically examines the errors made by children with severe (and moderate) learning difficulties. This study by McEvoy and McConkey (1990) revealed both similarities and differences between these pupils and normally developing preschoolers. They found that when counting sets the most frequent type of error for their sample of children with moderate learning difficulties was "word-point". These occur when a child does not perfectly co-ordinate saying a number word and pointing to an object. They may for example occur when the child points but omits to say a number word or when each point corresponds with only part of a number word. In procedural terms this might reflect a difficulty of simultaneously carrying out two acts, a verbal and motor act. Equally it may reflect an incomplete understanding of the one:one principle. Data provided in a series of studies by Fuson (1988) and her colleagues suggest, in contrast, that word-point is not the most common form of error made by preschoolers. Young children are more likely to show point-object errors . McEvoy and McConkey (1990) suggest that their pupils are more likely to say too few words when they count and preschoolers too many. It must however be noted that this error-type frequency relates primarily to counting sets and Fuson differs in her methodology from McConkey and McEvoy (1990), in that she uses increasing rows where the experimenter adds on a brick for each count demand.

An error type that was common to both pupils with severe/ moderate learning difficulties and preschoolers was that of recounting objects in the set. This could be seen as a difficulty in remembering those items which have already been counted or again as faulty, or non-understanding of the one:one principle.

When making a set children with learning difficulties encountered other problems. Quite often they counted in handfuls or used more number words than objects. There was also a high frequency of non-stop errors where the child continued counting past the designated number (McConkey & McEvoy, 1990). While the latter aspect could be related to memory, the other characteristics are reminiscent of Wynn's (1990) "grabbers". These were children who she felt did not understand the cardinal count transition and therefore made no attempt to systematically count objects in order to make a set.

Evidence from children's errors is therefore inconclusive. There is data which supports the notion of children having particular difficulty in recalling sufficient count words but this is the result of a single study by McConkey and McEvoy (1990) which uses a slightly different methodology to Fuson (1988). The source of the error may however lie not with a procedural difficulty but with children's understanding. It is to this area which we now turn.

Understanding of Principles

So far, this discussion has centred on skills attained by pupils with SLD, rather than on their understanding. Adopting the notion of principles as expressed by Gelman and her colleagues, Baroody and his colleague (Baroody & Snyder, 1983 ; Baroody 1986a, 1986b) have also investigated some aspects of understanding in their studies. Understanding of cardinality is tested consistently across studies by the "Hidden Stars" test. The child is invited to count aloud a set of stars and informed that when he has done so, the experimenter will hide the stars and ask him how many there are. A couple of practice trials ensures that the child understands this procedure. Repeating the last tag used (independent of accurate counting) is the criteria for a correct response. Understanding of order-irrelevance is assessed by first asking the child to count a set and then to predict the outcome of counting a different way- either in reverse direction or starting with a middle object. Understanding is further checked by the addition of an extra brick on some counts. Thus, both order-irrelevance and cardinality are tested by quite strict criteria. Two further principles are investigated in single studies. The stable-order principle is included in one study (Baroody, 1986a) and is credited providing the child does not recycle portions of the count, or repeat a numbertag in close proximity. The abstraction principle (included in Baroody & Snyder, 1983) is credited providing the child counts all of a mixed set of objects.

Given the types of task used to measure this understanding, it would appear that there is some evidence that pupils are reasonably successful in demonstrating their understanding of cardinality, abstraction and order irrelevance. Baroody and Snyder (1983) found that between 80-100% of their older aged sample of pupils and young people with SLD understood the cardinality rule, abstraction principle and order irrelevance and that 9/13 younger pupils understood cardinality for sets 1-5 and 5/13 understood order irrelevance (Baroody, 1986a).

There is however far less conclusive evidence that they understand the stable-order principle. For example only 2/13 younger pupils demonstrated understanding of this principle in their own counts (Baroody 1986a) as judged by the presence of stable unconventional portions to their counting string. This finding is in-keeping with the arguments made previously with regard to pre-schoolers in Chapter Two, namely that young children are unlikely to be guided in their acquisition of the number string by the stable-order principle.

Another issue which arose in relation to pre-school children was the question of whether understanding the principles of counting was likely to be subject to set size differences in the same way as skill based aspects of counting. Data from Baroody's (1986b) study supports the view that SLD children respond in the same way as preschoolers. 62% demonstrated an understanding of cardinality with small sets and 54% with large sets, and for order-irrelevance 38% demonstrated understanding with small sets and 31% with large sets. Thus it would appear that SLD children are capable of acquiring at least some of the principles of counting.

Obstacles to Understanding - The Case of Brian

Clearly not all children with severe learning difficulties are able to understand the principles of counting and there are clearly many reasons why this should be so. As noted earlier Spradlin et al (1974) suggested that many children with severe learning difficulties experience particular difficulties with counting tasks that placed demands on working memory. Baroody and Mason (1984) further investigated this possibility in a case study of a child who still had to make the transition between counting to simply enumerate and counting to make sets. The authors provide an account of the responses made by Brian to a variety of counting tasks which are designed to reveal whether the pupils difficulty is procedural or conceptual.

In this study Brian's task is to produce subsets from different size sets. Typically, when presented with this task he counted beyond the required amount- a "no stop" error. Baroody and Mason distinguish between two possible explanations of this difficulty. Firstly, they suggest that Brian might not be able to keep in mind the target number. Secondly that, due to the demands on working memory to actually carry out the count process, there is no available capacity to simultaneously match the target number to the count number being processed (which the authors refer to as a "matching failure"). One might hypothesize that the latter difficulty would be more common in pupils for whom the count process was not yet fluent and it is notable that both Brian and another child Baroody and Mason describe appear not to have fully acquired the conventional number-word sequence.

Brian is also required to carry out two tasks where the procedural demands are apparently reduced. Firstly, he has to predict the outcome of counting having been told the number of objects and secondly, he is asked to stop a puppet counting when he has reached the target number for the set. Unfortunately the results of the study are not clear-cut. When asked to predict the outcome of counting, he recounts which may be taken as uncertain understanding of the question in much the same way as it has been argued that pre-school children see the question "how many" as a command to count. His response to the puppet counts was equally mixed either being inattentive, incorrect or on one occasion correct.

Although the authors conclude that the information they obtained from Brian points to a conceptual deficit, their evidence is by no means conclusive. They could for example have provided an easier task which would have provided evidence of procedural difficulties without demanding any conceptual understanding by for example, requiring Brian to rote count to a target number. Successful execution of this task would show that the child's difficulties were not processing difficulties. The study by Spradlin et al (1979) suggests in fact that SLD children often experience difficulties with both tasks although there can be no conceptual aspect to rote counting to a specified number other than understanding the question. The difficulty with pupil co-operation makes an additional problem in judging this study.

Predictors of Success

Most studies which report individual rather than summarised data reveal considerable variation in attainments among the SLD pupils studied (e.g. Baroody, 1986a) with only the top 20% approaching the levels acquired by normally developing preschoolers. The key question must be- why do some children acquire these skills and understanding and others don't ? One possibility is that development is dependent on some global level of cognitive ability (as measured by mental age or IQ), another that it depends on the range of experiences and the obvious third that these factors interact. Therefore we need to ask are children who succeed, brighter, older or have a higher mental age ? Have they received optimum experiences for development in this domain or are there particular children who benefit from particular experiences ?

Distinguishing between these factors is not easy. Children who are chronologically older are more likely to have a higher mental age. Similarly individuals with a higher IQ are also likely to have a higher mental age. Simple correlations between one of these factors and children's ability to perform counting tasks can be misleading . None of the attainment studies include statistical analysis where one or more of these variables are held constant. Recognising these limitations however several studies do indicate the probable importance of both cognitive ability and experience in predicting success.

With regard to MA, Baroody (1986a) for example draws the conclusion that "even mentally handicapped children with a MA of less than 4½ years can learn basic counting skills and principles" but equally found that his sample of moderately retarded children were skilled in only four out of ten aspects that pre-school children are "typically" able to complete (Baroody 1986a). One of the riders he gives in predicting attainments is the assumption that there are no additional emotional difficulties. Interestingly none of the performance studies include comments on the emotional state of their sample.

With regard to IQ, whereas five out of the nine studies define their sample with reference to IQ, only one makes specific reference to the relationship between counting ability and IQ. Baroody (1986b) notes that IQ is not necessarily an accurate predictor. He makes this comment on the basis that there was overlap between the attainments of his samples of moderately and mildly handicapped pupils. Some of the pupils in the moderately handicapped group out performed those within the mildly handicapped group. None of the studies however includes a systematic testing of the relationship between IQ and counting ability although McConkey and McEvoy (1991) found that good counters achieved higher scores on the PPVT (and were significantly older).

Studies which include samples representing a wide age span suggest that there is improvement with age (Cornwell, 1974; Baroody, 1986b; Marx, 1989) but many point to limitations in the progress made. Cornwell (1974) for example concludes that achievements were made in only rote aspects of the task. Similarly, Marx (1989) shows that although on some measures there is overall improvement, there is limited progress between the age of 11-17 years. Further support for a possible decline in pace of learning is provided by Baroody (1986b)'s data where oral count was found to be the only skill which showed significant improvement between the elementary (6-10 years) and intermediate (11-14 years) groups.

In spite of the findings just mentioned there is also some suggestion that the type of experience has an important to role to play in the attainment of skills and understanding. Baroody (1986a) when indicating the poor response made by his sample with learning difficulties compared to the average pre-schooler does recognize that the informal experiences received by the two groups may not be comparable. Additionally Marx (1989) proposes that one reason why all his subjects appear to do so much better on cardinality than ordinality tasks may be familiarity. Both adults and children are reported to be more accurate at counting and making sets than at indicating the ordinal position of an object either verbally or non-verbally. The extent of this difference however is unclear from the available data.

3.2.2 Summary

In summary the attainment studies reviewed in this section reveal that :

* Children with severe learning difficulties do not seem to attain all the skills and understanding of pre-school children.

* acquisition is not limited to rote aspects

* there is a considerable range in the achievements of individuals with severe learning difficulties.

* it is unclear what predicts the successful acquisition of skills and understanding, IQ, mental age, chronological age or experience.

* it is also unclear what impedes further development- a lack of understanding, or particular procedural difficulties.

3.3 Comparison Studies

In the previous set of nine studies, comparisons between the performance of children with SLD and preschoolers were incomplete in that they drew on data provided by independently run studies. In the present section we turn to studies which were specifically designed to compare preschoolers and SLD children. An outline of the three studies is presented overleaf in table 3.2.

3.3.1. *The Findings*

In the first study, by Thurlow and Turnure (1977) an impressively large sample of 115 Trainable Mentally retarded (TMR) pupils are assessed on their money skills together with a sample of Educable Mentally Retarded (EMR) and four groups of mainstream children. It is unclear exactly how the groups were matched but it would appear that the EMR and TMR pupils are the MA peers of kindergartners and that the third-graders were equivalent in chronological age to the EMR pupils. Elsewhere, we learn that in fact the TMR group had MAs "slightly below" that of the kindergarten children and were unsurprisingly "slightly below" the kindergarten pupils in their performance on money skills. Testing is followed by intervention with the TMR (and EMR) pupils and their increased scores again compared to mainstream. This time performance was seen to be "just above" the mainstream children. Whilst the message of the authors appears to be the power of intervention to lift the performance of TMR pupils towards that of their mental age counterparts it is notable that the few items concerned with counting showed little improvement. This may have been because the TMR pupils did not reach this stage of the intervention, the reporting does not make this clear.

Two studies, both comparing normally developing children to children with Down syndrome, also meet the criteria set. In the first study, Gelman and Cohen (1988) investigates children's ability to carry out a "constrained counting task". This is identical to the novel counting task described in chapter two, in which children are asked to count by giving a specified object a target number in the sequence. Through this unusual task children can demonstrate their understanding of the order-irrelevance principle. Eight of the ten pupils with Down syndrome in Gelman's study had great difficulty with this task whereas the remaining two proved to be "excellent counters" and in many instances outperformed the mainstream children. In their description of the performances Gelman and Cohen (1988) emphasize the number of different strategies developed by the pre-school children and their propensity to self-correct

Table 3.2 Comparison Studies

Citation	*Sample*	*Tasks*	*Findings*
Thurlow & Turnure 1977	115 TMR CA mean 14.5 years IQ mean 42.5 [64 EMR IQ mean 71.1] 117 non-retarded children in kindergarten, 1st grade, 2nd grade 3rd grade.	Assessed all three groups on 40 money skills, including some counting items as well as money knowledge, equivalence, making change. Gave TMR [&EMR] instruction over 12-20 weeks largely based on language and vocabulary of money in 4 books.	On first assessment non-retarded correctly answered between 40-82% of items, TMR answered 23% [& EMR 35%]. After instruction TMR answered 42%- "just above that of MA peers". [& EMR increased to 64% of items] . If look at counting items TMR appears to be still below that of MA peers.
Gelman & Cohen 1988	10 Children with Down syndrome. M.A. 4 years- 6 years 10 mths (median 5.8) CA.10-13 years (median 10.6 years) IQ circa 43-73 16 preschool children CA 4 years 16 pre-school children CA 5 years.	Set sizes 5 & 8. Constrained counting, DS Group: 1. Count set 2. Make 2nd, 3rd & 4th item number 1. 3.Make target item number 2. Pre-schoolers: half as above others had same target item to make 2,3,4 etc.	Two children with DS outperformed all children- near ceiling level. Both pre-school groups better than remaining children with DS. Also 4 year olds made more progress over trials as result of "hints". Generalised from x=1 to x=2 trials, DS appear not to, although learning effects appear in x=3. DS group with fewest self-initiated recounts.
Caycho, Gunn & Siegal 1991	15 Children with Down syndrome MA 4 years 7 mths (PPVT-R) CA mean 9 years 7 mths IQ 40-60 15 pre-schoolers: MA 4 years 7 mths (PPVT-R) CA mean 4 years 6mths	Sets sizes 1-8. Error Detection: puppet counts with stable order, cardinality and 1:1 errors Self-Performance: Count sets 5, & 8, Make sets 4. Modified Counting Task: Count set of 5 starting with 3rd and 4th item in array.	Error Detection: No significant difference between 2 groups. Self-Performance: No significant difference between the 2 groups. 22/30 correct on count sets, 13/30 correct on make sets. Modified Counting Task: No significant difference Correlations to MA: Count scores and error detection . If partial out CA only count scores.

when they made an error. In contrast, the children with Down syndrome failed to benefit from hints, including demonstrations and showed limited strategies. Gelman & Cohen (1988) conclude therefore that in a number of ways children with Down syndrome, unlike the mainstream pupil, show evidence of only rote learning. They are unable to generalise their counting skills to generate new solutions to a novel task.

The study by Caycho, Gunn & Siegal (1991) represents a broader, more carefully designed attempt to compare performance on a range of self-performance and error-detection tasks. Children were required to watch videos of a puppet counting sets, on some of which he made stable-order, cardinality and one:one errors. The child's task was to detect error trials. In addition they were required to count and make sets and to carry out a similar modified counting task to that of Gelman and Cohen (1988). Following a demonstration the child was asked to count a set of five objects starting with the third object in the array and then with the fourth object. The most striking aspect of their findings was the lack of statistical difference between the two groups, across all categories of task. The conclusions of Caycho et al (1991) are antithetic to those of Gelman & Cohen (1988). Caycho et al conclude that children with Down syndrome are capable of being guided in the acquisition of counting principles in the same way as pre-school children.

In these studies one might have expected to find that mental age correlated highly with all aspects of performance as no differences had been found between these two groups and they had been matched on this basis. However the interactive nature of mental age and experience was revealed in the fact that whilst mental age correlated positively with both error detection and counting scores, once chronological age was partialled out the relationship was confined to counting scores. Calculated the other way, correlations of chronological age with the effect of mental age partialled out, revealed that chronological age was only positively correlated with the ability to count sets.

One possible reason for the disparity in the results of the study by Gelman and Cohen

(1988) and that of Caycho et al (1991) may lie with the method of matching. Whilst Caycho et al matched their sample on a Picture Vocabulary Test, Gelman and Cohen claimed to match their samples on counting ability. Unfortunately however each group in the latter study was not asked to perform exactly the same pre-test. Whilst the Down syndrome children proved their proficiency in counting sets and giving a cardinal response, the mainstream pupils were required to make sets. Given the previous discussion it is quite possible therefore that these two groups were not in fact matched at all and therefore would not necessarily perform at the same level.

3.3.2 *Summary*

The three studies reviewed in this section are almost impossible to summarise. The first study suggests that intervention can improve performance, possibly to a level commensurate with mental age although it is unclear whether gains are made in some areas more easily than others. As for the remaining two studies, differences in the sample selection make it impossible to be sure whether children with Down syndrome differ from their mainstream counterparts or not. As with the attainment studies however there is further evidence of variability even with a single etiology.

3.4 Intervention Studies

The intervention studies vary considerably in their scope, focus and adequacy of design. Some nine studies fall within this category and the summary details can be seen in Table 3.3. Typically these studies have been rather small scale with six of the nine studies providing fewer than 10 children with training. Although most studies do provide some form of baseline and post-intervention information, the level of detail varies considerably and only a very few provide evidence of maintenance and generalisation. In the better designed studies, effectiveness has been measured by comparison with a control group which receive the same number of hours of other non-arithmetical intervention, alternative mathematical intervention, (Baroody & Ginsburg, 1984; Baroody, 1988a), or the "usual" method of teaching the same skills

(McConkey & McEvoy, 1986; McClennen & Harrington, 1982). Alternatively one study has used multiple-baselines (Young, Baker & Martin, 1990).

In some studies the intervention was individually devised so that pupils were being taught skills according to their profiles of attainment. This rather diagnostic approach to intervention was recommended by Baroody (1986b). For the most part it is difficult to assess the key elements of effective intervention.In some cases the descriptions of the intervention used are so vague that it is unclear exactly what was done. In others, the methods used are reasonably precisely described but there is no underlying rationale provided. Intervention ranged from 4-45 hours but the majority of studies appeared to favour about 15 hours spread over approximately 6 weeks. With the limited nature of the available literature one can do little more by way of an overview than to isolate three emerging themes.

3.4.1 The Use of Games in Intervention

One of the strongest themes to emerge from intervention studies is the introduction of games to bring about new learning. Four studies provide training in this way (Baroody & Ginsburg 1984; Baroody 1988a; Baroody 1988b; McConkey & McEvoy, 1986). A rationale for this approach is provided by McConkey and McEvoy (1986). In their view, games meet certain identifiable criteria for training: the tasks are fun and meaningful; they provide an appropriate level of difficulty; very often they provide a natural context for giving a model (as one player shows the next what to do); lastly they provide an appropriate context for giving support in the form of tips and encouragement. Elsewhere, Baroody (1986b) reiterates that practice " should be in a meaningful and interesting context (e.g., a game) and should be accompanied by explicit instruction." p298. However it is not clear whether the use of games has developed primarily as a way of motivating individuals to learn and gain repeated practice or whether it is a method which has been seen as leading to increased understanding.

Table 3.3 Intervention Studies

Citation	*Sample*	*Intervention*	*Findings*
Brown, Bellamy & Gadberry (1971)	4 TMR students CA 18-20 IQ 31-39	Task: discriminate between arrays of 1-5 Generalise to new items Method: group teaching with praise for correct response. Demonstration for incorrect + request to count objects. Duration: Until all reached criterion of 3/3 correct on all five set sizes	Took 72 teaching & measurement trials of 15-20 minutes in total. Took 39 trials on first type of objects, then 10 trials to generalise to 2nd type and a further 7 to generalise to 3rd type.
Thorley & Woods 1979	8 pre-schoolers with Down syndrome CA 3.5-5.2 years	Tasks: Up to 38 "Minimal objectives in Number" involving counting and numerals up to match set with symbol 1-10. Method: To teach count and numeral items concurrently, with items broken down into smaller sets. Rote count accompanied by clapping etc, counting modelled and pupils praised. Duration: 54 individual sessions of approx 5-10 minutes over 23-26 weeks.	1/8 reached criterion on all items before programme started. Others ranged from acquiring 1/38-30/38 items. Mean gain was 12. Errors: skipped object and double counted object as a result of partitioning difficulties. Rate appeared to depend on previous teaching. Those without (4/8) took minimum of 10-18 sessions to master first objective and one child took 46-54 sessions.
McClennan & Harrington 1982	12 severely retarded CA 15-25 years IQ Below 30 Divided to form: 6 experimental group 6 control group	Tasks: Derived from a curriculum of 47 hierarchical, functional skills divided into A) Perceptual Correspondance - 16 levels demanding no communication B) Numerical Correspondance - 31 levels Method: uses "careful cueing so that the correct actions are performed" p27 and includes games to provide practice that will ensure speed, accuracy & generalisation. Duration: 15 minutes 2-3/week for 6 weeks.	Experimental group gained a total of 12 new skills, averaging 2 new skills each Control group gained 6 new skills averaging one new skill each. Errors:- "no-stop" syndrome where student continues until all materials used. Inability to generalise to count items arranged randomly.Show me... produced more errors than give me. "one" confusing so repeated noun, "enough" not understood so used "no extras". No relationship between the ability to identify a symbol and its functional use.

Baroody & Ginsburg 1984	46 TMR CA 6.0-14.1 years IQ 33-50 [74 EMR CA 5.10-13.3 years IQ 51-78]	Given pre-test and those unable to count to 40 paired and assigned randomly to experimental and control groups. Tasks: individualised Method: Experimental group given games in " deficient" skills. Control group given other instruction in IEP objectives that were unrelated to counting. Duration: Each pupil given 11 hours of instruction over 7-8 weeks.	TMR subjects improved on 4/5 counting scores and retained their learning better than EMR although latter made greater initial gains. In general training was not successful in leading to transfer. 4/26 pupils made good progress in their ability to count in 10's. Enumeration of large sets much less successful with TMR than EMR. Training did not result in learning the order-irrelevance principle or equivalence. Success not dependent on MA.
McConkey & McEvoy 1986	35 Moderately mentally handicapped. CA 9-18	Task: "How many" and "Give me" for set sizes 2-20. Method: 24 students experimental group played games & 11 control students provided with the usual teaching. Duration: six weeks	Control group made no progress. Experimental group- average scores rose and so did those of both the lowest and highest in the group. Teachers reported greater confidence.
Baroody 1988a	24 students CA 6 years 10 mths- 20 years 10 mths. IQ 31-49 6 students IQ 52-66	Task: mental arithmetic of adding 1 and adding 0 to N (1-10) Method: Experimental given games involving additions given with symbols and a range of supporting items e.g. dice dots, abacus. Control- tutored on non-arithmetic aspects e.g. tell the time, coin recognition. Duration: 51 sessions of 20 minutes over 20 weeks.	Experimental: 5/9 learnt N+0 4/11 learnt N+1 Control: 1/13 learnt N+0 0/13 learnt N+1
Baroody 1988b	21 pupils MA 3.67 years- 6.75 years CA 6.33 years- 20.33 years. IQ 37-74 (WISC-R)	Task: Number comparison of numbers 1-10 Method: Experimental Group received a sequence of games for making gross comparisons, number after 1-4 and 5-9 and comparisons of 1-5 some of which involved explicit feedback and praise and some drew attention to the count sequence. Control Group were given unrelated maths games. Duration: 54 sessions of 20 minutes over 21 weeks.	Experimental group outperformed controls on both immediate and delayed post-test on trained number pairs. 2/11 did poorly on all tasks. No significant improvement was made in small number neighbour comparisons but small gains made in gross comparisons. In the first post-test pupils were able to transfer some learning.

Young, Baker & Martin 1990	5 pupils: CA 8-10 years IQ 35-54 (WISC-R)	Tasks: counting, recognition of numerals & numerosity, number recognition. Method: Comparison of Distar to discrimination learning theory (DLT) based on error-less learning, match to sample, sequencing and feedback. Duration:30 minute sessions (during which individual received 10 minutes) 3 days/ week for 26 days.	Both academic engagement and mastery level higher in DLT than Distar. DLT - engagement levels increased with group size, Distar -highest level when group of 1. 4/5 subjects increased engagement level by 40%+. Distar- average mastery levels 18-73%, DLT- levels 69%-96%.
Vacc & Cannon 1991	4 pupils with moderate handicaps CA 6-12 years IQ 35-50 (WISC-R)	Task: Identifying month, date, naming days of week, rote count, count 10 objects, identifying number words 1-5 and matching them to symbols. Method: Peer tutors trained for 30 hours in signing & behaviour management, making materials. Included practice with non-target children & recording Duration: tutored for 30 minutes a day, 4 days a week for 6 weeks	Assessed through attitude questionnaires and observation of performance during last three sessions. All areas improved for all subjects. Positive feelings reported by tutees, tutors & teachers. Follow up 2 years later, not all areas maintained: 3/4 subjects less able to identify number words, 2/4 less able to match numerals.

Baroody and Ginsburg (1984) compare the use of games to no instruction as their comparison group receive an equal amount of IEP instruction on non-number objectives. Despite the use of the word "objectives" it appears that the purpose was to increase both skills and understanding. Instruction was provided for a total of 11 hours over 7-8 weeks and resulted in the TMR group improving to a significant extent on four out of five counting tasks when compared to the control. Moreover they report that this group (unlike the EMR group) maintained their gains on follow-up although transfer was limited. Given that the transfer tasks involved sets of a much larger size this is perhaps unsurprising. The TMR group were less successful in counting larger sets although some did learn to use counting for mental arithmetic. A few made gains in counting in 10's. Limited gains were made in other areas including order-irrelevance and equivalence. It might appear that some areas of understanding were less amenable to intervention of this nature and duration. Equivalence depends both on the ability to make sets and the knowledge to use counting as a strategy. It has also been argued previously that an understanding of order-irrelevance is the last principle to be acquired. It is also possible that games training facilitates skills rather than understanding.

McConkey and McEvoy (1986) also provide evidence for the effectiveness of games by making comparisons between the progress made by a group who receive games and another who receive the "usual" instruction. Intervention lasted 6 weeks. The data is provided in graph form in a way that makes any conclusion impossible other than a general one that the experimental group improved on both counting and making sets whereas the control group made no progress. It would appear from their criterion for measuring success, that the purpose of their study was to increase skills rather than understanding.

Two rather more ambitious studies have been carried out by Baroody (1988a, 1988b). The first study (Baroody, 1988a) lasting 20 weeks, aimed to develop mental addition through the use of games. The children were atypical in the sense that they were screened to ensure the ability to discriminate between numbers of increasing size, to make sets to 5, to count sets 1-12 and to read numerals to 10. From the performance studies this would appear to be a sample whom one would place in the top 20% of the SLD population. The games required the child to add two numbers which were presented simultaneously through symbols and sets. The experimental group were presented with these pairings in different forms, starting with sets in the form of dice dots, then blocks, then an abacus and lastly encouraged to use their fingers. These calculations were a pre-requisite to moving their "counter" towards a goal. The control children were tutored on non-arithmetical aspects such as telling the time. The targets were individualised and this is reflected in the reporting of results with five out of nine children learning to add where one number was zero compared to one of the thirteen control children. Four out of eleven children learnt to add 1 whereas none of the control children did. Baroody argues from this data that the successful pupils deduced a rule for adding zero and one, rather than relying on memory. Clearly even given the insurance of good entry skills not all children are capable of deducing this rule as a result of this kind and length of training.

The second study by Baroody (1988b) involved a similar sample learning to compare numbers through acquiring the rule that the number which comes after is the larger. Again a series of games were used to instruct subjects over a 21 week period. As before pupils were screened before entry to the study and divided into two groups with the control children receiving IEP training. The experimental group made significantly more gains than the control group in the ability to compare small numbers (1-5), a finding which was evident both immediately following training and some 12 weeks later. Interestingly he found that IQ did not predict success either in the acquisition or maintenance of understanding. Whilst children appeared to benefit from training in acquiring and applying a rule to small numbers this did not transfer to use with larger numbers. Baroody comments on the fact that many children did not achieve "automaticity", that is they took their time to respond and it may be that a more fluent level of responding is required before transfer.

To summarise so far, it would appear that games can be successful in leading to the acquisition of counting skills but have had a more limited impact on acquiring rules despite in some cases pre-selecting quite competent children. Improvements of skills in counting have been demonstrated after six weeks of practice, less successful intervention leading to the acquisition of rules spanned 20-21 weeks. In many cases however we have no clear idea of how many hours have actually been spent in game playing.

3.4.2 Mechanistic Approaches

A second less prominent theme relates to the type of teaching approach adopted with some intervention studies providing evidence of the efficacy of using more overtly mechanistic forms of teaching. For example, an early study by Brown, Bellamy and Gadberry, (1971), utilised reinforcement and modelling to teach the discrimination of numerosity. Students were trained to select the numerically correct array using sets of 1-5 objects. It took some 40 sessions of between 15-20 minutes to achieve this using one set of objects and a further 10 sessions to generalise it to a different set of objects. Such approaches do much to recommend those utilising games!

Almost two decades later a study by Young, Baker and Martin (1990) demonstrates some of the developments in these intervention principles in which demonstration and reinforcement are combined with errorless methods based on discrimination learning theory. Other than indicating the inclusion of matching to sample, the precise intervention details are lacking. The study aims to compare these combined method to those used by Distar to develop counting, numerosity and recognition of numerals. The study does provide clear descriptions of the procedures for comparing with the Distar control group nor for the frequent measurement of responses. The data is collected and reported in a way that provides evidence for superior engagement levels (which they acknowledge may in part be due to the novelty of a new approach) and for an increase in the number of skills attained although it is still unclear exactly what has been learnt. They conclude that the essential elements leading to success are the removal of the need for a verbal response, a group model and yet individualisation.

Interest in the approach to intervention rather than the content is also apparent in the study by Vacc and Cannon (1991). This utilises peer-tutoring to develop number skills. Twelve hours of peer tutoring was provided almost daily over a six week period following some 30 hours of tutor training. The pupils were taught a range of tasks including rote counting, counting objects, identifying number words and matching them to numerals. Details of the methods used by the peer tutors are not reported. A significant portion of the evaluation concerns the feelings of trainees, tutors and the trainees teacher. This is supported by assessment of skills during the last sessions of intervention and some two years later. Whilst there was progress made in all areas by all subjects, perhaps unsurprising not all gains were maintained. For three out of four subjects the follow-up revealed that they had lost their skills in identifying number words and two out of the four had lost their gained ability to match numerals. Interestingly these are both areas which require no numerical knowledge or understanding.

It would appear that mechanistic approaches to intervention place little emphasis on the nature of the skills to be acquired. Prime importance is given to the methods used at the expense of examining the content of teaching. Taking the common aspects of the studies, success seems to result from intensive repetition and the use of reinforcement.

3.4.3 Curriculum-Based Studies

The final two studies are more overtly curriculum based with the details of the subjects and of their progress overshadowed by discussion of the appropriate skill content. The reader has therefore to guess the ability levels of the sample of 8 preschoolers with Down syndrome in Thorley and Woods (1979) study, and to deduce why data is provided on these 8 rather than the other 12 youngsters also receiving the programme. The authors make a strong case for teaching number skills to such young children because of the nature of the task. They argue that the added difficulty of learning both the symbol system and the referent make it a harder task than reading and thereby justify its inclusion in a preschool programme. It would appear that the actual methods used were developed with experience rather than by design but the curriculum objectives included the development of both numeral use and counting concurrently. Two aspects of data are striking. Firstly the apparent levels of attainment of some youngsters suggest that here too there were "excellent counters" including a child who would clearly surpass his peers of the same age. Secondly, however is the wide range of both attainment and speed of learning. One subject for example learnt a single item in the 6 month period. Whilst others made better progress it must be remembered that four of the eight pupils had already received some instruction prior to the programme.

The data provided in a study by McClennan and Harrington (1982) to support the use of their curriculum is even more cursory and is perhaps unfairly included in a section providing research data. Like Thorley and Woods (1979) the emphasis appears to be on providing support for their checklist for teaching, which the authors rather ambitiously describe as hierarchical and developmentally based. The curriculum has resulted from interactions with 72 pupils with moderate and severe learning difficulties or autism and the authors have concentrated on functional contexts for teaching pupils who in some cases have either very limited or no communicative skills. It contains 47 items divided into two scales- perceptual correspondence and numerical correspondence. The perceptual scale is based on matching items so that the child is able to operate without language or counting to the point of being able to create sets of one and many. The second scale does require communication but this might be achieved through sign, symbol or electronically. It includes seriation, addition, subtraction, multiplication, division and conservation. Using small samples the authors suggest that this curriculum has resulted in a doubling of the skill acquired although the provision of averaged data preclude us from knowing whether this is attributable to the success of particular individuals within the group with some making no progress or it is due to a curriculum which is appropriate for all.

In providing "useful" guidelines McClennen and Harrington (1982) comment on strategies to cope with such behaviours as the "no-stop" syndrome, where pupils carry on until all the materials are used up. They also have suggestions for dealing with the failure of pupils to generalise counting skills when given a large heap of items and who always say yes to questions which called for discrimination. Such errors are portrayed by the authors as atypical and yet the behaviour of the children are again reminiscent of Wynn's (1990) group of preschool children who had not achieved the cardinal-count transition. Equally, the tendency of pupils to acquiesce may be akin to the difficulties that Briars and Siegler (1984) experienced with their youngest group of preschoolers judging puppet counts. This study highlights the dangers of providing a functional curriculum where the "meaning" is provided through the practice of everyday tasks such as laying the table . Such a curriculum is essentially skill orientated and driven therefore by the acquisition of appropriate procedures. Failure is met by the refinement of cues resulting in correct performance only in tightly controlled situations rather than through the adoption of methods which will lead to the acquisition of understanding.

3.4.4 *Summary*

Setting aside the many problems inherent in the nine studies reviewed in this section, the following tentative conclusions can be drawn:

* a mechanistic approach can lead to the acquisition of a limited range of skills.
* the use of games has been used successfully to develop skills but has been less successful in developing understanding.
* increased opportunities for practice and reinforcement are two key features of successful intervention but other features of successful intervention remain unclear.

3.5 Conclusions

Many of the studies cited here do not hold up to close scrutiny and to be fair it is probable that some were not designed to do more than provide a starting place for discussion. Inadequate details of the samples, of clear matching procedures (where appropriate), imprecise descriptions of methodology, and averaging the resulting data contribute to a difficulty in drawing any firm conclusions. For example one difficulty for the reader in assessing these studies is the use of different terminology to describe similar tasks. Extracting a set of objects from a larger sub-set is referred to as a "quantity production" task by Baroody & Snyder (1983), a "perform test" by Marx (1989) "counting objects (subset)" by Spradlin, Cotter, Stevens and Friedman, (1974), and as "identification by numerical unit" by Cornwell (1974). Unless the investigator describes the presentation of the tasks fully one cannot be totally sure what experience the child received. These inadequacies are not limited to studies on pupils with severe learning difficulties however, the majority of studies of mathematics intervention have been carried out with those pupils who have mild or more moderate learning difficulties and here also methodological rigor is reported to be lacking (Mastropieri, Bakken, & Scruggs, 1991).

A point of particular note is that any conclusions that were reached in the preceding review may be generalisable to only a small proportion of the children currently being educated in SLD schools. Only two studies provide data on pupils with an IQ below 30 (McClennan & Harrington, 1982; Marx 1989) and the inclusion of studies where the mean IQ falls below 50 has led to the presentation of information which may relate more appropriately to pupils who would be educated in MLD schools.

The performance studies highlight several key points, firstly two notable methodological points of concern, the nature of the materials used and the context for testing. One of the most surprising aspects of the studies is the incredibly dull nature of the materials used for counting- paperclips and tongue depressors feature in some of Baroody's studies (Baroody & Snyder 1983). Bricks have also proved popular to experimenters (Baroody, 1986a, 1986b; Cornwell 1974) as have wooden beads (McEvoy & McConkey, 1990, 1991). There is a danger in reaching conclusions about the relative effectiveness of different materials when it would appear that little thought has gone into their choice in the first place. For example, allowing children to keep the paperclips when they have distinguished between N and N+1 (Baroody & Snyder, 1983) is a doubtful motivator. (It is worth noting that this aspect has been given greater attention in studies involving intervention!)

Whether the performance measure is either total count accuracy or type of error two factors must be considered . Firstly the methods of presentation and secondly the nature of the objects to be counted. Data from Fuson's (1988) studies suggest both aspects affect the type of errors made by pre-schoolers. In common with pre-school studies the experimenters typically present objects for counting in rows. Unsurprisingly those who have presented disordered arrays have found in some instances that children with SLD did not count as accurately e.g. Spradlin et al (1974). Almost all studies have used sets of homogeneous items. This conformity in terms of array, and lack of variety of objects across studies facilitates making direct comparisons across studies.

Interestingly when we come to look at studies which systematically investigate the effect of the nature of the object on counting accuracy several experimenters comment on the lack of effect. Cornwell (1974) for example used both blocks and keys and found no overall difference in subjects count accuracy but did find a small (non-statistical) difference with the most able of her sample and from this data she argued that using familiar objects may have helped children who were at a higher mental age level. No rationale is given for this. Presumably it refers to the difficulty in depressing an already low performance. Those children with the lowest MA scored zero on a number of tests. Similarly, Spradlin et al (1974) comment on the lack of effect of using pictures or three dimensional moveable objects.

To turn to the outcome of the performance studies, firstly (as with mainstream pupils) there is a wide range in the ability and understanding of pupils with severe learning difficulties that is not solely accounted for by mental age. Baroody (1986b) for example found that there was a considerable overlap between the achievements of the moderately retarded pupils and those of the mildly retarded pupils in this study. Pupils performance is likely to be related to experience as demonstrated by Marx's (1989) study but the important elements of this experience are not revealed by the author and nor is it clear how experience interacts with intellectual ability to facilitate the development of number skills.

For many pupils there would appear to be a hierarchy of difficulty although this should not be taken for granted. It is likely for example that many pupils will find it harder to make a set than to count a set but it is unclear whether this can be avoided by adopting a teaching style which reduces the additional demands on memory or whether this relates to the conceptual demands of the tasks. There would also appear to be a ceiling to the present level of attainments. Less than 20% of children are likely to be able to make sets greater than 6, be able to give the next number or know that N+1 is greater than N, count in tens or lastly invent procedures for addition. Again some of these difficulties relate to the requirement for more advanced conceptual understanding others to the development of procedures. Also, this might be at least partially dependent on the type and amount of teaching received.

One particular theme running through the performance studies is the extent to which pupils with SLD experience a conceptual difficulty in this field. It has already been noted that some authors view the attainments of SLD pupils in the area of number as exceptionally limited. Cornwell (1974) for example reaches the conclusion that what develops with age are essentially rote skills. Whilst children can be seen to develop the ability to rote count and count sets they do not in her view develop the understanding necessary to do more i.e. make sets. Gelman and Cohen (1988) echo the sentiments that children do not show principled understanding and consequently are unable to develop the strategies necessary to cope with novel tasks. They relate this in part to the type of mechanistic teaching experiences these pupils receive. Spradlin et al (1974)'s evidence also suggests that SLD children acquire such rote aspects as numeral recognition and naming early on with the implication that these are more easily acquired. Evidence from the study of Baroody & Mason (1984) might also be used in this context to support a claim for a "conceptual deficit".

A deficit implies that this difficulty is not shared with pre-schoolers of the same mental age. Comparison studies are currently limited in number and do not wholly support the idea of their being a difference between the two groups . Two out of three studies in this section because of the uncertain matching procedure could be said to provide parallel studies rather than comparison studies. The most recent study suggests that we need to be cautious about pointing to any particular difficulties whether in performance or understanding. The review of studies with preschoolers concluded that normal children initially acquire procedures for counting with limited understanding of the meaning of counting. Children with SLD may therefore *not* be different in their profile of acquisition. The current state of knowledge is too limited to firmly predict the outcome of severe learning difficulties on attainments in counting.

Finally intervention studies have largely been designed to target the development of skills rather than understanding. Success has been achieved by using mechanistic methods and games but the lack of methodological rigor makes evaluation of specific approaches to intervention difficult. Many studies appear largely atheoretical with limited rationales guiding either the adoption of techniques or the selection of particular areas for intervention. Experience of appropriate teaching methods may prove decisive in the development of counting skills in children with SLD but it is unclear what form that experience should take.

Chapter Four
Aims of The Thesis

This thesis sets out with the overall expressed aim of investigating the attainments of children with SLD in relation to both their performance and understanding of counting. The literature reviewed in chapter three was found to be limited both in breadth and depth. Existing studies are few in number, address only a limited set of questions, and appear to the reader, largely atheoretical in orientation. In spite of many design limitations however, the literature on counting in children with SLD does suggest that these pupils can develop a basic level of competence in counting. Whether they are capable of demonstrating understanding of the principles and why there is so much variation between children is much less clear (Cornwell, 1974; Gelman & Cohen, 1988; Gelman, 1982). In order to address this overall aim we need to look for additional sources of information elsewhere. In chapter one we argued that the main source of information should come from reviewing the developmental literature on typically developing preschoolers.

As part of the literature review of this thesis, a very detailed account of the work of Gelman and her colleagues was provided. This was done not only because Gelman's work has been so influential in shaping research on typically developing children but also because she is one of the few researchers to make a clear statement about the acquisition of mathematical skills in children with learning difficulties. As noted earlier, Gelman proposes that typically developing preschoolers are guided in the acquisition of procedures by implicit understanding of five principles of counting. These principles, formed the basis of an examination of how preschool children normally learn about counting. In contrast to the stance adopted here, her perspective was that children with SLD are different from typically developing preschoolers because they are <u>not</u> guided by implicit understanding but have largely acquired their competence by rote learning of the procedures for counting (Gelman & Cohen 1988). This, in her view, is the outcome of the type of teaching approach used in special schools which emphasizes drill and practice. However these views are based on very few published studies some of which are methodologically flawed so there is much scope for further investigation of this area of competence in pupils with SLD.

In contrast to Gelman's "principles first" view, other explanations of the acquisition process have also been proposed. In one formulation which is almost exactly the opposite of Gelman's position, Briars and Siegler (1984) suggest that children have to acquire the procedures for counting first, before they understand what it means to count. They describe the process of acquisition as an "induction" whereby children have to work out what are important features of counting.

In chapter two a conclusion was reached that the evidence on typically developing children did not support the theory that children were guided in the acquisition of counting by an implicit understanding. By examining the evidence in relation to each of the principles in turn it was clear that typically developing preschoolers' understanding could only be described as very limited at the early stages of acquisition. For example the literature on the development of stable order suggests that children's earliest understanding is that there is a "special list" of words and that this knowledge is manifested *after* the child starts to produce number words. Equally the evidence supports a limited or partial understanding when children do come to respond to a cardinal question that others have described as the acquisition of a rule (e.g. Fuson 1988). Whilst we cannot therefore support the argument that childrens' performance profile is compatible with an implicit understanding, although equally we cannot conclude that there is no understanding of counting at all.

One alternative mid-point position between the views of Gelman (1982, 1992) and those of Briars and Siegler (1984) is that children have to be able to count at least small sets before they begin to understand the counting process. For example, once pupils have acquired the procedures for counting small sets they may start to deduce the principles of counting. At this point the process of acquisition could become interactive with the development of procedures and understanding starting to influence one another. Children might use knowledge of the principles to inform practice through monitoring their own counting to ensure that they adhere to these principles. Feedback from improved accuracy of counting will in turn enable them to be sure of their understanding and to refine it as necessary.

Even among typically developing children, therefore the precise relationship between the acquisition of skills and understanding of counting has still to be established through research. An essential part of this thesis is to examine the temporal relationship between the acquisition of procedures and the development of understanding what it means to count. This clearly has relevance for what we perceive to be understanding. As we discussed more fully in chapter two this has largely been dominated by Gelman's notion of principles with a distinction between implicit and explicit (see page 29-31). If we are correct in our deductions from the literature that children acquire the procedures for counting small sets first we need to seek alternative explanations for the pattern of development and on this basis re-examine the nature of the understanding. An investigation of the attainments of pupils with SLD cannot therefore be carried out without reference to preschoolers.

If we are correct in our deductions from the literature and there is no evidence of children's implicit understanding underpinning their performance then we have to consider how else children may be guided in the acquisition process. There is some evidence to suggest that for typically developing preschoolers, mothers provide an environment which supports the acquisition of counting. From an early age mothers provide a linguistic environment where number words feature regularly (Durkin et al, 1986; Durkin 1991). There is also evidence to suggest that they adjust the task demands in line with the child's successes and failures (Saxe & Posner, 1983) although this may not always lead to the desired outcome (Durkin et al, 1986). In contrast, it is not known whether SLD children have the same access to number opportunities since no one has studied parents use of number with children with SLD. Similarly information on how adults use mathematical concepts and language in the *school* context with these two very different group of children is unknown. From what we do know about the teaching of maths in SLD schools evidence suggests that less emphasis has been given to this subject since responsibility for education passed from health to education. The introduction of the National Curriculum may have served to reverse this trend although it is not yet known what the impact has been.

For the teacher, it is very important to be aware of external factors which might contribute to development. Although we have been cautious in reviewing the role played by the environment (1.3.2) this has largely concerned studies which aim to bring about global changes, for example in IQ. If the school environment does play an important role in determining the specific achievements of children with SLD, as proposed in a rather negative way by Gelman and Cohen (1988), variations in this experience and the amount of experience/ opportunities may well be crucial factors. An indirect measure of this, within a single environment, would be the chronological age of the child, the assumption being that older children have been in school longer, have had more opportunities and consequently achieve more. There is some previous research evidence which supports this possibility (Cornwall 1974; Baroody 1986b; Marx 1989) but the data can only be viewed as tentative.

Although previous studies do not reveal precisely what children with SLD can learn in this domain, one finding that does emerge clearly from the preceding review is the considerable *variation* in pupils' achievements. What accounts for this diversity is unclear. At a theoretical level, of course, one can distinguish between within- child factors and external factors which may contribute to variation. To date, the study of within-child factors has tended to focus on the child's general level of intelligence or whether they have specific difficulties, such as a memory impairment, which might impede acquisition. In neither case, however, has a clear account of the relationship between outcome and predictor variable emerged.

Taking the various strands of evidence into account, the most likely way of predicting performance would be to consider a combination of internal and external factors. Thus a childs' progress might depend not only on his mental level but also upon being provided with opportunities for learning about number that are appropriate to his level of understanding. In other words, one might predict that children who receive experiences which are well matched to their level of ability will make good gains in the acquisition of skills and understanding and those who don't will make less progress. Therefore a further aim of this thesis is to explore a number of possible predictors of success and failure in the acquisition of both skills and understanding.

To date, investigators of children with SLD have largely concentrated their research on the more able group of pupils within the SLD school population, making it difficult to judge the potential of children with IQs below 50. Indeed only two of the twenty-one studies reviewed in chapter 3 provided extractable data on pupils with an IQ between 20 and 30. This has largely arisen because there is no published research which has been carried out in this country where there is a continuity of provision for pupils with IQs ranging from 20-50. As stated in chapter one, classifications based on American Psychiatric Association (1987) or World Health Organisation (1992) criteria distinguish between individuals with IQs between 20 and 35 and between 35 and 50/55. Since it is unclear whether children with an IQ below 35 are actually unable to count, it is important to attempt to collect data, at least initially, on *all* children with SLD.

For the present series of studies, therefore, an initial attempt will be made to include all children who would be found in the regular classes in SLD schools, regardless of the aetiology of their handicapping condition or the presence of additional impairments. As far as specifying the level of intellectual deficit is concerned, the relative merits of different approaches have been discussed in chapter one. For this series of studies the advantages of using mental age (rather than IQ) seem to outweigh the disadvantages. Consequently MA will be used throughout. In order to cover as broad a span of development as possible within the target population, the objective set will be to find children whose mental ages ranged from approximately two to six years of age. By definition, this means that children who would be classified in the UK as having profound and multiple learning difficulties will be excluded. Chronologically this group of children will range in age from 7 to 14. From personal experience of teaching children with SLD and from the literature reviewed earlier, it is felt that this group might contain not only children who are at the beginning stages of learning to count but also a few who are quite proficient.

The objective of extending the range of cognitive ability among the children (as measured in these studies by mental age) included in this study has important implications for the methodology. In the experience of the researcher many children will now be included who are limited in their ability to focus and maintain attention on a given task, and to comply with instructions. Individuals are also likely to be included who have limited language skills. Methods of assessment used with these pupils in school are often based on observation and the use of checklists to take naturalistic measures of typical behaviour. For the purposes of this investigation however the option of waiting for the spontaneous appearance of counting is considered to be a less useful approach than directly interacting with the child. Consequently, the development of an appropriate context for eliciting demonstration of both counting skills and understanding is seen as an important subsidiary aim.

In summary there are three overall aims of this thesis which, as the reader will see, undergo some refinement in the course of the data collection:

* to extend what is known about the attainments of pupils with SLD in the area of counting, both in relation to performance and understanding;

* to explore the temporal relationship between the acquisition of procedures and the development of understanding what it means to count;

* to explore selected factors which might contribute to differences between pupils' attainments.

In formulating the questions to be addressed in any original piece of research, it is always necessary to enquire into the potential generalisability of the results that might be obtained. This can only be done in relation to the particular methodology chosen and the state of knowledge in the field at that point in time. Since the emphasis throughout this work so far has been on the paucity of information available on what SLD children know, what they are taught and what determines how they learn, it might well be argued that the place to begin in this thesis is to survey a broad spectrum of schools for pupils with SLD to see what exactly is happening in relation to the teaching of maths and how this impacts on pupils knowledge. However what this kind of methodology gains in terms of breadth, it also lacks when it comes to depth. Without interacting directly with SLD pupils it would not be possible to elicit the kind of information about skills and understanding that is sought here. For this thesis, therefore, a considered decision has been made to employ the investigative techniques used so successfully by developmental psychologists in presenting pupils with a series of controlled tasks. In the following exploratory study we set out to identify the exact nature of these tasks together with the most appropriate method of presenting them.

Chapter Five
An Exploratory Study

The review of the literature on early maths skills in pupils with SLD has revealed just how little we know about the development of skills and understanding in this small population. Moreover, the more detailed studies have been largely confined to pupils with moderate learning difficulties or those with Down syndrome. Having established the general aim of this thesis it seemed essential to carry out a small scale exploratory study that would provide the author with experience of working in an experimental setting and serve to clarify the means by which these aims might be achieved. This will include solving some of the methodological difficulties referred to in chapter one which are inherent in direct investigation of the abilities of pupils with SLD.

In order to maximise the exploratory potential of the study a wide range of counting tasks were chosen with the prime consideration that they tapped as many aspects of the count process as possible. For example, tasks which elicited the component parts of reciting the number string and pointing to each object in turn separately were included alongside tasks which demanded their combined use. Additionally, tasks involving both recognition and use of number symbols were included.

At the time of undertaking this exploratory study, 1988, no research existed which systematically examined children with SLD's understanding of the processes involved in counting. Four approaches were considered, two of which were discarded as inappropriate and two which were included for further investigation.

One of the first possibilities to be considered, but rejected, was the constrained counting task used by Gelman and Gallistel (1978) and Gelman and Cohen (1988). This task is procedurally quite demanding and was felt that it not only tested the childs understanding of the principles but the additional ability to create a strategy that would enable these principles to be reliably adhered to. It could therefore be argued that this "novel" task tests not only simple understanding but also strategy creation together with successful execution of the strategy and therefore might serve to obscure *emerging* understanding in pupils unable to demonstrate strategy use.

The second method, considered but also rejected was an adaption of the method used by Baroody (1984) and later employed by Hersovics and Bergeron (1989) and Saxe et al (1989) with typically developing children. This involved presenting pupils with a situation in which two people had counted but had reached different amounts; the pupil's task was to judge which was right. Two potential difficulties led to the rejection of this task. First, it seemed probable that performance on this task would be affected by linguistic limitations and second there were possible social factors (already noted in chapter 2) which might influence the pupils' responses. In general, it was seen as important that the linguistic demands of any task in this study were reduced to a minimum as this had already been found to be a potential source of unreliability found amongst those working with preschoolers (see chapter 2 pg 57-58). On the same basis this ruled out the task suggested by Fuson (1988) in which one pupil is asked to teach another to count as this also placed high linguistic demands on the child.

The third approach considered for inclusion involved the use of an indirect measure, derived from pupils' counting performance. It has, for example, been argued that the ability to "make a set" suggests that pupils understand what counting is about. Like the approach used by Baroody (1986a), however, this task does only lead to an *inference* of understanding and cannot therefore be used as an objective measure of understanding. One can (and should) differentiate between the knowledge that counting is used to make quantities and the knowledge that counting can only be used in this way providing it is executed by adhering to certain principles. In spite of this difficulty it was decided to include this task in the current study in order to gain some insights into the way in which pupils approached the task, but also to use an additional more direct measure.

At the time of planning this study a number of authors had already demonstrated the value of using an error detection method as a means of assessing understanding independently of performance with typically developing children. The rationale for using this kind of procedure rests on the fact that it removes the performance demands on the child and thus taps directly into the child's understanding. This method however had not been used with pupils with SLD and it seemed an exciting prospect to try it out in this investigation. It was therefore decided to use a puppet task similar to that adopted by Gelman and Meck (1983) and Briars and Siegler (1984), with the initial aim of this study in determining whether "the task demands made sense," given the anticipated linguistic limitations of the pupils. A simple instruction and explanation would be devised to introduce the task together with a demand for either a verbal or non-verbal response from the pupil.

For a variety of reasons many children with learning difficulties are not easy to interact with. Each child has a different combination of difficulties and these often include problems of attending to the task, being able to identify the relevant dimensions, understanding instructions, maintaining interest and many others. For the teacher, techniques have been devised which take account of these difficulties and with experience good teachers become skilled at adapting their methods to meet the needs of individual children. However these methods are often in direct conflict with the tightly controlled procedures recommended for the collection of objective and reliable data. For instance, tests are typically carried out using consistent instructions, with no clues to correct responding and the presentation of items to the point of failure and beyond. In contrast children with SLD may be used to a regime whereby instructions are individualised according to the child's level of understanding, cues are given to correct responding including the use of errorless methods and praise given following the response (e.g. Foxen & McBrien, 1981). Additionally tasks are often broken down into easily managed steps (Gardner, Murphy & Crawford, 1983) with at least a tacit agreement that children do not experience failure, or at best, very rarely. This makes more formal testing situations potentially hazardous as children may search for cues from the adult and request help when they encounter difficulty. The presentation of hard tasks without help or feedback may also be discouraging.

In order to take account of these potential problems while at the same time ensuring that the data collected was both objective and reliable it was essential to develop a protocol for task presentation which would maximise the chances of successful interaction between experimenter and child. Important aspects of this plan of action was the selection of materials, their mode of presentation and the duration of testing. Firstly therefore an attempt was made to devise a situation in which attractive and motivating materials would be used as a means of getting the best out of children acknowledged to have limited attention span. The tasks were built around a real life context, a shopping situation. Using a shopkeeper and a shopper, as representative of tester and child, the counting tasks were placed in a familiar and relevant context. Children were provided with a choice of shopper and it was hoped that this together with the use of pennies would further contribute to making the context motivating and maximise the childrens' performance.

In addition to optimising the interest level of the materials it was also deemed important to keep the duration of testing to a minimum. Undue repetition in presenting tasks was therefore avoided by limiting the number of set sizes used for each task and interweaving tasks to ensure variety in response demands. Thus for example rather than presenting numeral recognition as a separate task this was done as part of the whole series of counting tasks. To provide additional motivation and encouragement children were given general praise mid-task such as "you're working really well" rather than give specific informative feedback. Testing was stopped when the child's interest/attentiveness was judged to wane and testing recommenced on a separate occasion.

Throughout this thesis, the problem of how one defines severe learning difficulties has been referred to. Indeed, given the rather arbitrary nature of the process of definition, it is perhaps unsurprising that there were studies reviewed in chapter 3 where it was impossible to determine the precise characteristics of the sample of children. It is however essential for the purposes of making comparisons between studies that a way of identifying the sample population is found and that the same method is maintained throughout. Additionally, it was felt important that this investigation was not limited to a narrow band of the pupils found in SLD schools. For the present study therefore an attempt was made to include all children found in the regular classes in SLD schools, regardless of the aetiology of their handicapping condition or the presence of additional impairments.

Choosing a test of intellectual ability for a population with severe learning difficulties is difficult. All the well known tests, including the WISC and Stanford Binet were reviewed and all were seen to have problems. This seemed especially true at the lower end of the scales where there are few manageable items, insufficient differentiation of scores, and inappropriate materials. In this study it was decided to explore the use of the British Picture Vocabulary Scale (Dunn, Dunn, Whetton & Pintilie, 1982). This was selected because it is quick and easy to administer, requires limited active response from the child and is therefore suited to pupils who may be restricted in their speech and physical movements. The test includes a scale that ranges from 1.8 years to 18.1 years and therefore avoids the possibility of any child reaching a ceiling whilst still including items for the least able. Although it has not been standardised on pupils with severe learning difficulties the earlier version, the English Picture Vocabulary Test, (Brimer & Dunn, 1972) has been used as a measure of mental age by others working in the field and has yielded satisfactory results, (e.g. Hogg & Evans, 1975; Beveridge & Evans, 1975; Leeming, Swann, Coupe & Mittler, 1979; Evans & Hogg, 1984).

In spite of the merits, it is essential to note that the BPVS is not without difficulties. Within the guidelines for administering the test to mainstream pupils the starting place for presenting items is based on chronological age. Clearly the conventional starting place would be inappropriate for pupils with severe learning difficulties as many would fail to score at all. Due to lack of information of how the test had been administered by other researchers working with children with SLD, an arbitrary decision was made to administer items from the beginning. Also, because of the likely low scoring by at least some pupils, (Leeming et al, 1979, found 30% of pupils to score below the 3 year old level) the short form of the test was rejected as it included too few items to ensure a meaningful measure for all pupils.

A final important role of the exploratory study was to investigate the reliability of pupils performance on counting tasks. Given the reported variability of pupil performance (Ellis, Deacon, Harris, Poor, Angers, Diorio, Watkins, Boyd and Cavalier 1982) it is in fact surprising that few investigators report the reliability of pupils with learning difficulties' response to counting tasks.

In summary, the purposes of this study were firstly to provide the author with experience of working with children with SLD in an experimental setting, secondly to develop a methodology that was appropriate to the target population and finally to provide some preliminary data on how a small group of children whose chronological and mental ages were in the identified range, respond to a series of counting tasks selected to tap in total the main aspects of the counting process.

Method

Subjects:

Seven pupils attending a school for pupils with severe learning difficulties participated in the study. They were all members of the same class of 10-12 year olds. All pupils were given the long form of the British Picture Vocabulary Scale (Dunn et al, 1982). Three of the pupils had Down syndrome but the etiology of the remainder was unknown. One pupil had an expressive language disorder. The chronological age of the pupils ranged from 10 years 8 months to 11 years 4 months (mean 11 years 1 month, median 11 years 4 months). Their scores on the BPVS scores ranged from 1 year 9 months to 4.0 years (mean 2 years 10 months). Details of individuals are included in Table 5.2

Materials:

The context for counting was a shopping game. This involved a cut-out shop keeper and customer, pennies, ten cards with numerals 1-10 printed on the top half and an envelope on the bottom half containing a card depicting objects equivalent in number. Following the shopping game, a glove puppet was introduced.

Procedure:

Each pupil was tested individually in the classroom setting. They were introduced to the cut-out figures and told that they were going to play a shopping game. The game consisted of counting pennies, selecting a card of equivalent number and finding the surprise purchase in the envelope- a shopping card depicting an equivalent number of items. Within this context some additional tasks were embedded e.g. rote counting and matching numerals to sets. The precise tasks were as follows:

1. Rote Count: Children were asked to count as many pennies as they could while the experimenter put them out in a dish in time with the children's counting. If the child paused, their last count word was repeated with an inflection to continue. The child received a total of two prompts before the process was stopped.

2. Recognition of small sets of 2 and 3 items and the recognition of numerals: Two pennies were taken from the child's plate and put in front of the shopkeeper. The child was asked "How many pennies are there ?" The child was corrected if wrong and given a choice of three numerals (1, 2, or 3) and asked to point to the numeral 2. They were then invited to look in the envelope and see what had been bought. The procedures were repeated with three pennies. A maximum score of 2 was given if pupils recognised both set sizes. In addition one point was given for recognising each of the two numerals involved.

3. Counting sets and recognition of numerals: The procedures were identical to the above except pupils were asked "Can you count and tell me how many there are," for set sizes 4, 6, and 8. A score of one point was given for correct counting for each of the three set sizes. As before a further three points were available for recognising each numeral.

4. Making sets and recognition of numerals: The pupil was asked to give the shopkeeper 1, 5, 7, 9 and 10 pennies. Pupils could get a maximum score of 5 for making each of the 5 sets correctly. They were then asked to select the appropriate numeral as for task 2, and were able to score a further five points for recognising the correct

numerals.

5. Naming Numerals: Ten numeral cards were presented singly in random order and the child was asked to identify the numerals. A score of 1 point was given for correctly naming each numerals, making a maximum score of 10.

6. Association of numeral with set: As the game was put away the pupil was presented with shopping cards for sets 4, 5, and 7, in turn and asked to put it away in the correct envelope- a choice of three numeral cards with envelopes were given. A maximum score of three was attainable for correctly matching set and numeral.

7. Tagging: A row of 5 and then 10 pennies were presented to the child who was required to point to each penny in turn. A demonstration was given and their attention was drawn to the fact that no words were said as they tagged. A point was given for each of the two tagging tasks.

8. Error Detection: Each pupil was introduced to a puppet which they were invited to name. They were then instructed to watch the puppet carefully as it counted the pennies to see if the puppet got it right or wrong. A total of nine trials were given, one of which was a demonstration and two were correct counts. Two trials were "skipped object" trials (one formed the demonstration), two included number word repetition, one included a skipped number word, and two were unconventional or pseudoerror trials. On one unconventional trial the puppet counted alternate objects, and on the other the puppet started the count with the middle item. Sets sizes were arrays of 5-9 pennies. Again a point was given for each correct error detection trial.

Each task was presented to the pupil twice with an intervening period of approximately six weeks. Pupils completed each batch of tasks in one or two sittings. Pupils' total scores for each task were converted to percentages to enable comparisons to be made across tasks. For example if the pupil correctly identified 9 of the 10 numerals they were given a score of 90%.

Qualitative Observations and Reliability of Performance

Observation suggested that the pupils found the tasks motivating and relevant as none refused to carry out the tasks and all expressed eagerness to "have a go". Each pupil was able to sit and work for between 15 and 20 minutes and some for much longer. Not all the tasks proved equally motivating. For example all pupils, irrespective of their ability displayed interest in the puppet. In contrast, rote counting proved less motivating, particularly when pupils were required to perform a second time.

In order to assess the reliability of the children's responses to the various tasks Pearson product moment correlations were calculated between responses made on the first and second occasion of testing. As can be seen from table 5.1 reliability coefficients ranged from 0.73 for the task of tagging to 0.99 for the task of rote

	Value of r	Significance level
Rote Count	.99	p<.01
Count Sets	.97	p<.01
Make Sets	.92	p<.01
Match Set to Numeral	.84	p<.01
Recognize Numerals	.73	p<.05
Name Numerals	.92	p<.01
1:1 Tagging	.71	p<.05
Puppet Errors	.89	p<.01

Table 5.1 Test-Retest Reliability Co-efficients

counting. Since all of these values met generally accepted levels of test-retest reliability we can proceed to consider performance on individual tasks.

Children's Performance on Individual Tasks

For ease of reference pupil responses to all tasks, taking their overall best response to each request are listed in table 5.2. Although all pupils were able to perform at

Table 5.2. Pupil Performance on Counting Tasks.

Subject	C.A.	BPVS MA	Rote Count	Count Set	Make Set	Recognise Numeral	Name Numeral	Pair Numeral and Set	Tag Sets	Detect Errors
1	11.4	1.9	1-9	60%	20%	60%	20%	33%	50%	17%
2**	11.4	2.4	N/A	80%	40%	80%	N/A	33%	100%	60%
3	10.8	2.9	1-4	20%	20%	70%	10%	-	50%	-
4	11.4	2.10	1-5	60%	20%	70%	40%	-	100%	50%
5	11.4	3.1	1-13	100%	80%	100%	100%	100%	100%	66%
6	10.11	3.3	1-59	100%	100%	100%	100%	100%	100%	100%
7	10.11	4.0	1-9	60%	40%	70%	40%	-	100%	33%

** Pupil with no expressive language
N/A Not applicable

least some of the counting tasks and all but one pupil was able to detect some of the puppet errors, with one pupil performing at a ceiling level on all tasks (S6) and another pupil (S3) only able to complete the easiest stages for all tasks except that of recognising numerals. The sample size is too small to perform statistical analyses of the relationship between ability and counting competence but it is perhaps worth noting that the child with the lowest mental age did not score the lowest on any of the counting tasks and the subject with the highest MA, as measured by the BPVS, was not the highest scorer on any count task.

Taking the tasks largely in order of presentation we can begin by looking at the pupils response to being asked to recite the number string. These rote count strings are set out in Appendix A and reveal that correct strings ranged in length amongst the group from 1-4 to 1-59. Since pupils had only been requested to count twice on each of the 2 testing occasions it was impossible to look at whether pupils included any stable unconventional portions in their count sequences using the criterion adopted by Gelman and Gallistel (1978) which was that the unconventional sequence should appear in 60% of trials. Given the limited number of trials, there were no individuals in this study who *consistently* produced a *sequence* of incorrect numbers.

Pupils were then asked how many items were in a set and for sets greater than 3 this included an instruction to count, the aim being to differentiate between the ability to recognise and to count sets. Unfortunately, it proved impossible to achieve this objective as pupils response was very often immediate and unstoppable, namely to count. This difficulty has been commented on by others working with typically developing children (Silverman & Rose 1980). Analysis of the pupil responses therefore groups these two items together. Interestingly, some pupils also automatically put items in a row before counting them while others didn't but the data was not extensive enough to establish whether those who did were better counters. During the "make sets" task many individuals carried on giving pennies until all those available had been used up. Some additional methodological questions are raised below in relation to this task.

Turning to tasks involving the recognition and naming of numerals, table 5.2 shows quite clearly that the children found the recognition task easier than the naming task, which in turn was easier than the task of matching set size to numeral. In many ways this outcome was unsurprising given what we know about these processes in typically developing children. It has been argued that symbol recognition and naming can be attained early with little requirement for understanding (Spradlin et al 1974) nor linking to the count process making their place in future studies questionable.

Finally, it was notable on the "tagging items" task that some individuals initially found it difficult to inhibit saying the number words as they pointed to each item. For these individuals it was necessary to provide a second emphatic model. This may account for the lower reliability levels. Tagging items in the smaller set size was an easy task for all seven pupils and five were successful with the largest set size. Three of these five were able to tag a set that they could not successfully count, whilst the remaining two scored at a ceiling level on both tasks. Two pupils were able to tag more objects than they were able to recite numbers.

Error Detection

One pupil was unable to detect any of the errors made by the puppet and said that all counts were correct. This was subject 3 who, whilst he did not have the lowest score on the BPVS, did have the lowest count profile. Of the remaining six pupils, only one was able to correctly detect all puppet errors. This was the most able counter, subject 6. Although subject 7 scored equally highly in counting sets he was not able to detect all the puppet errors suggesting that the ability to count on its own is not a sufficient pre-requisite for error detection. Subjects 2,4, and 5 detected between half and two thirds of all error trials, and subjects 1 and 7 less than a third of errors.

The easiest error to detect was a repeated number-word with five out of six subjects spotting this mistake. The second easiest was the skipped object with four out of six subjects detecting this error. An equal score was attained with four pupils accepting a mid-start count. The hardest counts to judge appear to have been omitting a number-word and alternate counts.

Order of Difficulty

Although the sample size is small which limits statistical analysis it was possible to carry out a series of sign tests to investigate the order of difficulty of the various tasks included in the study. These revealed that firstly counting sets was generally easier than making sets. No pupil's ability to make sets exceeded that of count sets although two pupils performed equally on both tasks ($n=5$, $x = 0$, $p = .06$, two tailed). Similarly, counting sets was easier than matching set to numeral. For five pupils performance on the former was superior to the latter ($n= 5$, $x = 0$, $p = .06$, two tailed) and two pupils scored 100% for both. In contrast, it would appear that making sets is not always harder than matching set to numeral. Although three pupils failed to score at all on this latter task, two pupils' scores exceeded those achieved for making sets, ($n =6$, $x = 2$, ns). Finally, although the effect did not reach the conventional level of significance, recognition of numerals appeared to be easier than naming numerals with no pupil doing better on naming than recognising numerals, ($N=4$, $x=0$. $p=.12$).

Discussion

In addition to providing the author with valuable experience, the objectives of this study were to explore some methodological issues and to take a preliminary look at pupils with SLD responses to a range of number tasks including tasks requiring understanding. In what follows we will begin by considering the methodological issues and their implications for future studies.

The methodological findings and their implications

The BPVS had been selected (see page 109) to identify the pupils for this study. Its use demonstrated that the pupils quickly understood the demands of the test and retained a good level of interest during its presentation. Despite the use of the long form and the need to present testing items from the beginning, its ease of use, including maintaining pupil interest together with its appropriateness for all the pupils suggested its continued use.

When this study began the objective was to include as many children as possible who fell within the SLD category. Almost immediately the inclusion of a pupil (S2) with no expressive language raised some interesting questions. Despite her inability to articulate any words she did vocalise during counting in a 1:1 manner. However, in order to elicit the outcome of that counting it was necessary to ask her to either use her fingers to make an equivalent set or to point to the appropriate symbol. This effectively added to the task demands and therefore provided some interesting but non-comparable data. Sadly therefore it was recognised that it would be necessary to exclude some children who, by nature of their additional impairments, experience altered task demands.

In this study, the children performed a series of 8 counting tasks, not all of which had been used with children with SLD before. It was therefore extremely encouraging to find that nearly all of the tasks interested the children and produced highly reliable data. Starting from this very positive position, one could then decide which particular tasks might be pursued and under what circumstances.

Beginning with the seven performance tasks which were designed to investigate children's skills in the procedures underlying counting there were several issues which arose. One methodological objective had been to establish positive ways of encouraging pupils to respond to quite a long series of tasks. Originally the classroom was chosen as an area for testing because its familiarity was felt likely to reduce any anxiety produced by working with a comparative stranger. However, as time passed it became clear that interactions with the children were affected in some instance by activities happening in the classroom, in some instances curtailing the duration of testing. An alternative method of reducing anxiety would be to spend some time with the pupils as a group prior to testing and then to withdraw them individually from class to a quieter, distraction free area. This procedure was adopted for all subsequent studies. This would also aid the researcher as occasionally some words were uttered without good clarity. To further facilitate the data collection it was decided to tape pupils responses and wherever possible use a withdrawal setting which would optimise the conditions for accurate recording.

With regard to the materials, it is worth noting at the outset that the context for the testing seemed to be secondary to the materials that were provided. Observations during testing quickly revealed that the pupils were not particularly interested in acting out roles - either of shop-keeper or customer but that they *were* interested in the actual materials for counting. All the children were keen to count real money and liked the items depicted on the cards. The use of envelopes for the cards appeared to add to the interest as it gave a small element of suspense. However, by chance, all the pupils had good fine motor skills and were able to pick up both pennies and pull cards from their envelopes. Since it might be necessary to use younger children in other studies and those with poor manipulation, it was decided to present larger materials which are easier to manipulate and to house these in containers rather than envelopes.

In spite of the good intentions, the naturalistic context adopted in this study created one or two difficulties when it came to analyzing the results. An interesting problem that had not been foreseen concerned the structure and layout of materials. Objects were presented for counting both in 3D, (the pennies) and in 2D (the cards). Whilst the 2D objects were fixed and presented in disordered arrays, the 3D objects could be moved and therefore presented both in rows and disordered arrays. Also some pupils automatically arranged the pennies in rows whereas others didn't thus potentially creating differences in the demands made of different pupils. In combination the two problems made it very difficult to gauge the effect of set size on pupils' ability to count. In subsequent studies therefore, a uniform procedure for selecting and presenting objects will be adopted, including presenting all items for counting arranged in rows.

In this study the duration of testing was deliberately shortened by reducing the number of set sizes for each type of task. For some set sizes, for example, pupils had to count the set, for others to make the set. However this made it difficult to compare pupils ability across tasks because it led to non-identical task demands for each set size. Moreover, whilst it avoided presenting pupils with repetitious tasks it made scoring complex and analysis difficult. In future, therefore, it will be necessary to find a way of ensuring that each pupil is tested on a full range of set sizes whilst continuing to minimise the degree of repetition. One way to achieve this will be to make a distinction between pupils ability to count large and small set sizes rather than sets of a specified number. This system of categorisation has been used by other investigators (e.g. Gelman and Meck 1983; Briars and Siegler 1984; Frye et al 1989) and could be used for subsequent studies for both counting and error detection tasks. Interweaving large and small set sizes (rather than presenting them in ascending size order) might also aid motivation.

Before a final selection could be made from the performance tasks it was first necessary to examine pupils response to the tests of understanding. Most importantly, this study demonstrated that puppets could be used successfully to elicit judgements about counting with this group of pupils. Only one pupil failed to discriminate between any of the puppet counts, claiming all were correct. This tendency to acquiesce has been noted by other experimenters (Siegelman et al 1981), and Briars and Siegler (1984) found a similar tendency in the three year olds they tested. Whilst this pupil did not have the lowest mental age score, his counting ability was poor and therefore this inability to discriminate between correct and incorrect counts was not entirely unexpected. However, future studies need to ensure that if pupils fail the task it is not because they do not understand the instructions or because they were reticent to say the puppet is wrong, but because they do not have the necessary understanding of what it means to count. One way of dealing with this problem is to include more practice trials before formal testing begins.

In addition to refinements in presentation, experience in this study suggested it might be useful to reconsider the response mode. In this study the non-verbal procedure that was initially adopted to enable pupils with poor speech to respond had to be discarded because, although it was quickly produced, it proved to be too salient. This had involved pupils indicating their approval or disapproval of the puppet performance by patting its head or wagging their finger to indicate whether the puppet was right or wrong. This was quickly replaced by a simple nod or shake of their head to indicate that the puppet "got it right" and proved to be a better response mode to be adopted in future studies.

In contrast to the puppet method of exploring understanding, the indirect measure of pupil understanding, "make sets," was found to be open to contamination through the provision of non-intentional feedback. Pupils would deliberately pause during their counting to see if they had "completed the task". It was essential that during this task the investigator gave no response to the pupils counts until it became very clear that they had finished the task. Secondly, as other investigators have noted, there is a tendency to "give all" (McClennan & Harrington 1982), with pupils using all the materials unless they receive some feedback to stop. The pupils positive response to the puppet coupled with uncertainty on the use of "make sets" suggested that the former task would provide a better measure of understanding and would be included in subsequent studies.

In order to investigate the *temporal* order of understanding and performance it is necessary to make direct comparisons between a childs' own counting and their ability to detect errors in the puppets' counting. Rather than look at children's ability to produce separate aspects of the counting task such as tagging or reciting the number string the focus will be on the combined production of these aspects and the incidence of errors. There is therefore a need for only two tasks, a performance task and a parallel error detection task, identical in every aspect of presentation, materials, set size and arrangement. The exploratory study has provided important information on these aspects.

Pupil Performance

One important aspect of the data obtained in this study was the indication that a child needs to be reasonably accurate in his/her own counting before being able to detect errors in the counting of others. In this respect the findings are consistent with the conclusions reached by Briars and Siegler (1984). Only one child was able to correctly judge all the puppet counts and he was flawless in his own counting. Other children were not necessarily 100% accurate on the counting tasks or on the error detection and therefore the temporal relationship between the two is unclear. Future studies, based on comparisons using identical set sizes and materials might clarify this relationship.

Clearly pupils did not find judging puppet errors easy but some errors appear easier to spot than others. For example, this study supports the finding of Briars and Siegler (1984) that skipped objects were easier to detect than skips in the list. However the most likely errors to be detected were repetitions in the number string and the least likely were omissions in the number string.

Pupils response to other tasks within this study provide tentative support for the argument made by Wilkinson (1984) that ease of counting will depend on the number of component parts to the task. From this theory it can be predicted that the child with SLD would find tagging and reciting numbers easier when carried out singly than when carried out together. The data obtained supports this notion as no child was able to accurately count a set which comprised more items than they were able to recite the number words for. Equally, pupils who were not able to count sets of five were able to tag five or more items with relative ease. Further, more pupils were able to tag ten items than were able to count accurately to ten. This finding is contradictory to an early study with preschoolers which did not find conclusive evidence that tagging on its own is easier than counting (Potter & Levy, 1968).

Conclusion

An essential element of this exploratory study has been to develop a means for investigating pupil understanding. Whilst its use suggested a few some further refinements, the demand to judge puppet counts worked well and in many respects provided the most interesting data. From this small scale study, however, it was difficult to be clear of why some pupils were able to judge puppet errors and some were not. To investigate this further it becomes quickly apparent that it is important to be able to make direct comparisons between the errors pupils make and those that they are aware of in the counting of others. It is only through these means that we can make distinctions between what pupils do and what they understand. The approach of future studies will therefore start by comparing pupils own counting performance to their ability to detect errors.

Methodologically some other important lessons have been learnt. Firstly, the requirement for a uniform method of presentation across trials became evident. Given that some pupils immediately put items out in a row it seems that this would be an appropriate method of presentation. This would also make administration of the puppet task easier as it requires the investigator to make a deliberate mistake without hesitation, loss of momentum or change in intonation. Given the need for concentration, the process of error creation and detection would be further facilitated by working in a quiet area outside the classroom.

With regard to other contextual issues the use of a shopkeeper and customer appeared to be largely redundant when compared to the pupils interest in the counting materials themselves. This feature of task presentation will be dropped from future studies. As an alternative, however, the task will be made additionally attractive by providing an element of suspense through hiding objects inside containers. This would be a natural extension of using the envelopes.

Finally the aim of including all children with SLD may need to be reviewed. Whilst it remains very important not to prejudge children's ability, some may ultimately need to be excluded from the study because the severity of their *additional* impairments require adaptations to the tasks in ways that jeopardised the comparability of their data.

Chapter Six

Study 1

Procedures or Principles- Which comes first for children with SLD ?

The previous small scale study yielded some very tentative support for the position taken by Briars and Siegler (1984) that children have to acquire the procedures for counting before they are able to understand the principles. All six pupils with SLD who were able to detect some of the errors made by the puppet did well on the counting tasks. Also, at the extremes there was a high correlation between counting ability and the ability to detect errors. The pupil who was unable to discriminate between any of the puppet counts was the poorest counter, only able to count very small sets and with a very limited ability to rote count. Similarly the pupil who was able to detect all the errors was able to rote count to 50 and beyond and was also successful on a variety of counting tasks. Whilst, between these extremes there was variation which violated the principle that children have to be able to count themselves before they are able to understand the principles of counting in that they were able to detect some of the errors and complete some of the counting tasks, the error detection and counting tasks did not involve identical set sizes in the exploratory study making interpretation of some of the data difficult. Clearly this is an issue which requires further investigation using a larger number of subjects.

Despite the variety of counting tasks the exploratory study did not directly address the question of which principles the pupils adhered to *concurrently* in their own counting. Pupils' responses had simply been recorded as correct or incorrect, with no distinction made between components of the count process. When pupils response to individual aspects had been recorded they had only been required to perform them separately. For example whilst the exploratory study had investigated tagging and rote counting it had not provided data on performance when the two aspects were carried out concurrently. Consequently in this study we move on to examine the pupils ability to adhere to the first three of Gelman's five principles of counting namely :

* the principle of one to one correspondence - every item in a set must be assigned a unique tag.
* the stable order principle - the tags must be drawn from a stable ordered list.
* the cardinal principle - the last tag used in a count has special status; it represents the cardinal value of the set.. " (Gelman & Meck, 1986, p30).

The previous literature review (chapter 2) had failed to find clear evidence of stable but unconventional count sequences except as an artifact of a prolonged testing situation when pupils where required to repeatedly count sets. The exploratory study also revealed no evidence of stable unconventional count sequences in the rote counting task. In this study, therefore, evidence of stable *conventional* order will be sought.

A further objective of this study will be to examine the pattern of performance in adhering to the counting principles in own counts as a function of set size. Fuson (1988) suggested that for pre-school children there is a set size difference between the ability to adhere to stable order and one:one principles in their counts but not for cardinality which is quickly generalised from small to large sets. It was therefore felt relevant to determine whether this pattern of performance in "own counts" was also true for SLD children. The "procedures first" model of development suggests that pupils should be able to detect errors that they no longer make in their own counting. A necessary element of the present study therefore must be to examine whether pupils are able to correctly tag objects with one:one correspondence before or after being able to detect one:one errors.

Two of the pupils in the previous study were at ceiling level in their attainments on the count sets task. It was decided therefore that younger pupils should be included in the study. Since experience suggested that pupils below the age of 7 years would be unlikely to have started to acquire these skills and understanding, this was chosen as the lower limit. As noted in the exploratory study this extension downwards of the age range called for a change in materials to be counted as pennies were small and sometimes difficult to manipulate for the younger pupils. For this study therefore, items were chosen on the basis of both attractiveness and appropriate size. The objects chosen were at least two cubic inches in size and could be handled with relative ease. All arrays were of homogeneous items but objects differed in colour and small detail. This combination of similarity and differences between items reduced the propensity for any particular item in the set to distract the child and hence interrupt the count process but also the use of different colours increased the overall level of interest in some sets. It was hoped that in this way interest in the arrays would be increased but not to the extent that it might increase the numbers of errors (Fuson 1988). Given the inclusion of younger children the safety of items was also considered so that no items had parts which could be removed and swallowed. All sets of objects were contained in tins/boxes. This facilitated administration but also gave the child a role in testing as they could discover what objects were in the tin and also return objects to the container at the end of each trial.

The exploratory study revealed that pupils with severe learning difficulties can make sense of an error detection task and that this would be a viable way of eliciting pupils' understanding of the count process. In order to make a clear distinction between what they know and what they can do however it is essential that the tasks demanded of the pupil and of the puppet are identical. This includes such vital aspects as the materials used and the mode of presentation. Since the exploratory study had revealed the tendency of some pupils to immediately put items in a line for counting, a useful strategy for reducing the task demands, this mode of presentation will be adopted for the puppet. It is also noted that the production of puppet errors would have proved more difficult with the items in a random array.

Although it seemed unlikely at the time, it is possible that the complete failure of one pupil in the exploratory study, to indicate that the puppet had made an error could have been due to poor understanding of the task demands. In the present study therefore a pre-test will be included to reassure pupils that it is acceptable to indicate that the puppet was wrong by presenting what were considered to be very obvious errors on very small set sizes. In addition, to minimise the language requirements pupils will be able to respond either "yes" i.e. he had got it right or "no" he hadn't.

In addition both correct and incorrect trials will be included to ensure that pupils are not encouraged to simply give the same response without thinking. Pupils will be required to identify three of the trials correctly- one of which will have to be an error trial and one a correct trial. Pupils who fail to discriminate between these counts will not be given the main test.

Finally, the previous study revealed considerable variability within a single class of pupils with SLD but the sample size was too small to examine specifically what contributed to individual differences in attainment. The objective of this study is to increase the sample size and to include pupils from a wider age span so that the influence of both chronological and mental age on performance can be explored.

In summary, this study has three objectives. The first is to examine the relationship between adhering to principles in counting and detecting principled errors in the counting of others. Evidence from the previous study together with an analysis of the literature suggests that children acquire the procedures for counting prior to an understanding of the principles. Secondly the study sets out to investigate the order of acquisition for adhering to the principles. Evidence from Fuson (1988) suggests that cardinality will be the last principle to emerge. Finally we start to investigate some of the factors which contribute to individual variation in performance by looking at the relationship between both chronological and mental age and children's performance on tests of understanding and counting skill. Evidence from the exploratory study suggests that mental age may be an important factor.

Method

Subjects. Fifteen pupils attending two schools for pupils with severe learning difficulties participated in this study. In an effort to ensure that each age group was fairly represented five children were randomly taken from each of three age bands, 7 to 8, 8 to 9 and 9 to 10 years. They ranged in chronological age from 7 years 3 months to 9 years 10 months (mean 8 years 5 months S.D. 9.6).

Procedure. Prior to attempting the counting tasks, each child was given the long form of the British Picture Vocabulary Scale. This test, described as a measure of receptive language ability, requires the child to recognise the meaning of words by successively identifying the correct picture from a set of four.

Basic counting task: In the first counting task, the children were presented with rows of 3 dimensional small toys and asked to count them and tell the investigator how many items there were. Six set sizes were employed. Small set sizes were defined as those including 3, 4 or 5 objects, large set sizes were defined as those including 8, 9 or 10 objects. Large and small set sizes were presented alternately with set sizes within each class presented in random order. For each of these six set sizes, three aspects of each child's counting performance was scored. They received one mark for pointing to each object once and once only, one point for producing a stable conventional order of number words, and one point for correctly emitting the last number tag word for each set size. This totalled a score of 18, 3 for each principle for small and large set sizes.

Error detection task: This task began with each child being introduced to a puppet, called "Wacky" who was just learning to count. They were immediately told that since Wacky was still learning to count he was not always right. Sometimes he was wrong. Following this verbal description, the children were then given a series of practice trials in which they were instructed to watch and listen carefully as Wacky counted a series of two or three objects. They were then asked "Did Wacky get it right?" Once the experimenter was sure the child understood this instruction, a series of five trials then followed in which the most prominent violations of counting principles were included. During these trials, small set sizes were consistently used since several studies have shown that these are most likely to elicit a clear understanding of the task demands (eg Briars & Siegler, 1984). The five trials proceeded as follows: (1) With a set size of three the puppet counted one, two and stopped thus omitting the last item. (2) With a set size of two the puppet counted correctly. (3) With a set size of

3 the puppet counted one, one, one. (4) With a set size of 3 the puppet counted a,b,c. (5) With a set size 3 the puppet counted correctly. Any child who did not respond correctly in three of these five trials was excluded from further testing.

For those children who demonstrated understanding of the task requirements, a series of 28 trials then followed. These were presented in blocks, each one directed towards the assessment of a single counting principle, one to one correspondence, stable order and cardination. Large and small set sizes were alternated within blocks, each error type was presented in both small and large set sizes and a ratio of 3 error trials to 1 correct trial was maintained throughout. The order in which blocks of trials were presented were randomly ordered. Any trial in which a child was deemed to be inattentive at any point was stopped, the child's attention regained and the trial restarted. The types of errors the puppet made are listed in Table 6.1. Children were scored as correct if they identified both error and non-error trials.

Table 6.1 Errors made by the puppet.

ONE : ONE ERRORS
Point but no word
Skip over an object
Point once at an object but say two words
Double point and say two words
STABLE ORDER ERRORS
Repeating a number word *eg* 1,2,3,4,5,5,6,7,8
Repeating a string of number words *eg* 1,2,3,4,2,3,4,5,6
Omitting a number word *eg* 1,2,3,4,6,7,8,9
Omitting a string of number words *eg* 1,2,3,7,8,9,10
CARDINALITY ERRORS
Count correctly but say there is one more
Count correctly but say there is one less
Count correctly but say a random number

Results

The fifteen pupils participating in this study ranged in mental age from "unscoreable" to 4.1 years on the BPVS. Of these 15, there were six children who failed to score on the BPVS and who did not demonstrate any knowledge of the counting process. The remaining nine scored between 2.1 years and 4.1 years (mean 2 years 9 mths).

Pattern of Performance

Table 6.2 sets out the scores obtained by each pupil for each of the three principles on the counting task and indicates which pupils were able to detect the errors made by the puppet. As can be seen from the table, six children were unable to adhere to any of the procedures for counting objects. However, the testing procedures did reveal that some of these children were acquiring isolated parts of the counting process. Three children, subjects 2, 3, and 6 were able to recite some number words in the conventional order and additionally one child, subject 5, was starting to develop the procedures for one to one correspondence by pointing to each object in turn on the smallest set size.

Table 6.2. Children's adherence to counting principles (maximum score 3) and performance on error detection tasks.

			Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS MA	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	Cardin-ality Errors	One: One Errors
1	7.7	u/s	-	-	-	-	-	-	-	-	-
2	7.7	u/s	(RC10)	-	-	-	-	-	-	-	-
3	8.7	u/s	(RC4)	-	-	-	-	-	-	-	-
4	9.0	u/s	-	-	-	-	-	-	-	-	-
5	9.0	u/s	-	-	1	-	-	-	-	-	-
6	9.10	u/s	(RC6)	-	-	-	-	-	-	-	-
7	7.7	2.1	2	-	3	-	3	-	-	-	-
8	9.5	2.1	3	3	3	2	-	-	-	-	-
9	7.3	2.5	2	-	2	2	2	-	-	-	-
10	9.5	2.7	3	3	3	3	3	3	-	-	-
11	8.1	2.8	2	-	3	2	2	-	-	-	-
12	8.7	2.9	3	3	3	3	-	-	-	-	-
13	7.11	3.3	3	3	3	3	3	3	+	+	+
14	8.11	3.4	3	3	3	3	3	3	+	+	+
15	8.0	4.1	3	3	3	3	3	3	+	+	+

u/s = unscoreable
RC = rote count
\+ = correct identification of error type

Of the remaining nine children, a wide but internally consistent pattern of performance was observed. Four children were able to count both large and small set sizes and could answer the "How many" question. Two adhered to the stable order and one to one principle on both set sizes, 3 adhered to all three principles but only on small set sizes.

Who was able to detect errors?

Only three pupils in the study demonstrated that their competence in counting extended to the detection of errors made by the puppet. All three of these children scored 3.3 years or above on the BPVS and all were consistently good at both tasks, their minimum success rate on the detection task being 83%. In contrast, all of the children who failed to pass the first phase of the detection task had some difficulty with the simple counting task.

While performing the error detection task the successful children revealed that their knowledge of the principles on which they were operating was quite explicit. In addition to simply noting that something had gone wrong, they indicated that they knew where the mistake had occurred and in cases where they were uncertain often spontaneously recounted to check. Moreover, a turn of events which proved to be most revealing of the children's level of understanding was their expressed desire to test the examiner!

CA, MA and performance

In order to explore the relationships between the children's chronological age, mental age and success on the counting task, Pearson's product moment correlations were computed. These revealed values of 0.05 (ns) for chronological age and 0.74 ($p < .05$) for mental age. Although one of these correlations reaches conventional levels of significance and the other doesn't, there is not in fact a statistically significant difference between them ($z=0.59$), (Ferguson 1966).

Discussion

The study set out to address three objectives. The first of these concerned the temporal order to adhering to principles in counting and detecting those made by others.

Procedures First or Principles First ?

Children in this study not only demonstrated that they were able to spot errors that someone else had made but it soon became clear that their own control of both counting principles and procedures was such that they could act with the puppet in a role reversal. Three pupils were able to detect errors and all demonstrated that they adhered to the principles in their own counting. This finding is consistent with those of the exploratory study and once again supports Briars and Siegler's (1984) suggestion that children begin to deduce the principles of counting once they have mastered the procedures. However, in contrast to the exploratory study sample, no child fell in the grey area between complete failure and total success. This was unfortunate as it precluded a comparison between the type of errors made by the child with the type of errors detected.

The profile of subject 10 suggests that the ability to adhere to the principles in one's own counting is not sufficient to enable one to detect errors. This pupil performed flawlessly on all of the count measures but failed completely on error detection. It would have been interesting to extend this exploration to a test of whether those children who were able to judge the puppet counts were able to detect errors in arrays that were beyond their own counting ability, as Gelman and Meck (1983) had done with other similarly competent children, but this was not possible.

Gelman and Cohen (1988) have however argued that children with "mental retardation" do not develop counting skills and understanding in the same way as preschool children. It is therefore important to extend this investigation to a comparison with pre-school children to see if there is a difference between children with severe learning difficulties and other children.

Is there an order to acquiring the principles ?

At first sight it might appear that the data from the six pupils who failed to score on the BPVS and who largely failed to adhere to any of the principles would be uninformative. However when asked to count a set of items some were able to rote count and one was able to tag objects in a small set. This pupil was not yet able to coordinate the two processes of tagging and saying the number words, a difficulty also noted among pre-school children (Beckwith and Restle, 1966; Wagner & Walters, 1982; Wilkinson, 1984). This initial profile supports the results of the exploratory study in finding that task difficulty increased with the number of components. Children at this stage could be seen to be starting to acquire single elements of the counting process.

Considering the other children, if we set aside the four who were perfect on the simple counting task, there were five children who might be described as "acquirers", i.e. children who were able to adhere to some of the principles in counting but were not yet competent in this. Among these children set size was one factor which separated them. Whereas two (Ss 8 & 12) had extended their acquisition to large set sizes, the remaining three (Ss 7,9,& 11) were largely restricted to small set sizes. This finding is similar to that of McEvoy and McConkey (1990) who found that pupils with moderate learning difficulties were also affected by set size in a similar counting task.

It is interesting to note in relation to the three pupils in the study who had difficulty with large set sizes that they were not actually required to be accurate counters to be credited with giving a cardinal response to large sets. They simply had to repeat the last tag used in their own counts, which is what they did not do. This contrasts with the performance reported for pre-school normal children in whom there is considerable consistency of last word responding often irrespective of the accuracy of the count (Fuson, Pergamet, Lyons & Hall, 1985; Wynn, 1990). In other words, if they were able to give the last tag word for small set sizes they could also do so for large set sizes. One possible explanation of this problem for the children with SLD is that they were reluctant to give the last tag if they were uncertain about whether they had counted correctly or not. However, for this to be true, it would be essential to demonstrate that these same children had a complete understanding of the relationship between accurate counting and last tag responding. This understanding was not evident in their performance on the error detection task and therefore at best could only be described as shaky.

The remaining two "acquirers" in the study showed a different profile of acquisition. They were able to produce the correct number sequence and coordinate this with tagging each object for both small and large set sizes but experienced great difficulty with the "how many" question. On being asked this question, these two children responded by recounting the array. This response also occurs in pre-school children prior to making a cardinal count transition (Fuson & Hall, 1983). There are two possible explanations of why some children have this difficulty. One is that they are unable to remember the last tag. An attempt was made to explore this possibility informally by allowing each child to recount the sets of objects and following this with a choice of answers which included the last number tag they had used. Typically, what happened then was that the child echoed the last tag stated by the experimenter, indicating that he had really no difficulty in remembering the last word heard. A more plausible argument, therefore, rests on the proposition that it is the significance of the last tag which eludes the child. Rather than it having meaning in terms of the properties of the set as a whole, the question "how many" is simply identical to the request to count the items. A difficulty in making this cardinal count transition has been noted by others working with pupils with learning difficulties (Baroody & Mason, 1984; McEvoy and McConkey, 1991).

Contributors to Performance

The relationship between counting ability and MA scores found in this study is worthy of comment. Those who failed to score on the BPVS were unable to adhere to the principles in their own counts, those with the highest scores demonstrated adherence to all three principles on both small and large set sizes. At a superficial level one might conclude that the BPVS has functioned as a screening test which has simply excluded children who are not yet able to participate in any formal numeracy task. For example, the finding might be considered in relation to Saxe and Kaplan's (1981) suggestion that children use gesture in counting simply to refer words to objects, just as they may do in other naming activities. On the basis of this suggestion, it might be that the test builds upon this point-name ability and therefore shares a fundamental capacity with the counting tasks used. A positive correlation between counting ability and receptive language scores has been obtained in a more recent study by Caycho, Gunn and Siegel (1991) in a study of rather more able children with Down's syndrome. However, this relationship did not extend to the tasks of answering the "how many" question or to the detection of cardinality errors.

Conclusion

On balance, this study provides evidence for the procedures first account of the development of counting in pupils with severe learning difficulties. No child who was unable to adhere to all three principles in their own counting was able to make correct judgements of the puppet counts. Correct counting on its own is not necessarily sufficient to enable the pupil to detect errors.

With regard to the other two aspects of the investigation. The pattern of adhering to the principles was varied but clearly some pupils did not follow the pattern suggested by Fuson (1988) for preschoolers. A comparative study will enable this difference to be investigated further. Finally, a significant relationship was found between counting scores and mental age. Given the small number of pupils who were able to perform on either measures of counting or on the BPVS, it is important to verify this finding with a second group of pupils.

Despite these findings, it is still possible that Gelman and Meck (1983) were correct in suggesting that there is a difference in the development of these abilities between children with severe learning difficulties and those of typically developing children (Gelman 1982) such that children with SLD acquire the procedures first, whereas typically developing preschoolers are guided in their acquisition by implicit understanding of the principles. It is therefore necessary in the next study to investigate how pre-schoolers respond to the same tasks.

Chapter Seven

Study 2

Counting by Pupils with SLD and Typically Developing Preschoolers - Similarities and Differences.

The results of the previous study suggested that pupils with severe learning difficulties have to learn to count before they are able to judge puppet errors. According to Gelman this is not the developmental sequence exhibited by typically developing children (Gelman and Meck 1983) although it has been argued (in chapter 2) utilising data collected by others, that preschoolers also acquire procedures first and, having gained some counting ability this facilitates the development of understanding which in turn enables the pupil to hone his performance. It is important that comparisons between children with SLD and preschoolers are made on the basis of data from performance of identical tasks. Clarification of this issue is the primary aim of this study.

The exploratory study raised the possibility that the process of error detection was susceptible to set size effects similar to those found in counting performance and further that some pupils might be able to detect errors before they were able to count *both* large and small sets perfectly. Shortly after the completion of these first two studies a study of preschoolers by Frye et al (1989) further extended our understanding of the order of acquisition. They found that preschoolers learn to count small sets, then large sets, then judge errors of small sets and lastly judge errors in large sets thus supporting the view that set size effects were present. A second aim of this study is, therefore, to look at the order of acquisition of counting performance and error detection taking into account set size differences.

Study one revealed that correct counting on its own was not a sufficient precursor for the detection of errors, suggesting that at least in pupils with severe learning difficulties the acquisition of procedures does not *automatically* lead to the development of understanding. Briars and Siegler (1984) report a similar outcome in their study of error detection in preschoolers. However poor performance on error detection tasks in this case may have arisen as an outcome of prolonged testing. Indeed one might argue that it is the very group of children whose understanding is just emerging who are likely to be most adversely affected by the effects of fatigue arising from prolonged testing. It may be precipitate therefore to argue that the pattern of acquisition is similar before comparisons are made in identical testing conditions.

Study one revealed that counting scores were significantly related to mental age- that is to say that pupils with higher mental age scores performed better on the count and error detection tasks than those with lower mental ages. One cannot conclude from this however, that pupils perform as well as their typically developing counterparts. If this is found to be true then, in addition to examining the pattern of acquisition of procedures and conceptual understanding, we need to consider possible sources of difference, for example the way in which they perform the tasks. Rather than focusing solely on absolute scores based on whether the child was correct or incorrect it is therefore important to also look for qualitative differences in performance. For example, some previous researchers have suggested that the performance of pupils with severe learning difficulties may be impaired by specific memory deficits (Spradlin et al, 1974; Baroody & Mason, 1984) which affect the ability to hold in mind a target number whilst counting. If pupils experience difficulties in memory it may also affect acquisition of the number string as some researchers have suggested difficulties with auditory sequential memory (e.g. Marcell, Harvey & Cottran, 1988; Marcell & Weeks, 1988; Hulme & Mackenzie, 1992). Equally however qualitative differences may arise due to the way in which pupils are taught, as proposed by Gelman and Cohen (1988).

If qualitative differences are found between the performance of the two groups this does not automatically imply that they lead to superior performance in one group. One might predict that at a global level pupils performance may be similar to preschoolers but performance on particular aspects may be different. To investigate this hypothesis, data on children's errors has to be examined. In this study three particular aspects of the own count performance were investigated: the number of different number words used, the type of one: one errors made, and lastly the response made to the cardinal question.

Another finding in the study by Frye et al (1989) was that pre-school children performed better on counting large sets when the how many question was asked *after* counting. Since the previous studies had asked the pupils with SLD "how many" there were *before* counting this may have contributed to the set size difference found for pupils who were able to give a cardinal response on small but not large sets. Inadvertently, the procedure may have placed additional demands on memory for some pupils. It could be argued therefore that in order to optimise performance pupils should be asked how many both before and after counting.

This study therefore set out to extend the findings of study one by examining whether the pattern of performance found in pupils with SLD was similar to preschoolers given identical counting tasks. It aimed to answer three questions;

1) Do children with severe learning difficulties count as well as pre-schoolers of similar mental age ? Although in study 1 mental age scores are significantly related to performance we cannot predict that they therefore perform as well as typically developing children.

2) Is the order of acquisition the same - accurate counting and then error detection ? Our analysis of the literature on typically developing, including the studies by Briars and Siegler (1984) and Frye et al (1989) lead us to predict that the order is the same, taking into account set size differences.

3) Are there any qualitative differences between the two groups ? Whilst we have expressed concern about the notion of *specific* deficits (see 1.3.2), this is not the only source of differences in performance. Differences in the experiences of SLD pupils could lead to qualitative differences in performance.

4) What factors contribute to individual differences ? We found in study 1 that mental

age scores predicted performance and we seek to verify this finding with a second sample of SLD pupils.

Method

Subjects. Fifteen pupils attending schools for pupils with severe learning difficulties participated in this study, all of whom were given the long form of the British Picture Vocabulary Test. Five of the pupils failed to score on this test and were excluded from the study leaving 10 children (5 boys and 5 girls). These ten pupils ranged in age from 7.0 years to 9.5 years (mean 8 years 2 months). Their BPVS scores ranged from 1 year 11 months to 3 years 10 months (mean 2 years 9.5 months). These pupils were matched individually with ten preschoolers attending a local nursery. Since permission to test the preschoolers on a mental age test was not given, the nursery children were matched on the basis of chronological age with the assumption being that their chronological ages were roughly in line with their mental age. Each nursery child had a CA which fell within a 6 month band of the BPVS score of a pupil from the SLD school. There was no significant difference between the two groups comparing MA with CA (t, $(18) = .26$).

Procedure. The basic counting task and error detection tasks used in this study were identical to those used in study 1 with the exception of one small procedural difference. In order to take account of Frye's study which indicated that children might forget to make a cardinal response, pupils were asked the "how many" question both before and after counting. The same system of scoring was used, a point for adherence to each of the 3 principles for each of 6 set sizes, totalling 18 points. Additionally a record was kept of the childs response, including the number words stated, the exact nature of the cardinal response and the objects pointed to.

1) Do children with severe learning difficulties count as well as pre-schoolers ?

Table 7.1 below provides a summary of the scores for both groups of children. For the SLD group the childrens total counting scores ranged from zero to eighteen with a mean score of 5.8 and for the nursery group from zero to sixteen with a mean score of 5. No significant difference between the count scores of the two groups was found, $\underline{F}$ (1,18) = 0.16.

Table 7.1. Summary of the total counting scores for the two groups.

Setting	Total Count Score	Range	Mean
SLD N=10	58	0-18	5.8
Nursery N=10	50	0-16	5

Table 7.2 sets out the individual counting scores for the pupils with SLD. Three children failed to adhere to any of the counting principles in their own counting,

Table 7.2. Scores of the Pupils with SLD on counting tasks.

			Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS MA	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	Cardin-ality Errors	One: One Errors
1	8.10	1.11	1	-	3	-	-	-	-	-	-
2DS	9.4	2.3	1	1	3	3	3	3	-	-	-
3DS	7.0	2.4	-	-	-	-	-	-	-	-	-
4	7.0	2.4	1	-	2	1	1	-	-	-	-
5	7.0	2.10	-	-	-	-	-	-	-	-	-
6DS	9.5	2.10	3	3	3	3	3	3	80%*	87.5**%	60%*
7DS	7.10	2.11	(RC2)	-	2	-	-	-	-	-	-
8	9.2	3.1	(RC2)	-	-	-	-	-	-	-	-
9DS	8.0	3.7	2	-	2	2	-	-	-	-	-
10DS	8.3	3.10	3	-	3	-	3	-	-	-	-

DS = Down Syndrome, RC = Rote count,
* on small set sizes only ** significant at 0.05 level.

although one demonstrated a limited ability to rote count. One pupil was able to adhere to all three principles across all set sizes. Table 7.3 sets out the individual scores for the nursery children. Two children failed to adhere to any of the counting principles in their own counts and no child successfully adhered to all three principles across all set sizes.

Table 7.3. Scores of the Preschoolers on Counting and Error detection Tasks .

Child and Sex	Age	Stable-Order		One:One		Cardinality		Error detection		
		Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable-order	One-One	Cardinality
1F	2.0	(RC7)	-	1	-	-	-	-	-	-
2F	2.0	-	-	-	-	-	-	-	-	-
3M	2.3	(RC6)	-	-	-	-	-	-	-	-
4M	2.4	2	3	1	-	-	-	-	-	-
5F	2.7	2	-	2	-	-	-	-	-	-
6M	2.9	1	-	1	-	-	-	-	-	-
7M	2.10	1	-	2	1	-	-	-	-	-
8M	3.1	3	1	3	1	-	-	-	-	-
9F	3.6	3	3	3	1	3	3	80%**	50%	62%
10F	3.10	3	1	3	2	-	-	-	-	-

** significant at 0.05 level.

2) Is the order of acquisition the same, accurate counting and then error detection ?
Unfortunately, this question cannot be properly addressed in this study since only one child in each group demonstrated any ability to detect errors in counting. Both children were the only children in their respective groups to be almost perfectly accurate in their own counting. Neither, however, were totally competent in detecting errors. The nursery child correctly judged 80% of stable order trials, 62.5% of cardinality and 50% of 1:1 count trials. Notably her lowest score for error detection related to the principle that she herself found most difficult. The child with severe learning difficulties also showed variation in the detection of different types of error.

She correctly judged 87.5% of cardinality counts but for other error types demonstrated competency on only small set sizes. She correctly judged 80% of stable order errors on small sets and 60% of 1:1 errors on small sets. Unlike the previous study neither group of children showed the levels of proficiency in error detection that had been apparent in study one. It therefore became necessary to consider closely whether these scores could have been arrived at by chance responding. Using Pascal's triangle it was calculated that in order to reach a 5% probability level pupils had to score 80% or more on the stable order and one:one trials and 87.5% on the cardinality trials. Using these more stringent criteria only the judgement of cardinality trials by the pupil with SLD reached significance level. This outcome therefore provides further limited support for the claim that children have to learn to count first.

3) Are there any qualitative differences between the two groups ?

Three aspects of children's own counting performance were investigated: the range of different number words used, the type of one: one errors made, and lastly the response made to the cardinal question.

There proved to be a significant difference between the two groups on the number of tag words used in the count in that typically developing children produced a greater variety of count words than the children with SLD, (U (9,9) = 22, $p < 0.05$). The facility with which one recalls and uses count words might make a difference to the number and type of one:one errors made. For example if one knows few number words one might be more likely to skip objects than to double count. However, a comparison between the two groups on whether they had more skipped object than double count errors was found to be insignificant.

Lastly the distribution of cardinal responses were compared. Children's cardinal responses fell into a total of six different categories, namely: to answer correctly and repeat the last tag or to make one of five different types of incorrect response, firstly to make no response, secondly to repeat the sequence of count words without tagging the items, thirdly to recount the items in the array, fourthly to make a random response or any number word, or finally to add or subtract one to the last tag word. Table 7.4 lists the error types and shows how errors were distributed for each group of pupils. Children with severe learning difficulties largely responded either with the last tag or made no response at all. These two responses occurred for 89% of trials. In contrast the nursery pupils demonstrated a range of different incorrect response types.

Table 7.4. Cardinal Responses made by SLD and Nursery Children

	Last Tag	No Response	Repeat Sequence	Recount	Random	Last Tag +/- 1
SLD	21 (39%)	27 (50%)	5 (9%)	0	1 (2%)	0
Nursery	10 (19%)	18 (33%)	6 (11%)	10 (19%)	6 (11%)	4 (7%)

In order to compare the distribution of these response types statistically, it was first necessary to place children in each group into one of three categories, those who on 5/6 trials or more made no response, those who on 5/6 trials used the last tag and lastly those whose response profile was mixed. There was however no significant difference between the number of nursery and SLD pupils who fell into each category [$\chi^2(2, 20) = 2.42$ ns].

4) What factors contribute to individual differences in performance ?

As before the relationship between the SLD pupils chronological age, mental age and success on the counting task was explored. In contrast to the previous study, chronological age rather than mental age proved to be a better predictor of count scores in the current sample of pupils with SLD. For mental age the correlation r = .151 whereas for chronological age r = .707, $p < 0.05$. Chronological age was found to be a better predictor even when the effect of mental age was partialled out, Txy.z= 0.6.

Because of the disparity between the performance of this sample and the previous one with fewer pupils who were able to judge puppet errors it was decided to ask an additional question.

5) Is there a difference in the performance between this group of SLD pupils and those in the previous sample ?
Although no attempt had been made to match the two SLD groups, they had both been selected on the basis of taking all children in that age band in the regular classrooms of the school. If one takes children who scored on the BPVS then there is considerable comparability both with CA and MA as measured by the BPVS. The mean MA for the previous group was 33.66 mths (S.D = 7.8) and for the current group is 33.5 months (S.D. 7.3 months). A one-way analysis of variance revealed that there was a significant difference between the two groups on their count scores ($F(1,17) = 7.91$, $p < 0.05$). Furthermore whilst there was no difference between the correlations for each group for chronological age and counting performance, there was a significant difference in the correlations for mental age (Critical Ratio:2, $p < .05$).

Discussion

There were three main outcomes of this study. Firstly, children with severe learning difficulties did count as well (or in this case, as poorly) as preschoolers. Secondly, the order of acquisition i.e. procedures first, seemed to be the same and finally, there were significant differences between the groups on their acquisition of the number string, and a nonsignificant difference in the way they responded to the "how many" question. There were however two unexpected findings. This group of SLD pupils were significantly different in their counting performance to the previous sample despite having been selected from SLD schools on the same basis (chronological age), and for this group of pupils mental age did not predict performance. Each of these findings will be considered in turn.

No overall difference was found in the profile of count scores and error detection scores between the group of pupils with severe learning difficulties and the preschoolers. This finding has been recently replicated in a study by Caycho et al (1991) using a sample of more able children with Down syndrome. In addition the study suggests that for both preschoolers and children with severe learning difficulties it is necessary to be able to reach some level of competence in counting before one can detect errors in the counts of a puppet.

No pupils in this study were able to uniformly detect puppet errors. The profile of the error detecting pupil with SLD (S 10) could be taken as support for the finding by Frye et al (1989) that there are set sizes differences in error detection. This, of course, is contrary to the proposition of Gelman and Meck (1983) that children are able to detect errors in both large and small sets because they understand the principles of counting. However, if we use the criterion of 80% or more correct (Frye et al 1989 took the criterion of 75%) then the set size difference starts to vanish and is replaced by a difference between types of error. Children were able to detect some errors but not others. It would be useful to replicate this study using a wider sample of more able counters in order to investigate whether there is a characteristic pattern to success on error detection tasks.

There were some interesting differences in the performance of the preschoolers and pupils with severe learning difficulties. For example, the nursery children used a larger vocabulary of number words when counting. Given the difference in chronological age and experience of formal instruction this could be regarded as surprising. However we do not know what experiences of counting are provided for children with SLD. It may be that although they have more experience of formal education this does not include counting opportunities.

A second and equally interesting finding was the difference in the way the two groups responded to the "how many" question. Typically one can characterise the pupil with SLD as either making no response or responding correctly, using the last tag. This contrasts to the preschoolers. Whilst fewer trials were responded to accurately, fewer resulted in no response. Instead pupils made a variety of incorrect responses, not only did they repeat the sequence but they also recounted, gave a random response or one which was either one more or one less than the correct answer.

There are several possible explanations for this difference. Pupils with SLD may feel reluctant to give an answer they know to be incorrect, they may feel either unconfident or unable to guess. Alternatively they may acquire the right answer by a different means to preschoolers. Gelman and Cohen (1988) for example characterise the learning of pupils with Down syndrome as associative. Following this interpretation it could be argued that pupils have not learnt the associative response to the "how many" question. In contrast one might portray preschoolers as willing to guess, or as deliberately trying to deduce an appropriate answer. Gelman and Cohen (1988) might argue that unlike pupils with SLD, preschoolers are guided by understanding of the principles. However this varied response pattern may not reflect greater understanding of the principles but children actively trying to work out the procedural rule. It might further be argued that different curricular experiences support these two varying profiles of acquisition. At present, however, there is no research which clearly indicates how pupils with SLD acquire the ability to answer the cardinal question correctly.

One unexpected outcome of the study was the finding that this sample of pupils performed very poorly compared to the previous sample despite using the same criteria for selection. The reasons for this difference are unclear. Whilst the two groups are similar with respect to mental age scores, the first group had acquired a higher level of both skills and understanding than the second group. It has been argued that one should not seek to make distinctions between pupils on the basis of their etiology and yet one account of the differences in performance between the groups might be that there was a difference in the etiology between the two. The only data which was available for etiology suggests that more children in study 2 had Down syndrome (50% of the children who scored on the BPVS compared to 11% in study 1). However, the sample sizes are too small to conduct a statistical analysis of any differences in the performance of children with Down syndrome.

An alternative explanation may lie with any presentation differences between the two studies. The only procedural difference between the two studies was the repeated use of the cardinal question but this should, in fact, have led to improved cardinal responses rather than impeded performance. A final account might rest in a difference in the curricular experiences of the two groups. The curriculum in the schools in study 1 may have lead to higher achievements in counting. This might be reflected either in the frequency with which pupils were provided with opportunities for counting, or the type of approaches used to teach counting. This would form a profitable area of further study.

Conclusion

This study again suggests that children have to learn to count before they are able to detect errors in the counting process made by others confirming the findings of Briars and Siegler (1984) and those extended by Frye et al (1989). As with the previous study there was no evidence that children were able to detect errors prior to successful execution of counting *both* small and large sets. Whilst one might be far more tentative about the ability of pupils with SLD to detect errors, there were no differences between the preschool and pupils with SLD in either the temporal order or in their ability to count. However this sample was also small and performance on counting tasks was poor. The study therefore requires replicating with a larger sample which includes pupils with severe learning difficulties and pre-school children whose performance on counting tasks is higher. This suggests that the sample needs to include older pupils with severe learning difficulties.

The only significant qualitative difference which we found in performance was in the variety of number words produced when counting. We have argued (in 2.3.1) that the acquisition of the number string is a serial recall task. For the early numbers at least, therefore, this may be viewed as a rote learning task and which is likely to be significantly affected by the frequency of opportunities to hear the number string. This issue will be addressed in the next study.

An important area for inquiry therefore lies in the experiences and opportunities for counting given to pupils with severe learning difficulties. No investigations have been made of this area although we know from past studies (see chapter 1) that teachers and parents of pupils with SLD view mathematics as having fairly low priority in the curriculum but this view may have been affected by the introduction of the National curriculum. This issue is considered in the next study.

Chapter Eight

Study 3
Children's Performance on Count Tasks and their Curricular Experiences

General Introduction

The previous studies have provided some valuable data on the acquisition of counting in pupils with SLD but comparisons with typically developing preschoolers proved far from conclusive. Although several children in each group in study 2 managed the basic counting task only one child in each of the samples proved able to detect any errors. Neither of these individuals were 100% correct in their judgements and their performance appeared dependent on the type of puppet error and set size. Both children however were able counters, supporting the premise that accurate counting precedes error detection. The importance of acquiring procedures for counting cannot therefore be over-stated. Moreover, whilst it would appear from the data so far that the acquisition of procedures does not *automatically* lead to understanding, we have not found a single child who has demonstrated understanding and not been able to count both small and large sets at a near perfect level. We need therefore to consider the way in which children acquire these procedures. In chapter 2 the process of acquisition put forward by the "procedures first" protagonists was described. Although little detail is presented by these investigators, explanations rest largely on learners copying examples present in the environment (Briars and Siegler 1984, Hersovics et al 1986.) An investigation into the nature of these experiences would be a fruitful area of enquiry.

Study 2, in addition to revealing similarities between the preschoolers and pupils with SLD in their count performance, also revealed a number of differences between the two groups. The preschoolers appeared to come to the count task with a richer count word vocabulary on which to draw and responded to the "how many" task with a wider range of responses than the SLD children. One possible explanation for the differences in vocabulary size lies in the experiences the two groups of children receive. Despite the advantage of being older, SLD children may not be exposed to the same rich source of number words as typically developing preschoolers. Alternatively within child factors might account for this difference with pupils with SLD finding it far harder to learn the number words in spite of comparable MA. A third explanation would suggest an interaction between these two factors, thus children may have greater difficulty in learning the number words than typically developing children and this difficulty is not taken into account by adults who use number words with the same or less frequency.

If children's initial acquisition of procedures is dependent at least in part on their exposure to models of counting then it is important to examine the beliefs of adults working with them as this will influence the curriculum offered. Counting forms part of the maths National Curriculum as well as being an important skill in everyday life. In the past, both teachers and parents of children with SLD have rated "academic" areas of the curriculum as having a low priority (De Souza and Bailey 1981, Carden and Robson 1985) but have seen the achievement of independence as having the highest priority. The National Curriculum was introduced along with the aim of preparing children for " the responsibilities and opportunities" of adulthood (Education Reform Act 1988) and therefore success in maths (together with all the other National Curriculum areas) is compatible with an overall aim of independence. Interestingly education for the under fives is seen by the government to share the same aims (HMI 1989). Officially therefore, staff in both settings should devise learning activities and opportunities with the same long term aims in mind. In the present study an attempt will be made to determine the extent to which this is in fact the case. Within this objective a distinction will be made between adult views of the importance of counting and, rather more specifically, the extent to which they view this area as a priority.

To achieve this objective, staff in both nursery and SLD settings will be asked first about the aims of their provision and secondly how important they see counting to be, compared to other curriculum activities. An investigation will then be carried out of the experiences individuals in each of the settings actually receive. It has already been argued that the ability to count constitutes an important independent living skill, and that even simple everyday activities such as visiting a friend, going shopping or cooking demand a variety of number related skills. It is likely therefore that schools do not limit exposure to "number" purely to timetabled "maths" periods but use opportunities to teach children about counting as they arise in everyday activities which may form part of other curriculum areas. Indeed it could be argued that these naturally occurring opportunities will provide the pupil with especially meaningful contexts for learning. The aim is therefore not just to look at maths teaching but to make observations across the curriculum.

The third aspect of this study extends the data already collected on pupils' performance and understanding of counting with a view to further exploring how we might account for group and individual differences. In spite of efforts to avoid this, one of the limitations of the previous studies was the small sample size. Whilst study 1 and 2 each involved fifteen pupils with SLD, in both cases a third of these children failed to show any co-ordinated counting ability. Out of 30 children therefore only 20 have provided counting data. Additionally only 4 pupils out of the 30 were able to detect errors at anything above chance level. In order to increase the number of children who are able to detect errors as well as count themselves, the age range will need to be extended upwards once more.

One of the outcomes of the previous studies was to draw attention to differences between samples of children. For example whilst no difference had been found between the performance of the typically developing and SLD children in study 2, analysis *had* revealed significant differences in performance between the group of SLD children in study 1 and those in 2. Others have noted differences between the performance of groups of preschoolers (Gelman, Meck and Merkin 1986, Hersovics and Bergeron 1989). In chapter 2, (see page 59,60), it was suggested that this might well be a reflection of children's differing curricular experiences. This has important implications for the design of this final study as it is the *interactive* relationship between pupils performance and their experiences which is informative, rather than purely to investigate to find "typical" curricular experiences. No previous studies of this nature exist, indeed, no studies have set out to systematically examine the types of experiences provided to pupils with SLD in the area of counting.

In sum, with respect to each of four settings (two nursery and two SLD schools), study three sought to investigate three key issues:

* The importance that adults accord to the development of counting;
* The number experiences the children receive in their respective daytime settings and including the variation within and between settings;
* The relationship between staff attitudes, the provision of number experiences and pupil performance on counting tasks.

Since the study is rather complex in its design and involved the use of quite different methodologies for each of the questions set, it will be described in three parts. In Part A the investigation of how SLD and nursery staff viewed counting is presented. In Part B, the experiences of the children in each setting is described and in Part C the counting of a much larger group of children from the same schools is described along with an exploration of the relationship between these variables.

Part A
Staff Views of the Importance of Counting

The aim of this part of the study is two fold. The first objective was to find out whether the staff in the four settings expressed different aims for their pupils. The second is to determine how important staff in all settings considered counting to be, and whether they make a distinction between acquiring the number words and learning to count.

There are various ways one might set about eliciting this kind of information from school staff. At first sight an interview might seem the most appropriate methodology. However, for the present purposes, a very simple fact ruled against this possibility. The SLD school system is relatively small and it was considered highly likely that the staff would have prior knowledge of the investigator's role as a teacher trainer; indeed some of them were known to have attended these training courses and/or had students on placement in their classes. In contrast, the staff in nurseries were unlikely to already have this knowledge and even if they did they were unlikely to respond to it in the same way. Since there was no way of avoiding the effect of this difference between the two "subject" groups in an interview situation, the alternative of using questionnaires which could be filled in anonymously was preferred. In addition questionnaires had the additional advantage that when time is limited they can be completed at home. Finally, as an additional means of avoiding response bias, staff were informed that the purpose of the study was to investigate pupils cognitive and language development.

Method

Questionnaire Development

Although the main aim of the questionnaire was to find out staff attitudes towards teaching counting, it was considered essential that this be placed within the context of other activities. Firstly it was felt that asking staff to rate counting as an isolated activity might be subject to contamination by the desire to please the investigator. Secondly, and equally importantly, attitudes towards counting could only be appreciated through comparison with attitudes towards other curricular activities. A preliminary literature search revealed a preschool questionnaire designed by Sylva, Smith and Moore (1986) to investigate the views of pre-school staff (prior to implementing a Highscope programme). This provided a useful starting place as it included a series of goal-related items for which respondents were invited to rate their importance on a five point scale from 1, vitally important to 5, not important. Since these items were directed specifically at nursery staff however, the questionnaire needed to be reworked to ensure that it was appropriate for SLD staff.

Firstly the items were divided roughly into curriculum areas to ensure a spread of items which covered the curriculum areas generally found in SLD schools. Secondly the wording of some goals was changed to make them more user friendly to staff working with older pupils. The overall target was to reduce the number of items to approximately 30 covering each of the five developmental areas. Embedded in these items were two specifically related to number activities and these distinguished between two aspects: "knowing the number words in sequence", and "counting objects". In this way, staff were asked to discriminate between activities which are purely based on acquiring a procedure without any suggestion of understanding and one in which understanding is implicit if not explicit. Goals were listed in a random order.

In addition to these structured questions the questionnaire also included an open ended enquiry into how the staff saw the aims of their work. It was deemed appropriate to ask them directly about their aims with an unstructured question because the information required was qualitative. This formed the first question.

In order to check the suitability of this adaptation of the questionnaire its use was tested in two volunteer SLD schools and two nurseries. This resulted in some minor alterations and additions which are reported in detail in Appendix B. The final questionnaire therefore included an open question asking staff to state their aims and a series of 34 goals for rating on a five point scale of importance.

Although this questionnaire was not developed to be used with large samples of nursery and SLD school staff it was still important to meet the basic criteria for good design and reliable data. Careful consideration was given to the language used, wording and ordering of questions, the use of open or closed questions, and the length of lay-out of the questionnaire in order to increase response levels (Smith, 1975; Wolf, 1988; Borg & Gall, 1989; Foddy, 1993). Additionally the respondents were pre-contacted and given good reasons for collecting the information and this together with (where appropriate) follow-up techniques all served to maximise the levels of response (Foddy 1993; Borg and Gall 1989).

The Main Study

This part of the study involved all the staff who were working with pupils aged 7-14 in two SLD schools with the exception of those who worked with pupils with profound and multiple impairment, and all the staff in two nurseries who worked with children aged 1.8 years and above. The questionnaires were handed individually to a total of 18 members of staff in the SLD schools and 10 in the nurseries.

Participants

Two SLD schools were paired with nearby nurseries and were selected on the basis of the following criteria:-

a) the catchment of both school and nursery should be drawn from a population for whom English was the first language for the majority of children.

b) the nursery was placed in close proximity to the school, within the same county division.

c) the nursery took children from the age of 1.8 years to 5 years and their entry criteria enabled children from a variety of backgrounds to attend.

d) both the nursery and the school were willing to accept all phases of the investigation (work with individual children including the use of mental age tests, observation and questionnaire) based on the knowledge that I was investigating areas of both cognition and language.

Results

The response rate was 93% with one teacher and one assistant from the SLD schools failing to complete the questionnaire. Additionally 4 individuals (2 from each setting) omitted to respond to a single item and 1 assistant from an SLD school completed question one but rated only the first 19 items from the remainder.

What are the aims of adults working in the SLD schools and nursery settings ?
A total of 74 statements were made to question 1. These varied in the type of response, not all of which were easily classifiable as "aims" Table 8.1 below reveals the number of statements made by each group of respondents.

Table 8.1. Number of Statements of Aim Contributed by Each Group

Group	Respondents (N)	Aims
School A- Teachers	5	10
School A- Assistants	4	15
Nursery A	4	15
School B- Teachers	3	11
School B- Assistants	4	9
Nursery B	6	14
Total	26	74

From these 74 statements it was possible to identify 4 main categories of aims :

1. Statements that pointed clearly to the future
2. Statements that reflected recognition of individuality
3. Statements which referred to the role of the environment

4. Statements which referred to the development of specific areas of skill and understanding.

Once these 4 over-arching categories had been established it was then easier to subdivide them to form 10 more detailed subdivisions. Initially, inter-coder reliability on this split reached 74%. However further discussion and clarification revealed that two categories were overlapping and when these were combined the agreement level rose to 90.54%. This resulted in nine categories with agreement levels ranging from 80-100%. These are shown in Table 8.2.

Table 8.2. Inter-coder Reliability for Each Category of Aim

Categories	1A	1B	2A	2B	3A	3B	4A	4B	4C
Percentage Agreement	90%	100%	80%	100%	100%	83.3%	90%	100%	100%

The final 9 categories were described as follows:

1A. This category included statements that, in pointing to the future, talked about independence. For example one member of staff from school A wrote: *"Independence and responsibility for themselves and their actions"*.

1B. This category included statements that, in pointing to the future, talked about specific placements. e.g. *"I hope to teach the children basic reading and writing skills to prepare them for school"*, (Nursery B).

2A. This category included statements that recognised that the children had individual needs and ability levels which had to be addressed if the child was to make maximum levels of progress, e.g. *" To help each child individually to gain the highest achievement in their age group and ability,"* (Nursery B).

2B. This category included statements that related to individual personal qualities, in particular ones that related to self-esteem, self-confidence, self-image etc. e.g. *"To* *develop awareness of themselves and a good self image,"* (School A).

3A. This category included statements which related to the role of the environment in terms of safety and security e.g. *" The welfare and safe-keeping of children in my care",* (Nursery A).

3B. This included statements which related to the role of the environment in bringing about learning. It therefore included reference to the nature and types of activity thought to be important e.g. *"To make the activities interesting so that you are able to capture and keep, for a suitable amount of time, the child's concentration, "* (Nursery B).

4A. This is a joint category because of the degree of overlap between reference to communication and social skills e.g. *"To develop a desire to communicate with others in a sociable, positive and effective way,"* (School A).

4B This category includes statements which refer to the development of cognitive abilities, e.g. *"Recognition of colour and shape,"* (Nursery A).

4C. This category includes statements which refer to the development of physical skills, e.g. *"Fine motor skills,"* (nursery A).

Table 8.3 below shows the distribution of responses by School A teachers and assistants, nursery A staff, School B teachers and assistants, and nursery B. Starting from the premise that staff in schools would be equally likely to make statements in each of the four main categories, a series of tests were carried out. In fact this was only true of staff in school B, (χ^2[1,4] =1.2 ns) where statements from staff were distributed across all four categories fairly equally. It was found that staff in the other three settings did not distribute their statements equally across the four broad categories, this was true for school A (χ^2[1,4] = 24.95 $p<.005$) for Nursery A (χ^2[1,4] =19.01 $p< .005$) and for Nursery B (χ^2[1,4] = 11.71 $p<.01$). Therefore in three out of four settings there was some consensus between staff on the aims of their provision.

Staff at school A, both assistants and teachers, placed particular importance on communication and social skills in their responses, with individual qualities such as self-esteem and self confidence and recognition of children's individual abilities also being emphasized. In Nursery A importance was placed on the development of cognitive, physical and social skills, whereas in nursery B the emphasis was placed on the environment and the need to provide stimulating activities. Staff in school B reported a number of aims that related to independence, a number which related to children developing their full potential and a number that stressed the role of the environment but relatively few were directed at acquiring specific skills.

Table 8.3. Distribution of statements of aims across groups

Types of Aim	Future Placements		Individuality		Environmental		Skill- Based		
	1A	1B	2A	2B	3A	3B	4A	4B	4C
School A Teachers			2	2			4	1	1
School A Assistants	2		1	2			9		1
Nursery A	1		1		2	1	3	4	3
School B Teachers	3		3			3	2		
School B Assistants	3		2	1		2	1		
Nursery B	1	1	1		3	6	1	1	
Totals	10	1	10	5	5	10	20	6	5

Out of the overall total of 74 statements only **one** reference was made to maths and this was offered by a teacher in school A who wrote "Understanding of the world in terms of maths and science". In contrast, again looking across all four settings, more statements contained reference to skills of interaction (communication and social skills) than any of the other categories.

What priority did Staff give counting in SLD and nursery settings ?

A comparison between the four settings was performed in two ways. To begin with, the ratings of the two count items were examined by taking the mean response of staff in each of the settings. These mean scores are set out in Table 8.4. No significant difference was found between the ratings of staff from the four settings for either "knowing the number words in sequence" [F (3,22) = 2.19, p=.12], or for "counting objects" [F (3,22) =1.23, p=.32]. These data also allow us to consider the similarity

Table 8.4. Mean Responses to Questionnaire Items for staff in 4 settings.

Staff Responses		*Knowing the number words in sequence* (Item 8)	*Counting Objects* (Item 23)
		Mean	Mean
SLD School A	N= 9	3.78	3.39
SLD School B	N= 7	2.86	2.83
Nursery A	N= 4	3.5	3.5
Nursery B	N= 6	2.83	3.0

with which each of the four groups viewed the two count items. Only staff in school A appeared to make a clear distinction between knowing the number words and counting [t=2.4, p<.05] and viewed the latter as more important. Staff in the other three settings made no significant distinction in their rating of the two items. To clarify the picture further the mean scores of all items were taken to put all 34 items in rank order for each of the 4 groups. These ranks are shown in table 8.5. This reveals that School A rank "knowing the number words in sequence" extremely low- 33rd out of 34 items. In contrast they see "counting objects" as a rather more profitable activity giving it a mean score that is 24th. In contrast school B make virtually no distinction between the two activities, a profile that is similar to the two nurseries.

Table 8.5. Mean Ranking of the Questionnaire Items

	Questionnaire Items	Ranking by SLD Staff		Ranking by Nursery Staff	
		School A	School B	Nursery A	Nursery B
1	helping other children	19	17	5.5	15
2	extending vocabulary	9	3.5	1.5	3
3	following instructions correctly	9	10.5	15	7.5
4	co-operative interaction with others	3.5	10.5	5.5	10.5
5	concentration and persistence	13	12	18.5	24.5
6	anticipating events and making predictions	18	23	29.5	28
7	completing jigsaws	34	29	11	24.5
8	**knowing the number words in sequence**	**33**	**26**	**24**	**24.5**
9	recognising and naming colours	29	20.5	11	15
10	describing feelings	14	15	18.5	22
11	pre-reading skills	24	23	29.5	19.5
12	pre-writing skills	24	23	29.5	10.5
13	finding their way around familiar environments	6	13	11	7.5
14	able to express needs and feelings appropriately	2	1	3	15
15	forming positive relationships	5	3.5	4	10.5
16	developing use of their sense	9	6	11	15
17	knowing about the jobs people do	24	32	32	33.5
18	developing balance and agility	16.5	20.5	15	15
19	drawing people and things	32	34	24	31.5
20	making choices about what to do	3.5	8.5	24	10.5
21	knowing about the seasons	30.5	33	34	31.5
22	communicating with others	1	2	1.5	1
23	**counting objects**	**27**	**25**	**24**	**28**
24	dancing	28	30.5	21	30
25	learning about time	21.5	27.5	33	28
26	matching and sorting	21.5	18.5	18.5	19.5
27	use of scissors	30.5	30.5	24	33.5
28	familiarity with daily routines	12	8.5	7.5	7.5
29	singing	20	18.5	7.5	19.5
30	solving problems independently	15	14	29.5	19.5
31	comparing and measuring	26	27.5	11	24.5
32	knowledge of the family	16.5	16	27	4
33	looking after one's own needs e.g. dressing, feeding, going to the toilet.	9	5	15	2
34	moving around the environment independently	9	7	18.5	7.5

In order to place this finding in context a quick comparison was made of the ratings given to all 34 items by staff in the four settings, (see table 8.5). This reveals the overall variation between settings for the remaining 32 items. We can see from this for example that staff in the nursery view item 9, "recognising and naming colours," to be more important than SLD schools but the SLD schools give item 30, "solving problems independently", a higher priority than the nurseries. Equally there is agreement and disagreement between comparable settings, for example, nursery A rate item 34, "moving around the environment independently ," as much less important than staff from nursery B. This profile of variation between and across settings serves to highlight the relative consensus on the importance of number. Interestingly good levels of agreement also exist for the top priority "communicating with others" (item 22).

Some further analysis was conducted on the questionnaires from the two SLD schools, firstly to make a comparison between teachers and assistants scores. These are presented in table 8.6 and reveal little difference between the two groups. Secondly a comparison was made between SLD staff who worked with older and younger pupils

Table 8.6. Responses of teachers and assistants in SLD schools

Staff Responses	*Knowing the number words in sequence*		*Counting Objects*	
	Mean	Rank/ 34 items	Mean	Rank/34 items
Teachers in SLD Schools	3.25	28.5	3.19	26
Assistants in SLD schools	3.5	27.5	3.14	22.5

in the SLD school (Table 8.7). Due to the way schools group their pupils, a distinction was made between those working with pupils aged 6-10 (N= 6) and those working with pupils 12-16 (N= 6). Whilst staff largely view counting items similarly there is some suggestion that staff in senior classes view knowing the number words in sequence as less important than the staff from junior classes, although this difference does not reach conventional levels of significance [$F(1,10) = 3.07$, $p < .10$].

Table 8.7 Responses of staff working with younger and older children in SLD schools.

Staff Responses	*Knowing the number words in sequence*		*Counting Objects*	
	Mean	Rank/ 34 items	Mean	Rank/34 items
Staff working with pupils aged 6-10 in SLD Schools	2.83	22	3.2	26
Staff working with pupils aged 12-16 in SLD schools	3.5	31	3.08	25

Discussion

Staff aims were divided into four global categories which related to either the future, individuality, the environment, or the development of skills. These were further subdivided to form a total of nine sub-categories. Despite the clarification of this question staff still had difficulty keeping their statements clearly to aims and many still included aims which were largely for themselves, hence the inclusion of a category with two sub-divisions that related to the environment.

Whilst it has been argued that counting is an important skill in a number of everyday activities which enable a person to be independent, only one member of staff included a specific reference to maths in this study. If staff mentioned specific areas of curriculum it was most likely to relate to communication and social skills.

Although there was considerable variation between staff in the four settings in their statements of aims, one school seemed to stand out as more different than the other three due to the lack of consensus between staff in this setting. Despite government guidelines it appears that there is no overall agreement between the staff in the four settings. It would also appear that there may no longer be the over-whelming emphasis on independence in the aims of SLD schools that had been previously noted by De Souza and Bailey (1981) and Carden and Robson (1985).

With regard to the second part of the questionnaire two particular points stand out. Firstly, staff ranked the number- related items very similarly in three of the four settings and secondly all groups rated these items relatively low in importance so that when the mean scores were ranked they fell into the bottom third of activities. This finding was especially notable when contrasted with the unanimously high priority given to communication skills.

If the responses of these adults are viewed as being related to their behaviour in the classroom then the outcome of this particular questionnaire suggests that staff in all settings are likely to provide their pupils with relatively few opportunities to learn about counting. Although the sample sizes are small for predicting differences between groups the data tentatively suggests that staff in school A view "knowing the number words in sequence" as being a particularly unimportant goal and may therefore be less likely to provide practice in rote counting. A nonsignificant second trend was for staff working with older pupils to again view "knowing the number words in sequence" as slightly less important than staff working with younger children. If this trend is an accurate representation of staff attitudes we might expect to see fewer opportunities for rote counting presented to older pupils.

This part of the study suggests that in relation to staff attitudes there is notable agreement between staff in the four settings that counting is not an important activity. This degree of unanimity is surprising given the different levels of attainment of pupils in study 1 compared to pupils in study 2. However whilst staff in these four settings show considerable agreement with respect to their attitude towards counting, one aspect that was notable was the extent to which there was agreement between staff *within* three of the four settings, but in the fourth, school B staff were very varied in respect of their views of the general aims of their provision. Part B of this study sets out the second part of the research into the use of number words across settings.

Part B

Children's Experience of Number Words.

To date, few systematic surveys exist of how adults use number words in the presence of children and all focus on interaction between caregivers and typically developing children. Gelman and Massey (1987) describe how infrequently parents/caregivers use number words at a museum despite the provision of count related materials, yet other studies suggest that parents at least view counting as important in the preschool years (Durkin, Shire & Reim 1986). The only longitudinal study has been made by Durkin and his colleagues who document the use of number words by a small sample of mothers and their young children (Durkin, Shire, Reim, Crowther & Rutter 1986). From this study we learn that mothers use small numbers most when the child is aged 27 months. Children increased their rate of number word output with age but did not reach the highest rate for the same number words until the last observation period at 36 months. Mothers therefore precede infants in using number words at a high rate. An earlier study, also reported in Durkin, Shire and Riem (1986) suggests that mothers are very likely to attempt to teach their preschool children to count and that the very ambiguities in the way number words are used may serve to promote understanding. In contrast Saxe, Guberman and Gearhart (1987) present a picture whereby mothers are adept at altering the task demands according to the responses made by the child. It must be noted that mothers in this survey, unlike those in the longitudinal study of Durkin and colleagues were explicitly made aware of the purpose of the research. This may explain the discrepancies between the findings of the more naturalistic studies of Durkin et al (1986) and Gelman and Massey (1987) and that of Saxe et al (1987) and furthermore suggest that whilst mothers are capable of quite specific teaching, they don't necessarily do so.

While the studies of very young children concentrate on mother and child interactions, as children get older experiences in nursery and school may be equally formative, with both teachers and peers having a role to play in providing models of counting. Although a peer model may be less accurate at times than a teachers model it could still provide a potential source of discussion and reflection. In nursery settings children are actively encouraged to play and work together (Ball, 1994) and peers may therefore have a more substantial role to play. In contrast, SLD schools have traditionally developed individualised methods of working with relatively little time being spent in group work (Coburn 1989). The adult:child ratio in schools reflects this bias. It is less likely therefore that peers will provide models of counting. In the present study, however, the contribution of both adult and peer is considered.

In addition to the frequency and the agent, a third potential source of difference between settings concerns how number words are used. Durkin et al (1986) largely differentiate between number word use by the contexts in which they appear. They identify 6 main patterns of use: nursery rhymes, stories and songs; sequential complements (123 go); recitation of the number string; repetition and clarification of cardinality; alternating strings; and lastly incidental number use (such as reference to house number etc). It is clear from this study that children receive a variety of different experiences of number words, many of which are contradictory. Using a rather different approach, Fuson (1988) divides the use of number words into different categories with a broad distinction made between: numerical use (as for example as cardinal, ordinal or measurement number); those which involve the sequence of number words (sequence situations and counting); symbolic use (numerals); and non-numerical or quasi numerical use (labels).

In the present study, information on both number use and the contexts in which they occur will be sought. Moreover an additional distinction, which was reached through trialling the observation proforma for this study, will be made between situations which might *directly* promote childrens' acquisition of skills and understanding of counting and those which are less likely to do so. This distinction will be made on the availability of cues which might guide the child in extracting meaning based on whether the referent was physically present or not. The development of these categories is described below.

A final source of difference between settings lies with the assignment of time to different activities which may in turn lead to variations in the use of number words.

For example, maths is a core curriculum area and therefore one would expect it to be well represented on the timetables of all classes (5-16) in an SLD school. Whilst "Maths" sessions may provide a focus for teaching, other curriculum areas such as home economics, also require the use of number and therefore number words are likely to occur across the timetable. Although maths is also included as one of the areas of learning and experience specified for the under fives (HMI 1989), it is unlikely to be timetabled in the same way as in schools but addressed during a range of activities.

The survey completed in Part A of this study suggested that staff in all four settings viewed counting activities as having a relatively low priority. This finding contrasts with that of McEvoy (1989/90) who as a result of interviews concluded that "teachers felt number was very important". In the current sample however, given the largely negative views of staff one might expect that the frequency of counting activities would be relatively low, although with regard to SLD settings there was some indication that this might depend on the age of the child. Equally one might predict that staff might vary their use of number words and the types of counting activity in response to the ability of the individual pupil. In preschool settings, it would appear from Durkin's study that one might also expect staff to vary their use of number words and the types of counting activities with the age of the child, with more input given to younger children, although individual differentiation might be less likely to occur. However staff might not be the only initiators of counting activities in either setting.

To investigate the issues discussed above, an observation schedule was designed to investigate how number words were being used across the four settings with particular reference to whether their use was likely to lead to the acquisition of procedures for counting. Using this schedule the following questions were then addressed:

1. How often do children hear number words used ?
2. Who contributes the most number words in each setting ?
3. Do adults vary their use of number words according to the age of the child ?

4. Is there a difference between the way number words are used in each setting ?
5. Which number words are used in each setting ?
6. What contexts provide the most frequent use of number words ?

Method

Construction of the observation proforma

Casual observation had suggested that number words occurred with a fairly low frequency in SLD settings. It was therefore felt that using a time-sampling technique to collect data would be inappropriate, given its tendency to over and under-estimate frequency depending on the interval length (Repp, Nieminem, Olinger & Brusca, 1988) and that continuous event sampling would be less likely to present a distorted picture. It was however recognised that event sampling creates its own problems (e.g. in maintaining attention to unpredictable and often infrequent stimuli) and therefore each observation period was divided into five minute portions.

The initial observation schedule was loosely constructed under five headings; Activity; Grouping; Child Words (Focal Child or Other Child); Adult Words and Context (noting referent and activity). The "Activity" section was left open to note the activity the target child was receiving. "Child Words" and "Adult words" provided space to record the actual number words used. It was anticipated that "Grouping" would include reference to whether the child was within a group or not and whether the child was the "star" child, as outlined by Croll (1986), and was therefore the focus of adult attention. The heading "Context" was a cue to make distinctions between the different ways in which number words were being used following the distinctions made by Durkin et al (1986).

In a pilot study, not reported here, the schedule was tried by the author for approximately 150 minutes in both a nursery and SLD school setting, neither of which took part in this final study. The proforma was found to be adequate in terms of the information it provided but was laborious to complete. Additionally, the open-ended nature of the recording made it easy to miss out parts especially on the few occasions when number words were frequently occurring. It did however provide a good range of qualitative information on which to base a more structured system. The trialling supported the use of event sampling as the frequency of occurrence of number words in the SLD class was inclined to be sparse.

On the basis of the pilot run, the schedule was then redesigned so that number words were recorded as before but there was a refinement of categories for recording. For example for the heading "Activity," a proforma with pictorial symbols was used in the nursery setting to indicate which of the following activities were occurring at the time a number word was emitted : table top (i.e. jigsaws, form boards etc), construction, home corner, swings/slides etc, water/sand play, story/book, singing, games, painting, plasticine, wandering about, and other.

The heading entitled "Grouping" provided space for entering the number of adults and the number of children who were engaged in an activity and time to record the instance that it occurred. The additional complexity provided by noting whether the child was a "star" pupil or not was abandoned. As before the number words used were written down in sections that were headed, adult, target child and other child.

The "Context" section was refined to indicate more clearly the way in which number words were used. A broad distinction was made between those which occurred where there was a referent physically present and those which occurred when there wasn't. This division was designed to discriminate between opportunities to directly experience number, and those which provided a less direct opportunity to learn about number. Non- referent situations were further sub-divided to include, rote counting, description (e.g. she had three sisters), sequential complements (1,2,3, go), money (providing the coins were not present), time and age. Use of number words in the referent condition were count and description. A space was provided to put in any conditions not covered (e.g. numeral use). The final version of this proforma is shown in Appendix C.

Subjects

The primary objectives for selecting SLD pupils for this part of the study was to select contrasting children from each class who would provide a picture of the range of use of number words by the staff in each class.

In the two SLD schools, all pupils between the ages of 7.0 -13.11 years who had a basic pointing response were tested on the long form of the BPVS (Dunn et al, 1982) and all those who scored on it were included in the following stages of the investigation. From this larger group, two focal children were selected from each class on the basis of scoring top and bottom on the BPVS. (This measure was chosen as children had not yet been tested on their ability to count. The overall experimental design required counting tasks to occur last in order to ensure a lack of bias in either firstly collecting the questionnaire information or secondly the observation data, see page 172 for further discussion.)

These 8 children from each SLD school were then matched with a group of nursery children on the basis of their BPVS scores thereby ensuring that in each pair of settings the children being observed were performing at a similar cognitive level. Their characteristics are set out in Table 8.8 below.

Table 8.8. Characteristics of Focal Children

Setting	N	BPVS Scores	Chronological Age
SLD School A	8	23 -70 mths, mean 41.75 mths, S.D. 16.46 mths	87- 143 mths, mean 123.75 mths S.D. 27.34
Nursery A	8	22-72 mths mean 41.75 S.D. 17.14	26-57 mths, mean 41.13 mths S.D. 11.72
SLD School B	8	20- 61 mths mean 38.63 S.D. 13.89	84-135 mths, mean 122.12 mths S.D. 31.58 mths
Nursery B	8	20-62 mths mean 39.38 mths S.D 13.15 mths	27-56 mths mean 43.75 mths S.D. 8.99 mths

Procedure

Initially observations were first carried out for 90 minutes per child in School A and Nursery A. Split half reliabilities were then calculated on these observations. For the pupils in the SLD school $r = .90$, and for the preschoolers $r = .82$, both significant at the .005 level.In view of the high reliability and the vast amount of data, observation times were then halved in the second pair of settings, resulting in observations of 45 minutes per child in School B and Nursery B.

As it seemed unlikely that staff limit the teaching of number to specific timetable slots it was seen as important that this observation time was allocated across the curriculum. In order to ensure that the observation periods were distributed in a way that truly reflected both the variation in organisation and activities of the two settings the following procedures were adopted with the underlying principle of ensuring a representative sample of experiences and activities.

First it was decided that observational data would be collected in a way that reflected the types and frequency of childrens experiences across the week. Time-tables were studied for each setting. These varied across settings, both in terms of the time allocated to different activities and in the terminology used to describe different activities. This was less true of the two nursery settings although the degree of detail in their time tables varied. It was anticipated that there would be less differentiation between times of the week although the morning activities might differ from the afternoon ones. The total observation time was divided to represent the proportions of time spent in different activities. In the school settings the time was divided between the top five activities, in the nursery it was divided between three. This disparity reflected the nature of a largely undifferentiated or at least unplanned time-table which operated in the nursery. The distribution of observation time is set out below in Table 8.9 for School A and Table 8.10 for School B.

School A : Data was collected on the five most frequently timetabled subjects for each of the classes, with observation length proportional to the total time devoted to those 5 areas in the course of a week. Overall there was some consistency in which subjects appeared on the timetable although the proportion of time devoted to each area varied from class to class. Each focal child was observed for half of the allocated time per subject area, totalling 90 minutes observation per child.

Table 8.9 The distribution of observation time (minutes) across timetabled subjects - School A.

Class 2	Class 3	Class 4	Senior 1	Senior 2
PSE 80	PSE 65	PSE 50	PSE 70	PSE 40
PE/Movement 35	English 40	English 45	PE 35	TVEI 40
Maths 25	Maths 35	PE 35	English 30	Technology 35
English 25	Music 20	Maths 30	H/E & Tech 25	PE 35
Music 20	PE 20	Geography 20	Maths 20	Topic 30
Total 185	180	180	180	180

Nursery A: In nursery A time was divided between the three categories of activity again in proportion to the time spent on them. Observations were therefore made for each of the focal children for 45 minutes "inside", 30 minutes "outside" and 15 minutes "drinks", a total of 90 minutes per child.

School B: Timetables in this SLD school were activity focused and these led to the selection of the five top activities for each class. Table 8.10 below shows the activities

Table 8.10. Distribution of Observation Time (Minutes) Across Timetabled Subjects - School B.

Class 2	Class 3	Class 4	Class 5
Group Language 18	English 32	Topic 22	News 28
Snoezelan 18	Swimming 16	Core 22	PSE 26
P.E 18	Cookery 16	Riding (1) 18	Cookery 16
Individual Objectives 18	Riding (2) 14	Classroom 15	Topic/Art/ Science 15
Swimming 16	Snoezelan 12	Cookery 15	Computer 14
Total 98	90	92	90

selected for each class together with the duration of observation time. Again each focal child was observed for half the allotted time for each activity area, a total of 45 minutes per child.

Nursery B: In nursery B, the timetable was relatively more detailed than in Nursery A with a distinction made between four types of activity. This did not vary between days. The four sessions were referred to as "free-play", "activity", "quiet-time" and "break". In "activity time" children were expected to complete one of the tasks set out by the staff, for example painting, colouring, brick-building etc, whilst "quiet time" was more likely to be a larger group time during which the register was taken and often a story or singing took place. During "break" children received a drink and a snack in the dining room. For all children observations were based on a representative time sample of each of the four activities resulting in observations of 14 minutes free-play, 10 minutes "activity", 15 minutes "quiet time" and lastly 5 minutes "break", a total of 45 minutes per child.

Measures taken to reduce bias

Observation is subject to a number of sources of bias or inaccuracy: reactivity, expectancy, the characteristics of the subjects and settings, and the reliability of the observer (Hartmann, 1977; Kratochwill & Wetzel, 1977; Croll, 1986; Repp et al, 1988).To combat these sources of bias a series of measures were taken.

Reactivity

Schools and nurseries were informed of the general nature of the research, i.e. that it involved parallel data collection in nurseries and SLD schools with a series of tasks and observations on the type of language used in the different settings. Where there were further enquiries participants were told of the researchers desire to investigate the area of cognition and its relationship to language. No mention was made of counting although early maths skills were mentioned if the participant continued to pursue their enquiry. Non-disclosure of intent provides the investigator with an ethical dilemma (Robson, 1993). It was hoped that non-specific information would not lead to a change in practices. Observations were made after the BPVS testing was completed but before children were given the counting tasks. This reduced the possibility that participants would be aware that the investigator was observing the use of number words.

Expectancy

It had already been noted during trialling that SLD schools seemed to use number words less frequently than nurseries and used a smaller range of number words. This knowledge could lead to bias in the observations although it has been argued that this does not readily occur (Kazdin, 1977) except where feedback is given to observers. In order to minimise the possibility of this occurring no analysis was made of the observations until the completion of observations in each pair of settings.

Characteristics of Sample and Settings

A particular source of bias between these two types of setting was predicted to be the clarity of speech of children. To some extent this was found to be lessened by differences in the number of competing noises. Generally speaking, there was less background noise in the SLD settings because there was usually fewer people in the room. It was therefore relatively easy to pick out target child voices. In the nursery settings children's voices, although usually better articulated were less distinctive and therefore it was harder to be sure that it belonged to the target child if they had their back to the observer. To counteract this the observer chose to position herself in relatively close proximity in the nursery settings. This seemed to work well and cause no intrusions largely due to the number of adults in the room. This measure was necessary to ensure that the measure of frequency taken reflected that received by the focal child. When observations were taken in difficult circumstances outside a radio-mike was used thus ensuring that a representative sample of language was recorded.

Checking the reliability of the observations

Inter-observer reliabilities were calculated to verify the data categories (Kratochwill & Wetzel, 1977; Hartmann, 1977). Measures were taken of session reliability across both nursery and SLD settings. These were carried out for both nursery and SLD data using samples of children that were not included in this study. Nursery observations were taken across two time periods 6 months apart and therefore helped in part to counteract any tendency to shift response category definitions (Repp et al 1988). Nursery data was recorded both live and on video, all SLD data was recorded live in the classroom. Video was used to supplement recordings in the nursery because of the difficulty of positioning two observers where they were equally well placed to hear children. Three focal children were used in the SLD setting over a period of 135 minutes. A total of 6 nursery children were observed over a period of 160 minutes. Agreement percentages were calculated for frequency levels of adult, target child and other child.

Children were chosen for the inter-observer reliabilities simply on the basis of their "chattiness" to ensure that both quiet and vocal children were included in the sample. Observations were taken across settings which were more or less likely to include number words to ensure that agreement was gained on high and low rate situations. The use of low rate situations precluded the training in agreement of categories of number word. Table 8.11 sets out the agreement rates. It is notable that the lowest agreement rate occurred in "nursery 1: live" where only three occurrences of number words occurred from other children.

Table 8.11. Inter-Observer Reliabilities Across Settings.

Levels of Agreement	Nursery 1 : Live	SLD: Live	Nursery 2: Video
Target Child	88%	84%	75%
Other Child	66%	88%	97%
Adult	82%	90%	80%

In recognition of the fact that there are limitations to using a method of calculating reliability which does not take into account agreement on the basis of chance (Hartmann, 1977; Kazdin, 1977; Goodwin, Sands & Kozleski, 1991) reliabilities were also calculated using Cohen's Kappa. Looking at agreement across the three categories, all three settings yielded values considered to be acceptable (Hartmann

1977): for the SLD setting, k = .86, for the nursery live, k=.70 and finally for the nursery videoed k= .80.

In order to ensure that low rate situations and high rate situations were reliably categorised a subsequent check was carried out of 265 minutes of observation data collected in both SLD and nursery settings. Intercoder reliabilities varied between 93% and 100%. When agreements were corrected for chance using Cohen's Kappa k = .95 for data collected in the SLD schools and k=.97 for data collected in the nurseries. A full table of these agreements can be found in Appendix D.

Results

In School B not all activities took place as planned, most notably riding was cancelled for the duration of the 6 weeks spent in school. The equivalent sessions were therefore observed as the cancellation of riding appeared to be a common occurrence.

1. How often do children hear number words used ?

Table 8.12 sets out the rate at which children across all four settings hear number words and shows how both peers and adults contribute. Taking pair A, the SLD child hears number words at a rate of 44 words per hour and the nursery child at almost 30.

Table 8.12. Exposure to number words (expressed as rate per hour)

	Exposure Rate	Peer Rate	Adult Rate
SLD A	44.11	5.20	39.0
Nursery A	29.11	5.35	23.68
SLD B	48.27	19.78	28.49
Nursery B	64.61	34.7	29.91

In contrast, in pair B there is a higher rate of exposure in the nursery setting with the focal child exposed to 48 number words per hour in SLD school B and around 64 in nursery B. Thus, whilst children in the SLD schools are exposed to similar levels of number word use, the experiences of children in the two nurseries are quite different.

2. *Who contributes the most number words ?*

Table 8.12 also revealed the rate at which adults and peers provide exposure to number words and reveals the extent to which different agents provide the focal child with experience of number words. These contributions can be seen even more clearly by calculating each agents percentage of the total number words produced. The process of interaction however suggests that we should take account of how vocal the focal child is. Conversations about number can for example be largely inspired by the focal child. Whilst the percentages don't reveal who initiates number "conversations" they do reveal the variation across settings. The contribution made by each of the three agents is shown in table 8.13.

Table 8.13. Percentage of number words used by different groups.

Setting	Focal Child	Peer	Adult
SLD School A	42.82%	6.74%	50.43%
Nursery A	8.8%	16.8%	74.4%
SLD School B	34.55%	26.82%	38.64%
Nursery B	20.25%	42.83%	36.92%

Pair A: In the both the SLD school and nursery there was a significantly uneven distribution across participants of number words [$\chi^2(2) = 300.77$ $p < .005$ and $\chi^2(2) = 283.24$ $p < .005$ respectively]. In the SLD setting peers contributed little to the use of number words, but the focal child and adult made similar contributions. In the nursery the adult provides by far the most number words.

Pair B: In school B there is greater equality in who contributes to the number words with little difference between the three groups, although the order of contributors mimics School A with adults providing most followed by the focal child and finally peers. In Nursery B the distribution of number word use was again significantly uneven [$\chi^2(2) = 36.14$ $p < .005$] with the greatest contributors being peers.

3. Do adults vary their use of number words according to the child ?

As adults overall were the greatest contributors to the count word rate, analysis was made of the way in which they varied their production of number words. Table 8.14 below sets out correlations between adults use of count words and the chronological age of the focal child.

Table 8.14. Relationship Between Adults Use of Number Words and Child's Chronological Age.

	School A	School B	Nursery A	Nursery B
Rate of Adult Words & Child's Chronological Age	-0.78*	0.07	-0.5	-0.80*

* significant at .05 level

In three of the four settings there was a negative correlation between adults use of count words and the child's chronological age, with two of these reaching statistical significance. In these settings, therefore, the adults used more number words with younger children. In the fourth setting, SLD school B, it appears that adults use of number words bears no relationship to the child's chronological age. Furthermore in neither SLD setting did adults appear to vary their use of number words with the child's mental age as measured by the BPVS (see Table 8.15). Thus children with the lowest mental age were as likely to hear number words as those who were amongst the more able.

Table 8.15 Relationship between Adults use of Number Words and Child's Mental Age

	School A	School B
Rate of Adults Words & Child's Mental Age (BPVS).	-0.14	0.12

4.Is there a difference between the way number words are used in each setting?

A distinction was made between 5 different ways in which number words were used: Symbol, Non-referent, Referent, Counting and Recite. The category "Symbols" included numerals and labels as for example in "class 2". The category "Non-referent" included number words used to refer to something that was not physically present, for example an adult may say that a child has two sisters, or that he is three years old. "Referent" contains words used to describe objects which are physically present. The "Count" category is used for number words produced as a string to count items physically present and lastly "Recite" includes those number words produced as a string when the objects are not physically present. Table 8.16 below sets out the percentage of the total number words which fall into each of the 5 categories for each setting.

Pair A: In the school the majority of number words were produced either in a count situation or to describe a set of objects. Only about 25% of words were used in a quasi numerical sense either to recite as part of a string, to refer to objects not present

Table 8.16. Distribution of the use of all number words across five categories of use.

Setting	Symbols/ Numerals	Non-referent	Referent	Count	Recite
SLD School A	12.93%	8.15%	25.22%	47.72%	5.98%
Nursery A	<1%	32.70%	23.78%	24.59%	18.65%
SLD School B	3.18%	6.36%	36.14%	52.27%	2.05%
Nursery B	3.16%	15.19%	18.57%	51.9%	11.18%

or use number as a symbol. In the nursery the use of number words was more equally distributed across categories although virtually no words were used to refer to the number symbol. Almost fifty per cent of number words occur in a numerical situation.

Pair B: Again in the SLD school the vast majority of words were used in a count situation or to describe a set of objects. Together the use of number words in these concrete situations totalled 88% of the total. Similarly nursery B provided almost 70% of count words in count situations or to describe the properties of a set.

5. Which number words are used ?

Number words were divided into four categories, those which fell between 1-5, 6-10, 11-15 and those beyond 16. Table 8.17 below shows the percentage of all number words falling into each of the 4 categories.

Table 8.17. Distribution of all number words

Setting	1-5	6-10	11-15	16+
SLD School A	78.90%	17.47%	1.54%	2.09%
Nursery A	74.05%	18.65%	4.32%	2.97%
SLD School B	72.18%	19.08%	6.21%	2.53%
Nursery B	79.96%	15.82%	1.69%	2.53%

Table 8.17 shows that taking all the number words used, there is little difference between the 4 settings with between 70% and 80% of number words being between 1-5, and with a gradual decrease of use with ascending size. This study however is particularly interested in the models provided to children and therefore the number words used by adults in this category are set out below in table 8.18.

Table 8.18. Adult use of count words

Setting	Adult Count Words as % of Total	1-5	6-10	11-15	16+
SLD School A	12.53%	86.84%	13.16%	0%	0%
Nursery A	21.35%	65.82%	25.32%	8.86%	0%
SLD School B	1.84%	100%	0%	0%	0%
Nursery B	10.97%	46.15%	34.61%	11.54%	7.69%

Adults use of count words accounted for between 1.84 and 21.35% of the number words used in each setting, suggesting that adults vary quite widely in how much they contribute to provision. In SLD school B, for example, adults counting accounted for under 2% of all number words and these counts were 1-5 or less. In contrast in Nursery A over 20% of the total number words which occurred were used by adults counting. A second point of interest from the table is that adults provide a model of counting larger sets in nursery settings, with some counts exceeding 1-15.

6. What contexts provide the most frequent use of number words ?

School A: An analysis across timetabled sessions revealed, not surprisingly that maths sessions produced the highest rate of occurrence (299.66 number words per hour), followed by TVEI (96 number words per hour), Music (54 number words per hour) and PE (52.35 number words per hour). A full list of the rates is included in Table 8.19. Not all maths lessons involved counting but when they did they produced high rates of count words. TVEI also produced high rates but this was largely due to a single lesson involving a guessing game where the teacher provided clues, and during music the teacher in charge was giving out a set number of each type of instrument.

Table 8.19. Contexts and Rates of Use of Number Words- School A.

Subject Area	Total Observation Time	Total of Number Word Occurrences	Rate of Number Word Occurrences	Average Group Size	Range of Group Size
Maths	88.5	442	299.66	2.75	1-7
TVEI	20	32	96	7	7
Music	40	36	54	11.5	10-12
PE	121.5	106	52.35	5.05	1-10
English	117.5	91	46.47	3.14	1-6
PSE	260.5	192	44.22	4.5	1-7
Home Economics	25	12	28.5	3	3
Technology	17.5	8	27.43	4	4
Topic	15	1	4	5	5
Geography	10	0	0	4	4

Table 8.19 also shows the average group size for each timetabled subject together with the range. Taking all the sessions the average group size was 5.52 with a range of 1-12.

School B: A full list of activities together with the frequency with which number words occurred (as expressed by rate per hour) is included in Table 8.20.

Table 8.20. Contexts and Rate of Use of Number words - School B.

Subject Area	Total Observation Time	Total of Number Word Occurrences	Rate of Number Word Occurrence	Average Group Size	Range of Group Size
Riding Equiv 1 *	16	166	622.5	2	2-5
PSE	16	53	198.75	2	1-3
Cookery	47	64	81.7	6	5-7
English	32	36	67.5	6	6
Topic *	37	41	66.49	5.5	4-7
Swimming	32	19	35.63	6	6
Computer	14	7	30	3.5	3-4
P.E	18	9	30	8	8
News	28	11	23.57	5	5
Core	22	8	21.81	4.2	3-5
Class-room	15	5	20	7	7
Riding Equiv 2	14	4	17.14	7	7
Individual Objectives	18	5	16.69	5.67	1-8
Group Language	18	4	13.33	7	7
Snoezlan	30	4	8	5	4-6

* Additional Computer Time

Table 8.20 reveals that the replacement for riding activities (1) proved to have the highest frequency at 622.5 number words per hour. These observations were made whilst a child used a computer number programme. Interestingly when computer was timetabled a shopping game was in operation and this produced fewer number words. The activity to produce the second highest rate was PSE although this produced only one third the rate of number words (198.75); this was a choice session where the child chose a number game to complete and the third highest rate occurred in cookery sessions (81.7). The activity to produce the lowest rate of number words was the snoezlan with only 8 number words per hour. Table 8.20 also reveals the average group size for each of these activities, together with the range. Overall the average group size was 5.12 with a range of 1-8.

Nursery A: The rate of occurrence of number words across settings is shown below in Table 8.21. This reveals that "drinks" provided the highest rate of number words at 58.43 words per hour where cups and children were counted, biscuits given out and songs sung. "Inside" produced the second highest rate and "outside" the lowest rate. Because of the constant movement of children it was not possible or meaningful to record group sizes in this third setting. Table 8.21 therefore reveals the average group size for the other two observation categories- inside and drinks. Taken overall the average group size for all the observations in this setting was 7.3 children.

Table 8.21. Nursery A: Contexts and Rates (per hour) of number words.

	Inside	Drinks	Outside
Rate of Number Words	32.18	58.43	18.38
Range of Group Sizes	1-13	7-16	N/A
Average Group Size	5.58	11.75	N/A

Nursery B: Table 8.22 below sets out the rate of occurrences of number words across contexts in the nursery setting. "Activity" produced the highest rate of number words, and break the lowest rate. During activity high rates occurred in two key activities- using the computer, and a commercial number game. During break cups, drinks and

Table 8.22. Nursery B: Contexts and Rates (per hour) of number words.

	Free-Play	Activity	Quiet-Time	Break
Rate of Number words	32.63	213.75	59.5	13.5
Range of Group Sizes	N/A	1-12	3-35	4-8
Average Group Size	N/A	4.25	18.25	6.57

snack were distributed largely without speaking. In this nursery the movement of the children was too rapid to note group size during freeplay but Table 8.22 provides data for the other contexts. Overall the average group size was 9.44.

Discussion

The observation proforma had been devised and carried out with a view to collecting data on the opportunities provided to pupils in four settings to learn about counting. The aim was to make comparisons both between and across types of setting with a view to establishing how variations in provision might be reflected in pupils attainments in counting. In order to gain a sufficiently broad picture of these experiences, data was collected across the timetable in a manner conducive to gaining a representative sample of the child's week. Eight children were chosen from each SLD school on the basis firstly of chronological age, with two pupils taken from each class, and secondly on the basis of their scores on the BPVS, with each child representing either the top or bottom scorers within that class. Using these measures it is possible to draw together a summary picture of the opportunities typically available in each of the four settings. Prior to providing this summary picture an outline will be given of the characteristics of each setting in turn.

Starting with **School A**, the timetables had revealed that the importance of mathematics appears to decrease with age, with a fall in the position of mathematics from third in the timetable of the youngest class selected, to fifth in the first senior group. Indeed it did not appear within the top five subject areas for the oldest pupils. This fall in importance with age supports the data gained from the questionnaires, that teachers view at least some aspects of counting as less important as the pupil gets older. Individual observation data also supports the conclusion that in this setting there is an inverse relationship between the child's chronological age and the frequency with which opportunities to learn about number are presented. Turning to the use of number words we see that not only do staff make a distinction in their attitudes towards acquiring the number string and counting activities, but this is clearly reflected in the opportunities offered. Indeed the vast majority of number words were used in a concrete context, either to count objects or in a cardinal sense when the referents were physically present. The distribution of number words across agents reveals that typically these were opportunities in which the focal child took an active part. Adults did provide a model of counting although this was restricted to sets up to ten. Opportunities to learn about numbers greater than ten appear to be limited.

The most likely context for all these number learning opportunities to occur in school A is the maths lessons, typically with a small group size. Staff did, however, include number learning activities in other lessons. For example, PE sessions often involved circuit training, where children's achievements using different pieces of apparatus were counted and recorded, and in TVEI the teacher gave number clues in a guessing game. In this and other ways the school provided a picture of planned opportunities. There was consistency in timetabling across classes, consistency between staff returns on the questionnaire and practice, and a clear relationship between timetables and activities.

In **School B** the picture presented was rather different. Maths did not appear on the timetable for any of the classes. Instead, the curriculum was dominated by activities rather than by subject area, with each class adopting slightly different ways of describing these. Whereas in school A a copy of each class timetable was held centrally, this was not the case in school B. This lack of consistency had also been found in staff statements about their aims. Number words were used with a similar frequency to school A but the agent of these words was equally likely to be adult, focal child or peer. No relationship was found between adult use of number words and either the child's chronological age or their mental age as measured by the BPVS. Indeed it appeared to be random as to whether a child heard an adult use number words or not. However, like school A, the majority of number words occurred when the referent was physically present, either to refer to cardinality or to count items. Adults provided very few models of counting and all involving sets of five or less.

This lack of input suggests that pupils who were still acquiring counting skills were largely doing so without the direct involvement of adults. Taking all of these observations together, the findings from this school support the views that staff expressed in the questionnaire , namely that counting activities have a low priority. Moreover, when we look at contexts in which high rates of counting did occur, these were often a result of pupil choice rather than teacher direction. These opportunities provided them with plenty of practice but resulted in fewer opportunities to extend their understanding as a result of direct teaching.

In addition to contrasting practices in the two SLD schools, the nurseries were also dissimilar in a number of ways. Starting with **Nursery A**, which had clear "class" groupings of children on the basis of age for some parts of the day (dependent on the availability of staffing), but a largely undifferentiated timetable. This setting provided the lowest overall rate of exposure to number words largely due to the low contributions made by the children. No distinction had been made in the questionnaire returns between acquiring the number string and counting activities and unsurprisingly this is reflected in the way in which adults use number words. Of the four settings, it has the highest percentage of number words used in reciting the number string and therefore has a high percentage of non-referent use of number words. It also however produced the highest rate of adults counting, suggesting that children were exposed to relatively frequent models of counting and some of these involved sets of up to 15. If we look at the contexts in which high rates of number words occurred it is clear that much occurred at drink time with activities of counting children and cups, and singing providing many occasions for using number words. These activities occurred in large groups and children were often passively involved in the process. The high rates at large group time (which typically involved children from several classes) may account for the fact that whilst adults used more number words with younger children it did not reach significance level. Other specific activities which provided high rates included ring games usually with heavy repetition. Children in this nursery were therefore exposed to frequent opportunities to see counting and hear the string of count words compared to hearing number words used as descriptors. Number words however also occurred when the referent was less clear thereby possibly adding ambiguous experiences.

In **nursery B**, children were again divided for parts of the day by age but with a common framework to the timetable. This setting produced the highest exposure rates but, in contrast to nursery A, this was due to the contribution of peers as much as adults. Adults typically used more number words with younger children. Number words were most likely to occur in count situations, these occurred for over half of the count words. Few references were made to numerals, but there was reference to cardinality, both when the object was physically present and absent, and some rote counting. In common with all other settings the most frequently used number words were between one and five. Adults did provide models of counting and these included sets of items greater than 16. In contrast to nursery A whole group sessions such as drinks provided the lowest instance of number words. Instead activity time provided high rates. During these sessions the staff organised a variety of activities, table-top, art and craft, construction and children largely chose what to do. Some activities included a member of staff others didn't. Two key activities accounted for the high rates, a computer programme (which the children used in pairs or singly, without a member of staff and a commercial number game. The latter was played both with and without a member of staff. Children therefore had access to models but were also given opportunities to practice alone on materials which promoted counting. Staff appeared to be less dominant in this nursery and in many respects learning was as much directly influenced by peers as by adults.

A Summary Overview

Although the profile of the four settings provides some interesting contrasts, overall comparisons are difficult to make from running text. In order to summarise the similarities and differences more succinctly, Table 8.23 presents the key characteristics for each setting. These are described as high, medium, or low depending on how the rate compared to provision in the other three settings.

Table 8.23 Summary of the characteristics of number provision in each of the settings

Characteristic	School A	Nursery A	School B	Nursery B
Overall exposure rate	Medium	Low	Medium	High
Exposure to adult models of counting	Medium	High	Low	Medium
Level of pupil participation	Medium	Low	High	High
Adult variation of input (in relation to CA)	Medium	Medium	Low	High
Range of uses of number words	Low	High	Low	Medium
Provision of concrete contexts	High	Low	High	Medium

The Implications of these Findings

Not all of the contrasting features may be influential in determining children's performance and understanding of counting. In chapter two (page 29) the rather mechanistic approach adopted to explain how children acquired the procedures first was described. This approach places emphasis on children copying models of counting and receiving feedback as to their own accuracy. In this rather simplistic account a competent counter plays an important role in showing the child how to count. Moreover the frequency with which the child sees these models is likely to influence the rate of learning. This theory predicts that children in settings with a high rate of exposure particularly to adult models of counting are likely to make good attainments in counting. From the data presented in Table 8.23 therefore we might expect that children in nursery A would perform particularly well compared to pupils in school B. This will be explored in part C of the study.

In contrast whilst the exact process is not explained, Durkin (1991) suggests that the very ambiguity of the use of number words may lead children to actively deduce meaning. Their data suggests that young children are exposed to a whole range of different ways of using number words and that the context for these are interactive in the sense that both mother and child contribute to the "number exchange". This suggests that settings where there is good variation in the contexts in which number words occur *and* where the child takes an active role in this process should result in good levels of attainment, probably of both skills and understanding. As Table 8.23 (lines 4 & 5) reveals, no setting provided this combination for whilst nursery A provided a variety of contexts the child was often a passive recipient. Nursery B however does provide a high level of pupil participation with access to a medium range of contexts.

In this thesis some additional dimensions have been considered. The first dimension concerns the nature of the experiences received with a distinction made between contexts in which the referent is physically present and those in which it is not. These concrete situations can provide the children with important clues to the meaning of counting and they are likely to be more readily accessible than contexts where the referent is not present. Both SLD schools largely restricted their input to contexts in which the referent was physically present.

The second dimension concerns the match of teaching to the individual child, the extent to which he is likely to be able to profit from these experiences. Durkin et al (1986) revealed that mothers use of number words extends as the child matures and the highest rate of use of particular number words precedes that of the child. Whilst chronological age may serve as a good signal of the preschool child's readiness to acquire the skills and understanding of counting it is unlikely to provide a clear indicator for pupils with SLD. For these pupils an individual measure must be considered and to date in these studies scores on the BPVS have been used with varying success. Observation data collected in this study suggests that adults in SLD settings don't vary their input according to mental age. It is however possible that adults do attempt to match their input according to the child's counting ability.

Whilst there is clear variation between the settings, no one setting provides an extreme example which follows either the characteristics set out by Durkin et al (1986) or those favoured by mechanistic explanations of learning. It is difficult to make absolute predictions on the basis of such data with each setting including some but not all critical factors. Additionally, few factors are typical to one type of setting but not the other although one aspect that the SLD settings do share is the provision of concrete contexts compared to the more varied range of contexts found in the two nursery settings. Of the four settings, School B appears to be the most limited with fewer instances of planned teaching of number reflected here in the low rate of adult models. Indeed pupils appear to be gaining experience of counting with little direct involvement of staff and therefore few opportunities to extend understanding. If these are critical factors then one can predict that the pupils in school B will show lower levels of attainment. It is against this backdrop that the final part of the study reports on the total sample of childrens abilities.

Part C

A Comparison of the Childrens Ability to Count and Detect Errors and Predictors of Success or Failure

Whilst the questionnaire had revealed that staff in all four settings unanimously view counting as having a low priority, the observation data revealed both a number of similarities and differences in the use and rate of number words across settings. In the final part of the study we set out to collect data on how children across the settings actually perform on counting and error detection tasks and to ascertain what variables measured in the study best predict performance.

From a consideration of the limited literature which exists to explain how children might acquire the *procedures* for counting together with considering the observation data, five characteristics of provision were identified. Since not all the characteristics identified in the observation study could be appropriately quantified for use in this analysis, a selection of the key features was made. These included childrens rate of exposure to count words overall, and more specifically to situations in which the object was physically present and finally in which adults provided a model of counting could be quantified in relation to each focal child. These variables could therefore be added to those of mental and chronological age to investigate what contributed to individual variations in performance and understanding of counting.

In part B of the study there was a suggestion that adults use of number words was varied in relation to the child's CA and with respect to the SLD pupils, in relation to their mental age. For example, staff in school A and the two nurseries were found to vary their input inversely with the child's chronological age. It could be argued that a more appropriate measure is how adults vary their input in accordance with the counting ability of the individual child. This part of the study set out to investigate this using data from the focal children.

In previous studies, the attempt to determine whether the children's performance on the BPVS was related to their counting performance had in some cases been difficult to interpret because of the small sample sizes. However, in study one it was almost invariably found to be the case that children who failed to score on the BPVS failed to demonstrate adherence to any of Gelman's principles of counting. One interpretation of this outcome might be, therefore, that the BPVS acts as a reliable screening instrument possibly because it calls for a similar ability to point and name. Pointing is a fundamental aspect of the early stages of carrying out a counting task. It is possible that this rather than a more generalised measure of mental age as measured by the BPVS predicts counting competence.

Recent studies have additionally indicated the need for caution is using scales based on receptive language with children whose language development is likely to be atypical (Howlin & Kendall 1991). Tests which are based on measures of vocabulary will be strongly influenced by chronological age and may over-estimate children's mental age (Facon, Bollengier & Grubar 1993).

To address these issues, all of the SLD children involved in this study were tested not only on the BPVS but also on a completely different measure of mental ability, the Snijders-Oomen Test (Snijders & Snijders-Oomen 1976). This test contains five sub-scales: mosaic, combination, memory, copying and sorting and has the advantage that it was standardised on pupils with hearing impairment (as well as typically developing children) and is therefore not reliant on understanding spoken instructions.

As noted above, in previous studies the sample sizes have actually been too small to undertake proper tests of the possible predictors of counting performance in SLD children. Although correlation coefficients between CA, MA and counting performance were computed they were often contradictory and difficult to interpret. In the present study we not only have an adequate sample size but also the opportunity to examine two separate measures of mental ability alongside measures based on focal childrens' exposure to count words derived from Part B of the study.

In summary therefore this final part set out to address the following questions:

1) Is there a difference between the attainments of pupils with SLD and typically developing preschoolers when matched on the basis of their scores on either the BPVS or SON ? Are there any qualitative differences ? Additionally, is the temporal order to acquisition of successful counting and error detection the same ? On the basis of previous studies we can predict that those pupils matched on the basis of the BPVS will demonstrate a similar level of attainment to typically developing children but may reveal qualitative differences in their production of number words. We can however be less confident about those matched on the basis of the SON. All children however are expected to reveal profiles consistent with the temporal order of acquiring procedures before the ability to detect errors.

2) What best predicts performance and in so doing accounts for individual differences, MA, CA or a measure of exposure to number situations ? The evidence from previous studies has provided conflicting evidence that requires studying in more detail with a larger sample.

3) Do adults vary their use of count words according to the pupils ability to count ? Given the heterogeneity of pupil ability within a single age range (seen in the exploratory study) we might anticipate that teachers would individualise their responses, however only in one school did we find variation with chronological age and it has been argued that this may have not been appropriate.

Method

Subjects

Table 8.24 sets out the characteristics of all the children in this final part of the study.

The SLD Groups

School A : The school identified 25 pupils of the 67 on role who were between the ages of 7.0 years and 13.11 years, who had a basic pointing response and whose first language was English. Of these 25, 14 pupils scored on the BPVS, but one who had a specific language impairment was excluded from the sample. (His only effective means of communication was a symbol book and this contained no numerical symbols.) The data from a further child had to be excluded from the study because there was no available match in the nursery setting. The final sample therefore comprised 12 children, (10 girls and 2 boys) with a chronological age ranging from 7 years 3 months to 13 years 11 months, (mean 10 years 2 months, S.D. 23.23 months). Scores on the BPVS ranged from 1 year 11 months to 5 years 10 months with a mean of 45.3 months, and S.D. of 15.32 months. Scores on the Snijders-Oomen ranged from 2 years 3 months to 5 years with a mean of 42.75 months, and S.D. of 11.80 months.

Table 8.24 Characteristics of the Children

Setting	N	BPVS Scores	Snijders-Oomen Scores	Chronological Age
SLD School A	12	23- 70 mths Mean 45.3 S.D. 15.32	27-60 mths Mean 42.75 S.D. 11.8	87- 167 mths Mean 122 mths S.D. 23.23
Nursery A- BPVS	12	22-72 mths Mean 45.17 S.D. 15.9		26- 57 mths Mean 43.33 S.D. 10.72
Nursery A- SON	12		24- 60 mths Mean 42.75 S.D. 12.28	27- 57 mths Mean 39.66 S.D. 10.59
SLD School B	13	20-61 mths Mean 40.85 S.D 11.44	24-60 mths Mean 40.85 mths S.D. 11.5	84-164 mths Mean 125.85 S.D. 29.48
Nursery B- BPVS	13	20-62 mths Mean 41.69 S.D. 11.5		27-56 mths Mean 45.69 S.D. 8.27
Nursery B- SON	13		24-63 mths Mean 40.85 mths S.D. 12.46 mths	29-56 mths Mean 41.54 S.D. 8.51

School B: The school identified 18 pupils of the 66 on roll who fell within the range of 7.0 years to 13 years 11 months, whose first language was English and who had a basic pointing response. Of these 18, 13 scored on the BPVS (9 boys and 4 girls).

The chronological age of the pupils ranged from 7.0 years to 13 years 8 months, (mean 10 years 5.85 months, S.D. 29.48 months). Scores on the BPVS ranged from 1.8 years to 5.1 years, with a mean of 40.85 months, S.D. 11.44 months. Scores on the Snijders-Oomen ranged from 2.0 years to 5.0 years with a mean of 40.85 months, S.D. 11.5 months.

The Nursery Groups

Nursery A. A total of 18 children were tested in this nursery setting from which a final 16 were matched to form 2 overlapping groups, 12 matched on the basis of BPVS scores (3 boys, 9 girls) and 12 matched to form the Snijders Oomen group (2 boys, 10 girls). These groups will be referred to as the Nursery A BPVS group and the Nursery A Snijders Oomen (SON) group and their characteristics are shown in Table 8.24.

Nursery B: A total of 25 children were tested from the nursery B setting from which a final 20 were also matched to form 2 overlapping groups, one matched to the SLD group on the basis of BPVS scores (referred to from here on as the Nursery B BPVS group) and the other matched on the basis of Snijders-Oomen scores (referred to as the Nursery B SON group). Both groups contained 4 girls and 9 boys.(See Table 8.24 for details).

Procedures

All children were given a set of counting tasks and requested to count and tell the investigator "how many" there were. The procedures were identical to those designed for study 2 with children being asked the "how many" question both before and after counting. The materials used for counting were extended with the interests of pre-teen and teenage pupils in mind. As before, however, each set was made up of three dimensional objects which were identical in form but not in colour and were housed in a series of containers.

All children were introduced to the puppet "Wacky" who was learning to count and given the pre-test comprising a total of 5 trials of set sizes 2 and 3. Those children who scored 3/5 or more on the pre-test were given the full number of puppet trials. The procedures were identical to those used in study 1 and 2.

Results

As before a point was awarded to each child for successfully adhering to each of the three principles for each of the three small set sizes and the three large ones. Each child was therefore able to gain a maximum score of 18. Table 8.25 below shows the total scores, range and mean for each group. (Since so many children are involved, individual data is given in Appendix E.)

Table 8.25 Group performance on counting tasks.

Setting	N	Range of Points	Mean
SLD A	12	0-18	10.83
Nursery A BPVS	12	3-18	12.75
Nursery A SON	12	4-18	10.17
SLD B	13	0-18	10.54
Nursery B BPVS	13	2-18	11.85
Nursery B SON	13	0-18	9.54

Comparison of Attainments of the four groups

Making comparisons firstly between the SLD and nursery group pair A, neither the BPVS matched groups nor the Snijders-Oomen matched group differed in performance from one another, ($\underline{F}$ (1,22) = 0.00, p=.98 & $\underline{F}$ (1,22) = 0.01, p=.75 respectively). Similarly comparisons between the performance of the SLD group with the Nursery group for pair B matched on the BPVS and on the Snijders-Oomen revealed no significant differences, ($\underline{F}$ [1, 24] = .32, p=.58, & $\underline{F}$ [1,24] = .13, p=.73

respectively).

In sum, there was no significant difference in the counting performance between either nursery and its SLD counterpart whether the children were matched on the BPVS or the Snijders-Oomen.

Error Detection

Table 8.26 below sets out the error detection scores for each group of children.

Table 8.26 Group Error detection Scores

Setting	N	Range of Points	Mean
SLD School A	5/12	2-7	5
Nursery A- BPVS	6/12	1-9	6.8
Nursery A- SON	3/12	7-9	7.67
SLD School B	2/13	1-9	4.5
Nursery B- BPVS	3/13	7-9	8.33
Nursery B- SON	4/13	7	8.5

Nursery A & SLD School A: With regard to the puppet errors, 5 pupils in the SLD sample revealed some ability to detect errors above a chance level. Two of these 5 were able only to spot errors of stable order and cardinality. The remaining three were able additionally to spot errors of one:one correspondence. All 5 pupils were almost flawless counters scoring at least 17/18 on count tasks. A further child scored 17 on count tasks but was unable to detect puppet errors. The successful group of 5 ranged in C.A. from 9 years 2 months to 13 years 11 months, (mean 10 years 10 months, S.D. 24.43 months) and in BPVS scores from 3.0 years to 5 years 10 months (mean 4 years, 7 months, S.D. 13.23 months) and finally on the Snijders-Oomen they scored from 3 years 9 months to 5 years (mean 4 years 3.6 months, S.D. 6.84 months).

In the BPVS nursery group, 6 pupils demonstrated some ability to detect errors, although one was limited to detecting one-one errors. Again all children scored between 17 and 18 on the count tasks. The 6 nursery children ranged in chronological age from 4 years to 4 years 9 months (mean 4 years, 3.3 months, S.D. 3.33 months) and their scores on the BPVS ranged from 3 years 4 months to 6 years (mean 4 years 9.17 months, S.D. 10.30 months).

In the Snijders-Oomen Nursery Group, 3 pupils demonstrated the ability to detect errors in puppet counts. Each was able to detect all three kinds of puppet errors and scored either 17 or 18 in their own counting. The three pupils range in C.A. between 4 years 4 months and 4 years 9 months (mean 4 years 5.6 months S.D. 2.89 months) and score between 4 years 6 months and 5 years 0 months on the Snijders Oomen (mean 4 years 9 months, S.D. 3 months).

In order to take into account performance on puppet tasks as well as performance on count tasks, children were awarded 3 points for correct detection of each error type providing they scored at the 5% level or above and 1 point if they scored at the 10% level, using Pascal's triangle as before. Children therefore had to achieve 80% on stable order and one:one trials to be awarded 3 points, and above 70% for 1 point. On the cardinality trials they had to correctly detect 87% of trials for 3 points and 75% for 1 point.The maximum score for the puppet counts was therefore 9. A one way ANOVA revealed that there was no significant difference between the SLD and BPVS group (F [1,22] = .75, p=.4) or the SLD and Snijders-Oomen group (F [1,22] = .04, p=.84) on count performance when performance on the puppet trials was taken into account.

Nursery B & SLD School B: Only two individuals in the SLD sample revealed any ability to detect errors and one of those was shaky in their judgement of cardinality and stable order trials. Both pupils were 100% correct in their own counting. A further two pupils were also 100% correct in their own counting but were unable to detect puppet errors. The two successful SLD individuals were between the ages of 11.5 years and 12.9 years, and were amongst the top scorers on the Snijders-Oomen, scoring 4.6 and 5.0 years respectively. One of the pupils was also the top scorer on the BPVS (scoring at the 5.1 year level) although interestingly this was the pupil who was less confident in detecting puppet errors. The other pupil scored 3 years 3 months on the BPVS.

In the Nursery B: BPVS Group, three preschoolers were able to detect errors in the puppet counts, correctly judging between 83% and 100% of trials across the three error types. The successful children were aged 4 years or older and scored respectively 4.2 years, 4.3 years and 5.2 years on the BPVS. All three were able counters scoring either 17 or 18 in their own counting.

In the Nursery B: Snijders-Oomen group four preschoolers were able to detect errors in the puppet counts, correctly judging between 83% and 100% of trials across the three error types. These children were aged between 3 years 11 months and 4 years 8 months and scored respectively 4.0 years, 4 years 6 months 4 years 6 months, and 5 years 3 months on the Snijders-Oomen. All four scored the maximum number of points in their own counting.

As with pair A, children who correctly identified error trials were assigned a score on the basis of the percentage of correct trials identified for each of the three types of puppet error. Again a one way ANOVA revealed no significant difference between the SLD and BPVS group ($\underline{F}$ [1,24] = .62, p=.8) or the SLD and Snijders-Oomen group ($\underline{F}$ [1,24] = .06, p=.8).

In addition to making comparisons between pupils performance in each pair of settings a final comparison was made of performance across all four settings. The observation data had revealed that the experiences provided to pupils in school B were limited in a number of ways. Whilst it is clear that performance on the counting tasks was comparable to pupils in other settings it appeared that pupils in school B did less well on the error detection tasks. A one way anova however revealed no significant difference in the scores of pupils on count tasks, ($\underline{F}$ [1,46] = .29) or on their performance on the error detection tasks.

Qualitative Differences in Performance

As in study 2, three aspects of performance were investigated, vocabulary size, one:one errors and cardinal response for those pupils who were acquiring the counting procedures. Five pupils in School A, six in school B, six in nursery A and eight in nursery B had started to acquire the counting procedures but were less than perfect in their execution. Taking first the vocabulary scores based on the number of different count words uttered in the counting process, no significant difference was found between the scores of the SLD and nursery children ($\underline{U}$ (10,13) = 65 ns). Turning to look at the type of tagging errors, all except one child was either more likely or equally likely to make skipped object errors than double count errors, again revealing no differences between the two groups. Finally with regard to cardinal responses these were distributed for both groups across six types of response, in addition to the five revealed last time in the typically developing group, a sixth category "other" was added for pupils who for example answered the "how many" question by saying something other than a number word, for example "I don't know". These responses are set out in table 8.27 below and reveal the similarity in the proportion of responses falling into each group.

	Last Tag	Repeat Sequence	Recount	No Response	Random	Last Tag +/- 1	Other
SLD N=11	9%	11%	21%	23%	32%	0%	5%
Nursery N=14	19%	6%	27%	24%	20%	0%	4%

Table 8.27 Distribution of cardinal responses amongst SLD and TD "acquirers".

Predictors of attainments among the SLD children:

Correlations were carried out using two sets of scores, the children's 'own count' scores and the combined error detection and 'own count scores', but this time including the second measure of mental age, the Snijders-Oomen. The data from these analysis are set out in table 8.28 below.

Table 8.28 Correlations between MA and CA and counting scores for pupils in school A.

School A N=12	**Count**	**Combined count & error detection**
BPVS	.74 (.003)	.76 (.002)
SON	.70 (.005)	.8 (.001)
CA	.20(.26)	.12(.36)

For school A, the correlations between the two cognitive measures and performance on the counting and error detection tasks were similar to each other and highly significant. In contrast, chronological age did not seem to relate to counting performance.

Table 8.29 Correlations between MA and CA and counting scores for pupils in school B.

School B N=13	**Count**	**Combined count & error detection**
BPVS	.4 (p=.09)	.39 (p=.1)
SON	.74(p=.002)	.74(p=.002)
CA	.80 (p=.00)	.74 (p=.002)

For school B the picture is rather different. Whereas the SON yielded similar correlations in the region of 0.7, the BPVS correlations were rather lower. As far as CA is concerned, this measure correlated highly with both count and combined count scores. There was a significant difference between the correlations of school B for CA and those for school A [CR= 1.96, p<.05] but not for MA. These differences are explored in chapter 9.

Further Analysis of the Attainments of the 16 Focal Children

In this final phase, additional analyses were made using the observation data from Part B on the 16 focal children. In this way it was possible to examine the relationship between each pupils count (and combined count) score, their exposure to number words as well as CA and MA. Two questions were asked. Firstly, does the addition of more independent variables improve the accuracy of predictions of count scores. Secondly, of these additional variables are some more useful than others for the prediction.

So far, the analysis has revealed that for both of the larger groups mental age, as measured by the BPVS and chronological age are correlated with count scores. Starting with these two measures very similar correlations were found for this subset of pupils: for the BPVS R= .73 and for chronological age R = .62. A series of multiple regression analyses were then carried out using, in addition to MA and CA, the rate of exposure to adult and peer number words, the overall rate of exposure to all adult number words, to adult number words used where their was a referent present and finally to adult models of counting. For all calculations the pupils mental age as measured by the BPVS proved to be the best predictor, (see table 8.30 for count score correlation coefficients, and table 8.31 for combined count score correlation coefficients). Taking the different measures of exposure firstly in relation to the childrens own-count scores, no difference was found between adult count and adult referent, although the latter was marginally larger and this together with CA and MA lead to the multiple correlation coefficient R= .88. Taking the combined count and error detection scores, the multiple correlation coefficients were slightly lower [R= .83] and adult use of number words when the referent proved the larger exposure predictor.

Multiple R .88 F(3,12) = 11.35 P<.000	Multiple R .88 F(3,12) =13.36 p<.000	Multiple R .86 F(3,12)= 11.59 p<.000	Multiple R =.86 F(3,12) = 11.35 p<.000
BPVS (beta) .64**	BPVS (beta) .66**	BPVS (beta) .6**	BPVS (beta) .61**
CA (beta) .50**	CA (beta) .49**	CA (beta) .49*	CA (beta) .48*
Adult Reference (beta) .18	Adult Count (beta) .18	Adult & Peer (beta) -.07	Adult .02

Table 8.30 Multiple Regression for Count Scores of the 16 Focal Children

Multiple R .83 F (3,12) = 9.15, p<.005	Multiple R .82 F(3,12) =8.4, p<.005	Multiple R .81 F(3,13) =7.8 p<.005	Multiple R =.81 F(3,13) =7.8 p<.005
BPVS (beta).65**	BPVS (beta).66**	BPVS (beta).61**	BPVS (beta) .63**
CA (beta) .43*	CA (beta) .41*	CA (beta) .41*	CA (beta) .40*
Adult Reference (beta) .20	Adult Count .15	Adult & Peer (beta) -.06	Adult (beta) .06

Table 8.31 Multiple Regression for Combined Count Scores of the 16 Focal Children

** p<.005
* p<.05

Whilst more variables do add to the accuracy of the prediction for both count and combined count scores, no exposure scores reach significance level. Furthermore a stepwise regression analysis further showed that the increment in R with the inclusion of the variable of adult use of count words in referent situations was not robust.

Finally, using data from the focal children, an analysis was made of the relationship between adults use of count words and the individual childs ability to count. The results of these correlations are set out in table 8.31 below and reveal that there was no relationship between the frequency of adults use of count words and the childs ability to count.

	School A	Nursery A	School B	Nursery B
Correlations between rate of adult count words and child count score	-.18	-.22	.19	-.08

Table 8.31 Correlations between rate of adult use of count words and childs count score

Discussion

The data from this study serves to consolidate that found in previous studies. There was no difference between the performance of the SLD pupils and the nursery children whether matched on the basis of their scores on the BPVS or their scores on the Snijders-Oomen. Whilst the ability to detect errors varied across groups this again did not reach significance level. As in previous studies all children who were able to detect puppet errors were almost flawless counters. There were however one or two children in both SLD groups who were able to count very well but were not able to detect errors. The data therefore is conclusive in indicating that the temporal order of acquiring the procedures first and then demonstrating understanding is consistent for both groups of children. As before the data supports the view that acquisition of the procedures does not *automatically* lead to understanding of the principles of counting.

A comparison between typically developing and SLD pupils revealed that, in contrast to the findings of study 2, there were no *qualitative* differences between the two. Both groups utilised a similar count word vocabulary and therefore unsurprising revealed a similar pattern of more skipped objects in their counts than ones which were counted twice, in line with other studies of counting in preschoolers (Briars and Secada 1988). Additionally, both groups of children were inclined to use a range of responses to the cardinal question. In this respect the results from this group of SLD pupils were also different from those reported in study 2 where pupils had a smaller count word vocabulary and were likely to either make no response or to correctly use the last tag. Since the pupils in study 2 were younger and more were at an earlier stage of counting it is possible that these characteristics are more likely in emergent counters. By comparison, although the "acquirers" in this study were not flawless in their counting they were considerable more proficient as denoted by their higher mean count score. This pattern of similarities and differences in performance is explored more fully in chapter nine where the performance of the total sample of 50 SLD pupils is considered.

The observation data had revealed a number of similarities and differences between the four settings with respect to five critical factors of provision with no one setting either including or excluding all identified characteristics. It was however predicted that if pupils in one setting did less well it was likely to be those from school B as there was limited evidence of direct involvement by staff. Comparisons across all four settings did indeed reveal that there were fewer pupils in school B who were able to detect the puppet errors and that the mean score for this group was the lowest. However this difference did not reach significance level.

Mental age proved to be overall the best predictor for counting performance, although it must be noted that when the data for each SLD group is considered separately the picture is as not clear cut. (This issue will also be considered fully in chapter nine.) Chronological age proved also to be an important contributor although its predictive powers appears much smaller. Of the four measures of exposure used in this part of the study, the best proved to be adult models of counting and adult use of number words in concrete situations with little difference between the two overlapping measures. In contrast the total exposure rate which includes non-referent use of number words made little contribution. Whilst this suggests that pupils with SLD benefit more from exposure to concrete situations, it must be noted that the contribution made by this was small. One important reason for this may be that staff in neither SLD setting individualised their use of number words indicating that no systematic attempt was made to match the rate of use of number words with the child's level of counting ability. This practice did not occur in the nursery setting either although we know that mothers of typically developing children do vary their rate of use of number words (Durkin et al 1986). If pupils are going to benefit from experiences of counting then they need to be provided at a level that is appropriate to their skills and understanding.

Additionally, from the observation data (summarised in table 8.23) we can see that in fact neither school A or B can be described as presenting high levels of adult models of counting. Although school A did rather better than school B, neither provided as high levels as the nursery A setting. Both SLD settings however provided a high level of contexts where the referent was physically present.

Whilst it is disappointing that the child's performance was largely determined by their mental age it is important to note these two factors, namely the lack of individualisation of number word use and the provision of either medium or low levels of models of counting. The questionnaire had revealed quite clearly that staff view the acquisition of counting as having a low priority and this view no doubt had an effect on classroom practice. Before any conclusions are reached however about the role of the environment it must be noted that this data only considered experiences provided in the school setting. It is quite possible that parents and other carers, including siblings provide some pupils with SLD with high levels of models of counting and that they provide a better match in relation to the pupils level of counting ability. Nevertheless, on the basis of this current evidence mental age is likely to be the determining factor in predicting the attainment levels reached by the individual child.

Conclusion

This study set out with three general objectives, to examine staff attitudes, to discover what experiences children receive in their respective daytime settings and finally to examine the relationship between these two aspects and pupils skill and understanding of counting. In contrast to the views expressed by parents of typically developing young children, counting activities were viewed by staff in both SLD school and nurseries as being relatively unimportant. Observations revealed considerable variation in the practices of the four settings with none providing all the characteristics identified as important by those investigating mother-child interactions. Conversely no setting provided all the characteristics identified by those favouring mechanistic explanations of acquisition. More typically staff provided a combination of practices, although given the lack of importance given to the area we cannot assume that this amalgam is planned. It was against this backdrop that the final part of the study revealed that by far the best overall predictor of performance was mental age, a fact that later proved unsurprising given that staff in the SLD settings largely failed to match their input to the counting competencies of the individual child. The final part of the study confirmed the previous findings that all children acquire the procedures for counting before demonstrating understanding.

Chapter Nine

An Overall Assessment of the Evidence

In chapter four, three overall aims of this thesis were established and the questions they yielded addressed in three separate studies. Although more than fifty pupils with SLD participated in these studies the number in each was small and the findings not always consistent. Furthermore, small scale studies provide particular difficulties when the data is collected in order to test the *strength* of a relationship between two variables, as has been the case here in the inclusion of correlational data. The aim of this chapter therefore is to examine all of the data from the three studies *together*, thereby providing a stronger basis for inferring relationships between variables. This final data analysis will then provide a framework from which to explore the theoretical implications in chapter 10. In this chapter we review the total data in the light of the original aims of the thesis.

9.1 Levels of attainments of pupils with severe learning difficulties with reference to both their performance and understanding of counting.

Rather than take a broad look across a range of counting tasks, it was quickly established through the exploratory study that more could be gained by looking in depth at *how* pupils performed on a single counting task. This took the form of counting three dimensional objects in a fixed row arrangement as it enabled both subject counts and puppet counts to be presented in an identical format. As far as measurement was concerned, interest centred on the ability to co-ordinate parts of the count process, namely uttering the number words *and* tagging objects and this was taken as the beginning of a distinctive count process. Evidence for understanding was derived from pupils ability to detect counting errors made by a puppet.

Study one revealed that children with SLD could count and that all those who could attempt to co-ordinate elements of the count process also scored on the BPVS. Furthermore a few children were also able to demonstrate understanding of counting through the detection of puppet errors. One child appeared to be in a transitional state in that she could count perfectly but could not yet detect puppet errors.

Although study two generally supported these findings it also highlighted the problems associated with variability that were to recur throughout the studies. Despite having been selected in an identical way to those in study one, the children in study two were far less able with respect to both performance and understanding of the count process. A significant difference found between the performance children in the two studies. In study three, we again found differences in attainment with more children from school A able to detect errors than those from school B. However at a general level all three studies supported the finding that some children were in the process of acquiring the skills of counting, a few could demonstrate understanding and a minority were at a transitional stage. Since none of the three samples had proved sufficiently large to fully investigate the pattern of acquisition of children at different stages of attainment, in the following analysis the data from all fifty children in studies one two and three were grouped together.

Using the procedures introduced in study one, (page 133) the total sample of fifty children with SLD (and 35 TD children) were divided into four groups according to their attainment. Firstly, there were the group of children who were "non-counters", that is they did not show the ability to *co-ordinate* any of the procedures for counting (although testing revealed that some had an isolated ability to produce the number string). The second group we have already referred to as the "acquirers". They were able to coordinate some of the procedures but were not yet able to do so with ease. The third group are referred to as the "transitional" group, they were able to count almost flawlessly but had not yet deduced the principles and consequently, like the previous two groups, were unable to detect puppet errors. Finally, the fourth group of children, "the error detectors", were able to demonstrate understanding of the principles of counting. Using this framework, we can look firstly at the proportion of children who fall within each of the categories and secondly examine some of the characteristics of each category of children in more detail than was possible with a single sample.

Table 9.1 summarises the data from all three studies and reveals an unequal distribution of children across the four categories [$\chi^2(2) = 12.28$ $p < .002$], with the majority of children falling in the acquiring group but with equal numbers of children classed as non-counters and error detectors. The smallest category is the transitional group.

Table 9.1 Summary of Children's Performance Across Studies

Study	Sample Size	Age Range	Mental Age (BPVS)	Non-Counters	Acquirers	Transitional	Error Detectors
Study 1	15	7.3 - 9.5	u/s - 4.1	5	6	1	3
Study 2	10	7.0 - 9.5	1.11- 3.10	3	6	0	1
Study 3 School A	12	7.3 -13.11	1.11 - 5.10	1	5	1	5
Study 3 School B	13	7.0-13.8	1.8 - 5.1	2	6	3	2
Total	50	7.0-13.11	u/s- 5.10	11	23	5	11

If we then look at the characteristics of children falling within each group we can see that there is some evidence for a progression between the four "stages". Table 9.2 sets out these characteristics for the fifty SLD children and Table 9.3 for the total 35 typically developing children from studies 2 and 3. This reveals a picture for the SLD pupils of both progression and overlap with the mean MA ascending from non-counters through to error detectors and with a less pronounced pattern for CA.

	Non-Counters	Acquirers	Transitional	Error Detectors
N	11	23	5	11
Range CA	84-147 mths	84-151 mths	113-164 mths	95-167 mths
Mean CA	100.45 mths	106 mths	137.4 mths	123.09 mths
Range MA	u/s-37 mths	u/s-59 mths	31-53 mths	34-72 mths
Mean MA	27.83 mths (n=6)	36.14 mths(n=22)	42.80 mths	49 mths
Range Count	0	1-14	16-18	17-18
Mean Count	0	7.09	17.04	17.91
Range Combined	0	1-14	16-18	19-27
Mean Combined	0	7.09	17.04	23.73

Table 9.2 Characteristics of the 4 groups of SLD children

However we can also see that there is overlap in the range of CA and MA for each of the four groups suggesting possibly that some children move more readily through these stages. If we turn to look at the 35 typically developing children this pattern of progression and overlap is also apparent, a child of 3 years 9 months, for example, might fall within either of three groups, acquirer, transitional or error detector.

	Non-Counters	Acquirers	Transitional	Error Detectors
N	2	22	1	10
Range CA	24-27 mths	24-53mths	45mths	42-57mths
Mean CA	25.5mths	37.91mths	45mths	51mths
Range Count	0	1-15	16	16-18
Mean Count	0	7.5	16	17.80
Range Combined	0	1-15	16	19-27
Mean Combined	0	7.5	16	24.8

Table 9.3 Characteristics of the four groups of typically developing children

Turning now to the SLD data and taking each category of attainment in turn. Just over one in five children fell within the first category of "non-counter". The children in this group range in CA from 7.0- 12.3 years with a mean age of 8.45 years (S.D. 19.64 mths).

Subject	Study	Chronological Age	Mental Age
1	1	7.7	u/s
2	1	7.7	u/s
3	1	8.7	u/s
4	1	9.0	u/s
5	1	9.10	u/s
6	2	7.0	2.4
7	2	7.0	2.10
8	2	9.2	3.1
9	3a	12.3	2.1
10	3b	7.0	1.11
11	3b	7.1	1.8

Table 9.4 The SLD Non-Counters

Further details of these eleven children are set out above in table 9.4 from which we see the variation in mental age, from unscoreable to 3.1 years.

In most instances either the pupils fail to score on the BPVS or do so at a very low level. The exception are the children from study 2 who, on the basis of their BPVS scores one might have expected to have acquired at least some of the skills of counting. One can only speculate at this stage that failure to do so might be due to a lack of opportunity for learning or other difficulties.

Almost half of the total sample of fifty children fall within the "acquiring group", that is pupils who are beginning to gain competency on the co-ordination of the counting process but are not yet consistently proficient. Data for this sample of 23 children is shown in table 9.5 below. With this larger sample it is possible to look at the pattern of acquisition both in relation to set size and adherence to principle.

Table 9.5 Summary of the Performance of the 23 SLD "Acquirers"

	Stable-Order		One:One		Cardinality	
Mean	2.65		3.43		.83	
S.D.	2.33		1.83		1.47	
	Small Sets	Large sets	Small Sets	Large Sets	Small Sets	Large Sets
Mean	1.78	.78	2.30	1.13	0.70	.26
S.D.	1.17	1.28	0.82	1.22	1.02	.69

If we take data from these 23 pupils we find that there is a significant effect for principle, [F, (44,2) = 12.18 p <.000). Taking the mean scores for adhering to each principle, independent of set size, the pattern of acquisition is 'one:one' (mean 3.43, S.D. 1.83), 'stable order' (mean 2.65, S.D. 2.33) and then 'cardinality' (mean 0.83, S.D. 1.47). Unsurprisingly, there was also found to be a significant effect for set size [F, (22,1)= 30.68 p<.000], and these two factors, set size, and principle had an interactive effect [F(44,2) = 5.38, p=.008] which when combined provided the following pattern of acquisition from first to last; one:one small sets, stable order small sets, one:one large sets, stable order large sets, cardinality small sets and finally cardinality large sets.

For interest, the same analysis was carried out using the data from the parallel group of "acquirers" from the sample of typically developing preschoolers. Using data from studies 2 and 3, 22 children fell in this group. A summary of their data is presented

9.6 Summary of the Performance of the TD "Acquirers"

	Stable-Order		One:One		Cardinality	
Mean	3.82		2.91		.45	
S.D.	2.34		1.38		1.06	
	Small Sets	Large sets	Small Sets	Large Sets	Small Sets	Large Sets
Mean	2.23	1.64	2.05	0.86	0.36	.09
S.D.	1.11	1.40	0.90	0.89	0.9	.43

in Table 9.6. A repeated measures Anova similarly revealed that there was a significant difference in pupils adherence to the three principles [F (42,2) =35.51, p=.000], a significant effect for set size [F(21,1) = 37.93, p=.000] and that these two factors again had an interactive effect [F (42,2) = 4.3, p=.02]. This combined sample of typically developing "acquirers" adhered, as a group, to the following pattern of acquisition, starting with the first; stable order for small sets, one:one for small sets, stable order large sets, one:one large sets, cardinality small sets and finally, the last to be acquired, cardinality for large sets. This pattern follows the findings of Fuson (1988) namely that stable order is adhered to by typically developing preschoolers before they adhere to one:one. Also, however, this pattern reveals a difference between the typically developing and SLD pupils, in that stable order (for both small and large sets) is adhered to before one:one for similar set sizes. The reverse is true for the our sample of pupils with severe learning difficulties. Furthermore there was a statistically significant difference between the two groups in their pattern of adherence to the principles [F (86,2) =3.72, p=.02].

In contrast to the group of "acquirers", relatively few SLD children, five, fall within the transitional stage of being able to perform the procedures but demonstrating no understanding of the principles through error detection. They range in age from 9.6 years to 13.8 years, (mean 137.4 mths. S.D. 24.32), and their scores on the BPVS range from 31-53 months (mean 42.8, S.D. 8.44 mths). A profile of the scores of this sub-group are set out in table 9.7 below. Clearly these pupils range in scores on the BPVS. Anecdotal evidence from the school suggested that the transitional pupil who had the lowest MA had achieved this success through the hard work of her parents. The remaining four pupils scored quite highly on the BPVS.

It is interesting to compare these data with that of the typically developing children. Although there were an almost identical number of TD children in the "acquirers" group, only one preschooler was at this transition stage and 10 were able to detect errors. In contrast among the SLD group, eleven children were able to detect errors, but five children although they were able to count almost flawlessly, were unable to detect errors.

			Stable Order		One:One		Cardinality	
Study	**Chrono-logical Age**	**Mental Age-BPVS**	**Small sets**	**Large sets**	**Small sets**	**Large sets**	**Small sets**	**Large sets**
1	9.5	2.7	3	3	3	3	3	3
3a	11.6	4.5	3	3	3	2	3	3
3b	9.5	3.7	3	3	3	2	2	3
3b	13.3	3.3	3	3	3	3	3	3
3b	13.8	4.0	3	3	3	3	3	3

Table 9.7 Profile of SLD children who are at the transitional stage

One explanation of this difference is that as progress is likely to be slower in the SLD child, children will spend longer at this transitional stage. When tested statistically however, the difference between typically developing and SLD pupils in the distribution of children across categories did not reach significance level [χ^2 (3,1) =6.5, p= .09].

Finally to turn to examine the profile of the error detectors. Table 9.8 reveals the mean scores for each error type for both groups of children. The SLD children falling within this group ranged in age from 7.11 years to 13 years 11 months (mean 10 years 3 mths, S.D. 23.75) and in their scores on the BPVS, from 34-72 months (mean 49 mths, S.D. 12.72).

Number of pupils with SLD	**Variable**	**Minimum Score**	**Maximum Score**	**Mean**	**S.D.**
11	One:one	20%	100%	68%	28.5
11	Cardinality	63%	100%	83%	12.86
11	Stable Order	50%	100%	88%	16.73
Number of Pre-schoolers	**Variable**	**Minimum Score**	**Maximum Score**	**Mean**	**S.D.**
10	One:one	25%	100%	83%	23.5
10	Cardinality	62%	100%	94%	12.57
10	Stable Order	20%	100%	90%	23.14

9.8 Profile of children who detected errors

A two factor mixed ANOVA revealed that there was no significant difference between the two groups on their ability to detect errors, but there was a significant effect for error type, [$F(42,2) = 8.22$, $p = .001$]. For both groups of children one:one errors prove the most difficult to detect. However, while for preschoolers one:one correspondence was both the most difficult principle to adhere to and the most difficult principle in which detect errors, for the pupil with SLD one:one errors were the most difficult to detect, but, when they were learning to count, the most difficult principle to adhere to was stable order.

In study one it was noted that not only did the children detect the puppet errors, but they also revealed a desire to handle the puppet and to produce errors for the investigator to detect. Clearly these pupils had reached a level of competency in counting where they were able to produce controlled errors. Informal observation suggested that those children who were not able to detect errors with such ease were also not able to make errors despite revealing the same wish to handle the puppet. We can further add to these observations by illustrating the variety of overt strategies used spontaneously by both TD and SLD pupils. One pupil, for example, moved his finger along with the puppet counts, a strategy that kept his attention closely focused on the puppet movements, a strategy which seems to be geared towards aiding the most difficult aspect of the detection task, checking for adherence to the one:one principle. Another pupil counted each time the puppet finished to find the amount, while another used the same strategy only when he was unsure about a puppet error. It can be argued that both of these children clearly demonstrated a full understanding of cardinality in utilising this strategy. Other children obtained high scores on the error detection tasks without *overt* use of a strategy. No strategy use appeared to be adopted by pupils whose error detection was confined either to small sets or to one type of error trial. Casual observation suggested that it was the high scoring pupils who were more likely to use a systematic strategy.

9.2 *The temporal relationship between the acquisition of procedures and the development of understanding of what it means to count.*

The data from all three studies confirm that children have to be able to count before they are able to demonstrate understanding of the principles. By taking exactly comparable counting tasks with respect to set size, materials and presentation it was clear that for both SLD pupils and typically developing preschoolers perfect or near perfect count skills are a necessary pre-requisite to understanding the principles of counting. Clearly however these skills are not sufficient on their own to automatically lead to detection of errors. The presence of a small number of transitional children bear testament to this.

S	Study	Chrono-logical Age	Mental Age- BPVS	Detection of Puppet Errors		
				Stable Order	One:one	Cardinality
1	1	7.11	3.3	100%	100%	87.5%
2	1	8.11	3.4	90%	100%	87.5%
3	1	8.0	4.1	100%	85%	87.5%
4	2	9.5	2.10	50% (60%ss)	40% (80%ss)	87.5%
5	3a	12.0	3.0	70%	30%	70%
6	3a	13.11	4.0	100%	20%	63%
7	3a	10.0	4.11	100%	70%	87%
8	3a	9.2	5.2	80%	80%	80%
9	3a	9.4	5.10	100%	70%	100%
10	3b	11.5	3.3	100%	100%	100%
11	3b	12.9	5.1	78%	56%	63%

Table 9.9 Profile of the SLD error detectors

S	Study	Chrono-logical Age	Mental Age- BPVS	Detection of Puppet Errors		
				Stable Order	One:one	Cardinality
12	2	3.6		80%	50%	62%
13	3a	4.0	3.4	90%	100%	100%
14	3a	4.4	4.8	100%	100%	100%
15	3a	4.0	4.9	20%	25%	75%
16	3a	4.4	4.9	100%	75%	100%
17	3a	4.3	5.1	100%	80%	100%
18	3a	4.9	6.0	100%	90%	100%
19	3b	4.0	5.2	100%	100%	100%
20	3b	4.8	4.2	100%	83%	100%
21	3b	4.8	4.3	100%	89%	100%
22	3b	4.3	5.0	100%	100%	100%
23	3b	3.11	4.5	100%	100%	100%

Table 9.10 Profile of the TD error detectors.

Scores reaching 5% probability level (calculated using Pascals triangle) are those which exceed 80% on stable order and one:one error trials and 87.5% on cardinality error trials;
Scores reaching 10% probability level are those of 70% (or more) for one:one and stable order error trials and 75% for cardinality.

Children's profile of scores on the error detection tasks provide us with some insight into the way in which children may progress to understanding the principles of counting. The most important information is probably present in the data from pupils who were not yet perfect error detectors. These are set out above in table 9.9 for the SLD pupils and 9.10 for the typically developing preschoolers. If we look at the profile of pupils 5, 6 and 15, these pupils demonstrated that they had an understanding of the error detection task in that they correctly detected one type of error at an above chance level. However these same pupils performed in an identical fashion to the non-error detectors on trials involving the other error types, namely they said the puppet got all the trials right. No distinction was made between correct and incorrect trials and therefore their judgements were correct for the small number of error free trials. For all three individuals, therefore, this was their response to the one:one trials, they appeared to have no basis for making judgements i.e. they did not know the principle of one:one correspondence. Subject 15 additionally made the same response to stable order errors. Thus these pupils whilst they counted automatically correctly themselves *understood* only *some* of the principles of counting.

Once pupils do understand the principle they start to discriminate between counts. Clearly however this is not initially carried out flawlessly. In subject 4 we see that there is a set size difference, she is able to detect one:one errors and to a lesser extent stable order errors more accurately with small than large sets. Whilst other pupils did not show this set size difference, it is quite plausible that her less than perfect performance rests with the attentional demands of the task, possibly with some error types more salient than others. For example the child may know that it is necessary to adhere to stable order in the count but repetitions in the count list may be easier to detect than omissions. From these four children, therefore, we get some clues about how the transitional children may progress, namely that insight is likely to be gained with respect to one principle first (probably either cardinality or stable order) and that at least with respect to stable order there may be set size differences in the child's response. Later children's full awareness of the principles is demonstrated by their spontaneous use of strategies that serve to reduce these attentional demands.

In chapter 2 and 4 we suggested that the process of development might best be described as interactional with children's acquisition of procedures leading to an understanding of the principles and that this enables an extension of counting skills. One possibility that was discussed was that children are able to count small sets, for example, and that this facilitates the development of understanding of the principles and in particular to detect errors in small sets, which in turn enables them to refine the accuracy with which they count large sets. There was no evidence to support this interactive effect in the current study. However small and large sets are not absolute descriptors and it would be hasty to reach a conclusion without considering other available data. During the course of this research Frye et al (1989) published a study utilising sets of between four and fifteen items. Although the procedures used were slightly different, the conclusion reached was rather similar in that there was no interaction in this sense, at least with regard to arrays of this size. Indeed their data, like ours, suggests that children learn first to count small sets, then large and then are able to detect errors, firstly in small sets, secondly in large. Indeed the transition may be an important time during which children achieve reliability in their counting that enables them to deduce the principles.

The interactive process that was evident with a few of our children occurred in a different way. Children's understanding of the principles enabled them to develop procedural strategies to detect errors with greater ease. It is important to emphasis that this interactional process was evident amongst both typically developing and SLD children. Thus children had to attain a level of understanding before developing new procedural strategies. The interactive nature of understanding will be explored more fully in chapter 10.

9.3 *Some factors which might contribute to individual differences*

In study 1 and 2 children's performance in relation to their mental age and chronological age was investigated and additionally in study three we investigated the kinds of counting experiences they typically receive.

Throughout the studies the BPVS was used as a measure of mental age, pairing it with the use of a second non-verbal measure in the final study. Overall the BPVS proved to be a reliable predictor of both the ability to count and the combined measure of counting and error detection. Indeed in study three it was found to account for 73% of the variation between focal children. In study one it had been found to act almost as a screening device to distinguish between children who had not yet acquired the ability to produce any co-ordinated aspects of the count task and those who had, with children who failed to score on the BPVS also failing to adhere to any of the principles of counting, although some were able to recite the number words.

Whilst the BPVS provides a measure of MA which is based largely on pupils receptive language vocabulary, the second measure, the Snijders-Oomen (SON) is composed of five sub-scales which measure different aspects of cognitive functioning. One advantage of using tests of this sort is that performance on specific sub-scales might turn out to be more predictive of performance than others. For example, in this case, one might predict that sorting and pattern recognition form part of a maths curriculum that the two sub-scales which measures these skills- Sorting and Mosaic, would be a better predictor than say performance on the Combination sub-scale where pupils are completing puzzles. In order to investigate the possibility further, data from the total sample of children who completed this test, a total of 50 children, 25 pupils with SLD and 25 typically developing preschoolers, was considered.

For both groups of children, as we can see from Table 9.11 and Table 9.12 below, all sub-scales other than that which set out to measure children's visual memory were highly correlated to both count and combined count scores with no discernible pattern to the profile of scores. The authors reveal an awareness of the unreliability of such memory tests (Tellegen 1993; Tellegen & Laros 1993) and the new version of the SON does not include this memory task. The profile of scores from the SON therefore proved not to be indicative of specific skills related to counting.

N=25	Combination	Copying	Memory	Mosaic	Sorting
Count	.67*	.76*	.27	.71*	.67*
Combined Count	.63*	.72*	.28	.75*	.69*

* Significant at .001 level

Table 9.11 Correlations of SON scores with count scores for SLD pupils.

N=25	Combination	Copying	Memory	Mosaic	Sorting
Count	.76*	.59*	.32	.75*	.73*
Combined Count	.71*	.59*	.24	.76*	.71*

* Significant at .001 level

Table 9.12 Correlations of SON scores with count scores for preschoolers.

Whilst the BPVS proved on the whole to be a robust measure there were two samples of children for whom the test proved to be a less adequate predictor; pupils in study two and those in school B in study three. In these groups chronological age was found to be more highly correlated with counting performance. One possible clue to this discrepancy lies with the pupils' performance on counting and error detection tasks. In both of these groups aspects of the pupils' attainments were surprisingly weak with only 1 pupil in study 2 and two pupils in school B able to detect errors. This contrasts to the five pupils from school A who were successful on this task.

In study 2 we suggested that there were two possible reasons for the differences in performance, firstly that in some way the samples were comprised of pupils who were significantly different possibly due to etiology or secondly, the more plausible reason, that differences resulted from the types of curricular experiences offered. If we start by re-examining explanations based on etiology, we can reconsider the view that a common etiology results in differences in performance that are specific to that group.

Surprisingly 50% of the sample of children in study 2 were pupils with Down syndrome, compared to 13% in study 1. In school B 46% of the pupils had Down syndrome (compared for example to 8% of the sample from school A). These two "low functioning" schools therefore had a large percentage of children with Down syndrome in their samples. Was it possible therefore that in some way the pupils with Down syndrome were performing less well than those children with other etiologies. In order to investigate further the data for all 13 pupils with Down syndrome was pooled. This contained therefore children from all sample groups. Their full performance scores can be found in Appendix F, and the summary data is provided below in table 9.13.

	Mental Age	**Chronological Age**	**Count Scores**	**Combined Count Scores**
Range	23-61 months	84-164 months	4.0 - 18.0	4.0 - 27.0
Mean	37.15	122.46	12.31	13.31
S.D.	10.07	27.06	5.69	7.16

9.13 Profile of Children with Down Syndrome (N=13)

For this *total* Down syndrome sample the BPVS is significantly correlated to both count ($r= .62$, $p < .01$) and combined count scores ($r=.57$, $p < .02$) but when the effect of CA is partialled out the resulting correlations are not significant. We therefore *do* have a group of pupils whose counting performance is not predicted by their scores on the BPVS. We need therefore to ask if their pattern of performance differs significantly from other pupils ? To answer this question a comparison was made between pupils with DS and those with other etiologies who scored on the BPVS, the data for this group is set out below in Table 9.14. No significant difference was found between the two groups on any of the measures of CA, MA or the two count scores [$F (120,3, 3) = 2.15$ $p =$ ns].

	Mental Age	Chronological Age	Count Scores	Combined Count Scores
Range	20-72 months	84-167 months	0 - 18.0	0 - 27.0
Mean	39.31	110.72	9.79	11.55
S.D.	13.69	22.16	6.69	9.21

9.14 Profile of Other Children with SLD [Non-Down Syndrome] (N=29)

To make a further comparison of the two groups, an analysis was made of the proportion of each group which fell in the sub-groups of non-counters, acquirers, transitional and error detectors. The proportions are set out in table 9.15 below.

	Sample Size	Non-Counters	Acquirers	Transitional	Error detectors
Pupils with DS	13	0	8	2	3
Pupils with mixed etiology	32	6	15	3	8

Table 9.15 Performance of pupils with DS compared to other pupils with SLD.

If we compare the distribution of children across the four categories of attainment there is no significant difference [$x^2(3,1) = 3.14$, p= ns] between the two groups of children. It seems unlikely therefore that etiology accounts for the lower pattern of performance by some children, nor the difference in what predicts performance, indeed it is unclear how etiological factors could account for this difference. It is therefore appropriate to consider the alternative explanation, that the differences are due to variation in curricular experiences.

In study 3 a number of important factors were drawn from the observations carried out across settings. Variation was found to occur with respect to 5 aspects, the overall exposure rate, the extent to which pupils were exposed to adult models of counting, the level of participation of the pupils in the number experiences, the overall range of uses of number words and more specifically the level of provision of referent (or concrete) experiences and lastly whether their was evidence that adults varied their use of number words in relation to some aspect of the individual child. Both the rate of adult count words generally and the use of number words where there was a physical referent, were found to improve the accuracy of predictions of counting. However the contribution made by these measures was small. In discussing this outcome we pointed in study 3 to two factors which may have lessened the potential effectiveness of the experiences received. Firstly, it was noted that in neither SLD setting could the level of models of counting be described as high. (Indeed adults in nursery A provided a higher level.) Secondly, the question of whether there was a good match between these experiences and the pupils needs was raised. On the basis of the data collected in study 3 it would appear that adults were not individualising the frequency of their use of count words. Indeed, in school A it appeared that, rather like the nursery setting, there was an inverse relationship between the rate of use of number words and the childs' chronological age. Moreover, in part B of study 3 it seemed possible that pupils were being exposed to more opportunities to learn about counting when they were younger but unfortunately less ready to profit from this experience. In part C this supposition was confirmed, there appeared to be no relationship between the rate with which adults used count words and the childs level of counting. These two factors alone may explain why even the best of our measures of exposure contributed so little to the variation in children's performance when compared to mental age.

If we return to the issue of why some groups of children performance is not predicted by performance on the BPVS and whose progress is weak in at least some aspects of either performing or understanding counting then we need to consider further the concept of mental age. This score is the outcome of a pupils performance on items of a test which have not been specifically taught. At its best it is designed to reveal a pupils ability and indicate their potential. If the performance of a group of pupils is not well correlated with their test score it is possibly that those pupils are underfunctioning, that the experiences they are provided with do not enable them to perform in line with their ability. This tentative conclusion was supported by the number of non-counters in study 2 who fell well within the mental ages of those children who were "acquirers".

Firstly, if we look in more detail at provision in school B we find that although an active role was taken by the child, the provision was notably lacking in other respects. Few models of counting were provided by adults and these were all restricted to set sizes under five. Additionally there was no variation of input with mental age. Indeed it could even be said that the pupils were "teaching" themselves as the highest rate of numberword use came as a result of self-selected activities. In addition to these specific factors it is important to consider some of the more general aspects of provision in this school. For example, in this setting there was little evidence of continuity and progression in the type of curriculum areas offered. Each class timetable allotted time quite differently and highlighted different types of teaching on their timetable. Many of the classes for example listed activities, it being unclear what the curricular focus of these activities were, others used alternative reference points e.g. one to one work, core skills etc. In this setting some lessons were repeatedly cancelled and the relationship between timetable and session was less certain. The picture that was built up was of each class being largely autonomous with the likely result that over their school life pupils might well receive an uncoordinated set of experiences, ill-matched to meet the needs of the pupils and ensure that they reached a level of attainment suggested by their mental age.

9.4 *Generality and Reliability of the Findings*

Before we can finally draw together the findings of this thesis it is important to discuss whether we can, with confidence, generalise the findings to the SLD population as a whole. The data from the fifty pupils here includes children from a wide range in ability, with BPVS scores ranging from 1.8 to 6.0 years. Additionally the initial study provided children who failed to score on the BPVS the opportunity to demonstrate their ability on counting tasks. A wide age range of pupils participated in this study from seven to almost fourteen years. Finally no attempt was made to restrict pupils on the basis of etiology and few children were excluded on other grounds. For example, we failed to find a pre-school match for only one child from our SLD schools and only children whose first language was not English were excluded as testing on the BPVS would provide misleading scores. [Studies of mainstream children suggest that there may be cultural variations in their attainments (Phillips & Birrell 1994)]. One child with a severe expressive language disorder was excluded because his only means of communication- a symbol book contained no numerical symbols but children with emotional and behavioural disorders were included although testing took much longer to ensure an optimum level of performance was achieved.

Despite the exclusion of this small group of children there was considerable similarity in the size and ability range of the samples. In the final study the two SLD schools were in comparable size and yielded almost identical samples with similar span and mean scores on both the BPVS and Snijders-Oomen tests. This was achieved despite using schools in different locations. The same comment can be made about the samples in study 1 and 2, where again the fixed variable was age but the pupils in the two samples were comparable in terms of BPVS scores. It would appear therefore that the solution to achieving representative samples had largely been achieved.

The exploratory study revealed that both the counting and puppet detection tasks had high test-retest reliability. The grouping together of set sizes in subsequent studies into small and large provided each child with three attempts to demonstrate proficiency. Prolonged testing of children can result in unreliable data due to fatigue and a fall in motivation and therefore the number of puppet trials was purposefully reduced to ensure optimum performance throughout. Careful attention was also paid to materials to ensure good levels of interest and children were given general encouragement throughout such as "you're working really well" as advocated in the BPVS manual. Furthermore testing stopped when the child showed any signs of losing attention and recommenced on a second occasion. Taking these factors together, we feel confident that the data produced in this study is robust and meaningful.

9.5 *The Parameters of the Study*

In addition to examining issues of reliability and generalisability with regard to the sample and methods of data collection it is important to be clear about the parameters of the investigation. From the very beginning it was decided that this thesis would consist of an indepth examination of a narrow band of tasks in preference to examining performance across a wide variety of tasks. This has been partly determined by the focus of the study and its attendant methodology (discussed in chapter 5) but also by practical issues such as the characteristics of the sample population which determined the need to keep task length to a minimum. Previous studies (reviewed in chapter three) with samples largely confined to pupils with moderate learning difficulties have elected to use a battery of tasks with pupils (e.g. Spradlin et al 1979, Baroody and Snyder 1983, Baroody 1986a, 1986b, McEvoy and McConkey 1991) but as we discussed in chapter 5, whilst this approach provides interesting data it does not succeed in the same way in distinguishing between what children can do and what they understand.

In determining what came first, procedures or principles we elected to carry out a cross sectional study from which to infer a temporal relationship. An alternative approach would have been to carry out a longitudinal study and to note the emergence of skills and understanding. One pragmatic difficulty with this approach, given the nature of the pupils' learning difficulties would have been the extended period of investigation. A second and related difficulty would be the contamination arising from repeated testing.

An investigation has been made of both formal and informal opportunities for pupils to learn about counting, but this has been limited to the school context. In considering the generalisability of this procedure two factors must be considered. Firstly, the observations may not have focused on <u>all</u> the important variables. (Indeed, naturalistic observation studies may not fully reveal the optimal conditions for learning.) As we have already discussed there were some very general aspects of provision such as issues of continuity and progression across the curriculum, that may have contributed to the low performance of one group of children. However, it was neither theoretically possible nor practically feasible to study more variables at this point in time.

The second factor is that parents and siblings rather than staff employed in school may be the prime teachers of counting. (We noted earlier that one transitional pupil with the lowest mental age of children in that group had reportedly acquired the *skills* of counting through the intervention of parents.) Although not without controversy, there is now considerable evidence that this may be true for typically developing children. In addition to the well documented experiences provided in the home (Durkin et al, Saxe et al, etc) a recent study of ten nurseries (Munn & Schaffer 1993) found relatively few numeracy experiences. In many ways those with slightly higher rates had characteristics closer to home with a system for assigning children to the same adult and a smaller group size. This more interactive context contrasts to the more frequently found nursery practice of passive large group sessions which as Munn (1994) states requires a "fair amount of faith on the teacher's part that learning is happening." Whilst this study suggests a rather insignificant role played by the school environment it is probably indicative of weaknesses within the current provision rather than of the environmental effectiveness per se. Indeed an interesting extension to this study would be to investigate opportunities provided at home.

9.6 *Summary of the key findings*

Whilst recognising these strengths and limitations, we can now draw together our main findings. Out of a total sample of fifty pupils with SLD, almost half of the children fell within the category we have termed the "acquirers" with a pattern of acquisition for procedures of adhering first to one:one and stable order for small and then large sets, and then to cardinality for small and large sets. Some 22% of children were able to demonstrate understanding through the detection of puppet errors and a further 10% were at a transitional stage between the two, able to count flawlessly but not able to detect errors. Only minor differences were found when comparisons were made with TD preschoolers, namely that the pattern of acquisition of one:one and stable order was reversed and secondly that fewer children were at a transitional stage.

Throughout the studies all children who demonstrated understanding were competent counters. Conversely no child who was unable to count well revealed understanding. The pattern of transition appears to be gradual with children initially having no basis to distinguish between correct and incorrect counts and consequently responding to all counts identically, to an understanding of a single principle prior to gaining understanding of all three. At this time we see in some pupils the use of strategies, indicative of an interplay between understanding and procedures.

Finally the data from these studies supports the notion that performance and understanding of counting is well predicted by a variety of measures of mental age, irrespective of etiology. In contrast we found only a weak relationship between childrens scores combining performance and understanding, and a number of specific measures of pupils' number experiences in school.

Chapter 10

Theoretical and Practical Implications

10.1 Introduction

There are two main reasons why research is carried out with individuals whose development differs in some way from others, either through differences in rate or profiles of relative strength and deficit. The first is that the development of these groups is of interest in its own right, not least because of the practical implications. If we do not understand how and what these groups of children can achieve we are limited in our own ability to facilitate their progress and are unreliable in our expectations of achievement. The second reason concerns the extent to which studying these groups of children inform us about processes found in typically developing children.

From the outset the primary focus of this thesis was on the first of these two options. However this could not be achieved in a theoretical vacuum and a decision was made to employ the considerable literature available on the development of counting in preschoolers. In drawing on this literature it becomes evident that the findings of these studies can add something to what we know about the development of this area of mathematics as a whole. We start this chapter therefore with an affirmation that adopting a developmental approach was appropriate and then consider in detail the theoretical implications of the findings together with suggestions for future studies. Finally we return to our primary focus to supply the teacher with some practical suggestions.

10.2 The Developmental- Difference Controversy

The design of this thesis was heavily influenced by the work of Gelman and her colleagues and specifically set out to investigate the conclusions reached by her that typically developing children are guided in their acquisition of counting by implicit understanding of the principles but that children with "mental retardation" could be characterised as different, developing skills through associative learning, and furthermore lacking an understanding of the principles (Gelman and Cohen 1988, Gelman and Meck 1992). As a result of these studies we can refute her arguments on both counts. At a global level we found no difference either in the attainments of typically developing preschoolers and children with SLD or, more importantly, in the temporal order of acquisition. Both groups acquired the procedures for counting before they demonstrated understanding.

As stated above these findings can be discussed from two different perspectives. To begin with we consider what they tell us about the progress of children with SLD. As we have noted in chapter one, Detterman (1987) has suggested that the argument for difference or delay is dependent on the unit of analysis. More specifically that at the micro level differences might be seen which at the macro level are no longer apparent. Clearly to some extent this is complicated by issues of the sensitivity of the instrument of measurement used. Alternatively, however, this may be truly instructive of the nature or scale of the difference.

At the macro level we found no evidence to suggest that the two groups are different. Indeed, characteristics which were previously viewed as atypical, such as using labels instead of count words (Gelman 1982) in the earliest stages of acquisition, were found in both groups of children. If at this macro level we view children with SLD as simply delayed then it is quite likely that their slower development make such characteristics more apparent.

At a more refined or micro level, however, there are some qualitative differences which must be considered. In study 2 we found that there was a significant difference between the two groups in their acquisition of the number string. More specifically, children with SLD produced fewer number words. However, this was not a finding of the larger group of pupils who formed study 3 and requires further investigating with a view to whether this discrepancy can be viewed as specific to groups who are at the earliest stages of counting. In chapter 9, the analysis of the order of acquisition for each principle based on the complete data from 50 pupils with SLD and 45 TD children revealed a more robust difference: a reversal of acquisition of procedures for adhering to one:one and stable order for those with SLD, but the same order of acquisition for understanding.

Taken together, then, these findings suggest that children with SLD are both delayed and different when compared to TD children. Hodapp, Burack and Zigler (1990) have argued that there must be a relationship between "molar and molecular functioning", that if there are differences in one then there must be differences in the other. However it is clear that the differences found in this study were not sufficiently extensive to alter the overall course of development, supporting the view of Kopp and Recchia (1990) that there may be several routes to achieving the same end.

10.3 The Concept of Mental Age

Our own position of adopting a developmental approach was further supported by the significant correlation of counting score with mental age. Indeed mental age proved to be the better predictor of performance and accounted for some 70% of the differences between individuals, on performance on the counting task. This does however raise questions about the relationship between counting and "mental age" scores and furthermore on the very concept of mental age.

One of the limitations of correlational studies is that although they indicate covariation between variables, and the direction of this covariation they do not signify causal relationships. Mental age scores simply tell us where an individual is placed in relation to a group of other individuals, in the case of the tests used here, in relation to scores on a test of receptive language (the BPVS) and the scores of a number of separate sub-tests (which together produces an intelligence quotient). Thus pupils relative position on the range of counting scores was well predicted by their position in the range of test scores. If we exclude the memory sub-scale for which there was no correlation with our measures of performance and understanding, there proved to be no single sub-test of the Snijders-Oomen whose predictive powers were superior.

This suggests that pupils scores were significantly related, not to single cognitive functions but to some more generalised cognitive ability or process. One explanation is that the tests, including scores on the counting tasks, all tapped into one generalised aspect, such as learning ability or stated a slightly different way, pupils ability to profit from instruction.

Given the variety of aspects of functioning tested, the data, perhaps more importantly, suggests that these early counting tasks are unlikely to derive from a separate domain. Again this runs contrary to Gelmans view of "domain-specific principles" and "domain-relevant data abstraction processes" (Gelman 1990) and further supports our view that children are not guided in their acquisition by an implicit understanding of the principles of counting. Wynn (1992a) and Starkey and Cooper (1995) make a useful distinction here between learning the "counting system" and awareness of numerosity for which there is evidence to suggest domain-specific cognitive abilities (Strauss & Curtis, 1984; Moore, Benenson, Reznick, Peterson, & Kagan 1987; Starkey, Spelke & Gelman, 1990; Wynn, 1992).

10.4 Understanding, Rules and Principles

Prior to considering the processes that might characterise children's progress through the counting tasks studied in this thesis it might be useful to discuss briefly the terms used. An important aspect of the study is to clearly formulate what is meant by understanding. As we saw in chapter two, Gelman distinguishes between two types of understanding, implicit and explicit understanding, implicit understanding being inferred from childrens' incorrect performance in much the same way as we might infer an understanding of the rules of grammar. Explicit understanding, in contrast, was considered to be present when the child was able to say why it is necessary to adhere to the principles. The evidence reviewed in chapter two did not support her view that children were guided in the acquisition of procedures by an implicit understanding. We were not however able to fully support the extreme position put forward by Briars and Siegler (1984) who concluded that

> "children very early learn to execute the standard counting procedure and then gradually learn which of the typical accompaniments are essential and which are optional" p616,

and that this acquisition process was not guided by knowledge of the principles. This account did not really provide an explanation of how or why children "gradually learn", other than with reference to induction, and portrayed the child as largely passive in the process.

An alternative approach to viewing understanding is to make a distinction between **rules** and **principles**. Whereas rules relate purely to procedural knowledge (Fuson and Hall 1983) whereas principles are the outcome of a more fundamental understanding of the underlying concepts. As Baroody (1992) has indicated principles rely on more general knowledge, whereas rules are characterised as typically situation-specific. Indeed, McShane (1991), refers to a rule as the strategy which a child uses "to respond to particular conditions". A procedural rule could therefore be adopted which resulted in a better match in their performance to other proficient counters, but with no understanding of the importance or relevance of this procedure. In addition to being context bound, as we have also found, rules appear to function largely independently of one another. As we shall see the data collected in these studies supports an explanation of the acquisition of procedures as characterised by the formulation of a series of rules which undergo refinement with experience. Once these rules have been accurately deducted and the child consistently accurate in his counting he is in a position to develop a more fundamental understanding of the underlying concepts of number.

If we incorporate the notion of rules in our discussion of children's development of counting then it is apparent these cannot occur in a social vacuum. Gelman largely rejects the role of adults in the acquisition of the count process (Gelman and Massey 1987, Gelman and Meck 1992) and yet clearly if we find no evidence of prior understanding of the principles we need to consider how children acquire the skills of counting. Counting has been described, by others, as a culturally transmitted activity (e.g. Riem 1985, Saxe, Guberman & Gearhart 1987, Elbers 1991) with adults inducting children into what is worth knowing in a given culture as well as imparting more specific meanings. Recent evidence, however, suggests that in the early stages preschoolers have a much narrower view of the counting activity than adults (Munn 1994). Whilst adults view the activity as inherently meaningful and assume that children make the links between counting and cardinality (Reim 1985), for children it appears that learning to count centres on saying the numberwords. Given this scenario it is unsurprising that ambiguities occur in exchanges between adults and children (Reim 1985, Durkin et al 1986, Munn 1994). These researchers document exchanges which are typically described as occurring in a one:one setting, as part of an on-going dialogue with shared attention and a negotiation of meaning. If this forms an optimum setting for learning it is perhaps unsurprising that, in the third study in this thesis, we found a rather limited relationship between children's attainments and environmental provision. In general staff did not appear to individualise their use of number words, and in some settings the activity was conducted in a large group with children taking a mainly passive role. Similar shortfalls in the provision of number experiences have also been noted by Munn & Schaffer (1993) and Munn (1994) in a much larger survey of nursery practices.

10.5 The Acquisition Process

At the start of the acquisition process the non-counting children in the present studies made relatively few responses to a request to count. If they made any response at all other than to play with the objects, they typically produced either a short sequence of countwords or they pointed to objects. A few children labelled the objects, a response that Gelman (1982) suggests is typical of children with learning difficulties but which we found in both groups of children who we described as non-counters. For these children a request to count clearly meant very little even when it was then accompanied by a model. These children did not appear to understand or be familiar with counting even at the general level of an activity.

At the second stage, it seems safe to conclude that the children described here as the "acquirers" had at least some idea of the demands of the task. These children responded to the instruction with an approximation to the correct response in that they said some number words *whilst* pointing or touching the objects but the activity at this stage had not been refined. How does it come to match those of competent counters ? Whilst we know that adults model responses and give children reinforcement (Reim 1985) it would be misleading to conclude that children learn from this by simply copying. In these studies, for example, it was found that children made responses that they would not have seen competent counters make.

One of the most immediate sources of information on *how* children acquire these skills comes from considering childrens' responses to the "how many" question. In study 3 we characterised these as falling within five types, one being a catch all of "other" for children who for example said "I don't know". This gives some indication of the variety of responses both typically developing and SLD children made.In addition to those response types noted by Fuson (1988) of recounting and giving a single incorrect digit, we found children reciting the whole sequence of number words (i.e. with no pointing), adding or subtracting one to the last tag, and making the same random response of a particularly salient number across set sizes. Some children constantly altered the response type they made, including those who made a correct response on some occasions, whilst others largely made the same response type throughout trials.

As noted above, it is unlikely that simple imitation would produce these response types (nor enable improvements in performance). Indeed Gelman and Meck (1992) have even argued that adults don't typically count and repeat the last tag. Clearly, however, children are generating a whole host of different response types, some of which gain favour and are largely retained over trials and some of which appear to be used only irregularly. Yet, ultimately, one (correct) response type is retained. This is consistent with a view of the child quite *actively* trying to work out a rule for how one should respond in this situation. Longitudinal evidence provided by Fuson (1988) supports the view that these rules change over time, presumably as children gain more knowledge of the procedures and receive feedback about the adequacy of their response. Evidence to further support a "how many" rule is provided (as it was for Fuson) by the relative ease with which children generalise the rule from small to large set sizes as indicated by our order of acquisition. Wynn (1990) provides further evidence of children acquiring a rule as they adjust their counting to fit a given last tag. It would appear that these rules act fairly autonomously as this is an example of children sacrificing stable order to adhere to last tag rules.

Do children in fact produce rules for each aspect of performance ? Baroody (1992) has argued that one of the first rules concerning stable order is to produce the words from the number list. This coincides with Munns' (1994) observation that children see counting as being able to produce the number words. This is possibly the only rule necessary for acquiring this aspect of the procedure. If we are right in concluding in chapter 2 (p36) that this is a serial recall task, then learning "the list" automatically assumes that each word appears once and once only. No further cognitive analysis or rule forming is necessary to be able to recite the list. Given the very simplicity of this rule it is unsurprising that in typically developing children we found adherence to this aspect first.

Turning to one:one correspondence, Reim (1985) proposes that in the context of mother child interactions children learn the rule of saying a word as you point. Briars and Siegler (1984) have argued that children see it as important that you start at an end and count adjacent objects. We saw in the exploratory study that some children automatically placed objects in a row, a strategy that could well be indicative of such a procedural rule. Whilst relevant data was not collected here, a number of studies have similarly indicated an order irrelevance rule whereby children know that it is acceptable to count in the opposite direction, or with alternating objects, prior to a full understanding that the outcome of counting is the same (Baroody 1984, 1992, 1993).

Childrens' understanding is therefore characterised at this stage as largely centering around knowledge of procedures. This rule based knowledge is limited in that the rules (or strategies if we use McShane's term) are context bound. For example, the rules may be applied to own counts but not used to make judgements of puppet counts. Additionally these rules appear to exist relatively independently from one another. Despite these limitations however, the formation of rules probably forms a vital function in that it enables the child to gain consistency in their counting. With this increased reliability the child can gain confidence and is therefore in a position to develop a conceptual component to the procedural rule that will ultimately lead to the formation of principles. Until a child adheres to these rules consistently he will not reach the same number when he counts and recounts a given set, and therefore will be in a poor position to understand the link between counting and numerosity.

Having acquired the rules for counting and gained both consistency and ease in his production the child is in a position to go beyond viewing counting as an activity and develop an understanding of the meaning. As the development of rules was carried out over time, it is likely that we will also see a development of understanding rather than a flash of sudden insight. Two factors in particular support this view, firstly the process is not an automatic one, execution of the skills of counting does not guarantee that the child understands the basis for making judgements about correct and incorrect counts. Secondly, it is also apparent that not all the error types are deduced at once. These two factors, together with the later use by some children of particular types of strategy for error detection, suggest that children develop from a simple rule base to reach a level of principled understanding over a period of time.

One of the interesting outcomes of the task for the experimenter was the difference in response pattern between those who demonstrated understanding by detecting errors and those who didn't. Those who didn't almost invariably made the same response type to all trials i.e. there was no guessing, either the counts were all viewed as correct (this was the most common response) or occasionally they were all viewed as incorrect. The children appeared to have no basis on which to make a distinction between what constituted a correct or incorrect trial. This included some children who were able to count flawlessly themselves. The pattern for some other children was that error detection was restricted to some aspects of the count process only. Clearly whilst these children had acquired the rules, their understanding of counting was limited. Indeed, the inability to apply those rules in a new context and the inability to apply all three rules together reveals the limitations of their previous learning. These are important twin achievements which are characteristic of children whose response to the error detection situation revealed the development of understanding in additional ways. For instance, we have already commented on the way in which some children were able to use this understanding firstly to deliberately generate strategies that aided performance and secondly to "play the game" and generate incorrect counts. These were children whose level of understanding enabled them to use counting strategically in what was probably a novel or at least unusual context.

It is at this stage of acquisition that we can most clearly see an interaction between procedures and understanding. The childrens' level of understanding enabled them to have a clear picture of the goal and to select appropriate procedures to carry out that goal. Facility with executing the procedures enabled them to carry out the strategy competently. For example some children moved their finger along the line in time with the puppet counts which because they were able to execute the strategy flawlessly enabled them to judge where the puppet had made an error. It is at this stage also that we see children monitoring their performance and taking action to improve it. If the child was uncertain about a puppet count then they utilised a particular strategy.

10.6 Mechanisms for Change

This set of studies has successfully resulted in a description of the succession of stages which children pass through in the acquisition of the procedures and understanding of a simple count task. This has been achieved through investigating changes in what children can do, and, drawing from this, conclusions about changes in the characteristics of children's thinking in relation to this task. The inclusion of children with severe learning difficulties has probably enabled greater insights into this process as at least one of the stages passed through by typically developing children very quickly, namely the transition stage, is more readily seen in children with SLD.

From these three studies we have concluded that thinking changes from being procedurally rule based to an understanding of the underlying principles and that at one level at least, the formation of rules themselves is a mechanism for change. It is the formation of rules which provides the child with consistency in their counting. Without this consistency children are unable to extract the true meaning of counting- that is that providing you adhere to the rules, the number of objects does not change. We have also seen however that accurate counting on its own does not lead to understanding and therefore it is possible that we need to look further into the mechanism of change.

We have described the child as active in the process of rule formation. Evidence from the variety of cardinal responses suggests that children produce a variety of response types. We need therefore also to be able to account for changes in the format of these rules. There remains however a further question- why do children change their response types ? Put another way can we further clarify these mechanisms for change (Albali & Goldin-Meadow 1993).

We have therefore advanced our knowledge on the developmental stages but still have unanswered questions on how children move between these stages. One way to investigate this would be to look in more detail at particular stages, such as the transition stage or at children's move between cardinal response types. Siegler and Crowley (1991) have proposed the use of what they term a "microgenetic" method to enable "intensive analysis of both qualitative and quantitative aspects of change". This method of exploring periods of change would need to be coupled with the provision of a range of experiences which are proposed to facilitate the underlying cognitive mechanism. For example, if we take the transition period between accurate counting and error detection, one might posit that a possible mechanism for change is promoting the child's awareness of a *mismatch* between their own counting of a given set and the puppets'. One might also hypothesize that this awareness is more likely to occur on small sets that the child feels especially confident in counting, than large sets.

If change is dependent on the child's awareness of mismatch then we might also hypothesis that this is a condition for changes in children's response type at an earlier level. For example, we have seen how children's responses to the cardinal question change (Fuson 1988) from a single incorrect digit to recounting (or in some of our own samples repeating the sequence of count words). We might hypothesize therefore that this is due to a mismatch between the childs expectations of the outcome of counting and what actually happens. The child may assume that his counting is the same as others and will therefore expect others to accept his count. A mismatch will therefore occur when others don't accept his count. Clearly there is an important social dimension here as the presence of a peer or adult plays an important role in providing feedback on the outcome of counting. Observational studies of the transition in response types across a variety of social conditions would illuminate this process of change.

It is important to make a distinction here between an investigative approach that is geared towards promoting change- any change, and intervention studies where a particular behavioural outcome is desired. For example, in an investigative study it is not essential for the child to move from non-solution to solution to provide us with valuable insights into the mechanism for change. Qualitative differences in response can be just as informative. In contrast, intervention studies are more likely to be desirous of creating a particular change. It could be argued that this type of qualitative investigation is an important pre-requisite for future successful intervention studies.

10.7 Practical Implications

Although the studies described in this thesis were designed to explore the attainments of children with SLD rather than to investigate intervention methods, we feel it is important to make some practical suggestions that might be helpful to the teacher in the classroom. Ultimately, of course, it will be essential to test these suggestions empirically.

For the SLD teacher, the outcome of these studies may be viewed as both encouraging and disappointing. On the positive side, the most important and encouraging finding of these studies was to demonstrate that children with SLD can develop both skills and understanding of counting. That is not to imply that *all* SLD children will make this twin achievement but that this goal can be pursued with confidence for at least some. As a tentative guideline we can suggest that the demonstration of understanding is more typical of children with a mental age of around 4 years and a chronological age of 10 years. However, what was also apparent from our studies was that children with measured mental ages as low as 3 years were capable of this achievement many children were achieving this even though teachers and other staff saw counting as relatively unimportant and, more importantly, did not appear to match experiences to pupil capabilities.

On the negative side, the teacher may well feel disappointed that the environment seemed to play such an insignificant role in the process with children's progress being largely predicted by mental age. However it is quite possible that children could achieve more if attitudes and experiences changed accordingly and it is therefore important to consider these findings for their curricular implications.

The first point that it may be useful to note is that it is probably simplistic to divide the SLD population into children who can, and children who can't count, as it denies the passage of progress. By dividing children into much smaller groups as was suggested from the studies undertaken in this thesis it is hoped that teachers will be able to see children within a sequence of progression and to respond with more appropriate learning opportunities. It is not sufficient for counting and mathematical activity to occur in the curriculum for only some children. The curriculum needs to be planned with a view to coherence and progression across the key stages.

Turning to the first group of children, the non-counters. All three studies included some children who were not yet able to count at all. These were usually, (but not always), the youngest children or children with the lowest mental age. It is likely that, with time, a good proportion of these children will become acquirers given an appropriate level of input. If we look at settings with the highest levels of achievement, such as for example the schools represented in study one and school A in study 3, we see that, taking children who scored on the BPVS, only one child in the combined sample of 20, had not yet developed adherence to any of the principles. How might less successful schools start children on the process of acquisition ? The results of the exploratory study suggested a relationship between the accuracy of counting and the number of component parts in the task. It is possible that children at the earliest stage would benefit from a sharing of the counting process, working with a more competent peer or adult, and taking turns to carry out each part of the count process. This might for example involve the adult producing the number string whilst the child points to each object in turn or vice versa. This is an area which would warrant further investigation but is consistent with descriptions of mother-child interactions in counting activities (Reim 1985, Durkin et al 1986).

Our analysis of the performance of children described as "acquirers" revealed that, as a group, the order of acquisition was, from first to last, one:one small sets, stable order small sets, one:one large sets, stable order large sets, cardinality small sets and finally cardinality large sets. This order may help to reassure teachers who feel that children are not making progress because they cannot answer the how many question. It is important to note however that this order is not obligatory and should not form a straight jacket for teaching, as we saw with preschoolers the order of acquisition for adherence to one:one and stable order is reversed.

It is likely that some children will find learning the number string difficult. For instance, study 2 revealed that some children will come to the counting task with a poor vocabulary of number words. As others have pointed out (e.g. McConkey and McEvoy 1986) children need feedback about their counting, in particular they need to know which aspects of the count process are inaccurate rather than simply being told they are wrong. If the production of the number string is the inaccurate aspect of their counting then they need to be informed of this and helped to make associative links correctly between number words. Serial recall tasks benefit from repetition but memory may also be aided by introducing a strategy to aid recall of particular numbers. Other children may find it difficult to point to each object in turn. These children may benefit from being taught a strategy such as moving the objects as they count them but they need to know why the strategy is useful so that they don't see it as a component of the count task in its own right. Informed feedback will enable children to improve their counting, to form appropriate rules and ultimately to gain understanding of the principles.

A relatively small proportion of children were at the transition stage, that is, able to count but unable to detect errors, suggesting that they have knowledge of the rules of counting but that these are both context specific and exist independently. The practical implications for this stage are two fold. Firstly, children need to develop conceptual understanding. This is not something that can be acquired through demonstration but is developed through encouraging reflection on a range of experiences. Children with SLD will need to be exposed to different types of counting, not simply left to right adjacent counting, using small set sizes. Moreover, their attention needs to be drawn to the fact that providing there is adherence to the three "how to count" principles the number of objects remains the same. It could be argued that the use of errorless learning techniques will actively interfere with the development of this understanding. Exposure to a single model for example will limit the need for reflection and deduction. Secondly, pupils need to be actively engaged in the count process, predicting the outcome, spotting deliberate mistakes, devising strategies to check whether someone else has counted accurately. The use of these strategies was apparent in those children who were able to detect puppet errors easily. It is likely that this aspect of teaching is best carried out in contexts which are meaningful to the child, where the outcome of counting matters. Others have suggested the use of games (Baroody and Ginsburg 1984; McConkey and McEvoy 1986; Baroody 1988a; Baroody 1988b) and these could well provide an appropriate context, one which staff can utilise to the full as a teaching devise. Equally routine everyday occasions where the outcome of counting is important to the child (such as giving out snacks or other favoured items) can be utilised.

If children are to take an active role in the learning process then this must be reflected in classroom organisation. One of the emergent factors from the observations in study three was the clear link between organisation and children's opportunities to contribute to the count process. For instance, children in big groups were provided with a largely passive experience. This however is not to suggest that all counting experiences should be provided in a 1:1 setting. The observations also revealed that small groups, including those which are not teacher-lead, can provide parity in the opportunities they present each individual. It would seem important that children are not mixed solely on their ability to count as the experience of watching others, whether they are competent counters or not, can act as a spur to reflect on the accuracy of counting.

Finally, although the staff of the two SLD schools in the final study rated counting activities relatively low in importance, the children did not necessarily share this view. The use of number words by focal children was surprisingly high, especially when compared with some nursery children. Additionally children *chose* activities in which number played an integral part. Teachers can capitalise on this interest and provide children with the opportunities to develop an important area of skill and understanding.

10.8 Conclusions

As a result of our studies we have characterised the process of acquisition of skills and understanding as a gradual one where children can be described as passing through four stages in the acquisition of counting. We have characterised the changes in children's thinking as moving from rule based (where each rule is applied in turn in specific contexts) to a principled understanding where children are able to be flexible in the application of their understanding and to generate strategies for use in problem solving situations. We have suggested that the likely mechanism underlying these changes is the child's awareness of a mismatch between the expectation and the outcome of a particular action or sequence of actions but that further investigation is needed, studying children in transition states across a variety of social and asocial contexts.

In global terms no difference was found in the performance of children with severe learning difficulties and those of preschoolers when matched on two measures of mental age. Both groups demonstrated acquisition of procedures prior to an understanding of the principles. There was however some evidence for qualitative differences between the groups, suggesting that children with SLD may experience difficulty in the acquisition of the number string. The scale of this difference however is not sufficiently large to alter the parity of pupils' development but serves to remind us that there may be more than one route to acquiring a given task.

Finally as this thesis started with Gelman so it is appropriate to reflect back on her contribution. Historically the view of children's understanding reflected through Piaget and others was that children did not understand number until well after starting school. Gelman and her colleagues have been undoubtably influential in recognising that children did have some conceptual understanding prior to that (Baroody 1992). These studies have confirmed that typically developing children can attain what might best be described as a strategic understanding of counting well before they start school.

Whilst we disagree with her about the nature of early understanding we must however also recognise that like many others before, we have coined her terms of stable order, one:one and cardinality to make distinctions between three different aspects of the count task. Her theory has proved pivotal in this respect. In proposing that children acquire rules we are not denying that children use their cognitive abilities to make deductions about the counting task and are not therefore portraying children as passive in the acquisition process. In many respects however we are seeing those processes as being directed towards acquiring skills, becoming a competent participator in the activity of counting rather than in trying to understand the meaning. Here we find the distinction made by Munn (1994) about the differences between how children view counting and how adults do, an important one for both teachers and researchers. We can therefore take particular encouragement from the finding that whilst teachers and other staff members may not view counting as important, for children it is a significant activity and one in which children with SLD will choose to engage.

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Appendix A

Subject	Test	Retest
3	1,2,3,4,8,6,7 1,2,8,2,9	1,2,3,5,6 1,2,3,4,8,3,6
4	1,2,3,4,5,10 1,2,3,4,8	1,2,3,4,11 1,2,3,4,5
7	1,2,3,4,5,6,7,8,9 1,2,3,4,5,6,8,9	1,2,3,8,9,10 1,2,3,4,5,6,7,8,9
1	1,2,3,4,5,6,7,8,9,9,7,12 1,2,3,4,5,6,7,9,12,13,16, 16	1,2,3,4,5,8,7, 1,2,3,4,5,6,7,8
5	1,2,3,4,5,6,7,8,9,10,11,1 2,6,7 1,2,3,4,5,6,7,8,9,10,8	1,2,3,4,5,6,7,8,9,10,11, 12,13,16,11 1,2,3,4,5,6,7,8,9,10,11, 12,13,16,18
6	1-59, 90-98 1-47	1-59

Table A.1 Counting Strings of the Pupils in the Exploratory Study

Appendix B

Pilot Study of the Questionnaire

Fifteen questionnaires were distributed for piloting. Six were sent to two pre-school nurseries taking pupils aged 2-5 years, six were sent to a school for SLD pupils aged 2-12 years but completed by staff working with pupils aged 7 years and older. The remaining three questionnaires were sent to a senior SLD school with a request that they were completed by staff working with pupils aged 12-14 years.

Results

Fourteen (93%) of the questionnaires were returned, the omitted age band was for 7 year old SLD pupils. Two teachers however taught pupils aged 8-9 years and so the omission of the youngest age was not felt to be significant.

These pilot questionnaires were firstly analysed according to the degree of agreement between the two different groups in rating items. Any item that was consistently rated as not very important was to be removed. In fact no item was seen by the majority as being totally irrelevant and therefore none warranted exclusion. The pilot however revealed a number of potential problems:

1. Four respondents omitted to answer one item each.
2. One person rated two items twice. The solution to this was to include an invitation for people to check that each item had received one and only one rating at the end of the questionnaire.
3. One person from the SLD school had difficulty completing items due to the extreme heterogenity of their group. The inadvertent inclusion of a teacher of a class of pupils with profound and multiple learning difficulties may have exacerbated this problem as all other class teachers felt largely competent to assign a single rating even where they wished to qualify their response. This suggested the need to include in the introductory explanation clarification that the questionnaire was to be answered in relation to the majority of their class/group.
4. Eight of the respondents did not use all of the 5 rating categories. The category

which was not used by all eight was "this is not very important ". This may be an outcome of using largely relevant items. One solution that was considered was to include obviously irrelevant items, however this was rejected as firstly 43% of respondants already felt the questionnaire included low priority items and this included two nursery workers as well as SLD staff and secondly the deliberate inclusion of irrelevant items was felt to challenge professional integrity.

5. Four respondents provided a total of ten suggestions for "Other" goals. As the aim was to keep the number of items as low as possible not all ten suggestions could be included. The solution was to adopt four of the items which were rated as vitally important. Four of the suggestions overlapped with existing items and therefore the existing items were clarified or extended. Two items were not included as they were not rated as vitally important, and nor were they mentioned by more than one respondent.

6. An examination of the responses to the first question revealed that some members of staff were filling in aims for themselves rather than aims for their children. There was a variety of responses both in length and content. As one would expect, teachers in SLD schools appeared to find this item easier to answer in the sense that the question was a familiar one. Their aims were therefore largely expressed in terms of the long-term outcomes. Nursery staff are probably invited less frequently to reflect on this aspect. In order to help nursery staff understand the significance of this question it was rephrased to include reference to the fact that the aims would provide guidance in selecting activities/learning opportunities .

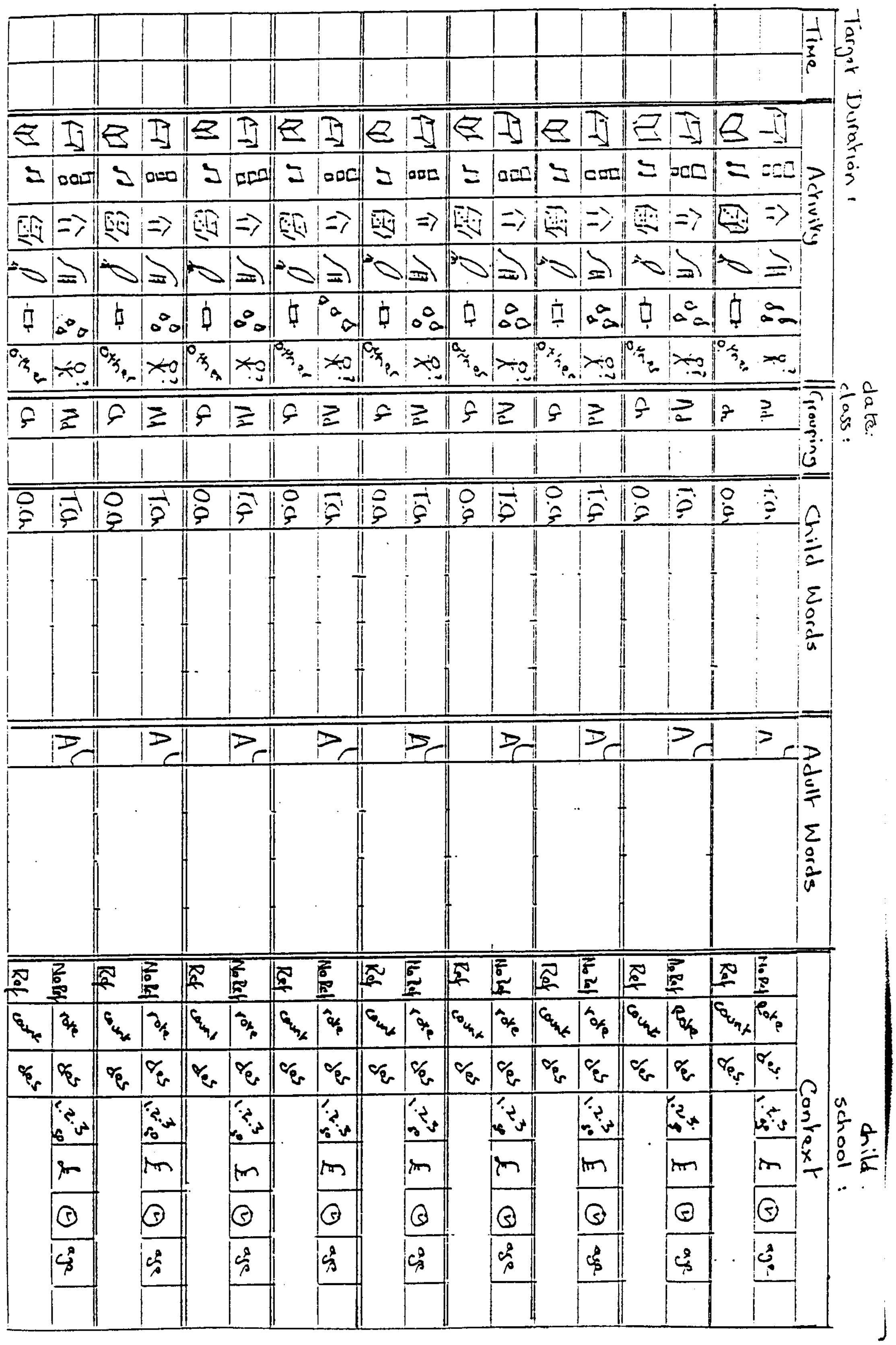
Appendix C

Observation Proforma- SLD Schools

Lesson :
Target Duration :
date :
class :
child :
school :

Time	Activity	Grouping		Child Words		Adult Words		Context							
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch.		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					
		Ad.		T.Ch		A		No Ref	rote	des	1.2.3 sp	£	◷	age	
		Ch.		O.Ch				Ref	count	des					

Observation Proforma- Nursery



Appendix D

Speaker in SLD Setting Time= 174 minutes	Symbols/ Numerals	Non-referent description	Referent Description	Count	Recite
Adult		23 (23)	48 (49)	5 (5)	3 (3)
Target Child		2 (2)	6 (6)	41 (41)	
Other Child		1 (1)	3 (3)		

Table D.1 Table of Agreements of Intercoder Reliability: SLD setting (2nd coder in brackets)

Speaker in Nursery Setting Time= 91 minutes	Symbols/Numerals	Non-referent description	Referent Description	Count	Recite
Adult		26 (28)	20 (20)	45 (45)	8 (8)
Target Child		3 (3)	4 (4)		
Other Child		5 (5)	15 (15)	2 (2)	

Table D.2 Table of Agreements of Intercoder Reliability: Nursery setting (2nd coder in brackets)

Appendix E

Performance of individuals on counting tasks- Study 3.

Table E.1 School A: SLD

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Child	**CA**	**BPVS**	**S-O**	**Small Sets**	**Large Sets**	**Small Sets**	**Large Sets**	**Small Sets**	**Large Sets**	**Stable Order Errors**	**One: One Errors**	**Cardin -ality Errors**
1	7.3	1.11	2.3	-	-	3	-	-	-	-	-	-
2	12.3	2.1	2.3*	-	-	-	-	-	-	-	-	-
3DS	9.11	2.8	2.6	3	2	2	1	-	-	-	-	-
4	8.10	3.0	2.6	2	-	1	-	-	-	-	-	-
5	12.0	3.0	3.9	3	3	3	3	3	2	70%	-	70%
6	7.10	3.5	4.6	2	-	3	2	-	-	-	-	-
7	13.11	4.0	3.9	3	3	3	3	3	3	100%	-	63%
8	11.6	4.5	3.6	3	3	3	2	3	3	-	-	-
9	10.0	4.11	5.0	3	3	3	3	3	3	100%	70%	87%
10	10.1	4.11	3.9	2	-	2	-	-	-	-	-	-
11	9.2	5.2	4.9	3	3	3	3	3	2	80%	80%	80%
12	9.4	5.10	4.3	3	3	3	3	3	3	100%	70%	100%

DS= Down syndrome

* = Based on 1 sub-test

Table E.2 Nursery A: BPVS Group

			Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS MA	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	One: One Errors	Cardin-ality Errors
1 F	2.2	1.10	2	-	1	-	-	-	-	-	-
2 F	2.3	2.1	2	-	2	-	-	-	-	-	-
3 F	2.10	2.7	3	2	1	1	-	-	-	-	-
4 F	3.0	2.10	3	3	2	-	-	-	-	-	-
5 F	3.1	3.0	3	3	2	1	-	-	-	-	-
6 F	4.0	3.4	3	3	3	3	3	3	90%	100%	100%
7 F	4.4	4.3	3	3	3	-	3	3	-	-	-
8 F	4.4	4.8	3	3	3	3	3	3	100%	100%	100%
9 M	4.0	4.9	3	3	3	3	3	3	-	-	75%
10 F	4.4	4.9	3	3	3	3	3	3	100%	75%	100%
11 M	4.3	5.1	3	3	3	3	3	3	100%	80%	100%
12 M	4.9	6.0	3	3	3	2	3	3	100%	90%	100%

Table E.3 Nursery A: Snijders-Oomen Group

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS	S-O	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	One: One Errors	Cardin -ality Errors
1 F	2.9		2.0	3	2	2	-	-	-	-	-	-
2 F	2.10		2.0	3	2	1	1	-	-	-	-	-
3 F	2.3		2.9	2	-	2	-	-	-	-	-	-
4 M	2.4		2.9	3	-	-	1	1	1	-	-	-
5 F	3.0		3.6	3	3	2	-	-	-	-	-	-
6 F	2.7		3.6	2	-	2	1	-	-	-	-	-
7 F	3.1		3.9	2	1	3	1	1	-	-	-	-
8 F	4.4		3.9	3	3	3	-	3	3	-	-	-
9 F	3.1		4.6	3	3	2	1	-	-	-	-	-
10 F	4.4		4.6	3	3	3	3	3	3	100%	100%	100%
11 F	4.4		4.9	3	3	3	3	3	3	100%	75%	100%
12 M	4.9		5.0	3	3	3	2	3	3	100%	90%	100%

Table E.4 School B: SLD.

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS	S-O	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	One: One Errors	Cardin -ality Errors
1	7.0	1.11	2.3	-	-	-	-	-	-	-	-	-
2	7.1	1.8	<2	-	-	-	-	-	-	-	-	-
3	7.9	4.6	3.9	3	-	2	-	1	-	-	-	-
4	7.11	3.9	4.0	-	-	3	3	1	1	-	-	-
5DS	9.5	3.7	2.9	3	3	3	2	2	3	-	-	-
6	9.7	3.3	<2	3	3	-	-	1	1	-	-	-
7DS	11.5	3.3	4.6	3	3	3	3	3	3	100%	100%	100%
8	11.8	4.2	3.0	3	3	2	-	-	-	-	-	-
9	12.3	3.0	2.9	3	3	2	3	-	-	-	-	-
10DS	12.7	2.10	3.6	-	-	3	2	2	1	-	-	-
11DS	12.9	5.1	5.0	3	3	3	3	3	3	56%	78%	63%
12DS	13.3	3.3	4.6	3	3	3	3	3	3	-	-	-
13DS	13.8	4.0	4.3	3	3	3	3	3	3	-	-	-

DS= Down syndrome

Table E.5 Nursery B: BPVS Group

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS	S-O	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	One: One Errors	Cardin -ality Errors
1	2.3	2.3		-	-	2	-	-	-	-	-	-
2	2.11	1.8	2.3	-	-	2	1	-	-	-	-	-
3	3.3	2.11	3.6	3	3	3	2	-	-	-	-	-
4	3.7	3.3	-	3	3	3	2	-	-	-	-	-
5	3.9	2.10	3.6	3	3	3	2	3	2	-	-	-
6	3.11	3.5	4.0	3	3	3	2	-	-	-	-	-
7	3.11	3.5	4.9	3	2	3	1	-	-	-	-	-
8	3.11	3.7	4.6	3	3	2	1	1	2	-	-	-
9	4.0	5.2	4.6	3	3	3	3	3	3	100%	100%	100%
10	4.3	3.8	4.9	3	3	3	1	1	-	-	-	-
11	4.5	4.7	-	3	3	3	-	3	3	-	-	-
12	4.8	4.2	5.3	3	3	3	2	3	3	100%	83%	100%
13	4.8	4.3	-	3	3	3	3	3	3	100%	89%	100%

Table E.6. Nursery B: Snijders-Oomen Group

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Child	CA	BPVS	S-O	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	One: One Errors	Cardin-ality Errors
1	2.5	2.3	2.0	1	-	-	-	-	-	-	-	-
2	2.6	-	<2.0	-	-	-	-	-	-	-	-	-
3	2.8	2.7	2.9	3	3	3	1	-	-	-	-	-
4	2.11	1.8	2.3	-	-	2	1	-	-	-	-	-
5	3.3	2.6	2.9	3	1	3	-	-	-	-	-	-
6	3.3	-	3.9	-	-	3	1	-	-	-	-	-
7	3.4	2.3	3.0	3	3	2	1	-	-	-	-	-
8	3.11	2.3	3.6	3	-	3	1	1	-	-	-	-
9	3.11	-	4.0	3	3	3	2	-	-	-	-	-
10	3.11	4.5	4.0	3	3	3	3	3	3	100%	100%	100%
11	4.3	5.0	4.6	3	3	3	3	3	3	100%	100%	100%
12	4.0	5.2	4.6	3	3	3	3	3	3	100%	100%	100%
13	4.8	4.2	5.3	3	3	3	3	3	3	100%	83%	100%

Appendix F

		Mental Age		Stable order		One:One		Cardinality		Error Detection		
Study	CA	BPVS	S-O	Small Sets	Large Sets	Small Sets	Large Sets	Small Sets	Large Sets	Stable Order Errors	Cardin- ality Errors	One: One Errors
1	8.7	u/s		RC4	-	-	-	-	-	-	-	-
1	8.1	2.8		2	-	3	2	2	-	-	-	-
2	8.10	1.11		1	-	3	-	-	-	-	-	-
2	9.4	2.3		1	1	3	3	3	3	-	-	-
2	7.0	2.4		1	-	2	1	1	-	-	-	-
2	9.5	2.10		3	3	3	3	3	3	80%ss	60%ss	87.5%
2	8.0	3.7		2	-	2	2	-	-	-	-	-
3a	9.11	2.8	2.6	3	2	2	1	-	-	-	-	-
3b	9.5	3.7	2.9	3	3	3	2	2	3	-	-	-
3b	11.5	3.3	4.6	3	3	3	3	3	3	100%	100%	100%
3b	12.7	2.10	3.6	-	-	3	2	2	1	-	-	-
3b	12.9	5.1	5.0	3	3	3	3	3	3	56%	78%	63%
3b	13.3	3.3	4.6	3	3	3	3	3	3	-	-	-
3b	13.8	4.0	4.3	3	3	3	3	3	3	-	-	-

Table F.1 Performance of pupils with DS- across studies 1-3. N= 14