Invented Spelling:
An Indicator of Differential Problem-solving Strategies of Good Spellers and Poor Spellers at Kindergarten and Grade One

by

Una Poole-Hayes

Thesis submitted to the School of Graduate Studies and Research
of the University of Ottawa
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Education

Ottawa, Canada, 1995

ISBN 0-612-15660-5

Dedicated

to the memory of my mother

and to my father.

Their individual ways

of loving books, life, and learning

and their tenacity in the face of all obstacles

have been my inspiration.

Acknowledgements

This research was prepared with the supervision of Dr. Jean-Paul Dionne, whose dedication and commitment to his students are extraordinary. His enthusiasm and gentility in supporting attempts to examine the illusive in novel systematic ways, and his guiding hand in unearthing, corralling, and molding vagrant thoughts into manageable constructs of quality and substance are unparalleled. I am grateful for the privilege of his counsel and for the opportunity of affiliation with an educator of such excellence. My heartfelt appreciation to him for accepting me as his student.

Special appreciation is extended also to the kindergarten and Grade 1 children from Western Quebec schools who generated the rich data base, and to their teachers and principals for their enthusiasm, support, and co-operation. My gratitude also to the "expert judges", Mairi and Sandra, for the endless hours spent in validating the categorization scheme and coding grids, to Nancy and Mel for coaching a novice video equipment operator, and to Leslie who assumed the tedious task of recopying the visual protocols into random order.

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Table of Contents

List of Tables

Table

List of Tables

List of Figures

Figure

Abstract

Invented spelling is the way in which emerging and developing spellers attend to and use their limited knowledge of the relation between letters and sounds to create their own unconventional representations of words. The concept, identified by Read (1971) from a study of the early independent writings of precocious children in nursery school at Harvard University, has generated a series of classroom and case studies since its inception as researchers confirmed and extended Read's initial findings. Learning to spell, once regarded as a memorization task, has evolved to a problem-solving view of gradually refining successive approximations of conventional form through invented spelling.

Henderson has studied the process of learning to spell (Beers and Henderson, 1977; Henderson, 1981, 1984, 1986, 1990; Henderson & Beers, 1980; Henderson, Estes, & Stonecash, 1972; Henderson & Templeman, 1986; Weber & Henderson, 1989). Over an interval exceeding two decades, he has developed and refined a series of five cognitive developmental stages through which learners grow in the process of developing conventional spelling form.

Some children become skilled spellers easily; others have difficulty advancing through the stages. Children who experience difficulty often exhibit chronic and steadily worsening deficiencies as they progress through the grades because they lack the ability to organize and retrieve information--to manage and monitor their problem-solving activities (Gerber, 1984a, 1984b, 1985, 1986, 1987; Gerber & Hall, 1987, 1989; Hall, Gerber, & Stricker, 1989; Scott, 1993). Poor spellers can be taught the problem-solving strategies they lack (Hall, Gerber, & Stricker, 1989; Scott, 1993).

Read (1986) described invented spelling as a "window" into children's language and cognition. However, until recently, no reliable rating system had been established to rate qualitatively the earliest efforts of young invented spellers. In 1991, Tangel developed

and established reliability for a developmental spelling test (DST) with a 7-point scale designed to rate the invented spellings at kindergarten and Grade 1.

Case (1984, 1985, 1991) has examined the nature and function of children's problem-solving and has proposed an intermediate level framework for cognitive development. His "mind's staircase" addresses general and specific aspects of the process and structure of children's knowledge at different stages and substages of development. The structure throughout the stages and substages is presumed to be universal and general; the processes, represented as specific entities called control structures, are specific to the individual and are major contributors to differences found in problem-solving. Control structures are made up of three component parts--problem situation (initial state), objective (goal state), and strategy (a set of operations bridging the gap between the initial state and the goal state). Within Case's framework, the present research explores the possibility of differentiating problem-solving operations generating success and difficulty to spellers at kindergarten and Grade 1.

Four kindergarten girls and four kindergarten boys were identified in each of three schools. Two boys and two girls believed by their teachers to be advanced in spelling development and two boys and two girls perceived by their teachers to be delayed in this regard constituted the sample. The Dionne observation table was used to enrich the data collection methodology used by Case by recording, in individual sessions, all verbal and non-verbal operations performed by each of the subjects while attempting the research tasks in June of the kindergarten year, during the first week of February of Grade 1, and during the last week of May of Grade 1. Visual protocols, verbatim transcripts, and photocopies of invented spellings produced provided the experimental data.

Based on the literature and on the protocols collected, the researcher constructed coding grids to describe 32 data related operations and 24 cognitive control related operations observed during the invented spellings of the target words. The two grids were used to analyze the invented spelling processes of the 19 subjects for whom there was complete data from all three data collection sessions. Videotapes were replayed as often as required to complete the coding grids. Differences in relative frequency distributions of use of each operation were calculated by ability and gender. Differences in progression over time between three data collection points within a one year time frame were examined for all subjects, for subjects by ability group, and for subjects by gender group. A difference of 25% or more was established as a discerning pattern for the purpose of the research.

Strong and weak spellers used the same data related operations when inventing spellings. The sequence in development was the same for both groups, but operations emerged at a faster pace in strong spellers. Patterns of differences by ability were discerned for most consonant, vowel, and meaning related operations. Patterns of differences by gender emerged for only two data related operations--3-consonant blend and -ing ending.

Patterns of differences by ability were discerned for some cognitive control operations in all five categories established during coding: Response style (responds rhythmically, responds thoughtfully, displays confidence), focus of attention (attends to entire task), articulation of a plan (patterned sequencing, self-monitoring, rationale for choices evident), memory (copying, repetition of target word, visual imaging, sounding out, and letter naming), and automatic production (of letters, of letter patterns, and of words). No patterns of differences by gender were discerned.

Patterns of change by ability over time emerged on 18 data related operations during the June to February interval. Pattern of change tended to be on operations of an intermediate level in the developmental progression. Only one data related operation, correct use of the -ed ending (the most advanced operation), produced a pattern of change during the February to May interval. During the first interval, 7 cognitive control operations generated patterns of change over time: Automatic production of letters, automatic production of letter patterns, repetition of the target word, visual imaging, letter naming, attending to the entire task, and orthodox movement. During the second interval, no patterns of change over time were discerned. It appeared that a growth spurt during the first half of first grade is followed by a period of consolidation of both data related and cognitive control related operations.

For difference in change over time by ability, weak subjects outperformed strong subjects in data related growth by 12 patterns to 4 patterns during the first interval. The 2 patterns of difference identified during the second interval favoured the strong group. Patterns favouring the strong group were produced on operations not yet in the repertoires of weak subjects. Again, a growth spurt during the first interval appears to be followed by a period of consolidation during the second interval. Weak subjects outperformed strong subjects 6 patterns to 3 patterns in differences in change over time on cognitive control related operations over the first interval. Again, no patterns were discerned during the second interval. Differences in changes over time by gender were inconsequential for both data related and cognitive control related operations.

The Dionne Observation Table offered an elegant elaboration to verbal protocols as a means of interpreting cognitive processes, especially for subjects at the interrelational and early dimensional stages of thought for whom cognitive developmental limitations affect verbal protocol productions. Through the interpretation of cognitive operations made possible by its use, the extent of progress made by weak spellers in both data related and cognitive control related operational use has been underscored. The research opens an avenue for exploration of the extent to which operations can be taught to children in this young age group.

CHAPTER 1
THE PROBLEM

An attempt is made to study invented spellings of kindergarten and Grade 1 children as indicators of their problem-solving strategies. The study has been motivated from observations made of the early writing behaviours of young school aged children over a thirty three year interval. During this period, emphasis in literacy programs has changed from product to process, from the teacher and teaching to the learner and learning, and from looking for response cues in the environment in order to find the correct answer to constructing an answer from one's own existing knowledge. Learning to spell has changed from a memorization task to a developmental orthographic problem-solving task of gradually refining successive approximations of conventional form through invented spelling.

With this shift in perspective, it appears that increasing numbers of students are leaving elementary schools writing increasingly unconventional spellings for basic words, yet continuing to lack the problem-solving skills required for effective decision making. However, conventional spelling production continues to be an expectation of parents, of higher educators, and of the public at large. Correct spelling is regarded as "the front line" of good writing. Poor spelling is equated with poor writing.

After years of observing and interacting with pupils, teachers, parents, administrators, and professional experts, it became apparent to the researcher that the invented spellings processes of children may be indicators of their problem-solving strategies. By observing children in the process of writing, how the speller "figures out" what to write could be hypothesized. Based on this information, a decision could be made, not only what to present next, but how to present the new learning for easy integration to existing knowledge. It seemed possible, therefore, that invented spelling in production could portray the cognitive operations performed if a microscopic view of word writing in progress could be captured. If the operations used by strong spellers could be differentiated from those used by weak spellers, an attempt could be made to help weak spellers develop the operations critical to good spelling which they lacked.

What is Invented Spelling?

Invented spelling is the way in which emerging and developing spellers attend to, depend on, and use their perceptions of the relation between letters and sound and meaning patterns to create their own unconventional representations of words. Read (1971) identified the concept of invented spelling. Extending Read's initial work, Henderson (1972, 1981, 1984, 1990) and his colleagues (e.g., Beers & Henderson, 1977; Gentry, 1977; Henderson & Beers, 1980; Henderson, Estes, & Stonecash, 1972; Henderson & Templeman, 1986; Schlagel, 1986, 1989) documented the cognitive developmental aspects of spelling systems based on the invented spellings generated by school-aged children in naturalistic settings. They demonstrated that, for optimal learning to take place, learning experiences must be structured in accordance with level of cognitive development . Young children must be regarded as active problem-solvers, rather than as passive "vessels to be filled" (Henderson, 1990; Vygotsky, 1962, 1978). Henderson (1990) has revised his fixed sequence of five developmental stages of learning to spelling conventionally, described the developing spelling abilities within each of these stages, and provided model practice activities conducive to growth of the various developing abilities within each of the stages.

Problem-solving Strategies

Polya (1957) has suggested that "solving a problem means a way out of a difficulty, a way around an obstacle, attaining an aim that was not immediately understandable". To solve a problem necessitates movement from an initial state to a goal state employing strategies selected by the problem-solver.

Growth in the field of cognitive science during the last decade has resulted in extensive study of problem-solving in which the term "strategy" is used with a broad range of interpretations. When Taylor (1992) reviewed the literature on problem-solving strategies, she found a set of common elements in criteria: "1) strategies are sequences of activity rather than a single event, 2) strategies are goal directed, and 3) strategy use is largely under conscious control" (p. 6). Case's definition of strategy includes all three elements. For Case (1991), a strategy is a sequence of operations performed by the problem-solver in moving from the initial state to the goal state. Children develop cognitive control strategies. Case's problem-solving interpretation will be adopted in the research.

Case (1991) has focused on how children's problem-solving strategies are developed. For children, the complexity of the problem-solving challenge is augmented by a cognitive-developmental component. Children's memory capabilities and knowledge bases are developing concurrently as they discover strategies that for adults are quite routine, and then attempt to find out where these new strategies apply. As children acquire more experience in a domain, they begin to form new connections among the basic elements of which the domain is comprised. These new connections lead to integration of knowledge structures which were previously discrete. Once integrated, new knowledge structures lead to new strategies for approaching problems in the domain and to new memory capabilities. The different sorts of intellectual development that are observed are the result of this cumulative process of learning, as are the changes in underlying memory capacities.

Case (1985) focused on problem-solving as the key aspect of children's intellectual development. In his 1985 publication, he reworked Piaget's theory of cognitive development in the light of recent developments in learning theory and information science. He represented children's problem-solving processes as specific entities called control structures containing three components: problem situation (initial state), objective (goal state), and strategies (sets of operations) to bridge the gap between the problem situation and the objectives. These components form the "internal program or executive control structure" of the problem-solving process (Case, 1991, p. 19). Case (1991) has examined the knowledge that resulted from, or that supported the use of, these processes in real world contexts, in atypical as well as typical development. From this examination, he has hypothesized a conceptual "staircase" as a cognitive-developmental framework for intellectual development within which problem-solving activities occur. Information processing concepts are integrated with his earlier neo-Piagetian model, demonstrating that structure and stage develop concurrently (p. xii).

Siegler (1986a, 1986b, 1987a, 1987b, 1988a, 1988b, 1991), Siegler & Jenkins (1989), and Siegler & McGilly (1989) have studied children 's strategy choice and strategy construction in the process of strategy development. Because invented spelling requires both strategy choice and strategy construction as word writing strategies are developed, within Case's framework, the work of these researchers will guide and enrich the analysis of differential problem-solving strategies in the invented spelling process.

Spelling as Problem-solving

Hall (1984) and Gerber and Hall (1982) have established spelling as an orthographic problem-solving process in which a significant number of pupils experience great difficulty because they lack managing and monitoring skills (Gerber, 1984a, 1984b). Consequently, they have problems organizing and retrieving the information, routines, and knowledge that they have. This leads to ad hoc decision-making (Gerber, 1984b, p. 50). Children who have difficulty early on tend to have augmented difficulties as they progress through the grades (Gerber, Hall, & Stricker, 1989). Gerber (1985), Gerber and Hall (1987), and Hall, Gerber, & Stricker (1989) have developed strategies for improving the problem-solving difficulties through modelling, through clear, concise corrective feedback, and by providing sufficient time for practice to apply the new knowledge in related contexts.

Scott (1993) has suggested that children can develop their own repertoire of spelling strategies using an active problem-solving process. She has consolidated spelling strategies into three arbitrary categories--phonological, visual, and morphological strategies-- and elaborated strategies within each of these categories. Children must be exposed to thinking about how words sound, how they look, and how their meaning is represented if they are to develop a broad pool of spelling strategies on which to draw when an unfamiliar word is encountered. In Scott's view, the goal in teaching spelling is to help children develop strategies in order to become independent strategists.

Research and personal experience have demonstrated that some children learn to spell very well with little effort while others have great difficulty even with supreme effort. Those who experience difficulty often exhibit chronic and steadily worsening deficiencies in all aspects of writing, particularly spelling. However, the productions of poor spellers can be improved by teaching them to manage and monitor their problem-solving activities, to organize their data and their thinking about that data (Hall, Gerber, & Stricker, 1989). It appears that, for some children at least, difficulty moving forward in spelling development stems from a lack of ability to organize and retrieve information rather than, or in addition to, difficulty in acquiring information, and that this information processing difficulty might be reduced if it were identified and addressed early in academic life.

The Research Problem

The inventing spellings for target words of kindergarten and Grade 1 subjects will be explored over a one year period in an attempt to determine by ability and gender possible differences in operations used. To interpret the operations performed in problem-solving, the writing in progress of girls and boys identified by their kindergarten teachers as strong spellers and weak spellers, collected in individual recording sessions, will be examined over three test administrations--end of kindergarten, first week of February of Grade 1, and last week of May of Grade 1. Henderson's (1990) stages of word knowledge will be studied within an information processing structure. Data driven operations and cognitive control related operations observed during the production of invented spellings will be interpreted within the conceptual framework elaborated by Case (1991). Drawing on the strategy construction information put forward by Siegler (1991) and Siegler & Jenkins (1989) and the role of spelling strategies described by Scott (1993), an attempt will be made to differentiate by gender the problem-solving operations used by good spellers and poor spellers while inventing spellings for target words and to explore how these operations change over time.

CHAPTER 2

A FOCUSED REVIEW OF THE LITERATURE

The Genesis and Evolution of Invented Spelling

Charles Read (1971), a doctoral student of linguistics, identified and reported on the invented spellings he observed in the early writings of twenty nursery school children at Harvard University. Read viewed invented spelling as an indication that children had begun to develop an awareness of the internal structure of words. Once aware that a word has internal structure, children begin to use alphabetic transcription. Read demonstrated that there was logic to the error patterns of children's early spelling, and that their logic changed over time and with experience. He identified three strategies used in early spelling production:

1. Letter naming. The consonants p, t, k, b. f, v, s, z, j, m, n, r, l, and d have good sound to letter match (e.g., be is written B).

2. Tense (long) vowels. Children use letter naming much like they do with consonants (e.g., GAT represents gate).

3. Lax (short) vowels. Children reflect on the articulatory features of sound and match it with the long or tense vowel that is formed in the same place in the mouth (e.g., FES represents fish; FAL represents fell; GIT represents got).

With Read's work as a point of departure, Chomsky (1971) incorporated early writing in invented spelling into the school activities of four and five year old children. She found that when encouraged, or even not interfered with, kindergarten pupils produced quantities of words with letter sets or alphabet blocks and, later on, longer messages with paper and pencil. They labelled their drawings, kept diaries, and wrote notes, all systematically spelled without yet being able to read. Chomsky believed that the atmosphere of a kindergarten classroom, supportive of individual activity and internally motivated pursuits, was conducive to encouraging growth and fostering ability in invented spelling.

Chomsky (1971, p. 506- 507) found the following invented spelling features common to the children's innovative spelling:

1. Words containing long vowels were written in close approximations of English spelling, and were easiest to identify (BOT--boat, TIGR--tiger, LIF--life);

2. Typically L and R functioned as a syllable, with no vowel at all (GRL--girl, KLR--color, AFTR--after, BRD--bird, PKGR--picture);

3. Vowels other than those pronounced as the five vowel names A E I O U were often omitted from children's earliest writings (DG--dog, MN--man, PKGR--picture);

4. Nasals before consonants were typically omitted (PLAT- plant, BOPY- bumpy, NUBRS- numbers, AGRE- angry);

5. Often CHR and JR were used in place of tr and dr (CHRAN--train, JRAGIN--dragon, CHRIBLS--troubles);

6. Letters sometimes were used according to their full pronounced name (THAQ- thank you, YL- while, R- are, U- you).

In Chomsky's view, children formed hypotheses about the relations of spelling to pronunciation, changed these hypotheses as new evidence was added, and eventually arrived at a system of interpretation that was in accord with convention. She concluded that hypothesis construction took children far beyond the "rules" offered by the best patterned, programmed, or linguistic approaches to early writing.

Henderson, Estes, and Stonecash (1972), of the University of Virginia, studied invented spelling using Read's analytic framework to show that regular classroom pupils in Grade 1 were using the same spelling strategies that Read and Chomsky had identified in nursery school and kindergarten. They collected the spellings from one week's creative writing produced during the month of January by 594 pupils from 21 first-grade classes participating in a language-experience curriculum. The misspellings provided information about general knowledge of word form and qualitative differences between pupil productions of high, middle, and low thirds of the group. The researchers concluded that a long term study might provide a systematic index of ascending levels of word knowledge from which a relatively simple test for principles could be derived.

With the shift to successive approximations of conventional form, rating spelling as merely correct or incorrect became simplistic and outdated. A qualitative measure was required. Beers (1974) developed the first qualitative rating scale--a four-stage scale used to rate the development of tense (long) and lax (short) vowels as exemplified below for invented spellings of the word step. This initial qualitative measure provided scaled point values for successive approximations of conventional spelling.

	Strategy	Score	Example
Stage 1	Omission of a vowel	1	STP
Stage 2	Letter naming (long/short pairing)	2	STAP
Stage 3	Transitional	3	STAEP
Stage 4	Correct	4	STEP

Beers and Henderson (1977) reviewed Beer's (1974) work. They took spelling samples from the same children at different points in their first grade year and were able to delineate rough developmental stages through which the children's spelling seemed to progress. Most children were found to pass quickly through the same sequence of stages. Some progressed quickly, others took a longer time. Some skipped the initial stage. They noted the following points concerning each of the four stages:

1. At Stage 1, letter naming strategy was utilized and consonant nasals were generally omitted;

2. At Stage 2, children developed the ability to use letters to represent consonants, short vowels, and consonant nasals correctly;

3. At Stage 3, children learned to use orthographic markers (e.g., "e" in MATE);

4. At Stage 4, correct spelling appeared.

Henderson (1981) demonstrated that a developing word knowledge underlies children's ability in both reading and spelling. He challenged the notion that spelling was nothing more than a passively derived product of reading instruction. While acknowledging that some experience with written language is necessary before children can learn to read and write, he argued that children's early spelling attempts can actually reveal much about their readiness to progress as learners. He found that children had learned many complexities about written language before they began to read, that children advance in their knowledge of words through conceptual stages revealed in their spelling, and that these stages held true across different methods of instruction.

Despite the fact that many children attempt to write before they establish the concept of a word, Henderson (1981) established that the word is the basic unit of spelling. In the preschool stage, children are not usually aware of the rationale underlying the relationships they establish. They scribble, draw shapes and letters, create letter strings, and lay important foundations for later word knowledge and for concept of what a word is. Young children's "spelling" at this stage reflects their concept of the form and function of print, but it is not until Stage 2 that they understand the first ordering principle of spelling--the alphabetic principle. In Stage 2, children may not be able to describe their concept of what a word is, but will begin to demonstrate through alphabetic spelling that they can match sounds and letters systematically. Their letter matching may appear confusing to adults who know how English spelling actually works, and who are not in the habit of thinking wholly in alphabetic terms. Children often note features of sounds to which adults no longer attend - JRIG (drag), CHI (try). Sight words become the initial source of understanding of what constitutes a word. The problem of young readers in difficulty, according to Henderson, is that, without a stable concept of word as a bound figure with a beginning and an end, they cannot know where to focus their attention.

Morris (1983) established a significant relationship between concept of word and phoneme awareness in beginning writing. Based on the work of Clay (1972) and

Henderson and Beers (1980), Morris described the child's ability to identify words in text as individual, nameable objects as a watershed in learning to write. Once children discover that the word unit is a group of letters bounded by white spaces, they are free to analyze the phoneme/grapheme properties of the word. Morris (1983, p. 342) identified a sequence of four measures of spoken word/ written word awareness in their relation to writing: (a) No sound letter relationships; (b) beginning consonant; (c) beginning and ending consonant or beginning consonant and appropriate vowel; (d) beginning and ending consonant plus appropriate vowel. He concluded that the concept of word develops along a continuum and that the learner moves from the whole to the parts. In a text, the child learns to find where the units are in a line of print, to establish a frame (the whole word and white spaces), and then to examine the parts (letters) within the frame (word) as discrete units.

The concept of invented spelling had emerged from nursery school and had been examined in kindergarten and grade one settings. Subsequently, researchers began to extend the study of invented spelling to older groups. Zutell (1980) examined the invented spelling of students from Grades 1 - 4 and created a scale to classify children's spelling development. Schlagel (1982) developed an informal spelling inventory to assist Grade 1-6 teachers in establishing children's independent, instructional, and frustration levels so that teachers might more accurately determine exercises, activities, and other learning experiences appropriate to children's level of functioning. Schlagel's (1982) inventory was designed to provide qualitative information about word knowledge by error analysis. After using a series of spelling inventories constructed from graded word pools, Schlagel studied student errors to obtain knowledge of how spelling develops. An orderly stage by stage progression of word knowledge, clear patterns of coherent change, and consistent difficulty with some features emerged from the data. Schlagel (1989) updated this qualitative inventory and concluded that approaches to instruction and assessment which capitalize on both structure of orthography and on children's changing strategies will greatly enhance teaching and learning.

Henderson (1984) mapped the development of spelling patterns across the grades by examining the system of English spelling, and noting the different levels on which spelling represents information about the English language. From this work, he identified three ordering principles in the spelling system of English: a) the alphabetic principle, b) the within word pattern principle, and c) the meaning principle. English spelling is alphabetic in that the letters match sounds in a more or less orderly way from left to right. The logic according to which letters are sequenced becomes apparent only when the next two ordering principles are considered. The within word pattern principle illustrates that the sound a letter or letters represent within a syllable depends on position and on the other letters that surround it. Children can master patterns and sequences when they know that such patterns exist and that it is pattern rather than simple alphabetic sequence which they must search out, attend to, and learn. The meaning principle is revealed by the fact that words or parts of words having the same or similar meaning tend to be spelled alike. A sensitivity to the way in which meaning is represented is required in order to note the common elements in more advanced vocabulary. Children can be taught to look for root or base words and to use prefixes and suffixes appropriately.

Based on the three ordering principles, Henderson (1984) described five stages of spelling competence, and outlined grade level appropriate activities to accompany these stages.

Stage 1-	Preschool stage	
Stage 2-	Letter naming stage	Grade 1- 4
Stage 3-	Phonetic stage	Grade 2 - 4
Stage 4-	Syntactic and Morphemic stage	Grade 4 - 6
Stage 5-	Conventional stage	Grade 6+

These stages of spelling knowledge were designed to predict the errors that children will make. Understanding the errors that children will make allows the teacher to determine the word features that children need to study if they are to advance in spelling competence.

Henderson and Templeton (1986) demonstrated that all children pass through the same stages in the same order, but at different rates as suggested by the divergence in grade ranges. For each stage, Henderson (1984) and Henderson and Templeton (1986) outlined the implications for direct instruction and for indirect activity, both of which they believed were important for school aged children. They concluded that English spelling was an orderly system, and that spelling was a cognitive developmental task:

> when spelling is understood linguistically and its acquisition is described developmentally, the process of learning to spell may be seen as progressive cognitive mapping of a complex but orderly system. Knowledge of English spelling begins with the discovery of "word" and the application of the alphabetic principle of sound-letter representation. Learners progressively differentiate the alphabetical system into subsystems of pattern and meaning relationships. Through such order, English spelling achieves a near-optimal visual presentation of our complex derived language (1986, p. 314).

Morris, Nelson, & Perney (1986) used Schlagel's (1982) Qualitative Inventory of Word Knowledge to explore the issue of instruction between a traditional quantitative (percentage correct) view of instructional level and a more recent developmental view of a pupil's instructional level. They hypothesized that the percentage of words that children could spell correctly at grade level would be a good predictor of the quality or orthographic sophistication of their spelling errors. The results were consistent across Grades 2-5, showing strong correlation between spelling power and quality of spelling errors. When the spelling power/quality of error relationship was established, it was found that the quality of spelling errors at the two lowest power ranges (0%-40%) differed significantly from that at the highest power ranges (60% -100%). Not only did the below 40% group have more spelling words to learn, but, in many cases, they also had more to learn about individually misspelled words. Morris, Nelson, and Perney concluded the concept "instructional level" merited consideration in spelling as well as reading, that there is an "optimal instructional level" in spelling, and that spelling achievement gains would be superior in classrooms where instruction was differentiated according to spelling level.

For more than two decades, studies of invented spelling development had been conducted in naturalistic settings in the "Virginia school". Stages of word knowledge had been identified, described, and revised. From testing the generality of stages and mapping development across the grades, Henderson (1984, 1986) concluded that the key to spelling development in the English language is to look for patterns using the three ordering principles in the spelling system of English--alphabetic pattern, within word pattern, and meaning. In developing the three ordering systems, children grow through five stages of word knowledge. Each of the five stages will be discussed in the section which follows.

Henderson's Stages of Word Knowledge (1990)

Henderson (1990) revised, redefined, and renamed his earlier five developmental stages of spelling competence through which on-going growth toward conventional spelling form takes place. The earlier stages were redefined to reflect Henderson's reconceptualization of the cognitive developmental nature of invented spelling as an on-going problem-solving process which continues throughout life. The revised continuum is established across five broad age groupings, rather than on the basis of grade levels, and accommodates the great diversity in spelling development that is evident within a single grade level. Henderson's renamed stages--preliterate, letter name, within word pattern, syllable juncture, and derivational consistencies--reflect the critical attribute of development within the stage. His schematic diagram of these stages is reproduced as Table 1. Highlights of the five stages of spelling development follow.

Table 1

Henderson's Stages of Spelling Development

Age	Stage	Performance
1 - 7	Preliterate (1)	Scribbles
		Identifies pictures
		Draws
		Imitates writing
		Learns letters
5 - 9	Letter Name (2)	Most sight words spelled correctly
		Invented spelling by letter name
6 - 12	Within Word Pattern (3)	Most sight words spelled correctly
		Invented spellings honor short vowels and long vowel markers
8 - 18	Syllable Juncture (4)	Sight words may or may not be transferred to spelling performance
		Invented spelling errors occur at juncture and schwa positions
10 - 100	Derivational Consistencies (5)	Sight words may or may not transfer
		Invented spellings "most frequently misspelled"

Adapted from Henderson (1990, p.44)

Preliterate Word Knowledge (Age 1 - 7)

Young children scribble, identify pictures, draw, imitate writing, and learn letters following a progression of activities as they grow and learn. Moving gradually from vague scribbles, to diagonals and circles, to actual pictures, to writing scribble, the young artist one day concludes that it's writing. At this point, children begin to ask to be shown how letters are made, and copy the models provided. Writing inventions gradually take the form of scribbles interrupted with letters, alphabetic strings recorded under pictures, and alphabetic strings with some phoneme-grapheme correspondence. Children who are encouraged to try experiment with writing. "The benchmark of the advent of literacy is the attainment of the concept of word. This concept is realized by children through supported experience with written text" (Henderson, 1990, p. 51).

Letter Name Spelling (Age 5 - 9)

The letter name spelling stage begins almost immediately after children have achieved a stable concept of word. The child learns to spell some sight words correctly. Other words are created in invented spelling by letter name. Spellings become letter perfect applications of the alphabetic principle. Children discriminate and represent sounds no longer heard by adults because they are not represented in the English language. They will spell truck as CHROK or HROK or dragon as JRAGN. They discriminate the actual speech sound that comes between the t and the r and the d and r in their intense effort to write the sounds they hear. Early on, children tend to use only direct letter to sound matches. They substitute a vowel letter name for the short vowel convention. Short a tends to be spelled correctly with an a, but long a substitutes for short e, long e for short i, long i for short o, long o for short u , and long u for short oo . During Stage 2, children tend to leave out consonant nasals, that is, they omit m and n when these come before a final consonant. Stamp tends to be spelled STAP, limp as LEP, and mint as MET. The nasal consonants are "swallowed" into the vowel. Long vowels are spelled by the letter vowel name alone, so that life is written LIF, pole as POL, and cake as KAK. The same letter name principle applies to unaccented syllables -- table , spoken , and winter tend to be written TABL, SPOKN, and WETR. Past tense inflection is predictable also -- stepped is written STAT, begged is written BAGD, and lighted is written LITAD or LITIT. When children encounter words in which the medial consonants are articulated identically, they guess on the basis of sound discrimination. As a consequence, they may transcribe invented spellings such as the following: later is written LATR or LADR: letter is written LATR or LADR; ladder is written LATR or LADR; and madder is written MATR or MADR. Letter name spelling leads to many words being spelled alike. As their sight vocabulary grows larger, children begin to notice that words that should look alike come out different, and words that should look different come out alike. They seek to find a better way.

Within Word Pattern (Age 6 - 12)

Children begin to form within word pattern and to attend to pattern and sound simultaneously. They learn long vowel spellings, and gradually examine, compare, and contrast other predictable vowel patterns. They begin to deal with the third ordering principle, meaning. The readiness indicator that children are ready to use meaning is their correct spelling of the -ed ending to the root word to denote past tense. Children are then ready to examine compound words and homophones for meaning and to examine prefixes and suffixes as attached to the root word. Most sight words are spelled correctly. Invented spellings honor short vowels and long vowel markers. The intuitive matching of short vowel in letter-to-sound fashion is abandoned, and short vowels begin to be spelled correctly consistently. The spelling of consonant blends is found with greater accuracy and the nasal m and n before a final consonant are included in children's spelling. When these are accomplished, children are ready to learn about within word pattern.

Patterns of letters must be seen in relation to elements of sound. Children must learn that there is a logical division between initial consonants and the vowel and what follows. Over time and with practice, they begin to see the vowel and what follows it as a spelling unit --a vowel pattern. Once this concept is realized, word study experiences through which actual patterns of English spelling are internalized must follow. When vowel patterns are underway, a third dimension, meaning, must be brought into classroom activity. It is a major responsibility of the teacher to plan these kinds of word study activities. Rules should not be used for teaching directly, for "teaching is not telling" (Henderson, 1990, p. 59). Children should learn to understand pattern and meaning through experience with written language. Through focused experience with written language, children learn that short vowel patterns have two basic forms--a single vowel is followed and "closed" by a single consonant, and a single vowel is followed by a blend, a double consonant, or by complex units like x , ck, and dge . There are four major long vowel "marked" patterns: consonant/vowel/consonant/e (as in sale, line, rose); consonant /vowel/vowel/consonant (as in tail, break, chief, and boat); consonant/ vowel/ consonant/ consonant (as in night, post, and fold); and consonant/ vowel/vowel (as in say, lie, see, and toe).

Syllable Juncture (Age 8 - 18)

During this stage, children master within word patterns in single syllable words, but not with polysyllabic words. Sight words may or may not be transferred to spelling performance. Conventions of syllable juncture begin. Invented spellings occur at juncture of base words with prefixes and suffixes. The following patterns and meanings are studied through examples and activities: 1) the rationale underlying joining of common inflections of single syllable words (e.g., matting -- c-v-c in the base word ; mating -- c-v-c-e as the base); 2) the role of vowel pattern within a single morpheme word (e.g., rabbit vs. hotel); 3) the role of stress in a word with more than one morpheme (e.g., referring vs.

conquering); 4) the role of "prefix assimilation" - sound and spelling are absorbed/ assimilated into the base (e. g., immovable, not inmovable ; approve, not abprove ; oppose, not obpose).

Derivational Principles (Age 10 - 100)

During Stage 5, emphasis is on meaning related words with similar spelling. Patterns and meanings to be examined include the following:

1. Silent sounded consonants in related words--sound changes meaning and spelling similarities (e.g., g in sign, signal, signature; n in condemn, condemnation).

2. The study of patterns of vowel alterations to be learned in sequence: (a) Accented long vowel in base word changes to short vowel in accented syllable of derived word (e.g., divine, divinity); (b) derivational relationships in which the long vowel in the base word alters with the "reduced" vowel or schwa in the derived word (e.g., define , definition; compose, composition; admire; admiration); (c) derivational relationships in which the short vowel alternates with the schwa (e.g.,local, locality; image, imagination); and (d) patterns in regular and predictable changes among related words (e.g., explain, explanation; critic, criticize; tract, tractor , traction, contract).

During the years in which the development of spelling patterns was being mapped across the grades, researchers, beginning with Beers (1974), focused on developing appropriate ways to rate the quality of spelling responses. In the section which follows, a brief overview of the evolution of qualitative ratings of invented spelling from Beers to date will be presented.

Rating Invented Spelling

With the shift to successive approximations of conventional form, rating spelling as merely correct or incorrect had become simplistic and outdated. Qualitative measures were required to reflect growth in word knowledge. Beers' (1974) four-stage scale, used to rate the development of tense (long) and lax (short) vowels by providing scaled point values for successive approximations of conventional form, is reviewed in Table 2 as the first effort at qualitative rating. Gentry (1977) added to Beers' scale by including consonants, to create a five-point scale. The 5-point scale was used by Gentry and Henderson (1978, 1980). Gentry's (1977) 5- stage scale for the spelling of the word TYPE is shown in Table 3.

In naturalistic settings, children did not choose to write every construction that researchers wished to study. Therefore, some researchers began dictating words. Beers, Beers, & Grant (1977) constructed and dictated a 24-word spelling test to 75 first-grade and 70 second-grade pupils. They discovered that first-grade children progressed through stages sequentially and that second-grade pupils who had been reading for more than a year could spell many words correctly.

Although Beers (1974), Beers and Henderson (1977), and Gentry (1977) provided a framework for assessing invented spelling, one common limitation was that spelling strategies were only vaguely defined, particularly for "prephonetic" and"transitional" stages. Both included some qualitatively different kinds of spelling (Read, 1986, Tangel & Blachman, 1991). In an attempt to refine further the "prephonetic" spelling stage, Morris and Perney (1984) dictated an 18-word list to first-grade pupils during September. Responses were rated on a 6-point scale in which points were awarded for representational letters in the correct sequence (beginning consonant, blend, ending consonant). Results were used to predict reading achievement at the end of grade one. Table 4 illustrates scoring of various invented spellings of the word BACK.

Morris & Perney were among the first to establish reliability for their scale. A limitation to their scoring system was that they did not give credit to lower level responses such as representation of a salient letter (T in pretty) or representations of a sound with a phonetically related letter ("ch" for TRACK) (Tangel, 1991).

Table 2

Beers' 4-Stage Rating Scale Applied to the Word STEP

Stage	Strategy	Score	Example
1	Omission of a vowel	1	STP
2	Letter naming (long/short pairing)	2	STAP
3	Transitional	3	STAEP
4	Correct	4	STEP

Adapted from Beers (1974, p. 32)

Table 3

Gentry's 5-Stage Rating Scale Applied to the Word TYPE

Stage	Strategy	Score	Example
1	Deviant	0	MENENA
2	Prephonetic	1	TP
3	Phonetic	2	TIP
4	Transitional	3	TIPE
5	Correct	4	TYPE

Adapted from Gentry (1977, p. 23)

Table 4

Morris and Perney's 6-Point Rating Scale Applied the Word BACK

Stage	Comment	Points	Example
Prephonetic	Random string	0	AEROR
Prephonetic	Inappropriate first letter	0	E
Prephonetic	Correct first letter	1	B
Prephonetic	Correct first and last letter	2	BK
Phonetic	Correct first letter, correct vowel, phonetically related final letter	3	BAC
Transitional	Incorrect silent final E added to correct spelling	4	BACKE
Correct	All letters correct	5	BACK

Adapted from Morris and Perney (1984, p.447)

Liberman, Rubin, Duques, & Carlisle (1985) attempted to create a scale based on two main features--the number of phonemes that children represented and the level of orthographic representation. An example of rating of approximations of the word SICK is shown in Table 5. Liberman et al. used this scale to analyze the proficiency in invented spelling and other linguistic abilities. They found that three language based tasks--phoneme segmentation, writing letters to phoneme dictation, and phoneme deletion accounted for 93% of variance in invented spelling proficiency. However, Liberman et al. did not establish reliability for their scale and did not give credit for representation of the initial phoneme of a word or for producing one salient letter.

Mann, Tobin, & Wilson (1987) created a scale that gave 1/2 point for responses that represent some salient part of the word other than the initial phoneme (e.g. E for ANGRY). A dictated spelling test was given in December to kindergarten and in January to Grade 1. A limitation to the method was absence of method for scoring intrusions (a common occurrence amongst emergent writers). Also, reliability was not established.

Tangel (1991) has recently devised and established reliability for a test of invented spelling using a 7-point rating scale. The Developmental Spelling Test (DST) was designed to measure the extent to which an unconventional response made at the kindergarten or grade one level captures the structure of the word. The DST is sensitive to lower level responses that capture the emerging literacy seen in children prior to formal instruction in reading and writing. In addition, it examines the more sophisticated productions of children who exhibit a developing awareness of the rule system that governs standard English. Credit is given for salient letters, phonetically related letters, and intrusions. The test words lend themselves to the sampling of phonemic, graphemic, and morphemic strategies. A written response for a dictated word could receive a score that ranged from 0 for a random or alphabetic string of letters, to 6 for the correct spelling. An example of rating of approximations of the word TRAIN is shown in Table 6.

Table 5

Liberman, Rubin, Duques, & Carlisle's 6-Point Rating Scale Applied to the Word SICK

Response	Points	Comment
PLTX	0	Random string
S; C	1	One phoneme in conventional letters
SK; CK	2	More than one phoneme, but not all
SEK; SEC	3	All phonemes in phonetically related letters
SIK; SIC	4	All phonemes with conventional letters
SICK	5	All phonemes with correct spelling

Adapted from Liberman et al. (1985, p. 169)

Table 6

Tangel's 7-Point Rating Scale Applied to the Word TRAIN

Response	Points	Comment
FMTXBR	0	Random string
J	1	Phonetically related letter--random string may follow
T	2	Correct first letter-- random string may follow
JRA, TAN	3	More than one phoneme but not all, with phonetically related or conventional letters
HRAN, TREN	4	All phonemes with mix of phonetically related or conventional letters
TRANE	5	All phonemes with conventional letters; correct short vowel; attempt to mark long vowel
TRAIN	6	The correct spelling

Adapted from Tangel (1991, p. 57)

Tangel's DST target words and accompanying detailed rating scale for each of the target words provide a structure within which to examine invented spelling products at lowest level responses. At the same time, the DST discriminates the more sophisticated productions of successive approximations of conventional form that, until recently, could not be rated with objectivity. The directions for administration of the 10-word DST are included as Appendix A. The DST rating scale and detailed scoring criteria are included as Appendix B.

Spelling Strategies

Siegler and Jenkins (1989) defined a strategy as " any procedure that is non-obligatory and goal directed" (p.11). A strategy was differentiated from a procedure in that a procedure may represent the only way to achieve a goal in situations where there is no alternative. The existence of alternatives is critical to strategies.

Read (1971) had identified three strategies used by nursery school children in their early writing attempts: 1) letter naming, 2) tense (long) vowels, and 3) lax (short) vowels. Chomsky found support for and extended the spelling strategy concept into the kindergarten. The "Virginia school" researchers expanded Read's work to include all age groups. In this section, the works of Clay (1975), Harste, Woodward, and Burke (1984), Dangel (1989), and Scott (1993), other researchers who studied principles and strategies used by emergent and developing writers, will be highlighted.

Clay (1975) noted that children first learn to write by attending to the whole and later the parts. During early productions, they may use one of several principles when trying to "spell" words: (a) The recurring principle (a long statement is created by repeating the same known symbol when only a few letters or words are known); (b) the generating principle (new statements are produced by combining or arranging known elements); (c) the inventory principle (a complete list, or a selection, of known letters or words is produced); (d) the contrastive principle (similarities and differences of letters, e.g., M, W; ip, pi, or words pairs, e.g., girl, boy; hot, cold; in, out, are compared); (e) the flexibility principle (new constructions are created by adding or subtracting parts, indicating that the child is able to attend to distinctive features of words. It is at this point that children realize that an L can become an E if two lines are added, and an E can become an F if one line is deleted). These principles of early writing have been integrated into Clay's Recovery Reading program.

Harste, Woodward, and Burke (1984) studied writing samples from middle and upper-middle class three to six-years old. Children as young as three-years old exhibited decision making strategies in their productions in terms of organization (directionality), intentionality (written objects are marks signifying meaning), generativeness (connecting meaning to print), risk-taking (writing to request), context (making connections with a written word and the context in which it appears), text (a surface text is created when productions are recorded), and demonstrations (based on the context of the situation, the writer refines and redirects his/her attention to new learning). From analyzing their productions, Harste et al. (p. 96) concluded that children employ strategies based on three aspects of language-- the phonemic, the graphemic, and the morphemic aspects. One or more of these strategies could be used in spelling a word. Using a phonemic strategy, the child may write "jrane" for "train". Using graphemic knowledge, the child may spell "first" as "frist". This strategy involves using visual memory to capture at least part of the word. The third strategy, morphemic and semantic organization involves spelling it "the way it means". "Once upon a time" might be written as 'WASAPANATAEM". In this instance, the child thinks of the phrase as one conceptual unit. A fourth strategy identified by Harste, Woodward, & Burke was "knowing one doesn't know". A substitute placeholder is put down to fill the space of an unknown letter or letters.

Dangel (1989) has proposed that effective spelling requires mastery of various processing subskills, such as phonetic segmentation and visual memory. To master these various sub-skills, students must be actively involved in setting goals, monitoring, and recording academic progress. Learning disabled students who were taught to use a student-directed strategy learned to spell as many words as students who received direct instruction from the teacher or who were monitored by the teacher to be certain that they were using the appropriate strategy, and more words than students who were permitted to devise their own study procedures without goal setting and monitoring. Student directed strategies appeared to be more effective and more efficient in helping students to learn spelling words.

Ruth Scott (1993, p. 135) has suggested that the ultimate goal is for each student to develop a repertoire of spelling strategies that he or she can draw upon independently. Students will often select the best strategies for themselves once they are aware of the range available. The child's own learning style and stage of development will influence the choice of spelling strategy. The role of the teacher includes exposing pupils to a broad range of potential strategies. Once an awareness is established, children can develop their own repertoire of spelling strategies which, when internalized, they can use in a variety of contexts.

Scott (1993) has arbitrarily grouped spelling strategies into three categories closely resembling those of Harste, Woodward, and Burke: (a) phonological (sound based strategies help children to capitalize on sound patters or cues); (b) visual (a sharp image of the word is locked in the learner's brain); and (c) morphological strategies (capitalizing on within word patterns to highlight meaning connections). She has added two additional devices as "special strategies" to help children learn to spell highly irregular words: (d)memory devices (mnemonics--"special strategies"or tricks used to aid memory); and (e) tactile strategies (sense of touch--tracing the word etc.)

Scott has emphasized that spelling strategies should be seen in an active learning, problem-solving context--as a tool rather than as a series of spelling exercises. In Scott's view, competent spelling requires active problem-solving on a variety of levels. Skilled spellers must be aware of basic sound-symbol patterns, structured patterns involving modifications to base words, meaning principles and unusual visual features. Less competent spellers may be blocked at the sound level analysis or the structural principles involved in spelling a word. They may employ only a narrow range of strategies when they encounter an unfamiliar word to spell.

If the strategies used by competent spellers over the one year period of schooling in which sound level analysis is focal (end of kindergarten to end of grade 1) were examined close-up and in-depth, and compared with the strategies used by less competent spellers over that same time period, it might be possible to uncover a reason for blockage at this early stage. Then appropriate teaching within Henderson's cognitive developmental framework might help the young speller "unblock".

A discussion of strategies used in the process of inventing spellings implies a transition from an initial state, a blank space, to a goal state in which the writer has produced spellings for the words to be invented. To accomplish this goal, spellers must process the alphabetic knowledge they have in order to solve the problem of deciding which letters to include in the spelling. In the section which follows, the literature on invented spelling as a problem-solving process will be reviewed.

Invented Spelling as Problem-solving

During the 1980's problem-solving as information processing developed prominence in the literature. Three components were established as basic to the problem-solving process--an initial state, a goal state, and strategies to mediate between the initial state and the goal state. Learning was studied as a problem-solving process in a variety of fields and subject areas.

Hall (1984) established invented spelling as an orthographic problem-solving process. He identified three components of information processing in spelling tasks: the data-driven component, the hypothesis-driven component, and the "executive". The function of the executive is to mediate between data-driven and hypothesis-driven information. In Hall's view, the orthographic problem-solving task of the speller is to provide, allocate, evaluate, and generally orchestrate resources from the data-driven and hypothesis-driven components. Spelling ability requires specific data-driven information about phonology, phoneme segmentation, sound-symbol correspondence, specific orthographic conventions, knowledge of sight words and spelling patterns, and the ability to retrieve data-driven and hypothesis-driven information according to a specific strategic plan. Error making is viewed as an attempt by the novice to use limited orthographic knowledge to reflect direction, intent, and adequacy of problem-solving abilities.

Gerber (1984a) outlined direct instructional procedures to foster generalization of spelling strategies to learning disabled (LD) students--students of whom it is a basic characteristic to spell poorly. He established that their errors are representations of their best attempts to use limited orthographic information, rather than illogical or deviant psychological processes. LD pupils lack managing and monitoring skills, and therefore have problems organizing and assessing the knowledge they have (Gerber, 1984, p. 50). This leads to ad hoc decision making. Through imitation, practice, and clear, efficient corrective feedback, he has demonstrated that these "disabled" spellers can learn how to attend to a task, strategies for retention of new information, and speed and accuracy of performance. With prompting to use what they know, over several attempts they make gradual qualitative shifts, and learn to transfer patterns learned to similar words.

Gerber (1985) suggested that spelling attempts represent a special case of problem-solving. In spelling production, the learner begins with a blank page--with little related information provided within the stimulus itself on which to build a response. Through attempts to find a response to a problem in which the stimulus (target word required) must be retrieved or constructed, spelling ability develops from early dependence on stimulus-driven task management to more mature, concept-driven problem-solving. Attention must be dynamically and strategically used, memory must be searched for task relevant information, and decisions must be made with the highest probability of reducing uncertainty. Spelling development depends on individuals' abilities to organize and rapidly access stored information, routines, and knowledge. LD pupils can learn to generalize spelling principles from study problems to similar problems if they receive sufficient time to master examples and if they receive corrective feedback to help them direct their attention to contrasts between their attempts and conventional spelling. LD students make decisions slowly compared to non LD peers. Gerber found that slowness in deciding on letter representation of sound correspondences begins a downward spiral.

Classifying speech sounds and mapping sounds onto the alphabet is rapid and automatic for some who are easy to teach--who require little external order. Other children lack internal structure. As a result, the process of acquiring data specific knowledge is slow. Lack of order in short term storage space reduces operating space, resulting in cumulatively reduced capacity to benefit from instruction, and cumulatively deteriorating achievement (Hall, Gerber, & Stricker, 1989). Hall, Gerber, and Sticker have demonstrated that "poor spellers" can be taught the problem-solving strategies they lack.

Students categorized as "poor spellers" in the studies of Gerber (1984a, 1985) and Hall, Gerber, and Stricker (1989) were students who had been identified as learning disabled. However, Lydiatt (1984) proposed that spelling development is on-going error detection and correction and that within the classroom environment the ability to detect and correct errors was as important as other spelling skills. He viewed the student's sensitivity to errors as a valuable resource to the teacher. Once a student's style in monitoring is known, appropriate instructional strategies could be devised and introduced. By using systematic approaches to uncover student strategy uses, teachers and diagnosticians could teach more effective strategies. Error detection and correction, Lyiatt believed, could lead to instruction in effective strategies that would assist the student in processes such as monitoring productions, detecting errors, and correcting words.

Based on the belief that poor spellers can be taught the problem-solving strategies they lack, and that students can be taught to detect and correct errors, it appears advantageous to identify problem-solving deficiencies as early as possible so that appropriate attention focusing, mapping, retrieval, detection , and correction strategies may be taught before progress deteriorates extensively. By studying systematically the alphabetic knowledge displayed and the strategies (set of operations) performed in applying that knowledge while individual strong spellers and weak spellers of both genders are in the process of inventing spellings, it may be possible to discern problem-solving difficulties at kindergarten and Grade 1. A review of the literature on children's strategies in problem-solving follows.

Children's Strategies in Problem-solving

Siegler and Jenkins (1989) studied children's strategies with the goal of "inferring the underlying thought processes that give rise to qualitative and quantitative aspects of learning" (p.9). Siegler's earlier studies had focused on identifying the strategies a child used to solve a set of problems, the sequence of strategies through which children's thinking progressed with age, and the ways in which existing rules and encodings influenced acquisition of new knowledge (Siegler, 1976, 1978, 1981, 1983, Siegler & Robinson, 1982). Piaget's scientific reasoning tasks were used as experimental tasks. Early focus was on situations in which individual children use a single rule. Development was depicted as a sharp qualitative change from use of one rule to use of another. Siegler (1986, 1987a, 1987b, 1988a, 1988b), Siegler & Richards (1979), Siegler & McGilly

(1989), and Siegler & Shrager (1984) then explored how children choose among strategies that they already know. These studies were built on the work of Anderson (1983) and Holland, Holyoak, Nisbett, & Thagard (1986), who had documented, using adult subjects, how strategies compete and generalize to new contexts through sudden insight into the nature of the problems. The diverse strategies that a given child used to solve certain types of problems, the change over time in the frequency of strategies used by each child, and the mechanics that enable children to choose adaptively among the multiple strategies that they used for solving problems were probed. Academic tasks such as addition, subtraction, and multiplication (Siegler, 1988a, Siegler & Shrager, 1984), and telling time (Siegler & McGilly, 1989) were examined for association among strategies, problems, and answers. Development was portrayed as a gradual change in the distribution of strategy use, with new strategies co-existing with rather than replacing previous ones. Siegler (1989, p. 14) concluded that three assumptions could be made about strategy choice in children's problem-solving:

1. Individual subjects choose from and use multiple strategies on diverse tasks.

2. Each strategy is used most frequently on problems where its advantage relative to other strategies is greatest. Strongest evidence came from studies of 5- to 7-year old children, but even preschoolers were found to use each strategy most often on problems where that approach yielded fast and accurate performance relative to performance that other strategies produced.

3. Knowledge about where strategies should be used comes primarily from past outcomes produced by strategies rather than through metacognitive analysis of where the strategies should be most useful. Experience with strategies helps subsequent strategy selection. Through repeated use of different strategies, children learn about the speed and accuracy produced from using each strategy, the effort required to use it, and the types of problems on which it is most effective.

More recently (1991), Siegler has detected children's use of back-up strategies used when retrieval strategies are not easily accessible. Retrieval qualifies as a strategy whenever it is one among several procedures that can be used to attain a goal, as long as it is directed at a goal and is used in a context in which other strategies can meet the same goal. Retrieval is used most often on problems where it produces the greatest accuracy and speed when compared to alternate approaches. Back-up strategies include all strategies other than retrieval strategies that can be used to solve problems that have the potential to be solved by retrieval (Siegler, 1991). Siegler found that children tend to use retrieval when an appropriate answer seems readily available and back-up strategies when an answer is not readily available. The more difficult the problem, the more often children use back-up strategies to solve it. As children make choices among multiple-alternative, competing back-up strategies, they tend to rehearse when the selection process is challenging. Children who are not doing well in school as well as those functioning successfully in school are capable of making strategy choices among multiple strategies in order to problem-solve (Siegler, 1991). In domains in which children have substantial experience with individual problems, lower income as well as middle-income children produce reasonable and systematic strategy choices (p. 95).

Siegler and Jenkins (1989) have regarded children as "universal novices" in that they constantly need to discover strategies to cope with situations that for adults are quite routine, and to determine where newly discovered strategies apply. They have portrayed the mind of a child as a workshop which contains a collection of materials (knowledge) and tools (learning processes) that can be used to make new products (rules, strategies, and hypotheses). Orders for products that need to be made constantly arrive at the workshop. The products that are fabricated in the process of filling an order later become materials and tools for making additional products. The broader the range of products the workshop has already produced, the greater is its potential to meet future demands. Diverse materials and tools must be not only present, but efficiently organized to prevent cluttering as new strategies are constructed and existing strategies are called into play. Competition among the strategies results in cognitive development.

Siegler and Jenkins (1989) have divided the strategy construction process into two parts: strategy-discovery and strategy-generalization. Strategy discovery involves the time leading up to and including the first use of a new procedure. A burst of discovery is accompanied by a conscious "aha" experience in which the discoverer uses the strategy for the first time and immediately knows why it works and what types of problems it can solve. Strategy generalization involves transition from having used the strategy once to using it in the full range of situations where it is the most effective approach. Generalization of existing strategies is "gradual, incremental, automatic, and rather dull when compared to strategy discovery" (p. 16).

Strategy discovery, a sudden discontinuous change from not knowing to knowing, has two key precursors with which each strategy can be executed--accuracy and efficiency. New strategies become members of a group of competing entities within a larger set of strategies. If an already known strategy is more accurate or more efficient, the new strategy will rarely be used in solving the problem. A strategy may be used because no other strategy works at all.

Siegler (1991) found that children could usually accurately describe the strategies they used on each trial. However, they often were much less articulate on the trial on which they discovered the new strategy and on the trial preceding the discovery. On these trials, pauses, incomplete sentences, and multiple starts and stops characterized their attempts. Some self reports clearly contradicted the evidence of overt behaviour; other strategy descriptions were partially consistent with overt behaviour on the trial and partly inconsistent; other self reports contained no information at all. Siegler concluded that inarticulateness accompanies strategy discovery because discovery requires more mental resources than using a well-established strategy. This leaves fewer resources available for monitoring exactly what had been done and generating the words to describe the activities.

Also, since a strategy is new, there would be no previously developed verbal label to describe it. Understanding the new procedure well enough to identify its component parts and finding a label or description to characterize it have proven to be difficult for children.

Strategies that have been discovered do not necessarily generalize (Reed, Ernst, & Banerji, 1974; Simon & Hayes, 1976; Siegler, 1991). Children often fail to apply strategies that they have learned to new problem situations (Chipman, Segal, & Glaser, 1985; Kail, 1984; Siegler, 1991). A person has not fully constructed a strategy until the person extends it to the entire range of situations in which it is useful--until the strategy is generalized.

Based on Siegler's findings, it would appear that invented spelling is a strategy construction process, in which, in its earliest stages, back-up strategies must be used almost exclusively. As a bank of generalizations surrounding the three ordering principles of English--alphabetic pattern, within word pattern, and meaning patterns-- are constructed both data driven knowledge and strategy construction (hypothesis driven) knowledge will have accumulated and will have to be stored more or less efficiently for retrieval when needed. At a time when kindergarten and Grade 1 pupils are beginning to construct spelling strategies and to represent these in invented spelling, back-up strategies should be more readily observable than at a later point in development when their interaction with retrieval strategies should be expected to be more complex. A microscopic view of operations performed during the invented spelling process could possibly reveal differences between strong and weak spellers in operational use.

Gender Differences in Spelling

Recent studies concerning gender differences as they relate to spelling/writing performance are limited in scope and number (Allred, 1990). Investigations of spelling proficiency at the Grade 4 level (Morton, 1984), of 11-year-old students (Riding &

Tempest, 1986), and at Grade 12 (Stanley, 1987), revealed gender differences favouring females. Broderius (1985) found girls at Grade 5 made greater gains in spelling than their male counterparts. At Grade 1, Leahy (1991) found that girls outperformed boys on the spelling subtest of the Comprehensive Test of Basic Skills. Hunt (1985) found discrepancies in story content written using invented spelling by first-graders. Girls wrote more frequently about themselves, their feelings, their families, and friendships, while boys wrote often about sports, war, fighting and catastrophes. Hunt did not examine potential gender differences in quality and quantity of invented spelling errors. Butler & Handley's (1989) study of Grade 1 pupils' spelling scores and Whorton's (1985) study of spelling scores of Grade 4 - 6 gifted students revealed no statistically significant differences between males and females. Recent results of testing in Ontario at the Grade 9 level revealed differences favouring females across the province.

The most extensive study of gender differences in spelling was conducted by Allred (1990). The focus of this study was gender differences in spelling achievement at Grades 1 - 6. By comparing the spelling achievement of boys and girls on both a written test and a proof reading type standardized achievement test using the same words, Allred found that girls, in general, spell better than boys do in each grade, and that gender differences were consistent across each of 6 geographic areas of the United States, and for high- , medium-, and low- achievement levels, on both proof-reading and written spelling type tests. Allred stressed the importance of learning more about the nature of these gender differences, so that learning experiences might be structured accordingly.

Some studies of the spelling patterns of learning disabled (LD) students have examined gender differences. Vogel (1990) found that LD females were somewhat more proficient in spelling than LD males. Leuenberger & Morris (1990) found differences favouring college females on both qualitative and quantitative measures. Healy & Aram (1986) investigated family histories of hyperlexic (fluent word reading with little comprehension) children of 5 to 10 years of age and found tendencies toward spelling disorders in male relatives, along with a high incidence of left-handedness.

Recent research on the physiology of the brain suggests gender differences. Johansen (1991) investigated the degree and nature of left-brain laterality and reading/spelling difficulties and found a significant correlation between the nature of left-sided laterality and reading/ spelling difficulties. He found also that auditory laterality for men with reading and spelling difficulties differs from auditory laterality for women with reading and spelling difficulties. Kimura (1992) has reported on differences in structure and organization of the brain between females and males. The right cortex of human fetuses has been found to be thicker than the left in boys, but not in girls. Gender differences have been identified in the physical size of the base of the hypothalamus, the area of the brain believed to organize male and female behavior. Cognitive variations between males and females reflect differing hormonal influences on brain development. These effects on brain organization have been found to occur as early as three years of age. Studies of stroke victims reveal that damage to the same brain areas produced different results in males and females. Aphasia is more common in men than in women after damage to the left hemisphere. However, women are more likely than men to suffer aphasia when the front part of the brain is damaged. Studies of left hemisphere damage reveal that motor selection relies on anterior systems in women, but on posterior systems in men. It appears that, from the start, the environment is acting upon differently wired brains in girls and boys. Although very little is known at the process level, evidence of distinct brain organization from birth opens the possibility of characteristic gender differences in emerging language strategies.

Summary

Henderson (1990) has viewed learning to spell as a progressive mapping of a complex but orderly system across five general sequential stages of word knowledge. Hall (1984), Gerber (1984a, 1985b, 1985) and Hall,Gerber and Stricker (1989) have suggested an information-processing, problem-solving approach to describe the specific nature of word spelling. Siegler and Jenkins (1989) and Siegler (1991) have studied how children choose among strategies in problem-solving, and how they discover new strategies and generalize these strategies to alternate situations. Lydiatt (1984) has focused on the importance of error detection and correction to spelling strategies. Scott (1993) has identified three general categories of strategies, and has outlined specific strategies within each of the three categories to which children should be exposed if they are to develop the broad repertoire of strategies they will require in order to spell unfamiliar words. In several studies, gender differences in spelling achievement favouring females have been recorded. Allred (1990) and Kimura (1992) have suggested potential gender differences that might affect the process of invented spelling and have underscored the need to examine these differences. A reflection framework which could address simultaneously the general cognitive developmental framework and the specific strategies used in the problem-solving process of learning to invent spellings for selected target words was required. An intermediate level framework was uncovered in the "Mind's Staircase" proposed by Case (1991).

CHAPTER 3
REFLECTION FRAMEWORK

Generality and Specificity in Children's Intellectual Development

Whether the human mind should be seen as developing in a general or specific fashion has been an on-going controversial issue. Those favoring the general view postulate that children's development proceeds through a sequence of stages often perceived to be universal in character. Those favoring the specific view suggest that children's development proceeds along many fronts at once, at different rates, in a continuous and contextually sensitive manner.

During the mid 1980's, Piaget's theory of intellectual development was reworked by proponents of both schools of thought (Case, 1991). Those favouring the more generalized view (Case, 1985; Fischer, 1980; Pascual-Leone, 1988; Pascual-Leone & Goodman, 1979) reworked the classic theory in light of the recent findings in learning theory and information science. The mind was regarded as a general or all purpose computing device whose basic capabilities undergo periodic changes in the course of development. As these basic capabilities change, the mind acquires the potential for formulating new and more sophisticated control structures as well as data structures and skills of increasing complexity. At the same time, those espousing a more specific view (Carey, 1985, 1988; Fodor, 1982; Gardner, 1983) reworked the classic Piagetian system in terms of recent developments in linguistics and in neuroscience. They viewed the mind as a computing device whose development proceeded on many fronts at once, with each of those fronts having its own unique capacities and structures. As these various capacities change, each of the structures which give rise to it change in its own way and follow its own unique developmental course.

In 1984, at a conference in Tel Aviv, the first attempt was made to bring the two views closer together for productive change. The Society for Research and Development continued this endeavor in 1986, and similar gatherings were held over subsequent years (Case, 1991, p. xi). From a synthesis of these two schools of thought, Case, who had participated in several of these meetings, revised his earlier neo-Piagetian conception of children's intellectual development. As he became familiar with the modular view and the data it was gathering, he concluded that both positions might be valid simultaneously. There might be aspects of children's intellectual development that were modular, each following its own unique developmental path, and, at the same time, there might be general systemic changes, broad in scope, but affecting ability to display any basic capacity in real world context. Case and his students studied this possibility longitudinally. Over a seven year period of weekly meetings of his research groups at the Ontario Institute for Studies in Education, each participant conceived, executed, and reported on empirical studies of his/her own area of expertise. Individual meetings of group members with Case were held to work out the details of their task and method of task analysis. Each member developed some particular aspect of his/her investigation into a master's or doctoral thesis. The resulting intermediate level framework preserves the general structure of Piaget's theory, but modifies the theory to include children's physical and cultural environments. Two different sets of methods and two classes of theory are combined in order to examine two types of data in different ways and in greater detail.

Case's (1991, p. 33- 34) aspects of development presumed to be universal and general are:

1. Piaget's four stages of development--sensorimotor thought, interrelational thought, dimensional thought, and vectorial thought. The stages are differentiated by the level of relationship that the child must represent and manipulate. Higher stages are assembled by intercoordination of two well consolidated, but qualitatively different structures from the previous stage.

2. Three substages of development within each stage--unifocal, bifocal, and elaborated--identified from an improving ability to enlarge focus within stages of thought.

3. Growth through a stage during a characteristic period of time across various content domains under conditions where adequate problem-specific experience is provided. A biological limit to how fast each progressively higher system can become integrated is controlled by a higher level neurological system.

4. Growth through substages during a characteristic period of time under conditions where adequate domain-specific experience is provided. Subsequent development is limited by speed of maturation of each higher level system. Rate of maturation sets the upper limit on operation of that level, and, in turn, sets the upper limit on working memory.

Case's aspects of development presumed to be specific and to account for considerable variability from one child, task, or context to another are:

1. Cultural and historical factors. Intellectual operations that children construct are cultural inventions that vary as a function of the culture children are raised in and the historical epoch within that culture.

2. Instruction, both formal and informal. Children depend increasingly on some form of instruction to acquire high-level operations that the culture values. Intellectual development will vary as a function of the social group within a culture in which they are raised and the access provided by that social group to educational resources.

3. Control structures. These are devices for dealing with specific problem situations. It is by the integration of specific structures that children progress from one stage or substage to the next. Development can vary in overall course and rate as a function of children's individual learning histories within their social group (Case, 1978).

4. Learning histories. These vary as a function of factors relating to any one of the three specific components of control structures-- representation of a particular situation,

representation of the goal to be achieved, and the set of operators (strategies) applied to reach the desired goals. A match between capabilities and operators is required.

Case (1991) has proposed a "Mind's Staircase" as a framework that describes in precise and general terms an intermediate position on children's intellectual development. This framework, presented in Figure 1, will be adopted as the reflection framework within which to study problem-solving strategies used by kindergarten and Grade 1 pupils when inventing spellings. A more elaborate description of Case's stages and substages will be provided below, followed by an account of how children use problem-solving strategies within the framework in developing intellectually from one stage or substage to the following one. Invented spelling will then be introduced as a possible indicator of problem-solving strategies when studied within the "Mind's Staircase".

Case's Developmental Stages and Substages

Case has maintained that children's intellectual functioning at different stages can be described as a sequence of increasingly sophisticated mental structures. He has adopted Piaget's four major stages of children's cognitive development--sensorimotor, interrelational, dimensional, and vectorial thought--and then subdivided each of these into three substages. Each stage is preceded by a preparatory reorganizational substage in which the control structures elaborated in the preceding Substage 3 regroup to create a major shift in thinking as the basis of the next stage. The integrated knowledge from the previous major stage is consolidated and "carried over" to the new stage, as represented in Figure 1. In Substage 1 children assemble a new class of operations (A - B), unifocal operations, out of two qualitatively distinct precursor structures, operation A and operation B, each of which was already available, but each of which previously filled a different function. As they practice these new operations within the developing memory system they enter Substage 2, bifocal operations, in which they become capable of executing two

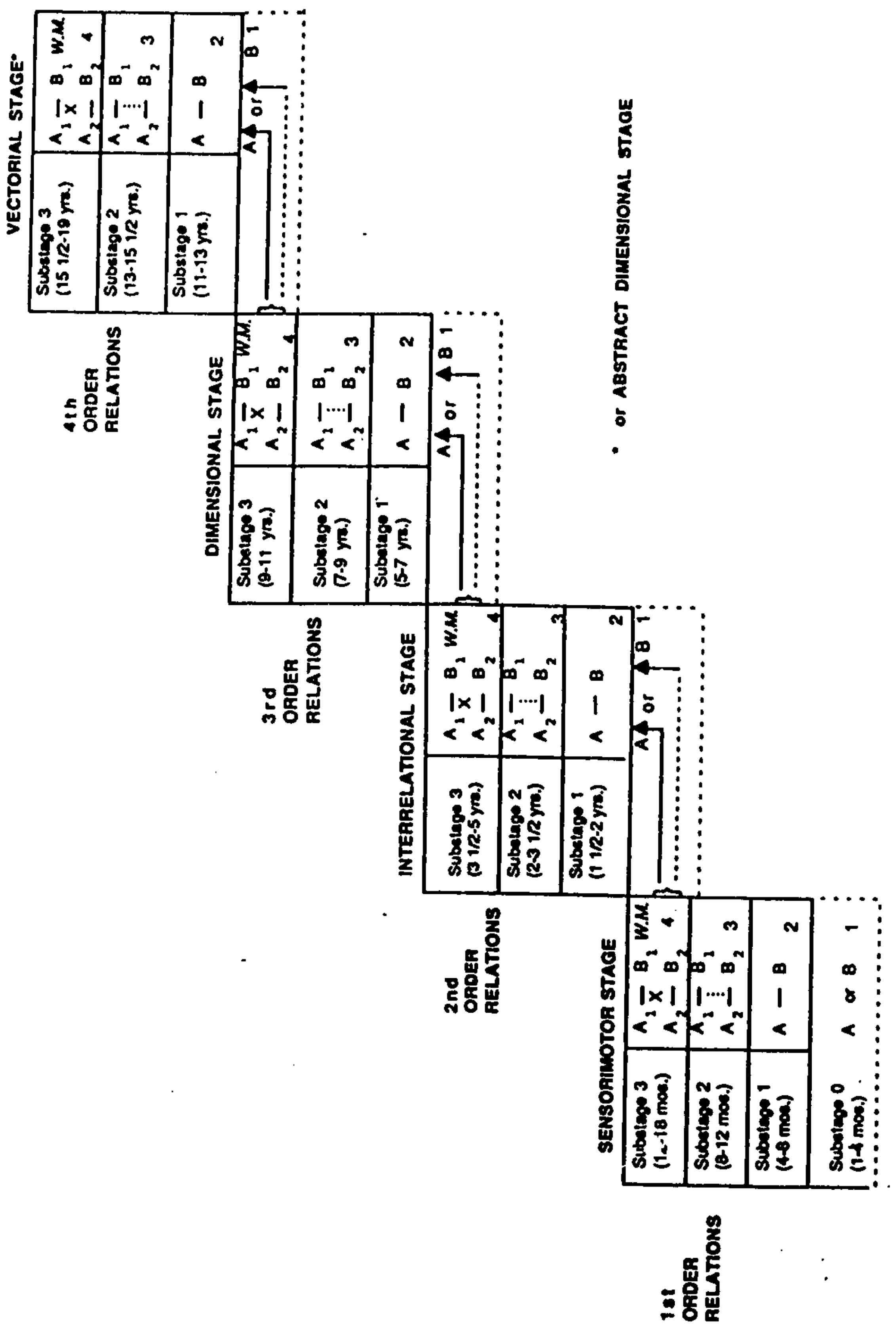


Figure 1. Hypothesized structure of children's knowledge at different stages and substages of development. Extracted from Case (1991, p.346).

such operations in sequence ($A_1 - B_1$), then ($A_2 - B_2$). With further growth and further practice, they enter Substage 3, consolidated (also called bifocal integrated) operations, in which they become capable of executing two or more operations of the new sort in parallel ($A_1 - B_1$) and ($A_2 - B_2$), and integrating the products of these operations into a coherent system $[(A_1 - B_1) \times (A_2 - B_2)]$. A brief overview of thought development by stage follows.

Sensorimotor Thought (Birth to 18 Months)

During the period of sensorimotor thought, children perform isolated operations, develop a repertoire of voluntary action schemes, and learn to differentiate key operations from each other. Sensorimotor operations consolidate during the first four months. Infants explore the visual world and apply their motor operations to an increasingly wide range of situations. During Substage 1, control structures begin to appear in sensorimotor thinking. The infant finds a motoric strategy to accomplish the desired goal. By Substage 2, infants are able to repeat actions that produce satisfaction and to perform subtle changes in motor action and thought. That is, they have learned to establish new goals for motor action. During Substage 3, they develop an understanding that the nature of their actions must be tailored to the nature of the effect desired. A more complex and elaborated control structure is assembled through differentiation and coordination of voluntary action schemes. Each successive coordination leads to a qualitative shift in behaviour. By 18 months, children can assemble complex sensorimotor structures in which effect of one operation reverses the effect of another. Children's knowledge of and insight into the world reflects the nature of mental structures they have available for exploring it. Early intellectual activity results from sensory experience. Children often work backwards from a goal state. Insight on how a goal is reached comes from establishing a set of pointers to a particular set of sub-goals or intermediate states that link the current state to the goal state. As children move from one substage to the next, they become capable of an additional task feature, and of setting one additional subgoal that relates to it. They become capable of employing existing strategies in more complex situations.

Interrelational Thought (Age 18 Months to 5 Years)

During the interrelational stage, children develop control of interrelationships--they begin to understand higher order rules and series of problems. The prerequisite to interrelational thinking is the ability to focus on a consolidated, unitary operation and its inverse relationship. For example, if one end of the beam is up, the other end is down (Case, 1991). During the period of unifocal coordination (1 1/2 - 2 years) children learn to focus on and control thinking about two different types of relationships, action and reaction, simultaneously. Subordination or hierarchical integration is required. Children learn to use language in the thought process. During Substage 2, bifocal coordination (2 - 3 1/2 years), the focus expands to include two systematic relationships. By the third substage, elaborated coordination (3 1/2 - 5 years), children become capable of reversing operations of bifocal coordination. Structures for understanding and controlling well-differentiated and reversible relational operations are established. By age 5, relational structures can be assembled into complex higher order structures, and the effects of one interrelationship can be compensated for or reversed by that of another. Children are capable of thinking about a goal and repeating or mastering interesting relational operations. They can move backwards from an operation they hope to execute to some other operation. Insight into the goal often comes through a set of operations to a particular set of subgoals which link the current state to the goal state. Movement from one stage or substage to the next is accompanied by an increase in the number of task features that can be taken into account and subgoals that can be set. The result is a change in strategy that can be executed, and/or expansion in range of contexts to which existing strategies can be applied.

The only difference between sensorimotor and interrelational thought is the nature of the operations that form the basic unit of thought. In the former, sensory objects and motor actions form the thought unit; in the latter, the relationship between such objects and motor actions form the thought unit.

Dimensional Thought (Age 5-11)

For dimensional thinking to develop, representation of a single dimension of something at a time is prerequisite. During the dimensional thought stage (age 5 years - 11 years), integration involving subordination of one structure to another is focal. During Substage 1 (5- 7 years), new structures are assembled out of two qualitatively distinct precursor structures, each of which was already available, but each of which previously filled a different function. Integration involves subordination of one structure to another in means-end fashion. In the process of this integration, subtle changes take place in the components of each structure. A large qualitative shift takes place in children's behaviour, and in the insights of which they are capable. In Substage 2 (7- 9 years), children begin to focus on a second qualitative dimension. The control structure is capable of containing an additional feature in its problem situation, an additional subgoal in its list of objectives, and an additional sub-routine in the strategy. During Substage 3 (9- 11 years), children learn to assemble flexible control structures for solving problems. By the end of this stage, children can solve readily problems requiring insight into compensatory or reversible effects of different dimensions. They are capable of a shift in thinking--of reorganizing knowledge.

Vectorial Thought (Age 11- 19)

During the vectorial stage (11 years - 19 years), children learn to understand abstract systems in which there is no concrete referent for purposes of comparison. Concrete groupings are reconstructed to a new level of abstraction. The adolescent is capable of thinking beyond the present. Reflective thought becomes possible during Substage 1 when children become capable of deductive reasoning. They then operate on operations by casting them into the form of propositions. These propositions become part of a cognitive structure that is derived from past experience, but makes possible hypotheses beyond real experiences. Adolescents begin with the possible, check possibilities against representations of past experiences in memory and against sensory feedback from concrete manipulations. The content of the problem becomes subordinated to the form of relations within it. One has only to translate a problem into propositions, into the realm of pure thought which is independent of action. Equilibrium can be achieved through operating on the operations -- through a second degree of operations.

Case's (1991) studies have focused on the thought processes of children in the dimensional stage across three broad domains--logico-mathematical thought, social and emotional thought, and spatial thought. Case has concluded that "major re-workings tended to occur at about the age of 5 or 6. The minor re-workings tended to occur at 7 to 8 and 9 to 10" (Case, 1991, p.366). The major re-workings coincided with shift to a new major stage; the minor re-workings coincided with shifts between the substages.

The children in the present study can be expected to be approaching or having entered the earliest substage of dimensional thought-- to be in a period of major re-working. The process through which growth between the stages and substages occurs will be presented in the next section

Problem-solving and Children's Intellectual Development

In outlining how transition from one stage or substage to another takes place, Case has viewed the child as a problem-solver with "the capability for overcoming barriers by refining and recombining the inborn procedures with which he comes equipped" (Case, 1985, p.58). Children's problem-solving processes are represented as specific entities called control structures containing three components: a representation of the essential features of some particular class of problem, a representation of the goals that this problem class most frequently occasions, and a representation of a sequence of operations that will bridge the gap between the problem's initial and terminal states (Case, 1991, p.344). Case has represented executive control structures by tagging the three component parts as "problem situation", "objective", and "strategy".

Problem solving strategies are effected within working memory, also known as an "executive processing space" . The working memory has two functions--activating new schemes to resolve a problem and maintaining and/or retrieving recently activated schemes related to that problem. The working memory can entertain a maximum of four unrelated meaning pieces of information at a time, so information is "chunked" into meaning related pieces in order to maximize information retained and its accessibility for recall when required (Case, 1984, 1991). Efficient organization and coordination (chunking) results in additional space availability for activating new problem-solving schemes for particular tasks. Inefficient organization and coordination reduces the ability to activate new schemes. Efficiency in chunking increases with growth through the stages and substages.

The major change with development is the child's ability to assemble control structures and use these in problem-solving. Two levels of controls are used simultaneously--executive control structures and central conceptual structures. At each developmental level, children possess a more complex general conceptual representation of their world. These conceptual representations determine the nature of the hypotheses that they will assemble and use within the executive control processing space in meeting the requirements of particular tasks.

Case has defined central conceptual structure as " a network of semantic nodes and relations that plays a central role in mediating children's performance across a broad range of tasks" (Case, 1991, p. 352). As children develop intellectually, they assemble and use this central structure, more or less successfully, to guide the selection and operation of the particular executive control structures required to perform the task--to select and "chunk" what "fits together". The central executive system is responsible for identifying novel information, storing it for brief periods of time, assessing other information that may be relevant, and making decisions that permit some form of coherent action. The executive control structure is the internal "program", that can be represented by describing the problem, outlining the objective, and determining the strategy (set of operations) that children use to bridge the gap between the initial and goal states. The cognitive strategies children use at any level are influenced extensively by the nature of their central conceptual structures. Domain specific experience is necessary to "feed" the central system.

Intellectual development requires capability for goal setting, generating novel scheme sequences with which to pursue the goals (trial and error), evaluating effectiveness of results, restructuring sequences that have been evaluated positively so that they can be intentionally used in future, and practicing new structures until they become automatic (Case, 1984b, p. 27). Intellectual development is constrained by maturation and experience. Maturational growth through the stages and substages sets an upper limit within the intellectual capacity of the brain. Measures of working memory appear to make a rapid increase with the shift to a new stage and qualitatively more sophisticated level of thinking. The major re-workings of children's conceptual structures appear to occur at the beginning of each stage. The more minor re-workings are likely to occur between substages. When a major reworking occurs, children become potentially capable of analyzing their experiences in any domain in a qualitatively different fashion. External events that previously had little effect may suddenly exert major influence. Experience with an operation is required in order to take advantage of neurological maturation. Automaticity develops with stage appropriate practice.

Invented Spelling as an Indicator of Problem-solving Strategies

Hall (1984) established spelling as an orthographic problem-solving process, and identified three components of information processing in spelling tasks: the data driven component, the hypothesis driven component, and the executive or strategies that mediate between data driven and hypothesis driven information. Gerber (1985) had established that spelling attempts represent a special case of problem-solving in that the stimulus must be retrieved or constructed and produced on a "blank page". He confirmed that development depends largely on individuals' abilities to organize and rapidly access stored information, routines, and knowledge, and that children who lack internal structure have difficulty. Hall, Gerber, & Stricker (1989) demonstrated that "poor speller" LD students can be taught the problem-solving strategies they lack.

In the present research, an attempt is made to use the invented spelling processes of five- and six-year-old children as indicators of their problem-solving strategies. It appears, from the literature, that the problem-solving strategies emergent spellers use in the process of invented spelling have not been examined fully, nor has invented spelling been studied as a "window" to problem-solving. The lack of an instrument to rate children's earliest productions qualitatively, combined with difficulty in finding a method of collecting information about strategies being used in inventing spelling at the detailed level of operations, have undoubtedly discouraged exploration of a possible relationship between these two variables with five- and six-year-old children.

The recently constructed Developmental Spelling Test (Tangel, 1991) was used to rate the quality of the spelling productions of kindergarten and Grade one pupils. Video protocols (Blanchet, 1981; Schael, 1994; Siegler, 1989, 1991), verbal protocols (Ericsson & Simon, 1984, 1993; Schael, 1994; Siegler, 1989, 1991; Taylor, 1992) and the DST scripts (Tangel, 1991) were collected concurrently using a recently designed observation table (Schael, 1994) to collect data on problem-solving strategies. The Dionne observation table made it possible to "zoom in" on the problem-solving process to the extent that strategies used by subjects in moving from a problem state (dictation of word) to an objective state (invented spelling produced) could be identified and examined at the precise level of operations performed within the cognitive developmental framework proposed by Case (1991).

Summary and Research Questions

Henderson (1990) has established a series of five developmental stages through which learners grow in moving toward conventional spelling form. He has documented the learning outcomes generally noted within each of the stages. All learners progress through the same stages, but at different rates. Henderson has outlined the development of word knowledge expected within each stage, but he has not addressed the problem-solving operations children use in the process of inventing spellings.

Hall (1984) has established spelling as an orthographic problem-solving process. Hall, Gerber, and Stricker (1989) have demonstrated that learning disabled children, characteristically "poor spellers", can be taught the problem-solving strategies that they lack. Lydiatt (1984) has established that error detection and correction are critical to efficient development in all students.

Case (1985, 1991) has examined how children formulate and develop their hypotheses in intellectual development. He has constructed an intermediate level framework, in which problem-solving can be used to bridge the gap between the Piagetian view of development proceeding through a sequence of general age related stages and the situation-specific view of development proceeding along many fronts at once, at different rates, and in a continuous and contextually sensitive manner. Case has proposed that the major change resulting from children's intellectual development is in ability to assemble control structures and to use these control structures in problem-solving. He has demonstrated that the problem-solving strategies that children apply to bridge the gap between the initial state and the goal state account for much of the variability that exists in learning. These strategies are composed of a set of operations performed in the process of moving between the initial problem state and the objective state. An obvious step, therefore, is to select some children who are advanced in word knowledge and others who are lagging in this regard and identify the series of operations that they perform in their earliest form of written expression, invented spellings. In order to invent spelling words, the stimulus (letters to represent the dictated word) must be retrieved or constructed and produced on a "blank page" (Gerber, 1985). Young spellers must choose from amongst all that they know, and through data related and control related operations, translate the information selected to the graphics that most suitably represent the target word.

Siegler (1991) and Siegler and Jenkins (1989) have conducted microgenetic studies of how individual children make diverse choices among existing strategies and how they develop new ones across a wide range of tasks. However, no in-depth analysis at the concentrated level of operations within spelling strategies in progress have been published, possibly due to the special challenge presented when attempting to capture the detail of writing in progress. When videotaping, letters of the alphabet are distorted by inversions and reversals, making interpretation of strategy use highly challenging to the researcher. The novel Dionne Observation Table used by Schael (1994) was designed to overcome this obstacle.

Since the matter of gender differences in spelling achievement has favoured females (Allred, 1990; Broderius, 1985; Hunt, 1985; Leahy, 1991; Leuenberber & Morris, 1990; Morton, 1984; Vogel, 1990), or found no statistically significant differences (Butler & Handley, 1989; Whorton, 1985), and since recent evidence exists suggesting gender differences in the structure of the brain (Johansen, 1991; Kimura, 1992), gender was introduced as a possible differentiating factor.

When invented spellings were examined in the light of Case's hypothesized structure of children's knowledge at the unifocal dimensional substage of development, the basic question which arose was: What are the operations by gender of good and poor spellers? Case has suggested that children's intellectual functioning at different stages and substages can be described as a sequence of increasingly sophisticated mental structures. Within the dimensional stage, he has claimed that all major re-working in central conceptual structures occurs at 5 or 6 years of age, as dimensional thought is emerging (Case, 1991, p.366). As the result of a major re-working, children become potentially capable of analyzing their experiences in a qualitatively different way. External events that previously had little effect suddenly begin to exert a major influence (Case, 1991, p.370). If during this "growth spurt" operations used in the invented spelling process are examined in the light of Henderson's progression of word knowledge, evidence of the progression of development of the central structure should be reflected in the strategies used. This opens the avenue to an important research question concerning intellectual development during the unifocal dimensional substages: How do operations used change over time?

Hall (1984), Gerber (1984a, 1984b), and Hall, Gerber, & Stricker (1989) have established spelling as an orthographic problem-solving process in which a significant number of pupils experience great difficulty because they lack managing and monitoring skills. They have found that poor spellers pass through the same stages of word knowledge as good spellers, but at a slower pace. Because poor spellers lack organizational and monitoring skills required to "chunk" efficiently and effectively, the entry of new information into working memory is retarded. In other words, it appears that poor spellers are lacking strategies, or are using their strategies differently, than their good speller peers. When the findings of Hall, Gerber, & Stricker are combined with Henderson's stages of word knowledge within Case's framework, an additional variable, differences in progression of learning between good and poor spellers, is added. The question of how strategies develop can now be differentiated further: Are there differences in progression of operations of good spellers and poor spellers over time?

On the basis of recent brain research, the gender issue must be addressed. Kimura (1992) has reported differences in structure and organization of the brain between females and males. It appears that, from the start, the environment is acting upon differently wired brains in girls and boys. Allred (1990) has established differences in spelling achievement favouring girls at each of the grade levels one through six across each of six geographic areas of the United States. These differences were evident in both proof reading and written spelling type tests. However, very little is known at the process level. Evidence of distinct brain organization from birth opens the possibility of characteristic gender differences in emerging language strategies. This leads to an additional question of interest: Do the strategies (sequence of operations) of kindergarten and grade one boys differ from the strategies (sequence of operations) of kindergarten and grade one girls over time?

To summarize, the purpose of this study is to explore, identify, and analyze, within a cognitive developmental framework, the problem-solving operations of kindergarten and grade one girls and boys in the process of inventing spellings for dictated words. Accumulated from the discussion above, the research will be guided by the following questions:

1. What are the operations by gender of good and poor spellers?
2. How do the operations used change over time?
3. Are there differences in the progression of operations between good spellers and poor spellers over time?
4. Do the operations of boys differ from the operations of girls over time?

The first question addresses what operations are used. The three ensuing questions relate to how the operations change-- over time, differentially with spelling ability over time, and with gender over time. The table of observation introduced in Schael's (1994) study offers an innovative approach to the study of these questions.

CHAPTER 4
METHODOLOGY

Methodologies For Studying Problem-solving

Four of the most useful methods that have been used to study children's thinking are chronometrical analysis, error analysis, analysis of eye-movements, and protocol analysis (Siegler, 1986a, p. 116-132). In each of these methods, pattern of data, rather than its absolute level, is the consideration. Each method yields data about the thinking of individual children rather than simply revealing group tendencies. Averaging over groups may be carried out to reveal gross patterns. The methods may be used in combination, depending on the nature of the study. A brief overview of each of the methods follows.

Chronometrical Analysis

The pattern of solution times is analyzed, most frequently by using the subtractive technique to define the time people take to perform a single mental process. In its origin, the researcher devised two tasks that differed only in the need to perform a particular process. The difference in solution times was the time required to perform the process being investigated. Sternberg (1966) multiplied the power of the subtractive factors approach by devising several versions of the basic task, with the versions differing only in how many times it was necessary to execute the process under review. Keating and Bobbitt (1978) used Sternberg's theoretical goal and method to extend this form of analysis to research with children. Chronometrical methods require that the experimenter present a great many trials, that children pay close attention and respond quickly, and that the experimental procedure be carefully controlled. The length of time required to arrive at an answer is defined using this method, but the quality of the answer is not considered.

Error Analysis

Piaget relied heavily on the error analysis method when analyzing his careful observations and detailed reporting of minute reactions of children across developmental stages. The method has been extended so that patterns of correct answers and errors become ways of testing precise models of people's reasoning (Siegler, 1986a, p. 121). For example, Siegler (1976) examined children's correct answers and errors on six balance beam problems carefully designed and selected to differentiate the rules they used in arriving at an answer. The children were required to make predictions concerning balance, weight, distance, conflict-weight, conflict-distance, and conflict-balance. After making their predictions, the experimenter asked them to explain how they knew which side of the balance beam would go down.

Case (1984b) used Siegler's (1978) version of Inhelder and Piaget's (1958) balance beam task as a starting point for his work in establishing a developmentally based theory and technology of instruction, and in establishing that the control structures underlying this progression could be characterized as proceeding through a sequence of four levels--pre-dimensional, uni-dimensional, bi-dimensional, and integrated thought (1985). Case (1991) adopted Siegler's 1978 version of Inhelder & Piaget's (1958) marbles task and shadow casting task, and adapted DeMerssman's (1976) version of Damon's (1973) Distributive Juice task, and Noelting's Juice Mixing task (Noelting, 1982) and for each of these tasks, constructed test items to fall into his four differentiated categories of thought to determine strategies used (Case, 1991, p. 350). By carefully focusing on the strategies a child used in moving from the initial state to the goal state, and by comparing these with strategies used across categories, Case demonstrated that students could be moved from incorrect strategies toward more expert strategies. To analyze the basic cognitive developmental processes of children with specific types of learning disability (Crammond, 1991) and the development of children with various types of giftedness (Porath, 1991), chronometrical analysis methods were combined with error analysis methods to provided information on both how concepts were resolved and how long it took to get an answer.

Error analyses are useful for revealing how children solve problems and how they understand concepts, but are less useful for determining the moment-by-moment processes by which children perceive their world. Eye movement analysis has proven useful in this regard.

Eye Movement Analysis

Javal (1878) used an analysis of eye movement to study thinking as visual information processing (Siegler, 1986a), the basic assumption being that the material on which the eye is focusing also is the material on which the mind is focusing. Close observations of the way the eye focuses have revealed that our eyes move in a two stage cycle: brief saccades (eye movements) that take roughly .01 seconds, followed by fixations that range from .2 to a few seconds. The saccades bring the eye to focus on the material desired as input. Information about visual forms is obtained during fixations. The durations of the fixations vary with the difficulty of the material, its importance, and many other factors (p. 125).

Analysis of eye movement has been used in experiments on reading (e.g., Just & Carpenter, 1980). To analyze eye movements during reading, the child sat on a chair and looked at a TV monitor on which a reading passage was projected. An eye tracking apparatus sent a beam of infrared light, invisible to the naked eye, into the child's cornea. The reflection of this light indicated the point where the child's eye is fixing on the TV monitor. Superimposing the material on the screen onto the corneal reflection revealed the material that the child was looking at on the TV screen from which he was reading. An eye camera photographed the corneal reflections every few milliseconds, to rapidly track changes in the eye position. The data were fed into a computer for automated scoring, crucial to analysis of eye movements. Five minutes of reading generate approximately

18,000 fixations. The analysis yielded information about the sequence of locations on which the eye focused and the duration of attention at each location. Eye fixation analysis yields complete and precise information on which objects people are thinking about, but does not reveal what people are thinking. Protocol analysis is often used for this purpose.

Protocol Analysis

Protocol analysis dates back to the end of the 19th century. Introspectionists, who believed that people could give insights into their own thought processes, began using verbal reports as evidence about how thought occurs. Early in the 20th century, behaviourists contested the use of verbal reporting as data, arguing that introspections were misleading and that they should not be used in scientific study. Later, the Gestaltists contended that verbal reports during the course of problem-solving were useful for generating hypothesis but not for providing conclusive evidence. Despite much controversy on the reliance on verbal protocols, these reports have continued to be used because they often reveal information that other methods cannot (Siegler, 1986, p. 128).

In view of this unique value and in response to the many criticisms levied, verbal protocol methodologies have been refined. Different forms of verbal reporting, such as concurrent verbal reporting, retrospective reporting, and immediate retrospective debriefing, have evolved and have been used in combination. Also, verbal protocols have been collected concurrent with video protocols to augment richness in data. The evolution of verbal and visual protocol procedures will be discussed under separate headings, within which various combinations used in data collection will be cited.

Verbal Protocols.

During the 1980's, with the surge of interest in cognitive science, verbal data were used increasingly to study cognitive processing in psychology, education, and cognitive science (Ericsson & Simon, 1993, p. xi). Verbal reporting, as proposed, elaborated, and updated by Ericsson and Simon (1980, 1985, 1987, 1993), is designed to aid in the interpretation of cognitive processing in as simple, yet robust, a manner as possible (1993, p. 10). Learners are given a problem to solve and are required to think aloud as they find a solution. To do so, they must understand the task they are performing, and must be able to transform the task into retrieval cues that select the relevant information from all the information available in long term memory. In addition, the subject has to put the retrieved information into a sequential form that allows the generation of a coherent sequence of verbalizations (Ericsson and Simon, 1993, p. xii).

The following general assumptions are made within the Ericsson and Simon framework (1993, p. 11-12):

1. A cognitive process can be seen as a sequence of internal states successively transformed by a series of information processes;

2. Information is stored in several memories having different capacities and assessing characteristics: several sensory stores of very short duration, a short-term memory (STM) with limited capacity and/or intermediate duration, and a long-term memory (LTM) with relatively large capacity and relatively permanent storage, but with slow fixation and access times compared with other memories;

3. Information recently acquired, attended to, or heeded by the central processor is kept in STM and is directly accessible for further processing. Information from LTM must first be retrieved (transferred to STM) before it can be reported; and

4. Any verbalization or verbal report of the cognitive processes would have to be based on a subset of the information held in STM or LTM.

The most prominent methods used to gather information about the contents of the mind within an information processing framework are "think-aloud" or concurrent protocols and retrospective data collection (Ericsson and Crutcher, 1991; Garner, 1988). These two forms of verbal reporting are now recognized as major sources of data on subjects' cognitive processes in specific tasks (Anderson, 1987) and are the two forms of verbal protocols that, in the view of Ericsson and Simon (1993, p. 16), most closely reflect cognitive processes. Concurrent verbal reports require the subject to talk aloud or think aloud about the task being performed. While doing so, cognitive processes are described as successive states of heeded information. In immediate retrospective reporting, a durable memory trace of the information heeded while completing the task is accessed directly from STM and reported immediately.

Two major criticisms have been levelled against verbal reporting as a form of data from which cognitive processes can be inferred: (a) Inability to express thoughts during production (especially children), and (b) inconsistency between subjects' verbal reports and their actions (Nisbett & Wilson, 1977). Ericsson and Simon (1993) contend that the accuracy of verbal reports depends on the relation between the requested information and the actually heeded information and on the procedures used to elicit them. Invalid reports, they have claimed, are often due to inadequate procedures for eliciting reports or from requesting information that could not be provided even if thoughts were accessible. They have suggested that probing for awareness, through concurrent and immediate retrospective reports of specific cognitive processes, would yield better insight into cognitive processing. Use of concurrent reports and immediate retrospective reports of specific cognitive processes are most likely to yield direct evidence of cognitive processing.

Gelzheiser (1991) used verbal protocols to study how Grade 2 and Grade 3 pupils gather sufficient understanding of the alphabetic principle to induce sound/symbol correspondence. She found that subjects had little ability to describe their strategies. She concluded that, although the groups did differ in post-test scores, verbal reports at these grade levels did not appear to accurately reflect the strategies of subjects in either the control or experimental groups. Gelzheiser, however, did not use concurrent verbal reporting or immediate retrospective reporting of specific cognitive processes. Verbal reports of cognitive processes were solicited after all words in the experimental task had been written.

In studies published by Case (1991) to describe research on the development of social and emotional thought (McKeough's development of children's narrative; Griffin's development of intrapersonal awareness; Case, Griffin, & McKeough's parallels in the development of children's social, numerical, and spatial thought) verbal protocols were collected as a data source for error analysis. To detect instances of covert strategy use, Seigler (1991, p. 91-93) combined immediate retrospective verbal reports with videotaped recordings. In doing so, he noted the verbal articulation ability of young children was different on tasks requiring strategy generalization from articulation on tasks requiring strategy discovery. He attributed the inarticulateness which accompanies strategy discovery in children of 5 to 7 years of age to the fact that strategy discovery requires more mental resources than are needed when using a strategy that has generalized.

Five and six year old children, when required to invent spellings, must construct their own strategies to create a representation of an unknown word. Inarticulateness, therefore, might be expected on many test trials in the present study.

Taylor (1992) investigated complementary use of concurrent verbal protocol (CVP) and retrospective debriefings (RD) when collecting data on problem-solving strategy knowledge from adult subjects. She found the complementarity of CVP/RD methodology enhanced the richness, validity and reliability of the data, particularly with actions taken during the problem-solving process. A content analysis revealed that CVP data were typically specific and local in nature, providing detailed accounts of the small steps taken in the problem-solving process. RD data were typically more global, having the tendency to summarize the major steps taken in the solution process. The finer detail of CVP data provided cues that were useful in shaping the discussion for the remaining RD and in interpreting the "big steps" in the problem-solving process not explicitly stated in CVP data. With the researcher free to probe or cross-examine the concurrent verbal reports, clarification and elaboration of information could be accomplished during the RD with the problem-solver. As a consequence, the level of inference required in interpreting verbal reporting data was reduced.

In view of Taylor's (1992) research, it would appear that by using CVP/RD data concurrently, the researcher might expect to locate data driven information during CVPs and then, during RDs, with probing based on information provided in the CVPs , acquire further insight from the young subjects about their uses of cognitive control structures. Immediate retrospective reports with probing could be expected to clarify and elaborate CVP information, contribute to completeness in verbal data, and reduce the extent of interpretation required. Consequently, the CVP/RD methodology used by Taylor to collect verbal protocols will be used in the collection of verbal reporting data in this research.

Visual Protocols.

Visual protocols have been regarded as a valuable trial-by-trial method of studying children's problem-solving strategies since the early 1980's. Blanchet (1981) collected data by videotaping children 7 to 12 years of age in order to study how they used pictorial representation in problem-solving. To study multiple strategies used by five to seven year-old children, Siegler and Robinson (1982) videotaped the ongoing behaviour of individual subjects while solving simple addition problems. The videotapes clearly identified that young children sometimes put their fingers up and counted them in varied ways to arrive at a solution. Early assessments of strategy development and strategy choice (Siegler,1983, 1986; Siegler & Shrager, 1984) were based entirely on trial-by-trial analysis of videotapes of children's behaviour over extended periods of time. Since 1987, Siegler (1987a, 1987b, 1988a, 1988b,1991) and Siegler & McGilly (1989) have combined videotape recordings with immediate retrospective verbal reports in an attempt to reduce ambiguity by detecting instances of covert strategy use. This has resulted in higher estimates of strategy use than did overt behaviour alone (Siegler, 1991, p. 91-94) . Bruchkowsky (1991), a student of Case, used a video camera to record, from a distance of 3.7 meters, the facial expressions of her dimensional stage subjects during presentation of stimulus materials when examining the development of empathic cognition.

In her doctoral study, Schael (1994) combined videotaped records and verbal reporting. By using a novel table of observation, Schael was able to record, up close, in precise detail, each movement made by each of the Grade 8 and Grade 10 subjects as they produced "rough copy" while solving mathematical word problems based in geometry, distance, and inclusion. A unique feature of her methodology was that the graphics made in the course of problem-solving and the subject's body movements and facial expressions were superimposed and presented on a single screen when recorded, so that error analysis, eye movement analysis, and protocol analysis were possible simultaneously. By studying the videotaped recordings of each subject during the problem-solving process, the transcripts from the verbal report, and the photocopy of the graphics produced as "rough work" while searching for a response to the problems, Schael was able to identify and interpret, within the mental model proposed by Holland, Holyoak, Nisbett, and Thagard (1986), the inductive reasoning strategies used by individual subjects while resolving mathematical problem of time, space, and inclusion.

In order to focus on strategies used during invented spelling production, a means of "zooming in" concurrently on the alphabetic script in production, hand movements, and facial movements and expressions during the writing episodes was required. To facilitate detailed study of the nuances of alphabetic knowledge in production, freedom from the mirror image normally produced by the camera lens was desirable. The table of observation used by Schael (1994) provided a means of filming, up-close and without inversion or reversal, alphabetic data during production , and the image of the problem-solver's hand, eye, and facial movements during the writing episodes, while, at the same time, collecting the subjects' most minute verbal utterances. Consequently, all three data forms could be collected concurrently and preserved for microscopic examination at a later time. The use of this apparatus appeared most promising for examining the production of alphabetic data by five- and six-year-old children.

Materials and Apparatus

The observation table constructed for data collection in Schael's study, was used to collect data. Video protocols, verbal protocols, and graphic productions were recorded concurrently and examined concurrently for each of the ten DST words as they were produced in invented spelling by each subject in each of three data collection sessions. Subjects wrote on prepared acetates, rather than on paper, to facilitate the videotaping. A description of the Dionne observation table and the developmental spelling test acetates follows.

The Dionne Observation Table

The Dionne observation table, the innovative apparatus designed for use in Schael's (1994) study, is illustrated in Figure 2. It provided the means through which alphabetic information could be recorded close-up, free of the inversions and reversals that normally result from filming. The letters being written and the subject's facial and hand movements during production were videotaped on a single screen as data to be analyzed. A tape recorder with a high intensity microphone attachment, which was integrated into the system, recorded verbal data. Transcriptions of verbal protocols created a second data form. Photocopies of invented spelling scripts were analyzed, triangulating the data.

The Dionne table was constructed as a sloping, Plexiglass topped writing desk attached to a wooden frame and possessing peripheral appendages -- a mirror, video camera and tripod, a video monitor, and a tape recorder with a high intensity microphone (see Figure 2). The mirror, which could be tilted on its wooden base mount, was placed on the floor under the Plexiglass table top. The video camera, suspended upside down

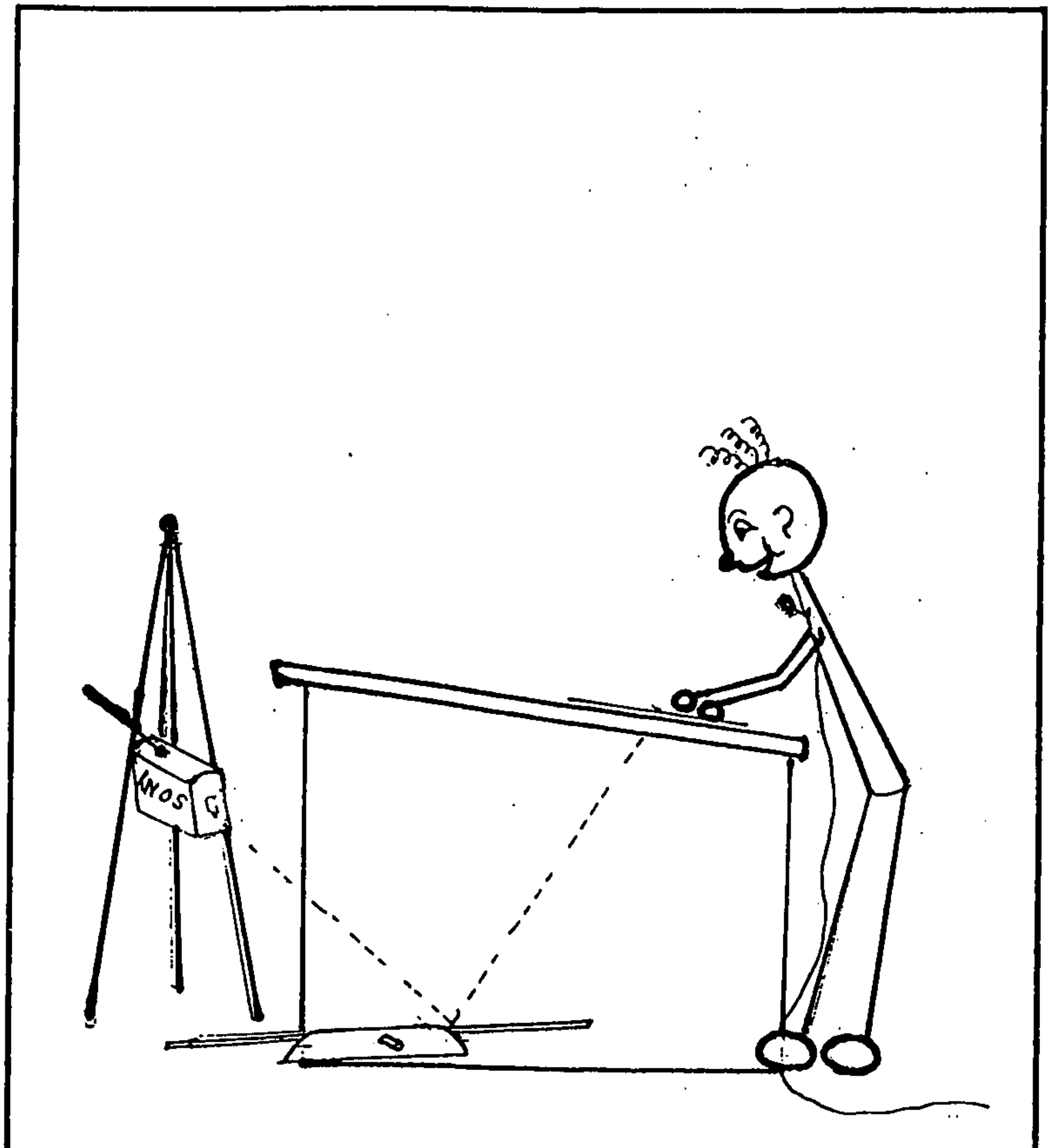


Figure 2. Diagram of the Dionne Observation Table.

from the tripod, was placed in front of the high side of the table, so that the camera lens, when focused between the tripod legs, targeted the mirror under the table. The camera was attached to a video monitor so that the researcher knew exactly what was being recorded. The subject stood or sat behind the lower side of the table to write on a prepared acetate. The high intensity microphone, leading from a tape recorder, was attached to the neck area of the subject's clothing. The focus of the camera and the tilt of the mirror were strategically aligned, so that, by placing an acetate sheet on the Plexiglass table top, the script in production was photographed, together with exact and detailed body movements, and projected on to the video screen. The details of all activity of the writer's head and hand during the invented spelling process were superimposed with the writer's response during production. Non-verbal data, such as facial expressions and eye and hand movements, visible only in rapid generality in face to face pupil/ teacher interactions, were recorded with precision and detail, along with the script being produced on the Plexiglass table top. By copying the camera tape to a VCR tape, the data was preserved for repeated review, examination, and intensive study.

<u>The Developmental Spelling Test Acetates</u>

For her work with kindergarten subjects, Tangel (1991) had adopted the one-word-to-a-page format used by Ball and Blachmann (1991). Her first grade subjects wrote all words on a single prepared answer sheet with numbered lines. For consistency over test administrations, the one-word-to-a-page format was used throughout the three data collections in this research. This format placed the emergent writer in a situation conducive to larger letter making which was optimal for study and interpretation of the spelling process from videotape. Tangel's tasks were photocopied on overhead acetate as shown in Figure 3. A model alphabet, printed in lower case script toward the top of the acetate, provided a visual reference to the problem-solver. A single line drawn across the middle of

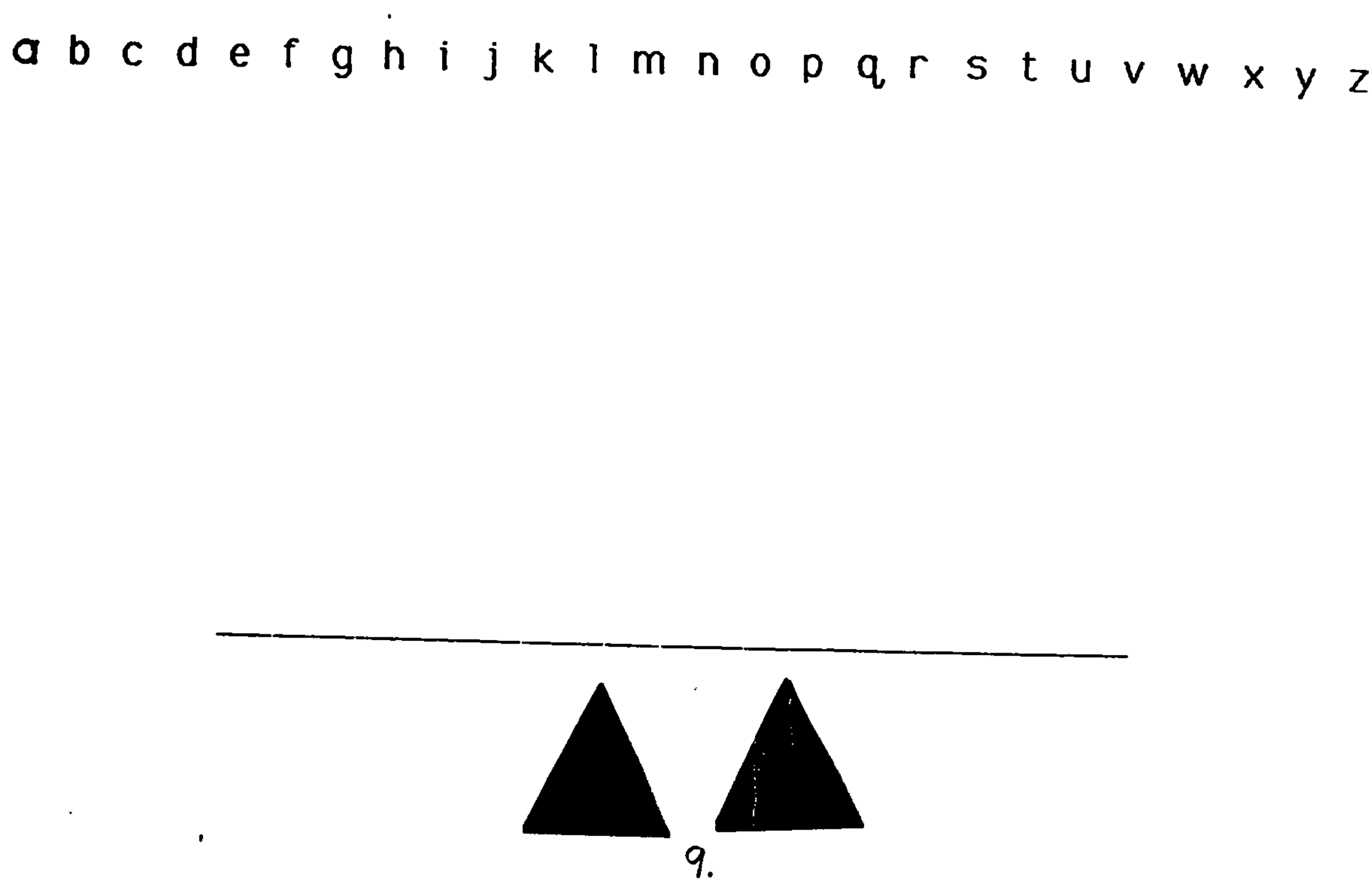


Figure 3. Acetate for the ninth word of the Developmental Spelling Test. Adapted from Tangel (1991).

the acetate designated the space in which the target word should be written. For easy identification by young subjects who might not recognize numerals, one or two triangles, squares, circles, stars, or trees were used to differentiate the acetates.

Medium tipped washable markers replaced pencils. Eight sets of 10 DST acetates plus two blank acetates and an extra prepared acetate to be used during the warm-up period were pre-packaged for use with the eight subjects in each of the schools. When completed, these were photocopied, washed, and used again in the next school.

The Production Task

The 10-word developmental spelling test (DST), designed and validated by Tangel (1991) to describe and analyze invented spelling development on a 7- point rating scale, was selected for use as a simple goal task. The DST was designed to deal with the less sophisticated responses and intrusions that often appear in the spellings of young children, and which would have been considered unscorable previously. Rating scales used to analyze the development of invented spelling prior to Tangel's work (Beers, 1974; Gentry, 1977; Beers, Beers, and Grant, 1977; Beers and Henderson, 1977; Morris and Perney, 1984; Liberman et al., 1985; Mann et al., 1987) had failed to sufficiently differentiate the many nuances in development of emergent spellers during the preliterate and early letter name periods. For the present research, the most precise and elaborate scale of progression available to rate invented spellings subjects operating within Preliterate, Letter Name, and Within Word Pattern stages (Henderson, 1990) was required as a framework within which to analyze development of word knowledge.

The end of kindergarten, midyear Grade 1, and end of Grade 1 data collection points used in the development of the DST provided an appropriate time structure within which to examine growth over time. Tangel (1991) had administered a 5-word DST in the final month of kindergarten, a 6-word DST in February of first-grade, and a 10-word DST in May of first-grade. The three tests were cumulative in their design in that five target words were written at the end of kindergarten, a sixth word was added in the test administered in February of first-grade, and four additional target words were added in the May of first-grade, resulting in a 10-word test. To measure growth over time, the problem-solving situations must remain constant in all test administrations. Tangel's 10-word DST was selected for use in all three data collections to ensure that the target words were sufficiently challenging to require strategy construction in inventing spellings for at least some target words. Tangel's DST offered both precision and reliability in rating invented spelling over the one-year-period spanning end of kindergarten through end of Grade 1. The detailed scoring criteria of the DST provided a strong framework within which to specify the data driven problem-solving components. Through microgenetic study of invented spelling in production, cognitive control structure strategies used in creating the graphics would be identified.

Tangel (1991, p.54) has stated that the prescribed target words in the 5-word DST, adopted from Ball and Blachman (1991), had been selected to represent the early developmental spelling patterns noted by Read (1971, 1986). The targeted spelling patterns were as follows: the spelling of short vowels (l<u>a</u>p, s<u>i</u>ck), the representation of the schwa (a vowel sound that is almost neutral as it is swallowed into the consonant) and consonant nasal (<u>el</u>eph<u>ant</u>), representation of the intervocalic tap (t) between two vowels (pr<u>etty</u>), the representation of the <u>tr</u> blend and the spelling of long vowels (tr<u>ai</u>n). In addition, the words elephant and train lent themselves to pictorial representation and offered a possibility to find out if children who could not yet spell would choose to draw a word instead. In the 6-word DST, subjects were required to write the same five words and a sixth word, <u>hunt</u>, added to determine whether children could represent the consonant nasal. (Tangel had found that although elephant did contain a consonant nasal, few kindergarten children represented any part of the final syllable. It was difficult to ascertain whether the length of the word or the consonant nasal was the problem). The four words added to the 10-word DST --kissed, street, order, snowing-- reflect later developing patterns: representation of morphemic endings (kissed, snowing), of a three-consonant blend (street), of a cvcc word pattern (kiss), of a long vowel pattern (street), of a vowel digraph (snowing), and of vowel plus r patterns (order) (Tangel, 1991, p. 54 - 56). The script for the 10-word DST is included as Appendix A. The detailed scoring criteria follow as Appendix B.

Tangel (1991, p.118) had established reliability for her 10-word test using interrater agreement (98.5%) for the responses obtained. Reliability for individual words ranged from .956 - 1.000. Concurrent validity was established between the 10-word DST and the WRAT-R spelling subtest measures. The Pearson correlation between the 10-word version of the DST and the standard score on the WRAT-R was $r = .85$, $p < .0001$.

The Pilot Study

Due to the innovative nature of the Dionne Observation Table, the amount of audio-visual equipment to be operated, and uncertainty surrounding the use of verbal reporting with 5-year-old and 6-year-old children, a pilot study was conducted to test the methodology (Hayes, 1993). An overview of the study and alterations in procedure resulting from the experience follow.

The objective of the pilot study was to determine if it were possible to use the Dionne Observation Table to differentiate, by grade, perceived ability, gender, and task difficulty, the problem-solving strategies used by kindergarten and Grade 1 children while inventing spellings for target words. During the month of February, two kindergarten girls, two kindergarten boys, two first grade girls, and two first grade boys from the same school were selected by their teachers. One pupil believed to be advanced in spelling development and one pupil perceived to be somewhat delayed formed each pair. The task was to teach a puppet how to spell dictated words by "thinking aloud" as they wrote the words. Following a training session on verbal protocols, children were asked to write the target words, dictated by the researcher from Tangel's 6-word DST script, and to think aloud so that the puppet could learn from them how to spell. The "keep talking" cue was used to encourage verbalization as the subjects wrote. All verbalizations were audiotaped and transcribed verbatim for analysis. Video recordings were copied to VCR (with back-up). The photocopies of subjects' scripts were analyzed using Tangel's 6-word scoring criteria. The verbal protocols were divided into word writing episodes, with the dictation of the target word and all activity surrounding its writing defining a single invented spelling episode. With pupil scripts and verbal protocols in view, VCR tapes were played and replayed, a single writing episode at a time. Gestures, facial expressions, eye and hand movements, and any other non-verbal cues were recoded by the researcher in point form. When superimposed, for each invented spelling episode, with the information provided in the verbal protocol, the data available for analysis was elaborated extensively, reducing the level of inference required for interpretation.

A one page summary of the test performances of each of the eight children across all test words was prepared. These summaries included the DST qualitative ratings as scored using Tangel's detailed scoring criteria for each test word, observations and perceptions about data driven knowledge, and detail noted about operations displayed across the words as problem-solvers decided what they would write. To consolidate the operations across subjects, the researcher prepared, by gender and ability, frequency tables describing categories of data related and cognitive control related operations. From the data related operations that emerged, categories were formed to describe growth in **letter form** (a focus in development during Henderson's preliterate stage), **consonants** (the major area of growth during Henderson's letter name stage), and **vowels** (the challenge during Henderson's within word pattern stage). Playing and replaying the videotapes a small segment of each writing episode at a time, the researcher carefully noted all verbal and non-verbal activity of each subject by word. Each body movement, facial expression, eye movement, and so forth was superimposed with vocalizations and sub-vocalizations of the verbal protocol transcript, so that each minute behaviour of the spelling activity was noted for each of the six target words written by each of the eight subjects. The operations which emerged were grouped into four categories which, within Case's (1991) framework, were interpreted as relative to cognitive control exerted during word writing of invented spelling: **response style, focus of attention, articulation of a plan,** and **memory**. The operations noted in the pilot study formed the basis for the scoring grids developed in the present research.

The pilot study revealed that the Dionne table was crucial to identifying problem-solving strategies used by kindergarten and Grade 1 subjects. The unique possibility to view eye movements, facial expressions, hand movements, and all other non-verbal movements on the same screen as the acetate DST response sheet while, at the same time, attending to children's vocalizations and sub-vocalizations produced data of extraordinary richness. While it was challenging to grasp all that was happening simultaneously and time consuming to interpret, the detail of data tapped using the observation table was unparalleled. The DST answer sheets and the verbal protocol scripts were valuable advanced organizers. The advanced pairing of visual and auditory hard copy directed the examination of behaviours in their minute detail from the videotapes.

As a result of the pilot experience, the researcher decided to make three alterations in the methodology for the present study:

1. The young subjects found it extremely difficult to talk aloud about their cognitive processes while producing invented spellings. The many reminders to "keep talking", designed to extract thinking processes during the writing episode, seemed to frustrate the young problem-solvers, and to produce little positive effect. As suggested by Siegler, the five- and six-year-old children in the sample clearly required the STM available to construct their strategies and to "draw" the letters needed. The frequent use of the "keep

talking" probe during writing would be replaced with retrospective probing immediately after the writing of each word. However, subjects would be taught "think aloud" protocol procedures in the warm-up phase, and the content of the concurrent verbal protocols (CVPs), produced without reminder during the writing episodes, would provide the basis of probes during the immediate retrospective debriefings (RDs) collected immediately after the writing episode for each target word.

2. The DST words would be dictated from a second tape recorder to eliminate the minor pronunciation differences experienced in the pilot. As noted by Read (1971, 1986), children in the earliest stages of invented spelling attend acutely to minor differences in sound. Tape recording the DST script would eliminate this complication.

3. Most information about use of cognitive control strategies was revealed when subjects were faced with tasks at the outer limits of their zones of proximal development (Vygotsky, 1978). Since the final data collection was planned for May of the Grade 1 year, the 10-word DST was considered most appropriate for use as a simple stable goal test for all sessions.

Population and Sample

Henderson (1990, p. 43) has written that the stages of word development have wide generality across methods of instruction, levels of intelligence, economic status, dialect, and even languages. However, Case (1991, p. 34-35) has suggested that, in addition to control structures, cultural and historical factors and instruction (both formal and informal) are specific aspects of development that account for considerable variability in growth through the stages of intellectual development.

To gain entry to the schools of the Western Quebec School Board, student records, teacher performance information, and information on family backgrounds and lifestyles were established as confidential to the school district and beyond the realm of inquiry for this study. Within this constraint, to minimize to the extent possible the influence of cultural, historical, and instructional aspects of learning when answering the research questions, the following precautions were established during the study design:

1. Control structures used in invented spelling were examined from the end of kindergarten to the end of Grade 1, so that the influence of instructional histories would be minimized. Within Case's framework for cognitive development, children in this age range are expected to be experiencing, or just having experienced, a major re-working in intellectual control structures, in transition from consolidation of thought from interrelational Substage 3 to the dimensional stage (1991, p. 366). In this process, the control structures underlying the progression may be characterized as proceeding through a sequence of levels, from consolidation of thought in the final interrelational substage, to unifocal, and possibly to bifocal thought in the dimensional stage (p.348).

2. The schools targeted for the study were chosen from among those who welcomed students from five to twelve years of age into environments in which pupils were learning to read and write only in English at kindergarten and Grade 1. An early French immersion programme was not an option for students in these school communities.

3. The three schools selected for the study were chosen to represent the diverse population of the school district--a large elementary school in a small community-oriented town drawing pupils from a geographically large rural area of the Ottawa Valley, a school in a "blue collar" area of the fastest growing city in Western Quebec, and a school in an elite bedroom community in the Gatineau Hills, housing senior management staff and members of parliament of Canadian federal government, hi-tech managers, consultants, university professors, doctors, lawyers, and other professionals. A sample of 12 kindergarten girls and 12 kindergarten boys was selected for gender and ability, then followed over a twelve month period. In May of kindergarten, four girls and four boys were identified by their teachers in each of three schools.

4. Good spellers and poor spellers were selected by each of the participating teachers. Based of their classroom performance on kindergarten writing activities, two boys and two girls believed by their teachers to be advanced in spelling development, and two boys and two girls perceived by their teachers to be delayed in this regard constituted the sample in each school.

5. Results were examined by ability and by gender for all schools as a single group rather than by school.

6. English was the mother tongue of all subjects selected for the sample.

The whole language curriculum mandated for the teaching of English language arts throughout the province formed the basis of an integrated approach to the listening, speaking, reading, and writing activities. How the prescribed curriculum was implemented appeared to vary with the belief systems of individual teachers. In each of the classes, it was evident that opportunities existed for subjects to interact informally with the printed word, and to use paint, crayon, modelling clay, plastic letters or letter cut-outs, pencils, markers, and chalk to produce invented spelling. From the researcher's very limited involvement in the classrooms from which the subjects were drawn, the way in which formal instruction in word related knowledge was conducted appeared to vary considerably from teacher to teacher.

Procedures

In May of the kindergarten year, meetings with the principal and kindergarten and Grade 1 teachers were held in each of the three participating schools to make explicit the study goals, procedures, and pupil and teacher roles and responsibilities during the current and next school year. The kindergarten teachers agreed to select the subjects and to obtain informed voluntary consent by taking the following steps:

1. Select from the total kindergarten enrollment of the school two children of each gender who they perceived, from their day-to-day observations and interactions, to be

advanced in written language ability, and two children of each gender who they perceived to be lagging in this regard;

2. Speak to parents of the selected kindergarten pupils, outlining the nature of the study and the role of the young student participant;

3. Talk to the children selected about participating in the experiment;

4. Send home the information letter and "consent to participate" and "permission to quote" forms (see Appendix C) prepared by the researcher for signature by potential subjects and their parents. The confidentiality of the participants' identities was guaranteed in these documents;

5. Collect these signed forms;

6. In the event that written consent to participate was not forthcoming from child and parent, repeat steps 1-5 until the eight places allocated had been filled.

Consent was obtained for all pupils selected. Two parents contacted the researcher for further information about the study. Both were highly supportive of their child's participation, but curious about the data collection procedure.

In each school, the Dionne apparatus was assembled in a private, quiet location assigned by the principal. After all attachments had been connected, the following equipment checks were made:

1. The camera was focused on the test acetate placed in recording position on the table top;

2. A test check was made of the high intensity microphone;

3. The DST tape was positioned to dictate the first target word;

4. The puppet was placed on the table top ready for introduction or renewed acquaintance.

During the individual kindergarten sessions, the researcher introduced the puppet and the equipment. Subjects were given the opportunity to play with Wrinkles, to see themselves in action on the television monitor, and to discuss the equipment at their levels of interest. They were introduced to the word writing tasks at the Dionne table in the following progression:

1. Subjects were encouraged to write words they knew (their names, names of others in the family, friends' and pets' names etc.) on a blank acetate with the medium tipped washable marker provided, and to view their actions on the monitor as they worked.

2. As protocols training, subjects were asked to show and tell the puppet how they would write potentially known words, such as hat, pig , Dad, Mom, and then a more challenging word, such as donkey. The prompts,"Tell Wrinkles what you're thinking", "Tell Wrinkles", or "Think aloud" were given as necessary to encourage verbalization. As soon as the subject had completed the writing of a word, an immediate retrospective was solicited using prompts based on the content of the concurrent verbal account. If the subject had produced little or no verbalization during the writing, the researcher promoted verbalization by statements such as, "Tell Wrinkles how you chose those letters", "Wrinkles wants to know about your choices", or " Tell Wrinkles about it". The researcher probed based on responses given. Dictation of warm-up words, with prompting to promote concurrent verbalization, and with probing during retrospective debriefing continued until the subjects demonstrated ability to reveal verbally the strategies underlying the choices they had made.

3. A DST acetate was introduced. After discussion about the nature of the sheet, researcher dictated a word, in context, in the following manner: "Cat. . . . Wrinkles would like to chase a cat . . . . . cat". Subjects were asked to write only the word "cat" on the line and to think aloud while doing so. During immediate retrospective debriefings, a rationale for specific choices made was sought, if not already provided.

The training session was followed immediately by taped dictation of DST words. Before setting the recorder in motion, the researcher quickly performed the following operations, in sequence, to ensure that all equipment was activated:

1. Checked to ensure microphone was attached to neck area of subject's clothing and that switch was in "on" position;

2. Turned on the tape recorder to which the microphone was attached;

3. Turned on the video camera;

4. Turned on the DST tape recorder.

After each word was dictated in context, the tape recorder was put on "pause", allowing as much time for writing and debriefing as the subject required . Then acetates were exchanged and the researcher set the DST tape set in motion for the next target word. All other equipment continued to collect visual and verbal protocols. When all 10 DST words had been written, the completed acetates were returned to their storage envelope, the packet for the next candidate was located, and the equipment was given a four-point check as outlined on page 76, in preparation for the next candidate. This procedure continued until all subjects in the school had been recorded.

Data Collection and Preparation

Data were collected in individual sessions with each of the 24 pupils during June 93 of the kindergarten year, then again during the first week of February 94 and the last week of May 94 of the Grade 1 year. Two days were required in each school for the first data collection; one day was sufficient for the second and third data collections. The kindergarten warm-up took longer because subjects required time to become familiar with the equipment and to learn verbal protocol procedures. Only a few practice words were required to review procedures during warm-up in the grade one data collection sessions. Otherwise, data collection procedures were identical in all three sessions. Recording was completed in all three schools in each of the three sessions within a seven day span. The sequence of schools was rotated over the three data collections; the sequence of subjects within the schools was decided by their teachers.

In preparation for the analysis of data, completed response acetates were photocopied, and copies stapled together to form a DST response booklet for each subject. The acetates were washed, and repackaged for reuse in the next data collection session. DST booklets were scored using the 7-point rating scale developed by Tangel (1991), included as Appendix B. A single page summary of total scores was compiled. Audiotapes were transcribed verbatim in real time in short line format to accommodate the analysis process. For easy reference to data, lines were numbered consecutively by subject and session and transcripts were partitioned into word writing episodes, with target word and all activity surrounding it forming a single word writing episode. Audiotapes and transcripts were stored until all data over the twelve month period had been processed. Videotapes were copied to cassettes (with back-up), labelled by school and session, and stored until all data had been collected.

Data Analysis

Only the protocols of the 19 subjects with data complete for all three sessions were analyzed. To reduce bias of ability and time, visual protocols for three data collections of 19 subjects were recopied into a single random string of 57 visual protocols by drawing of lots. DST booklets and verbal protocols were packaged together and numbered in sequence coordinated with the videotapes. The data in written form were used as advanced organizers and for confirmation during and after the playing of the videotape episodes. Excerpts of the tapes were replayed as required to abstract the behaviours displayed by the subjects. These behaviours were added to the coding grids under development by the researcher to facilitate, elaborate, and explicate the data analysis. Examples of verbal protocols from a strong speller and a weak speller used as advanced organizers and as points of reference during the viewing of the visual protocol and subsequent completion of the protocol analysis form are included in Appendix D. Although an initial independent reading may suggest little information of value to the interpretation of cognitive processes, when read immediately before viewing the videotape. the transcripts proved to be highly valued resources by placing the action in context during the viewing, and by directing attention during the video watching. With a hardcopy of verbalizations in hand, more working memory space could be devoted to the non-verbal action. The transcript became an excellent point of verification for "what one thought one had seen" before replaying a segment of the visual protocol and were most beneficial during the coding of protocols of weak pupils, who, on occasion, provided responses that initially appeared to be unrelated, or to make little sense to the viewer.

The Development of Coding Grids

Newell and Simon (1972) have stressed the important contribution of data itself on the development and elaboration of the coding grid. During the pilot, categories of behaviours had been defined to reflect the content of the protocols analyzed and the literature. Data related operations noted when viewing the videoclips categorized compatibly with the framework described in Henderson's (1990) first three stages of word knowledge. Development and elaboration of cognitive control related operations evolved from observations made during repeated viewing, an episode at a time, using verbal protocols and DST response booklets for advanced organization and verification. Cognitive control operations were identified by transcribing from repeated replay of the videotapes all verbal and non-verbal behaviours displayed by the subjects in the process of inventing spellings, and then grouping together similar operations. The operations categorized in the pilot served as the base for grid development. These were modified, extended, and elaborated to accommodate the new data related and cognitive control related behaviours that became evident from the administration of the 10-word DST over the longer time frame spanning end of kindergarten to end of Grade 1. The first 10 of the string of 57 protocols were scrutinized as in the pilot study to extend the operations identified in the data related and cognitive control related frequency tables created during the pilot, and to transform these into a coding grid. Each operation used in the spelling process was identified and defined, then a prototypical instance and non-instance were provided. The draft grids created were reviewed by a team consisting of a primary teacher, an elementary school principal, and a language arts consultant. Some operational definitions were tightened for precision and clarity. The evolution of the categories during grid development will be discussed under separate headings for data related and cognitive control related operations.

Data Related Operations.

Modifications were made in each of three categories that had emerged during the pilot-- **letter formation**, **consonants**, and **vowels** -- and the new category, **meaning**, was added. In the **letter form** category, five writing operations describing letter formation and spatial representation were maintained. The "carefully formed" operation was eliminated as it appeared to integrate more appropriately into the response style grouping of cognitive control operations. In the **consonant** category, word specific operations were rephrased to generic form. Correct initial consonant blend, phonetically correct initial consonant blend, correct consonant nasal, and correct three-consonant blend replaced the former word specific indicators. The **vowel** category required greatest modification due to the extent of vowel usage evident in development over time on the 10 word DST. To portray the sequence of vowel and vowel patterns as described by Henderson (1990), 14 operations were identified. The new **meaning** category required to accommodate the operations tapped by the target words kissed and snowing contained only two operations--use of -ed and use of -ing. A condensed version of the Coding Grid for Data Related Operations consisting of the coded behaviours and their operational definitions is presented in Appendix E. The single page summary form, DST Data Analysis Form, used to code the 57 protocols is included as Appendix E-1.

Cognitive Control Related Operations.

Automatic production was added to the four categories identified in the pilot-- **response style, focus of attention, articulation of a plan**, and **memory**. This new category surfaced when subjects were observed producing within word patterns and whole words "all in one piece". It became clear that such subjects had developed whole word production and/or within word pattern production, as well as the ability to recall and produce individual letters without prompting, cueing, or memory processing. Consequently, automatic production of letters, of within word patterns, and of words were the operations identified for coding. With the addition of **automatic production** immediate recall of letter form became redundant to the **memory** category. The remaining **memory** operations were regrouped and elaborated to reflect specifically the type and role of verbal and non-verbal behaviour exhibited. An additional behaviour was added to account for references made by subjects to previous knowledge/ experience. The five operations forming the **articulation of plan** category were maintained with only minor rewording. The **focus of attention** category was redesigned, so that the two operations identified during the pilot study were regrouped into three more definitive behaviours: selective attention to detail, attention to entire task, uninterrupted concentration on task. The three operations in the **response style** category were preserved, and two operations describing orthodox movement in letter making and interruptions to the taped dictation of the target words in context were added. A condensed version of the Coding Grid for Cognitive Control Related Data consisting of the coded operations and their definitions is presented in Appendix F. The single page summary form, DST Cognitive Control Analysis Form, used to code the 57 protocols follows as Appendix F-1.

The Coding Procedure

Although the coding grids were designed to require a low level of inference in coding data, the coding of visual protocol data always involves some level of inference in interpreting problem-solving behaviour. For this reason, the reliability of the coding process was assessed. To establish an index of reliability for the categorization scheme, the coding grids were presented to two independent judges who were trained to apply the grids to the protocols. A lengthy series of orientation sessions (12 hours 15 minutes over four meetings) was required to reach the desired level of intercoder reliability (.9 for each target word).

After providing a theoretical overview, presenting the coding grids, and discussing all of the categories, the researcher led the judges through a cooperative exercise of coding a complete protocol, a target word at a time, using the data related grid, then the cognitive control related grid. As a result of the discussion generated, two operations (correct and phonetically related initial schwa) were added to the vowel category of data related grid. As further training, three additional practice protocols were coded independently, in the same room, with discussion after each protocol.

When using the data related grid, the coefficient of agreement on individual DST words between two judges coding independently ranged from .719 to 1.00 and among the three judges from .688 to .938 . Overall agreement was .916, .928, and .903 between pairs of judges and .866 among the three judges. When using the cognitive control related operations grid, the coefficient of agreement on individual DST words between pairs of judges ranged from .833 to 1.00 and among judges from .833 to .958. Overall agreement was .942, .966, and .908 between pairs of judges and .908 among the three judges. When the differences in coding were analyzed, it became clear that discrepancies when using the data related grid were frequently the result of errors made in coding invented spellings provided as examples of instances and non-instances of the behaviour. The judges concluded that the difficulty of the task was primarily the result of trying to apply an overwhelming amount of coding information (56 identified operations across two grids) before automaticity in coding had been developed. To develop automaticity as quickly as possible, the judges suggested dividing the task into more manageable sections by coding all the required protocols using the cognitive control grid (24 operations), then coding the same protocols again using the data related grid (32 operations). This suggestion was taken. After coding three practice protocols, the overall level of agreement reached 1.00, 0.997, and 0.992 between two judges and 0.997 among judges for the cognitive control related operations grid and 0.997, 1.00, and 0.997 between two judges and 0.997 among three judges for the data related operations grid.

Six additional protocols from the random sequence (#11-#16) were coded independently in the same room, and a check for slippage in intercoder reliability was conducted after the third and the sixth of these protocols. The coefficient of agreement for the third protocol was calculated at .963, .983, and .946 between two judges and .946 among three judges for cognitive control related operations and .988, .988, and .981 between two judges, and .978 among three judges for data related operations. The extent of agreement on the sixth was calculated at .950, .979, and .954 between two judges and .942 among three judges for cognitive control related behaviours and .988, .991, and .981 between two judges and .981 among the three coders for data related operations. These results suggest that a high level of credibility was maintained throughout the six independently coded protocols for both coding grids.

The researcher coded the remaining Protocols (17-57) independently. As a check for slippage in the application of the coding grid, Protocols 17-22 were re-coded after Protocol 36 and after Protocol 57. The mean agreement between these codings was .984, demonstrating that little slippage had occurred. The first 10 protocols coded to develop the grids were re-coded using the grids as revised. Examples of coded analysis forms of a strong speller and a weak speller at June 93, February 94, and May 94 may be reviewed in Appendix G. Individual differences in use of operations between a strong speller and a weak speller are evident in the coding as are changes in use of individual operations by the same subject over the June, February, May sequence.

Frequencies of data related and cognitive control related operations were tallied and frequency tables were prepared to describe operations by gender/ability groups, changes for the group as a whole over time. the progression of ability groups over time, and the strategies progression by gender over time. As the sizes of the groups varied, all frequencies were converted to relative frequencies for purpose of comparison. These will provide a framework for discussion of the results in the next chapter.

The magnitude of the data generated by the 19 subjects over three data collections necessitated careful selection and sequencing in order to present results in a manner that reflects both the specificity and individuality in quality of responses and a general overview of the productions for the strong and weak groups and for the group as a whole. To this end, when all protocols had been coded, a single page synopsis of each subject's data related and cognitive control related behaviour was prepared in point form, compiling DST scores, frequency of operations by category over three data collections, and summaries of data related and cognitive control related changes in operations over time. The synopsis format was designed to condense the expanse of information gleaned from the three data sources to a skeleton of highlights describing growth over time, yet maintaining focus on subjects as individuals. The single page summaries were then grouped by ability/gender group so that patterns of data related and cognitive control related operations of individuals could be examined within reference groups. From these single page summaries, an individual case study from each of the ability/gender groups was selected for presentation in the text of thesis results. Examples of single page summaries are included as Appendix H.

Limitation of the Study

A major limitation of the proposed study was the necessary restraint in sample size due to time required for data analysis. In the pilot study, with one administration of the 6-word DST, time per subject for data collection and analysis ranged from 6 hours to 12 hours. A 10-word test was expected to increase the time range to 10 - 20 hours, or an average of 15 hours per subject per administration. With the potential for 72 protocols, (24 subjects and 3 administrations), it was clear that the time investment would be considerable.

Although there were only 57 rather than the potential 72 protocols, and although the researcher's proficiency in applying the coding grids improved with practice over time, the data analysis process proved time consuming as expected. The extensive amount of time (26 hours) required to establish a coefficient of reliability for the coding grid had not been anticipated. Because training of judges had not been calculated accurately, scheduling difficulties resulted in a lengthy coding interval.

CHAPTER 5

PRESENTATION AND INTERPRETATION OF RESULTS

The research objectives for this exploratory study of children's problem-solving are focused primarily on achieving a better understanding of the cognitive strategies used by girls and boys of strong and weak ability when confronted with the problem-solving task of inventing spellings for dictated words. To achieve this objective, the participants were assigned the task of inventing spellings for 10 target words on acetates placed on the surface of a specially designed observation table. The written responses, the verbatim transcripts, and the videotapes of word writing activity in progress over three data collection times formed the data base for each of the participants. Data related and cognitive control related analysis forms were completed during the video analysis to code existence or non-existence of each operation defined during the grid development at each of the data collection times for each target word. The density and richness of data obtained provided various avenues for exploration at different levels of depth and complexity.

To introduce the reader to the research results, a quantitative overview of the developmental spelling test scores will precede a qualitative assessment of strategies used. Samples of the target words invented by a strong ability subject and a weak ability subject will be presented and discussed. Against this background of information, each of the research questions will be discussed and interpreted. A brief summary will conclude the chapter.

Overview of DST Data and Research Questions

The descriptive statistics for DST scores by gender and ability over three data collections are presented in Table 7. Because the sample size is small (19 subjects), these statistics should be regarded as an overview and orientation to the results, a preparation for

Table 7

Descriptive Statistics for Developmental Spelling Test Scores by Gender and Ability

Time	Gender- Ability	N	Mean	S.D.
June 93	Girl- Strong	5	41.40	3.72
	Girl- Weak	6	18.17	10.80
	Boy- Strong	5	42.00	3.81
	Boy- Weak	3	10.67	9.50
	Total Strong	**10**	**41.70**	**3.57**
	Total Weak	**9**	**15.67**	**10.46**
	TOTAL	**19**	**29.37**	**15.28**
Feb 94	Girl- Strong	5	51.20	3.27
	Girl- Weak	6	33.17	15.08
	Boy- Strong	5	50.80	6.83
	Boy- Weak	3	30.67	23.18
	Total Strong	**10**	**51.00**	**5.06**
	Total Weak	**9**	**32.33**	**16.73**
	TOTAL	**19**	**42.16**	**15.10**
May 94	Girl- Strong	5	56.60	2.70
	Girl- Weak	6	36.33	12.72
	Boy- Strong	5	54.60	4.72
	Boy- Weak	3	42.33	14.84
	Total Strong	**10**	**55.60**	**3.78**
	Total Weak	**9**	**38.33**	**12.86**
	TOTAL	**19**	**47.42**	**12.61**

the presentation and interpretation of specific cognitive strategies identified in the coding of the visual and verbal protocol data, rather that a firm interpretation of test scores.

Results conform to observations in the literature and are congruent with expectations. Mean scores increased for each of the ability/gender groups over the three data collection times. Strong ability groups scored higher than weak ability groups across all three data collections. Increases for each of the four ability/gender groups and for the total group were greater during the June 93 to February 94 interval than during the February 94 to May 94 interval. Growth over time was greater for weak ability subjects (16.66 and 6.00 point differences in mean scores over the two intervals) than for strong ability subjects (9.30 and 4.60 point differences in mean scores over the two intervals). This growth difference between intervals is not surprising. Because both strong ability groups achieved mean scores above 50 (on a possible score of 60) by the February test, a saturation effect may have limited increases for high scoring subjects between February and May.

Within Case's (1991) framework, it would appear that, during the June to February interval, all groups were in the process of experiencing the period of major reworking expected for five- and six-year-old children. It is possible that the strong ability subjects were emerging during the first interval from the period of major reworking described by Case, while the weak ability subjects were entering the growth spurt period.

The standard deviation was larger for the weak ability groups than for the strong ability groups throughout the research. Variation was most extreme for weak boys, a sample of three subjects, each of whom produced very distinct profiles.

An analysis of variance with repeated measures on time was conducted to determine the source of variation between and within groups. Results are reported in Appendix I. No significant difference was found by gender. A significant difference was found between the DST test mean scores of strong and weak ability groups ($\underline{F} = 22.14$; df = (1, 15); $\underline{p} =$

.000). No significant interaction effect was evident between gender and ability. Significant time effect ($\underline{F}$ = 70.25; df = (2, 30); $\underline{p}$ = .000) was observed. The interaction effect between gender and time was not significant. The interaction effect between ability and time was significant ($\underline{F}$ = 5.83; df = (2, 30); $\underline{p}$ = .007). The interaction effect between gender, ability, and time ($\underline{F}$ = 2.94; df = (2, 30); $\underline{p}$ = .068), was not significant at the .05 level of significance.

To examine the interaction effect of the time variable on the ability variable, a graphic representation was prepared. As shown in Appendix J, the lines on the graph appear to be nearly parallel. While the two patterns of growth over time for strong and weak students look somewhat alike, the pattern displayed by their means varies. Mean scores for strong ability subjects differed from June 93 to February 94 by 9.30 points and from February 94 to May 94 by 4.60 points. Mean scores for weak ability subjects differed from June 93 to February 94 by 16.66 points and from February 94 to May 94 by 6.00 points. In the first interval, the differences between ability group means was 7.36 points; in the second interval, the differences between ability group means was 1.40 points.

With this quantitative overview as background locating the reader within the context of the data, the four process related research questions outlined in Chapter 3 will be discussed, and the data resulting from the investigation of the research questions will be interpreted. In review, the four process related research questions to be studied are:

1. What are the operations by gender of strong spellers and weak spellers?

2. How do the operations used change over time?

3. Are there differences in progression of operations between strong spellers and weak spellers?

4. Do the operations of boys differ from the operations of girls over time?

Discussion of these questions will be based on information obtained from the application of the coding grids during visual protocol viewing, from pupil response sheets, and from verbal protocols. Although there was no statistical difference in DST results by gender, gender related questions will be discussed. It is possible that there are differences in processes generating the products.

Operations by Gender of Strong and Weak Ability Spellers

To orient the reader to the similarities and differences in responses collected from strong and weak ability subjects and to develop familiarity with the operations coded, the invented spellings produced by a strong ability speller and a weak ability speller will be presented and discussed before the data produced by ability and gender groups is presented. As each subject is unique, no true prototype exists. The cases should be regarded only as examples to sensitize the reader to invented spellings produced by strong and weak spellers, to demonstrate the detail of operational data observed using the Dionne table (Figure 2), and to develop in the reader a familiarity with the operations coded in order to facilitate interpretation of operations by ability and gender groups.

Invented Spelling Sample from Strong Ability Girl

The 10 words as written by Hannah during the June, February, and May data collections are presented in Table 8. Although Hannah's invented spellings were unconventional for 7 target words in June, 6 target words in February, and 3 target words in May, all can be interpreted without difficulty from the phonetically related approximations produced. When Tangel's DST scoring criteria were applied, Hannah scored 46 in June (the second highest score), 52 in February (the fourth highest score), and 57 in May (the fifth highest score) of a possible 60 points.

Hannah wrote predominantly in capital letters at first data collection. Initial, final, and medial consonants were used in correct form in most instances, with an occasional miscue presented in phonetically related form. The phonetically related initial C was substituted for the initial consonant in kissed, and a T was introduced in medial position to

Table 8

Example of Responses of a Strong Girl Speller to 10-Word Developmental Spelling Test in June 93, February 94, and May, 94

June 93	February 94	May 94
LAP	lap	lap
SICE	Sike	Sick
PRTTY	pritty	pritty
ELEFIT	elefint	elephant
TRANE	trane	trian
HUNT	hunt	hunt
STRET	Strat	Street
CIST	Kissd	Kissd
ORTR	Order	Orden
SNOWING	Snowing	Snowing

Order of magnitude: June 93, 50%; February 94 and May 94, 90%

the word order. Two and three letter initial blends were produced correctly in Hannah's representations of pretty, train, street, and snowing. She wrote the consonant nasal correctly for hunt, but not for the three syllable word elephant. Hannah experimented with short and long vowel patterns with several successes (lap, elefit, hunt, cist, snowing), but with some confusion (sice, trane, stret). She made an attempt to mark the long vowel in "trane", but no attempt at long vowel pattern was evident in Hannah's invention of "stret". Instead, she produced an earlier stage sound/letter match. She wrote the initial vowel sounds in both elephant and order correctly and added the correct -ing ending for snowing. She wrote a phonetically related representation of the -ed ending by substituting the single letter T.

By February, Hannah wrote most letters in lower case form, although she sometimes used a capital letter as the first letter in a word. She wrote all initial letters, eight final letters, and all consonant blends and nasals correctly. The other two final letters were produced in a phonetically related form. She substituted a phonetically related medial F for PH in the word elephant. Hannah continued to experiment with vowel patterns, and produced short and long vowel patterns with great similarity to her June responses. She wrote the vowel followed by r sound correctly. Again, she produced a phonetically related intervocalic tap in "pritty". She continued to write the -ing ending correctly, but substituted the phonetically correct D for the past tense ending to her correct spelling of the base word.

In May, Hannah spelled seven words conventionally. Her letters were formed in a larger and more confident script. She chose the same invented spellings as in February to represent the intervocalic tap in pretty and the -ed ending in kissed. In her attempt to produce the long vowel pattern in train, Hannah wrote the two vowels in reversed order.

Hannah's use of data related operations could be interpreted directly from the invented spellings she produced, but few cognitive operations can be interpreted from written outcomes. Verbal protocols (Ericsson and Simon, 1993; Taylor, 1992) were collected to provide this information. Siegler (1991), however, had found that young children have great difficulty providing an account of their metacognitive thoughts during strategy construction. Inventing spellings for target words is a strategy construction process. The limited verbal information produced by Hannah during the kindergarten data collection is quoted here to illustrates the ability of this strong speller to elaborate her thought processes. In this excerpt, like all others that follow, T identifies the tape recorded script, S identifies verbalizations of the subject, and E identifies interjections by the experimenter. To differentiate letter names from letter sounds, in all transcriptions capital form is used to represent instances of letter naming and in lower case form is used to represent attempts at sounding out. A series of dots denotes a pause in verbalizations.

T: Lap. The baby was on her mother's lap . . . . . lap.

S: (Writes). . . . .

E: Tell Wrinkles what you're thinking.

S: L . . . . A . . . . P.

E: Tell Wrinkles how you chose those letters.

S: Because I sounded it out.

E: Show me how. . . Show him, too.

S: Cause I sounded an L and an A and a P. (Protocol 12, 1-8)

From the accompanying non-verbal data uncovered by coding the visual protocols (Blanchard, 1982; Schael, 1994), additional cognitive processing information became apparent. Hannah listened to the entire dictation of the target word with her eyes focused on the writing line of the acetate. As the tape recorder repeated the target word at the end of the sentence, Hannah's eyes moved upward to the right momentarily (an indication of visual imaging). Focusing again on the beginning of the line, she began to write the letter L in two movements (top to bottom, then left to right along the line). She kept her eyes focused on the line and her attention focused on her letter production. After a reminder from the researcher to tell the puppet her thoughts, Hannah named the letters she was producing, keeping her eyes focused on the line, and her letter making strokes slowly, smoothly, and definitively produced. The capital letter A was drawn with movement from bottom left upward, then from the apex down to the right to meet the line. Movement was from right to left as Hannah drew the horizontal stroke above and parallel to the line. To form the letter P, Hannah lifted her marker and began at the line to move perpendicularly upward beyond the height of the letter A, then drew a curve in clockwise direction to meet the perpendicular line approximately midway between top and bottom. Hannah's eyes shifted to the beginning of the line, she scanned her work from left to right, and then looked up at the researcher. When invited to tell Wrinkles how she chose the letters, Hannah continued to meet the researcher's gaze as she began letter naming. When the researcher touched the letters Hannah had produced as they were being named, Hannah looked momentarily at the A to which the researcher was pointing, then back at the researcher, while continuing to spell aloud.

Every detail of Hannah's non-verbal activity could be observed and noted in conjunction with her verbalizations. The researcher replayed the videotape word by word until all operational detail was exhausted. She completed the cognitive control analysis form recording use or non-use of each operation identified in the coding grid. From the brief writing episode described above, the following cognitive control information was extracted for her spelling of the word lap:

Automatic Production--Hannah produced letters, letter patterns, and the entire word automatically, without hesitation, without reference to the alphabet line, and without seeking environmental cues.

Memory--Hannah said letter names as she wrote, the result of probing from the experimenter rather than as a memory prompt. She retained the target word in retrospect.

Articulation of Plan--It was clear that Hannah's goal was to spell the word lap. She proceeded by selecting a letter at a time and recording these in sequence on the writing line. Self-monitoring was evident during letter writing and from the verification of the word written as Hannah ran her eyes along the word, left to right, after writing the word. A rationale for her choices was evident through correct spelling produced.

Focus of Attention--Hannah's attention was focused on task throughout the writing episode. She interpreted auditory detail from the taped dictation and selected appropriate letters to match the sounds she heard. She attended during the entire task, without interruption in concentration.

Response Style--Hannah did not produce her letters with orthodox movement. She wrote the first strokes of the letters A and P from the bottom up and made the third stroke of the A from right to left. She listened to the dictation of the word lap in context and the repetition of the target word without interrupting the tape to vocalize or subvocalize. She produced the three letters in rhythmic response style. She was thoughtful throughout the task production. Hannah's confidence was evident in her letter making movement, from her desire to look the researcher in the eye while letter naming even though the letters she had written lay before her on the acetate, and from her facial expression throughout the writing episode.

By May, Hannah could produce 7 of 10 target words automatically and "all in one piece". Her use of memory operations was reduced to only one instance of visual imaging over the 10 test words written. Goal setting, patterned sequencing, and self-monitoring continued to be used successfully throughout. Reference to previous knowledge and experience during immediate retrospective debriefings was evident for one target word in February and two words in May . Although not always able to verbalize it, Hannah was able to demonstrate a relevant rationale for her invented spellings at her level of thought at each collection point. Selective attention, attention to the entire task, and uninterrupted concentration of task were evident for each word during each of the writing sessions, as were uninterrupted dictation, rhythmic responses, thoughtful responses, and display of confidence. Use of orthodox movement increased from 0 words in June to 4 words in

February , and reduced again to 2 words in May. Clearly, letter form was not a priority in Hannah's otherwise neat productions.

Invented Spelling Sample from Weak Ability Boy

Wayne's efforts at inventing spellings for the target words are displayed in Table 9. Of all subjects in the research group, Wayne's growth over the year was greatest. His scores increased from 20 in June, to 46 in February, to 55 in May.

At the end of kindergarten, Wayne's letter formations were somewhat wobbly and uncontrolled. He produced letter reversals in 4 words, wrote only one letter for 5 words and two letters for 4 words, and produced 4 letters for the word elephant. All letters but K at the end of train and the symbol written at the end of pretty were phonetically related to the target words. He wrote correct initial letters in lap, sick, street, kissed, and order, and produced phonetically related initial letters for elephant, train, and snowing. The lone letter written to represent hunt was the correct final consonant. The correct final consonant was written also for sick. In Wayne's invented spelling of street, the phonetically related letter D replaced the correct final consonant T . He represented all three syllables of elephant with phonetically correct letters--AL represented the EL schwa, and the medial vowel A was substituted for the correct short E, and only the letter F (the dominant sound) represented the syllable -phant. Wayne's choices were thoughtful and data related rather than made randomly at whim. However, the data related information produced does not reveal the amount of effort Wayne put into his invented spelling products, how much more he knew than what he produced, or why he was unable to present more of the knowledge he possessed.

Verbal and video protocols of Wayne's work in progress provide much more detailed information. An excerpt from the verbal protocol during June production of the word lap, with non-verbal operations extracted from the videotape added within parentheses, are presented here to illustrate the quality of Wayne's productions. However,

Table 9

Example of Responses of a Weak Boy Speller to 10-Word Developmental Spelling Test in June 93, February 94, and May, 94

June 93	February 94	May 94
L	Lap	Lap
2K	sick	sick
P P	prite	prifey
ALAF	[illegible]	ELEfenant
TK	tran	train
t	[illegible]	hunt
2 d	stret	street
K	kist	kisst
O	odr	ordre
C	snowing	snowing

Order of magnitude: June 93, 50%; February 94 and May 94, 90%

this written format can in no way capture the empathy for the learner that is communicated as strategy construction is observed from videotape.

T: #1. Lap . . . The baby was on her mother's lap . . .

S: (Eyes on writing line, then upward to the right) l-l-l-l-luh- (Scans upward and to the left in space, then eyes scan alphabet line)

T: lap

S: (Eyes stop at the letter L) . . . L . . la- . . . la- . . . (Makes the capital letter L with stroke downward, then a line to the right) . . . . la- . lap (Eyes roll upward to right) . . . P. Where's P? (Eyes search alphabet line, then focus on left end of alphabet string as Wayne begins to sing, touching below letters with marker in tempo with voice) A B C D E F G H I J K (Looses one to one match, touch jumps incorrectly to N as voice continues letter naming) L M N O (Eyes move upward from acetate and focus in space as chant continues) P Q k-k . . . . k-k . . . . l-l-. (Stares into space) . .la- la- a- a- a- . . . p- p- . . . lap . . (Searches spaces upward and right while attempting to match sounds l-l-l- and k-k-k- , pronounces P) . . P. I need . . . P. . . . (Eyes to alphabet line and chanting begins again) A B (Starts over, this time successful in touching letters of alphabet line in one to one match with letter names) A B C D E F G H I J K L M N O P Q R S T U V W X Y and Z. (Eyes search left, right, left, right along alphabet line)

E: What letter were you looking for?

S: l-l-l- ap . . . . . P. (Eyes roll upward to right searches space, eyes down to line, left then right along line). There's no P in here. . . . (Shakes head, forehead puckers). There's no P. (Protocol 41, 2-12)

Wayne used touch, copying, repetition of the target word, visual imaging, letter naming, and sounding out in combination on most words in order to produce a spelling. His knowledge of the goal was always evident, as was his sequenced strategic plan for the first six words. By then, Wayne had had enough invented spelling, as reflected from his comments at the end of the writing interval for each of the following target words:

#7 street "I don't know any more." (Protocol 41, 126)
"Just one more" (Protocol 41, 132)

#8 kissed "I told Wrinkles, just one more!" (Protocol 41, 145)
"There's no more . . . . What! There's one more, two more!" (Protocol 41, 147-148)

#9 order "Ten. That's it! Ten, that's it! Right? (Protocol 41, 156-157)

Despite his lack of enthusiasm for continuing the task, Wayne attended selectively to detail and responded thoughtfully during his attempts at initial sounds for all words.

By February, Wayne wrote all letters neatly in lower case form, except for capitals placed at the beginning of lap and pretty. He wrote all initial letters correctly. He produced correct final letters for 8 words and phonetically related final letters for pretty (prite) and kissed (kist). The letter F replaced PH as a medial consonant in elephant. Wayne's two and three-consonant blends were correct , but the consonant nasal was not. He wrote some short vowel patterns correctly (lap, sick, kist), and use vowel/vowel substitution in others (eliftit, holt). He represented long vowels patterns by single vowel letter naming (prit<u>e</u>, tr<u>a</u>n, str<u>e</u>t), but correctly produced the long vowel pattern in sn<u>ow</u>ing. Wayne explained this spelling, "Um-m-m-, my class did something about um- . . . . ah- . . . . .a unit on snowing . . . . . so I know how to spell snowing. It's S N O W and I spelt there . . . . and then snow-ing, so I put -ing, I N G" (Protocol 51, 208-211). The -ed ending was represented by phonetically related T (kist). Wayne produced letters and letter patterns with automaticity. He used visual imaging (6 words) and sounding out (10 words) as memory prompts, and repeated one target word during writing. He remembered all words in retrospect and made reference to previous knowledge and experience in discussing five words during debriefings.

By May, Wayne spelled six words correctly. He chose correct initial letters for all words. He produced correct final letters for all words but kissed and order, for which he substituted phonetically related letters. He continued to write two- and three-consonant blends correctly and to substitute phonetically related F in medial position in elephant. Consonant nasals emerged in correct form. Wayne produced correct short vowel cvc and cvcc patterns and long vowel patterns, and the correct -ing ending. He continued to write the -ed ending as phonetically related T . Although spelled with an extra syllable, Wayne's strength of visual memory is suggested by his account of letter choices for the word elephant, "Well, elephant sounds like there's not another E, but there is. And and elephant, it sounds like el- la- fuh- in- tuh-, but it's A N T" (Protocol 29, 28-31).

Wayne wrote letters and letter patterns with automaticity on all words, and five words were written "all in one piece". He repeated the target word (9), used visual imaging (6), and sounded out (8) as frequent memory prompts, performing a range of one to three operations on any one word. He remembered all words in retrospect. He accounted for his letter choices by making reference to previous knowledge and experience during concurrent verbal protocols and debriefings on 7 words. While planning his response, he used goal setting, patterned sequencing, self-monitoring, and evidence of rationale for choices with 100 percent efficiency. Selective attention to detail, attention to the entire task, and uninterrupted concentration on tasks were observed during the writing of all words. Thoughtful responses produced with orthodox movement were characteristic on all word writing attempts. Wayne responded rhythmically and displayed confidence while writing spellings for 9 words. He interrupted the taped dictation to subvocalize initial sounds of the words kissed (Protocol 29, 62-65) and order (70-74). In addition to excellent development of letter form, consonant, and vowel operations, Wayne's automaticity in letter, letter pattern and word production, his efficiency in use of memory operations, planning operations, attentional focus operations, and response style operations all demonstrated a major developmental shift between June and February, with continuing growth and refinement noted from February to May. Wayne's growth in use of both cognitive control related and data related operations was exceptional.

To underscore the differing quality of invented spelling by ability, samples of invented spellings produced by subjects identified by their kindergarten teachers as a strong speller and a weak speller have been presented and discussed. The reader has had opportunity to develop an understanding of how a subject's use of data related and cognitive control related operations during the word writing episodes were interpreted from coding instances and non-instances of the various operations on the data analysis and cognitive control analysis forms. Patterns of operations across subject groups and over time will be the object of study as an attempt is made to answer the research questions, beginning with the most general question, "What are the operations by gender of strong and weak spellers"?

Operations by Ability/Gender Groups

For each question, data related operations and cognitive control related operations will be presented and interpreted. Frequency tables have been prepared to identify patterns exhibited in the process of writing the 10 DST words. As the groups for whom complete data was available were unequal, the results are presented as relative frequencies. Patterns have been discerned where there is a relative frequency difference of 25% across ability or gender groups. This 25% difference was selected by the researcher as a device to ease interpretation. Although characterized by a highly discriminating percentage, patterns are interpreted only as serious indications of the large observed differences in functioning between groups. The 25% span discriminates enough cases to make the study of growth by ability and gender interesting, while providing a standard for comparison of differences observed.

To identify operations by gender of strong and weak spellers, the information provided through the application of the coding grids to all 57 protocols (19 subjects with complete data over the 3 data collections) was considered. Relative frequencies of operations were calculated by dividing the number of instances in which each operation was observed by the number of trials on which the operation was possible. For data related information, the number of target words on which an operation could be performed ranged from one test word to all test words. The number of possible trials on which the operation can be performed is given in the table in parentheses immediately following each operation. Because all cognitive control operations were possible on all 10 test words, the number of possible trials is not indicated.

Patterns discerned on data related operations will be presented and discussed first. Presentation and discussion of patterns of cognitive control related data will follow.

Data related operations.

Relative frequencies of data related operations are reported for strong ability girls (SG), weak ability girls (WG), strong ability boys (SB), and weak ability boys (WB) in Table 10. Patterns are differentiated by ability and gender. Because kindergarten teachers selected strong (S) and weak (W) pupils, it is not surprising that ability patterns emerged for both girls (G) and boys (B) on many operations. There were only two instances in which gender patterns were found. The patterns will be discussed within the categories in which they were coded: **letter form, consonants, vowels,** and **meaning.**

No patterns of 25% or more difference were found by ability or gender on operations in the **letter form** category. For example, on writes in capital letters only, both strong girls and weak girls wrote only in capital letters on 6% of word writing trials-- a 0% difference by ability for girls.

Table 10

Relative Frequency of Data Related Operations by Gender of Strong and Weak Ability Spellers while Writing Developmental Spelling Test Words

Operation	Group				Pattern(s)	
	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Ability	Gender
Letter Form						
Writes capital letters only (10)	6	6	19	9		
Writes mix of capital and lower case letters (10)	45	62	47	44		
Writes lower case letters only (10)	49	33	35	46		
Writes reversed letter(s) (10)	1	16	0	13		
Writes inverted letter(s) (10)	0	4	0	0		
Consonants						
Writes letter string(s) (10)	0	22	0	30	B	
Writes phonetically related initial consonant (8)	100	75	100	67	G, B	
Writes correct initial consonant (8)	98	67	98	54	G, B	
Writes phonetically related final consonant (10)	95	55	90	53	G, B	
Writes correct final consonant (10)	89	49	83	48	G, B	
Writes phonetically related medial consonant (9)	90	53	88	44	G, B	
Writes correct medial consonant (9)	90	47	86	41	G, B	
Writes phonetically related 2-consonant blend (4)	77	33	88	42	G, B	
Writes correct initial 2-consonant blend (4)	75	31	83	39	G, B	
Writes correct consonant nasal (2)	77	25	73	11	G, B	
Writes correct initial 3-consonant blend (1)	60	11	67	45	G	W

(Table continues . . .)

Table 10 (cont'd)

Operation	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Pattern(s) Ability	Pattern(s) Gender
Vowels						
Writes with all syllables represented (10)	98	72	98	71	G, B	
Writes vowel/vowel substitution (10)	19	23	20	13		
Writes phonetically related initial vowel (2)	67	39	83	33	G, B	
Writes correct initial vowel (2)	63	33	79	28	G, B	
Writes phonetically related cvc pattern (6)	83	42	89	41	G, B	
Writes correct cvc pattern (6)	59	21	52	24	G, B	
Writes phonetically related cvcc pattern (5)	65	29	57	22	G, B	
Writes correct cvcc pattern (5)	41	9	36	13	G	
Writes phonetically related long vowel pattern (4)	63	28	62	36	G, B	
Writes correct long vowel pattern (4)	48	11	47	11	G, B	
Writes phonetically related vowel followed by r (1)	73	56	93	33	B	
Writes correct vowel followed by r pattern (1)	33	0	53	0	G, B	
Phonetically related intervocalic tap (1)	13	17	13	0		
Correct intervocalic tap (1)	0	11	0	0		
Meaning						
Writes correct -ing ending (1)	87	39	60	22	G, B	S
Writes correct -ed ending (1)	20	6	27	0	B	

Note. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing the frequency of occurrences of operation by the product of the number in the group and the number in parentheses ( ). Patterns can be discerned where there is a relative frequency difference of 25% or more cases between groups across ability or gender.

Legend. S = Strong W = Weak G = Girls B = Boys

Strong boys wrote only in capital letters on 19% of trials; weak boys wrote only in capital letters on 9% of trials. A difference of 10% was insufficient to discern a pattern by ability for boys. For patterns by gender, neither a difference of 13% between strong girls and strong boys, nor a difference of 3% between weak girls and weak boys was sufficient to discern pattern.

In the **consonant** category, all operations coded displayed a pattern by ability. A pattern by gender was discerned on only one operation--the three-consonant blend.

On letter strings, an operation negatively discriminating of ability (SG-0%; WG--22%;SB--0%; WB--30%), differences by ability of 22% for girls and 30% for boys were found. That is, a pattern emerged only for boys, and approached, but did not reach, the designated frequency difference for girls. Differences of 0% between strong groups and 8% between weak groups could not be considered patterns of large observed differences by gender. On 9 of 10 other consonant operations, patterns by ability were discerned favouring strong subjects over weak subjects for both girls and boys. For example, strong girls wrote phonetically related initial consonants on 100% of trials. Weak girls did so on 75% of trials. An ability pattern of difference of 25% resulted. Strong boys wrote phonetically related initial consonants on 100% of trials. Weak boys did so on 67% of trials. An ability pattern of difference 33% resulted. Differences of 0% for strong spellers and 8% for weak spellers did not produce a gender pattern. For the correct initial consonant operation, patterns of difference by ability favouring strong groups emerged for both girls (31%) and boys (44%).

For the correct three-consonant blend, a pattern by ability emerged for the girls only. This operation also produced the only pattern by gender for weak spellers, while strong spellers produced minimal difference in their performances. The results of weak boys are surprisingly high on the three-consonant blend operation, altering both ability and gender patterns from expectations.

The most highly discerning consonant operations were correct use of consonant nasals, phonetically related two-consonant blends, correct initial two-consonant blends, and correct medial consonants. The first three of these operations introduce letter patterns; the medial consonant is the latest one-to-one sound/letter correspondence operation to develop. Letter strings, phonetically related initial consonants, and three-consonant blends were least discerning. Operations which offered challenge to strong spellers produced greatest differences between ability groups; operations performed successfully by most subjects and operations which were difficult for all subjects produced fewer patterns of difference by ability.

Results across all four ability/ gender groups confirm the relatively orderly progression in development of consonant operations from letter strings, to initial consonants, to final consonants, to medial consonants, to consonant blends and nasals (Henderson, 1990). Excluding the negatively discriminating letter string operation, when frequencies are read down the columns, they are an approximation of descending order, with "phonetically related" operations found with slightly greater frequency than the "correct" counterpart on most "pairs". The trend in order of development of operations is the same for all four groups. This suggests that the earliest developing consonant operations present themselves one at a time, first as phonetically related approximations of conventional form, then transforming to correct usage with time and experience. This one at a time thinking, noted by Henderson (1990, p. 52, 56) as typical of Stage 2 letter-name spellers, illustrates also, within Case's (1991) framework, children's developing thought processes. During the unifocal substage of dimensional thought, children are able to focus on only a single qualitative dimension at a time. When inventing a spelling for the target word, they match letters directly to sounds. Emergence of correct consonant patterns (blends and nasals) demonstrates that young writers are advancing to bifocal thinking. They are developing the capacity to integrate two distinct precursor structures, each of which was already available, but each of which previously filled a different function--to integrate two or more known consonant sounds into a single blend or consonant nasal sound and to use both one-to-one matching and consonant patterns as required.

The data confirmed the findings of Hall, Gerber, and Stricker (1989) concerning the spelling development of poor spellers. Poor spellers use the same data related operations as good spellers, but progress through a developmental sequence at a slower pace. Consonants emerged as phonetically related approximations, and gradually refined to conventional form. Use of consonant patterns emerged as the one at a time thinking, and then, with development and experience, extended to bifocal thinking as children realized that two sounds blend to form a single blend or nasal consonant pattern.

Operations in the **vowel** category showed similarities to the consonant category in ability to differentiate between ability/gender groups, but differences in the developmental sequence of phonetically related and correct operations. Ability patterns were identified on all but three vowel operations--vowel/vowel substitution, phonetically related intervocalic tap, and correct intervocalic tap. Vowel/vowel substitution is unique to the vowel category in that it is a vehicle moving toward extinction with development. All other vowel operations, once developed, are maintained. Vowel/ vowel substitution emerges as a sound/letter name match (as for consonants), plays an introductory role in vowel development, then disappears as knowledge of within word patterns is acquired. Its absence does not necessarily suggest that pupils have not developed this operation. When studied within the context of other data related operations, it became clear that some strong ability subjects were outgrowing vowel/vowel substitutions at a time when some of the weakest subjects had not yet begun to recognize that vowels exist. The operation appears as awareness of phonetically related vowels and vowel patterns develops, then disappears as these refine to conventional form. Although of importance developmentally, a decontextualized frequency count is meaningless for this operation. The intervocalic tap, an advanced and difficult concept, was evident too infrequently in both phonetically correct and correct forms to denote a pattern.

Patterns were discerned by ability on all 11 remaining operations. Strong ability subjects performed the same vowel operations in greater frequency than weak ability subjects. Differences between strong and weak girls approached but did not reach the pattern criterion on phonetically related vowel followed by r. However, the greatest difference produced between groups was in use of this operation by boys. Phonetically related consonant /vowel/consonant operation and the correct initial vowel operation also produced highly discerning patterns. The least discerning pattern was the correct consonant/ vowel/ consonant/ consonant operation.

Vowel patterns by ability displayed a different developmental trend from the consonant operations. Consonant operations emerged in phonetically related form and refined to correct form sequentially (initial consonants, then final consonants, then medial consonants, etc.). Phonetically related vowel patterns appeared with greater frequency for all operations, then together gradually developed to correct form. This progression in use of vowel operations was the same across all four ability groups.

Once again, these results are not surprising when placed within the context of Henderson's (1991) Stage 3, within word pattern. Henderson (p. 56) has written that the pattern concept that children must master in the within word stage is far more complex than the direct matching plan of the letter-name stage. Particular letter groups must work as units in relation to symbol elements--a cognitive operation that requires relational thinking in contrast to one-at-a-time thinking. At this stage, word writing can no longer be considered as matching sounds one at a time, but as patterns of letters that must be seen in relation to elements of sound. Thinking must stretch from one-letter-at-a-time to patterns of letters, and to making sense of those patterns by noting similarities within situations in which those patterns are displayed. Over time and with experience using a variety of patterns, vowel patterns gradually and progressively refine to conventional form.

In Case's terminology, within word pattern operations emerge as children enter the bifocal substage of dimensional thought--as they learn to use more than a single dimension at a time in their thinking, and to integrate these dimensions as components of word structure. This is accomplished by experimenting with novel sequences, evaluating the results of the novel sequences tried, and restructuring the sequences to closer approximations of the goal objective. Growth occurs, not all-of-a-piece, but through a number of specific changes that occur within a general systemic constraint. Development of bifocal thinking is critical to development of within word patterns.

No pattern by gender was discerned on vowel operations for either girls or boys groups. Although high frequencies are observed, especially for strong girls and strong boys, differences between genders are insufficient to discern a pattern on any operation.

In the **meaning** category, differences in use of the -ing ending were identified by both ability and gender. Patterns were discerned by ability for both girls and boys. A pattern emerged also by gender, but only for the strong ability group. Strong girls produced the -ing ending correctly with very high frequency (87%), producing a difference sufficient to discern a gender pattern. As expected, the ed ending was used correctly less frequently by all four groups. A pattern was discerned by ability for boys only. Weak boys did not yet produce this past tense inflection, which requires an indirect match of letter pattern to sound pattern. Strong boys wrote the -ed inflection correctly on 27% of trials.

Henderson (1986, 1990) and Henderson and Templeman (1986) have written that invented spelling follows the course of three developmentally sequential principles--alphabetic principle, pattern principle, and meaning principle--and that there are few opportunities with young children to emphasize meaning. The plural marker -s is a direct sound/letter alphabetic match. The common inflection -ing is consistent in sound and pattern, and so, can be correctly spelled once recognized as a letter pattern. The correct use of the -ed past tense inflection marks the entry to the use of meaning pattern. Before this level is reached, the past tense is represented in a direct sound letter match represented by the letter D or the letter T at the end of the invented word. The alphabet principle requires a direct match of sound to letter. The pattern principle requires a match of sound to letter pattern. The meaning principle requires an indirect match of letter pattern to sound pattern. Meaning and pattern must be seen to take precedence over sound.

To function at the level of the meaning principle, a writer must be able not only to execute two operations in sequence, but to execute two or more operations in parallel and to integrate the product into a coherent system which functions as a working unit, that is, to have become capable of integrated dimensional thinking--Substage 3 in Case's mind's staircase. Weak boys had not yet developed this ability; weak girls were only beginning to do so.

Cognitive control related operations.

The relative frequencies of cognitive control related operations as coded for all 57 protocols are presented in Table 11. Patterns were identified by ability and gender. Patterns by ability emerged on 15 of the 24 operations. For 9 of these operations, patterns were discerned for both girls and boys. No patterns by gender were found. Cognitive control related operations will be discussed within the strategy categories amplified in the coding grid -- **automatic production**, **memory**, **articulation of a plan**, **focus of attention**, and **response style**.

Automatic production operations confirm the developmental progression of word knowledge described by Henderson (1990)--from automatic production of letters, to automatic production of letter patterns, to automatic production of words. Relative frequency for each of the ability and gender groups was found to decrease over the series of three operations coded. Henderson has underlined that much practice is needed before children can grasp the word object in the eye and mind and produce its elements smoothly, that children do not develop these early benchmarks by merely being told, and that they must practice to the level of automaticity through concrete experience with writing (p.46).

Table 11

Relative Frequency of Cognitive Control Related Operations by Gender of Strong and Weak Ability Spellers while Writing DST Words

Operation	Group				Pattern (s)	
	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Ability	Gender
Automatic Production						
Automatic production of letters	100	70	100	83	G	
Automatic production of letter patterns	89	39	85	42	G, B	
Automatic production of words	36	1	27	10	G	
Memory						
Touches	0	1	1	8		
Copies	1	43	2	43	G, B	
Repeats target word	29	49	27	66	B	
Visual images	34	83	35	72	G, B	
Says letter sounds	27	67	29	72	G, B	
Says letter names	10	30	1	33	B	
Refers to previous knowledge/ experience	3	5	10	12		
Knows target word in retrospect	100	77	99	81		
Articulation of Plan						
Goal setting	100	94	100	90		
Patterned sequencing	100	75	100	74	G, B	
Self-monitoring	100	79	99	72	B	
Self-correcting	9	7	11	8		
Rationale evident	100	70	99	62	G, B	
Focus of Attention						
Selectively attends to detail	99	82	100	84		
Attends to the entire task	97	57	97	59	G, B	
Uninterrupted concentration on task	99	78	99	76		
Response Style						
Orthodox movement	76	57	54	42		
Uninterrupted dictation	86	62	91	69		
Responds rhythmically	83	31	83	34	G, B	
Responds thoughtfully	100	79	100	74	B	
Displays confidence	98	62	99	39	G, B	

Note. Patterns can be discerned where there is a relative frequency difference of 25% or more cases between groups across ability or gender.

Legend. SG = Strong Girls WG = Weak Girls SB = Strong Boys WB = Weak Boys

Patterns by ability were found on each of the automatic production operations. The strongest pattern was displayed in the production of letter patterns, the operation of intermediate difficulty, to both girls and boys. All subjects in strong ability groups displayed automaticity of letter production with 100% frequency throughout the research period. Strong girls performed each operation in the letter, letter pattern, and whole word progression with more than 25% greater frequency than weak girls. Strong boys performed only the automaticity in letter pattern operation with more than 25% greater frequency than weak boys.

The first six **memory** operations of Table 11 are back-up operations children used to explore, observe, and imitate during the invented spelling process. The remaining two are retrieval operations. Within Case's (1991) cognitive developmental framework, and within Siegler's (1991) study of strategy development, organization and retrieval are critical functions of short term memory, and efficient functioning of short term memory is central to high level executive processing. Hall, Gerber, and Stricker (1989) have identified lack of order in short term storage, resulting in reduced operating space and deteriorating achievement, as the basis of difficulty for learning disabled poor spellers. It is not surprising, then, that each of the six memory back-up operations were used more frequently by the weak ability groups than by the strong ability groups. Nor is it surprising that strong subjects had made superior use of retrieval operations.

Visual imaging, the most frequently exhibited back-up memory operation of all four groups, discerned a strong pattern of difference by ability for both girls and boys. Saying letter sounds, also a high frequency operation, discerned patterns of 40% greater difference for girls and of 43% difference for boys. Copying, an infrequent back-up of strong girls (1%) and strong boys (2%), was displayed by both weak girls and weak boys on 43% of word writing trials. This difference by ability is not surprising, because copying letters, like drawing diagonals, circles, and pictures, and writing scribbles, was identified as an important step in the progression of activities in the preliterate writing stage (Henderson, 1990, p. 47). Subjects in the strong ability groups rarely needed to glance toward the alphabet line as a prompt to memory. Weak ability groups were observed seeking this assistance on 43% of test trials. Repetition of the target word during the writing episode and saying letter sounds during writing also produced patterns of difference only for the boys group. Girls' differences by ability approached 20%, but did not reach the difference in relative frequency established to discern pattern on either of these operations.

Touch, reference to previous knowledge and experience, and knowledge of the target word in retrospect produced no patterns of difference. The former two operations were used too infrequently to discern patterns. Infrequency of use was not the situation in the latter instance. Almost without exception, strong girls (100%) and strong boys (99%) retained the target word until the task was completed. However, after completing their writing of the target word, on 23% of trials by weak girls and 19% of trials by weak boys, weak subjects did not remember the word they had been asked to write! Although not at the level designated to represent pattern of difference between groups, this failure to retain the task while performing it was unexpected.

In the **articulation of a plan** category, goal setting, patterned sequencing, self-monitoring, and evidence of a rationale for choices made were evident with 99%- 100% frequency by both strong girls and strong boys. Patterns of difference by ability emerged for both girls and boys for patterned sequencing in procedure and for evidence of a rationale. A pattern was discerned for boys only for self-monitoring, and approached but did not reach the level designated for pattern for girls. All groups set goals with facility, so no pattern of difference emerged. Self-correcting, as one would expect, was observed too infrequently to discern a pattern--on less than 11% of word writing tasks. Nonetheless, a study of this operation revealed that subjects from each of the four ability/ gender groups were able to use this "looks right" component (Hall, 1984; Hall, Gerber, & Stricker, 1989; Scott, 1993) to verify their word writing attempts. Subjects in all ability/

gender groups demonstrated that they could detect errors and attempt correction (Lydiatt, 1984).

Case (1991, p.28 -33) has written that the basic processes, the functional invariants, on which all problem-solving depends are present from a very early age and that the complexity of problems that children can solve is the component that varies with age. Clearly, very high percentages of the sample in this research demonstrated goal setting, patterned sequencing, and self-monitoring operations, and ability to provide a data related rationale for choices made in invented spelling at first data collection. Strong and weak ability girls and boys performed the same operations, but strong ability subjects did so using a comparatively advanced level of complexity of word knowledge.

Focus of attention operations also were coded with near 100% frequency for strong ability subjects. They attended selectively to detail, attended to the entire task, and concentrated on the task until the invented word was completed with near perfect frequency. Subjects in the weak ability group performed these same operations with reduced frequencies, with both genders producing remarkably similar percentages (WG - 82%, 57%, 78%; WB - 84%, 59%, 76%). Patterns of ability were discerned for both girls and boys for attending to the entire task and approached, but failed to reach the difference established on uninterrupted concentration on task. Differences in selective attention to detail were limited by a saturation effect. The strong performance of weak subjects (WG-82%; WB- 84%), negated the possibility of a 25% difference by ability.

Patterns by ability were displayed on 3 of the 5 **response style** operations coded. Two operations, display of confidence and rhythmic response, discerned patterns for both girls and boys. The responds thoughtfully operation produced a pattern of difference only for boys; girls approached, but did not reach the level required for pattern. Similarly, differences approached, but did not reach, the extent of disparity required to discern a pattern on the uninterrupted dictation operation. Again, no operation produced a pattern by gender, but a difference of 23% favouring strong boys over weak boys emerged on display of confidence.

Summary of operations by ability and gender.

The problem situation for subjects in this research was that of inventing a spelling for 10 target words. The initial state was a blank DST acetate at the outset of the dictation of a target word. The goal state was the production of an invented spelling on the DST acetate. Strategies were investigated by recording in finite detail all verbal and non-verbal operations performed by each subject while inventing a spelling on each of the 10 words comprising the research task. Strategies were analyzed at the intensive level of operations using coding grids developed to monitor data related and cognitive control related operations.

What are the operations by gender of strong and weak spellers? Strong and weak spellers appear to make use of the same data related operations when inventing spellings (Table 10). Operations emerge at a faster pace for strong spellers. Letter form operations do not appear to differentiate by ability, but observable patterns of difference were discerned for most consonant, vowel, and meaning related operations . Large observed patterns of difference by gender emerged for only two data related operations--the three-consonant blend and the correct -ing ending.

Patterns of difference were discerned for cognitive control related operations (Table 11) on some operations in all five categories of coding: Response style (responds rhythmically, responds thoughtfully, displays confidence); focus of attention (attends to entire task); articulation of a plan (patterned sequencing, self-monitoring, evidence of rationale for choices); memory (copying, repetition of the target word, visual imaging, sounding out, and letter naming); and automatic production (of letters, of letter patterns, and of words). No pattern of difference by gender was discerned.

To answer the first research question, the data related and cognitive control related operations performed by kindergarten and first grade subjects while inventing spellings for target words have been identified. Patterns of difference have been discerned by ability and gender. The more specific second research question, "How do the operations used change over time?", will be the focus in the following section.

Changes over Time in Use of Operations

To establish an understanding of the extent to which individual growth over time can be observed using the Dionne system, the processes and products of a strong ability speller and a weak ability speller will be presented and discussed. Changes over time of the group as a whole, of groups by ability, and of groups by gender will then be presented, analyzed, and interpreted.

Invented Spelling Samples From Weak Ability Girl

The 10 DST words as written by Ann in June, February, and May are presented in Table 12. When Tangel's rating criteria were applied, Ann scored 26 points in June (second highest within the group of 9 weak ability subjects), 35 points in February (seventh within the weak group), and 34 points in May (seventh within the weak group). Her data related and control analysis forms also display increase, then stable use of operations over these intervals.

Ann's invented spellings of the first six words during the June data collection illustrate her knowledge of initial sounds. In all her invented spelling words but lap, additional correct or phonetically related letters have been written. Both the initial consonant and the final consonant are correct in sick. In Ann's word pretty, 2 of the 4 letters are correct, and the letter E is a phonetically related final sound (Henderson, 1990; Read, 1971). From the protocols, it is evident that Ann produced her second letter to

Table 12

Example of Responses of a Weak Girl Speller to 10-Word Developmental Spelling Test in June 93, February 94, and May 94

June 93	February 94	May 94
L	Ipa	Iqeu
S.K	Sick	Sieck
PNTG	petty	petty
6P	eler	elerefeet
ThRU	Teen	turrnr
heltma	henth	tutfr
ESKTnU	Coest	Stuet
KCSSW	KitSt	Kissa
vnIkLmnP	orond	Oudoor
SOUVUXV	Sowning	Soning

Order of magnitude: June 93, 50%; February 94 and May 94, 90%

match the r-r-r- sound, "P. . . . puh- puh- purr-rr-rr- . . . . um- pretty . . . tee- ee- ee- ee- . . . . Pretty. P. All finished!" (Protocol 9, 24-25). When spelling elephant, she exhibited dissatisfaction with her initial attempt at the lower case initial E, so wrote a capital E on top. Then, pleased and excited about her product, she remarked, "Look, that's the way I picked! It looks like the way it spelled!" (33-35). When asked about her choices, she simply responded, "El- foot" (39) as she touched each of the two letters in her word to match her two syllable pronunciation. Ann did not utter a sound as she invented her word train. When prompted, Ann's response suggests a lack of appreciation for the interruption to her thought processes:

E: Tell Wrinkles what you're thinking.

S: Umm- . . . . . I'm thinking in my head! I'm thinking it in my head!

E: Great! . . . .

S: (After completion of written word) . . . . That spells great?

E: Good work.

S: Tuh- r-r- ai- n-n-n- (Protocol 9, 45-51)

Ann "sounded out" to get back on task. When the word hunt had been dictated, Ann responded enthusiastically before beginning her invented spelling, "I can do that one too! . . . . huh- h-h-h- uh- uh- uh- tuh- tuh-- tuh-. Are we almost to the end?" (57-59).

For 3 of the 4 remaining words, Ann made no attempt to sound out, letter name, or otherwise regenerate information from memory. She wrote a correct or phonetically related initial letter and then added a random or alphabetically sequenced string of letters, while propping her head up with her hand, elbow resting on the Plexiglass. Next, she put her head down on the table, then put her chin on the table as she copied letters from the alphabet line on the acetate. Following the dictation of target word #9, order, she commented, "Oops! Let's see what I'll put for this one" (Protocol 9, 78), then worked in silence as she selected letters to copy in alphabetic strings from the alphabet line on the acetate. The one exception to this "random" writing style was the word kissed. The children's report that all the kindergarten children in the school knew how to spell kiss by rote from chanting it in the school yard was confirmed for the research sample. However, Ann added the letter A to kiss to represent the -ed ending.

Ann's words were written in a mix of capital and lower case letters. She reversed the letter J in two words, and both reversed and inverted the lower case letter N when writing the final sound in train. While Ann remained focused and motivated, she functioned with ease in the letter name stage of word knowledge. She produced correct and phonetically related initial, final, and medial sounds. When she became tired, her attention waned, and her productivity deteriorated to preliterate stage performance. Before Ann lost interest in the tasks, she responded thoughtfully, attended selectively to detail, attended to the entire task, established an appropriate goal, worked within a sequenced plan, and demonstrated a rationale for correct and phonetically related letter choices. She repeated the target word before or during writing, and used visual imaging or sounding out behaviours as memory prompts. On some attempts, she displayed confidence. During 3 of the 4 last word productions, focus of attention and planning operations were eliminated almost entirely, and only copying and visual imaging were observed as memory operations.

Ann's word writing had improved by February. Letters were presented in a more confident script, with majority of words written in lower case letters only. The word sick was spelled correctly. Lap was spelled with the correct initial and final consonants, but with the letter A added, compatible to Ann's pronunciation. Her continuing frustration with the "think aloud" task, probably the result of a memory overload, arose once again from a prompt during her writing:

E: Tell Wrinkles about it.

S: luh- l-l-l- puh ah- ah-. A. . . . . . . I'll tell him about it after I write it. (Protocol 35, 7-8).

Ann wrote the first three letters in elephant correctly while subvocalizing, "El- . . . . . el- . . . . el- . . . . . uh- uh- uh- " (44) , wrote the final T without subvocalizing, then traced over it with an F (the dominant sound at the beginning of the last syllable). When telling about her choices in retrospect, she letter named, " L . . . I mean . . E L E F." (48). During the taped dictation of the word train, Ann subvocalized, "Tch- tch- tch- tch-" (53), but did no further sounding out while writing. When invited in retrospect to "Tell Wrinkles", Ann letter named "J . . . . E. . . . E . . . . N" (58). Ann had produced the early level substitution of J for the TR blend (Henderson, 1990; Read 1971, 1986), had written the correct final consonant (in correct form and position, rather than rotated as in June), and had substituted vowels for vowels. While spelling hunt, the influence of Ann's minor speech impediment was reflected in the product. She substituted the TH sound for the T at the end of the consonant nasal, with which she had correctly included the letter N. However, her vowel/vowel substitution of E for U was common at her developmental stage.

Ann produced a surprising spelling for street , after having subvocalized, "S-s-s-s-t- tuh- uh-" (78), she wrote "roost". Because visual imaging was the only back-up operation observed during writing, it is difficult to account for her sequencing of the phonetically related letters she chose. Her invented spellings of order and snowing also suggest confusion in within word letter sequencing, as does her oral account in retrospect for her correct spelling of the word sick, "Because, I know it's I S, and CK makes the kuh- sound" (22-23). The difficulty she exhibited in sequence is not unique to her written language. Nonetheless, Ann did produce the -ing ending correctly at the end of snowing, and represented the -ed ending by placing a phonetically related letter T at the end of her now unconventional spelling of kiss (whether a letter sequencing difficulty or an approximation of her pronunciation resulting from a tongue thrust).

During the first interval, Ann demonstrated growth over time in the following cognitive control operations while writing the 10 words: Orthodox movement, (June--4, February--9); responds thoughtfully, (June--6, February--10); displays confidence, (June--4; February--10); selective attention to detail, (June--7; February--10); attention to the entire task, (June--5, February--8); uninterrupted concentration on task, (June--3; February-- 9); goal setting, (June--7, February--10); patterned sequencing, (June--5, February--10); self-monitoring, (June--5, February--10); rationale evident, (June--6, February--10). Over the same interval, an increase in use of 15 data related operations was observed: Phonetically related final consonants, (June--3, February-- 8); correct final consonants (June--3; February-- 6); phonetically related medial consonants, (June--3, February-- 6); correct medial consonants, (June--2, February--6); all syllables represented (June--6, February--10); phonetically related cvc, (June--1, February--2); phonetically related cvcc, (June--1, February--2); phonetically correct long vowel patterns, (June--0, February--3); correct long vowel patterns, (June--0, February--2); phonetically related initial vowel schwa, (June--0, February--2); correct initial vowel schwa, (June, February--2); phonetically related vowel followed by r, (June--0, February--1); phonetically related and correct intervocalic tap, (June--0, February--1); and correct -ing ending, (June--0 , February--1). When Ann's cognitive control operations increased, an increase in her data related operations was concurrent with the "major reworking" noted by Case.

However, unlike the other subjects, it became evident from Ann's May protocols that her difficulty in spelling stretched beyond activating the cognitive control operators leading up to efficient memory use. In May, Ann's DST scores showed a decrease of a single point from her February score. Her data related analysis form revealed a reduction in correct use of eight vowel operations.

Ann continued to produce the correct initial letter in lap, but reversed the letter P, and added two letters E and U after the P. When pressed for her underlying rationale for these additions, her account was, "E because it's a vowel, and U because . . . . . I think it's a U" (Protocol 53, 18-19). Her spelling of sick reflects her attempts to use a vowel pattern she had not internalized. It appeared from her protocols that Ann looked to her teacher for answers. "It's because S and I . . . . um- . . . . I think those are the letters, and E C K, my teacher told me that's right" (26-28). Ann's misspellings in elephant, train, street, and order reflect her pronunciations of these words. Her spelling of snowing illustrates a continuing difficulty in letter sequencing, but a continuing grasp of the -ing ending. But it is Ann's invented word hunt that is most intriguing. Ann subvocalized immediately after the taped dictation, then wrote in silence:

S: (Subvocally) T-t-t- un-n-n-t-t- . . (Writes) . . . .

E: Tell Wrinkles what you've written.

S: T U T R T

E: What word were you making?

S: Hunt.

E: You chose T for the first letter.

S: Because that's what it starts with (70-76).

Because Ann produced the initial H correctly on the two preceding data collections, it is unlikely that she lacked knowledge of the correct initial consonant. It is possible that, following the dictation, Ann "held on to" the most latent sound and produced it first.

Ann's speech and her sequencing difficulties influenced her spelling at all three data collections. Demonstration and guided practice with constructive, corrective feedback in oral language deficiencies would be of assistance to this weak speller. Although her attention and planning control structures were in working order, a developmentally earlier oral language difficulty was problematic and impeding her progress. Ann's invented spelling ability was curtailed by difficulties that must be addressed directly if she is to progress in her writing. Leaving her to learn from experience will only contribute further to the downward spiral already in motion.

Invented Spelling Sample From Strong Ability Boy

The DST words as written by Lee in June, February, and May are presented in Table 13. When Tangel's rating criteria were applied to Lee's responses, he achieved 47 in June (the highest score among the 19 subjects), 56 in February (second highest), and 58 in May (two students produced the highest score of 59). From the June data collection, Lee's responses, with the possible exception on his invented spelling of snowing, are quite readable. His unconventional spellings illustrate the types of miscues which result when subjects begin to develop an awareness of within word pattern. He produced all but one letter (lower case "i") in capital form during the first data collection. In all 10 words, first and last letters were correctly produced. Lee wrote the SN and STR blends correctly, and represented the PR and TR blends in the phonetically related manner which Read (1971) had found typical of early letter production (PER IT Y; TCH RAN). Both consonant nasals and both initial vowels were correctly written. Some short vowel patterns were correctly represented-- others were produced with vowel/vowel substitutions. The medial syllable in elephant was represented in a phonetically related form. Long vowels patterns were represented by the single vowel whose name most closely approximates the sound (tchran, stret) An attempt at long vowel patterning was made for "SNOEG".

In February, Lee spelled 6 words conventionally. He used all consonants, blend and nasal patterns, and short vowel patterns correctly. However, he produced vowel/ vowel substitutions within the vowel patterns in "pritty" and "elephint". He wrote the intervocalic tap in phonetically related form in pretty and the PH sound correctly in elephant. His attempts at long vowel patterns were correct in street and snowing, but he reversed the positions of the two vowels within the vowel pattern in train. Lee wrote both vowel followed by r sounds and the medial D conventionally in the word order. He produced the -ing ending correctly, but represented the -ed by a single phonetically related letter, T.

Table 13

Example of Responses of a Strong Boy Speller to 10-Word Developmental Spelling Test in June 93, February 94, and May, 94

June 93	February 94	May 94
LAP	lap	lap
SIK	sick	Sick
PERITY	pretty	prety
ELAFINT	Elephant	Eleaphant
TCHRAN	train	train
HANT	hunt	hunt
STRET	street	Street
KIST	kisst	kissed
ORTR	order	Order
SNOEG	snowing	Snowing

Order of magnitude: June 93, 50%; February 94 and May 94, 90%

In May, Lee wrote the two vowels surrounding the consonant to be doubled in the intervocalic tap correctly, but did not double the T between vowels. He wrote a long vowel pattern for the middle syllable in elephant. He spelled all other eight words correctly.

Excerpts from Lee's verbal protocols while writing the word pretty are quoted to demonstrate Lee's changing response capability over time during strategy construction. The excerpts demonstrate the pauses, incomplete sentences, and multiple starts and stops characteristic of discovery of new strategies (Siegler, 1991).

pretty	June	T: Pretty. The girl had on a pretty dress . . . . . pretty. S: (Writes without comment) . . . . E: Tell Wrinkles about your choices. S: (Subvocally) puh- puh- . . . I think how you spell pretty is . . . . E: Tell him why you chose those letters. S: . . . . b- b- . . . . because . . . . . . E: Any reasons you chose those instead of others? S: Because I think that's how you spell pretty. (Protocol 16, 17-26)
	February	T: Pretty. the girl had on a pretty dress . . . . . pretty. S: (Writes without comment) . . . . E: Tell Wrinkles how you chose those letters. S: I made the sound of pretty . . . . like puh- r-r-r-i-i-i-ih- tuh- tuy- ee-ee-ee- . (Protocol 33, 32-36)
	May	T: Pretty. the girl had on a pretty dress . . . . . pretty. S: (Writes without comment) . . . . Um-mm- I sounded them out . . . like puh- r-r-r-it- te- ee-ee- . . . . And there's lots of . . . . um-mm . . . .letters that make ee-ee- . . . . like E E, or E A, or some other ones . . . . but I forget. E: When there are a whole lot of them to make the same sound, how did you choose to put Y? S: . . . . . Well . . . . E: How did you know to do that? S: . . . . Because . . . . . like, last time I was here, I . . . . . . well, I kind of . . . . . I think I learned it at home. . . . . . . and it also is kind of like . . . . . it, it like it kind of matches the word. E: Matches the way it . . . . . . S: Spells. Ya. (Protocol 44, 28-46).

Although Lee was unable to efficiently describe his thinking process, it is clear from the video tape that he used cognitive control operations efficiently. He produced letters and letter patterns with automaticity throughout the data collections. Automatic production of words increased over time (June--1, February--4, May--6). In June, Lee repeated the target word and sounded out letters for all 10 words. On the last two words, he used visual imaging as a back-up to memory. In February, he neither repeated the target words nor sounded out words. He used only visual imaging as a memory prompt for only pretty, elephant, train, and hunt. During immediate retrospective debriefings, Lee made reference to previous knowledge and experience when describing how he made his letter choices. In May, when describing his cognitive activity, he related choices made on five target words to previous knowledge and experience, and remembered all words in immediate retrospect. In articulating his plan, Lee set goals, developed a patterned sequential procedure, self-monitored, and demonstrated evidence of a rationale for the choices he made. He self-corrected during the writing of two words in June; no self-correcting was noted in February or May. Lee's attention was focused throughout the data collections. He attended selectively to detail and maintained focus until the task was completed without interruption of concentration. His letters were produced rhythmically on most words throughout the research period (June, 8; February, 9; May, 9). Lee responded thoughtfully and displayed confidence in all word writing.

Changes Over Time for 19 Subjects

To identify changes over time in operations used, differences in progress on each operation coded were calculated for the 19 subjects for whom the data was complete for each of the three collection sessions. The total frequency of each operation at the June 93, February 94, and May 94 data collection times was converted to relative frequency. For each operation, change over time was obtained by subtracting the relative frequency at the earlier data collection time from the relative frequency at the later data collection time.

Frequency of each operation at June 93 is included in the table as a baseline for growth over time. Negative numbers resulted for operations observed in decreasing frequency over time; positive numbers resulted for operations observed in increasing frequency over time. Again, an asterisk following a number is used to highlight a pattern of change of 25% or greater difference established in this research to discern large observed change. Data related changes are presented first, followed by cognitive control changes. A brief summary concludes this section on change over time in use of operations.

Data related changes over time.

The relative frequency of each data related operation at the June 93 collection and the relative frequency of change for each operation from June to February, February to May, and June to May are reported in Table 14. Again, the relative frequency of each operation at June is included as a baseline. Changes are presented and discussed within the categories coded: **letter form**, **consonants**, **vowels**, and **meaning.**

In the **letter form** category, only the relative frequency of writing in lower case letters increased during the three data collection periods. Patterns of change on this operation were discerned from June to February and from June to May. Of the four operations on which frequency decreased over time, only writing in capital letters produced patterns of change. Mix of capital and lower case letters reduced gradually as the transition to lower case form evolved, short of discerning a pattern of change for the 12-month period. Writing of reversed letters and writing of inverted letters were observed too infrequently to denote patterns of change. The changes over time in letter form confirm the shift from capital to lower case letters as described in the literature (Clay, 1993; Chomsky, 1972; Dyson,1986; Henderson, 1991; Read, 1971).

The three earliest developing **consonant** operations listed in Table 14 produced no pattern of change. Over the full year, changes approached, but did not reach, the relative frequency established to discern a pattern. All eight more advanced consonant operations

Table 14
Relative Frequency of Change in Data Related Operations Over Time for the Whole Sample (19 Subjects)

Operation		Change Over Time		
	June 93	June- Feb	Feb- May	June- May
Letter Form				
Writes capital letters only (10)	29	- 29*	- 1	- 29*
Writes mix of capital and lower case letters (10)	59	- 9	- 7	- 17
Writes lower case letters only (10)	11	40*	7	47*
Writes reversed letter(s) (10)	13	- 7	- 2	- 9
Writes inverted letter(s) (10)	2	- 1	- 2	- 2
Consonants				
Writes letter string(s) (10)	22	-12	- 8	- 19
Writes phonetically related initial consonant (8)	72	15	8	23
Writes correct initial consonant (8)	71	11	9	20
Writes phonetically related final consonant (10)	48	36*	6	42*
Writes correct final consonant (10)	42	34*	10	44*
Writes phonetically related medial consonant (9)	44	37*	6	43*
Writes correct medial consonant (9)	41	37*	6	44*
Writes phonetically related 2-consonant blend (4)	33	37*	9	46*
Writes correct initial 2-consonant blend (4)	28	38*	13	51*
Writes correct consonant nasal (2)	24	34*	8	42*
Writes correct initial 3-consonant blend (1)	16	32*	21	53*

(Table continues . . .)

Table 14 (cont'd)

Operation	June 93	Change Over Time June- Feb	Feb- May	June- May
Vowels				
Writes with all syllables represented (10)	74	15	6	21
Writes vowel/vowel substitution (10)	23	- 3	- 5	- 7
Writes phonetically related initial vowel (2)	37	29*	3	32*
Writes correct initial vowel (2)	32	29*	3	32*
Writes phonetically related cvc pattern (6)	49	18	16	34*
Writes correct cvc pattern (6)	18	25*	13	39*
Writes phonetically related cvcc pattern (5)	22	27*	9	36*
Writes correct cvcc pattern (5)	7	19	16	35*
Writes phonetically related long vowel pattern (4)	20	30*	20	50*
Writes correct long vowel pattern (4)	5	30*	14	45*
Writes phonetically related vowel followed by r (1)	53	16	11	26*
Writes correct vowel followed by r pattern (1)	5	26*	0	26*
Phonetically related intervocalic tap (1)	0	21	-11	11
Correct intervocalic tap	0	5	- 5	0
Meaning				
Writes correct -ing ending	16	58*	0	58*
Writes correct -ed ending	0	5	32*	37*

Note. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing frequency of occurrences of operation by product of number in group and number in ( ).

* indicates a patterns of change in relative frequency of 25% or more between intervals.

displayed patterns of change ranging from 32% growth to 38% growth from June to February and patterns of change ranging from 42% to 53% from June to May. From February to May, no patterns were found. Only the correct initial three-consonant blend approached the change necessary for pattern.

As expected, writing in letter strings reduced with development over time. Patterns of change emerged on operations addressing final and medial consonants and for blend and nasal patterns. Results confirm the developmental progression established by Henderson (1990), and illustrate also the major shift in thinking (Case, 1991) at entry to the dimensional stage, followed by a minor shift between the substages. The major shift is portrayed from June to February by the eight intense patterns of change over time, ranging from 32% to 38% growth, as compared to no patterns of change during the February to May interval. Only one consonant operation displayed growth of more than 13% during this period.

During the June to February interval, 7 of the 14 **vowel** operations coded displayed patterns of change. No pattern of change was found during the February to May interval. Over the full year interval, patterns of change emerged on 10 operations.

During the June to February growth spurt, the increases in relative frequency ranged from 25% to 30% on the following operations: phonetically related and correct initial vowels, correct cvc patterns, phonetically related and correct long vowel patterns, phonetically related cvcc patterns, phonetically related and correct initial vowels, and correct vowel followed by r. Although growth in use of each of these operations continued from February through May, only phonetically related long vowel patterns approached a pattern of change. Over the June to May interval, 3 operations were added to the 7 patterns identified in the first interval. As a consequence, patterns of changes for operations in the vowel category were located on all but the earliest 2 and latest 2 operations. When relative frequencies of the 10 operations producing patterns of change were situated in descending order by data collection time, it became clear once more that, with the exception of the correct initial vowel sound (not a vowel pattern), phonetically related vowel patterns emerged with greater frequency than correct vowel patterns across all three data collection times. Phonetically related vowel patterns appeared, then gradually and consistently refined to correct form.

Once again, this finding is compatible with the sequence of development of within word patterns and the emergence of relational thinking necessary to the elaboration of vowel patterns (Henderson ,1990, p. 56-57). Results demonstrate also the major shift in thinking described by Case (1991) as subjects acquire the ability to produce patterns of letters in relation to elements of sound.

In the **meaning** strategy category, both word ending operations produced a pattern of change over the Grade 1 year. Correct use of the -ing ending augmented by 58% from June to February. No further growth was noted (0%) from February to May. At the same time, the -ed ending, which had displayed only 5% growth during the first interval, changed sufficiently during the February to May interval to display a pattern of change.

Henderson (1990, p.65) has written that the -ing ending appears first as a straightforward sound to letter pattern match. The -ed ending, however, produces at least three different sounds. When children begin to use the -ed ending correctly, it is an indication that they have begun to develop an understanding of the role of meaning to print. When the correct -ed sound is written, this suggests a knowledge of letter pattern as a representation of past tense, rather than a simple T or D sound/ letter match.

Henderson's interpretation of data related information can be extended within the cognitive developmental framework espoused by Case. While capable only of unifocal dimensional thought, a direct sound letter match is the required mode of invented spelling. When children learn to assemble new structures (words) out of two qualitatively different structures (sound/letter correspondence and sound/letter pattern correspondence), they have entered the bifocal substage in their thinking. At this time, one-to-one sound/letter matching can be subordinated to a match of sound/ letter patterns, a qualitatively different dimension, as and when required. When children develop a sensitivity to the meaning principle (e.g., past tense -ed is portrayed by particular letters, no matter whether the -t sound, the -d sound, or the -ed sound is heard), they are approaching entry to a new realm of thinking which demands the execution of two or more of the sound to meaning/ meaning to sound operations in parallel, and the integration of the products of these operations into a coherent whole (invented word). To use the meaning principle in invented spelling, subjects must be in the process of entering integrated dimensional Substage 3. Correct use of the -ed ending "opens the door" to the shift in thinking required to enter this third substage of interrelational dimensional thought.

Cognitive control related changes over time.

In Table 15, the relative frequency of production of each operation by all 19 subjects at June 93 and the changes in cognitive control related operations are reported from June to February, February to May, and June to May. Again, a minus sign denotes a reduction over time in the relative frequency of the operation.

Changes over the Grade 1 year in all three operations of **automatic production** were sufficient to display patterns of change. Automatic production of letters and automatic production of letter patterns produced patterns of change from June to February, but no change was produced from February to May. As expected, automatic production of words developed more gradually. Evident infrequently in June (1%), an increase of approximately 15% during the first interval and 12% during the second, producing a pattern of change in the June to May interval.

In the **memory** category, 4 of 6 back-up operations displayed a pattern of change, but retrieval operations produced no pattern of change. Patterns of change identified during the first interval did not endure for the June to May interval. Changes over the year-long interval approached, but did not reach, the difference required to discern a pattern,

Table 15

Relative Frequency of Change in Cognitive Control Related Operations over Time for the Whole Sample (19 Subjects)

Operations		Change Over Time		
	June 93	June- Feb	Feb- May	June-May
Automatic Production				
Automatic production of letters	65	27*	0	27*
Automatic production of letter patterns	34	44*	5	49*
Automatic production of words	1	15	12	26*
Memory				
Touches	1	- 3	1	- 3
Copies	37	- 22	- 4	- 27*
Repeats target word	57	- 27*	5	- 22
Visual images	71	- 27*	9	- 18
Says letter sounds	60	- 19	1	- 19
Says letter names	34	- 25*	3	- 23
Refers to previous knowledge/ experience	1	5	13	18
Knows target word in retrospect	82	14	2	16
Articulation of Plan				
Goal setting	94	2	4	6
Patterned sequencing	79	11	4	15
Self-monitoring	82	7	6	13
Self-correcting	7	3	1	3
Rationale evident	74	14	3	17
Focus of Attention				
Selectively attends to detail	88	4	3	7
Attends to the entire task	58	34*	- 3	31*
Uninterrupted concentration on task	81	11	1	12
Response Style				
Orthodox movement	38	33*	- 5	28*
Uninterrupted dictation	72	8	- 1	8
Responds rhythmically	50	8	10	18
Responds thoughtfully	82	11	3	13
Displays confidence	66	14	6	20

<u>Note</u>. * identifies pattern of change discerned by a relative frequency difference of 25% or greater between data collections.

having crossed the 25% criterion established in this research to ease discussion of results. Changes in copying, repeating of the target word, visual imaging, and letter naming hovered around the limit selected to describe large observed differences for June to February and June to May intervals. A pattern of change emerged during the year long interval for copying.

In **articulating a plan**, none of the five operations discerned a pattern of change over time. Very high frequency of use in June of goal setting, patterned sequencing, self-monitoring, and evidence of a rationale made a pattern of change impossible to unlikely. Subjects had already become adept in their use of planning operations. By May, four operations had been refined to greater than 90% of word writing trials. Self-correcting was used in only 7% to 10% of word writing trials across the intervals, and showed negligible change over time.

Case (1991, p. 28-33) has written that the functional invariants on which all problem-solving depends are present from a very early age and that it is the complexity of problems that children can solve that varies with development. He has written that problem-solving begins with the setting of a goal, followed by a trial-and-error component which draws on the systematic capability for activating familiar schemes in a novel sequence. When no solution is found by exploring familiar operations in sequence, children actively search for other operations, often ones they have never before used in this context or sequence, evaluate these, abandon those that are not working, and repeat those that are successful until some kind of consolidation has been achieved. Very high percentages of subjects in this research demonstrated the capacity to use goal setting, patterned sequencing, and self-monitoring, and provided an underlying rationale for choices made in inventing spellings. Planning operations were being used successfully by first data collection. A saturation effect limited the measurement of score increases.

Similarly, two of the three **focus of attention** operations were influenced by saturation. Selective attention to detail and uninterrupted concentration on task were evident in 88% and 81% respectively of trials in June. Attention to the entire task, observed with 58% frequency in June, displayed patterns of change from June to February and June to May.

The lack of ability in June to attend to the entire task can be understood within Henderson's (1990) cognitive developmental sequence of word knowledge. Production of medial consonants develops later than initial and final consonants. Some subjects focused intently on producing an initial letter and then abandoned the task; others focused intently during production of initial and final consonant before attention wavered. In June, several students were focused during the first half of the test, then exhibited fatigue non-verbally through yawning, sprawling across the table top, attempting to change markers for another colour, dropping markers on the table top or floor, or rapidly producing letter strings in immature script following dictation of the last four or five target words. Growing fatigue was exhibited by attempting to initiate conversation about unrelated topics and by questioning the researcher directly, e.g., "How much does it go up to?" (Protocol 13, 69), "Is this the last one?" (Protocol 29, 117), "How many more of these do I have to do on there?" (Protocol 41, 101-102), "Are we almost to the end? (Protocol 9, 57-58). Tangel's kindergarten DST was a 5-word test. Focusing and attending to tasks for the length of time and of the level of difficulty required by the 10-word DST was beyond the realm of the possible for some subjects at June data collection. By mid grade one, attentional focus had developed sufficiently with increased alphabetic knowledge, practice, experience, and maturation to complete the entire task without interruption of focus on 92% of word writing trials, a change of 34%. Minimal change (-3%) was evident during the second interval. By end of grade one, focus of attention operations were observed with 95%, 89%, and 93% relative frequency during invented spelling trials.

Only one **response style** operation discerned a pattern of change. From June to February, writing with orthodox movement, the most infrequently used operation in June, increased on 33% of invented spelling attempts. In spite of a 5% reduction from February to May, a pattern of change was indicated for the year. Relative frequency of display of confidence increased by 14% during the first interval, and by 6% during the second interval, so approached, but did not reach, the difference necessary to produce a pattern over the June to May period. Change in frequency of production of all other operations was less than 18%.

Summary of changes over time.

How do the operations used change over time? Patterns of change over time emerged on 18 data related operations during the June to February interval. The operations discerning patterns of change tended to be of an intermediate level in the developmental progression. Only 1 data related operation, correct use of the -ed ending (the most advanced operation), produced a pattern of change during the February to May interval. Over the first interval, 7 cognitive control related operations generated patterns of change over time--automatic production of letters, automatic production of letter patterns, repetition of the target word, visual imaging, letter naming, attending to the entire task, and orthodox movement. During the second interval, no patterns of change over time were discerned. A growth spurt during the first half of first grade appeared to be followed by a period of consolidation of both data related and cognitive control related operations.

Changes over time, as discussed in response to Question 2, have included all 19 subjects, considering neither ability nor gender. Discussion of the remaining two questions will be focused on changes over time when these variables are considered. The question, "Are there differences in progression of operations between strong spellers and weak spellers?" will be addressed in the following section.

Differences in Progression of Operations Between Strong Spellers and Weak Spellers

To examine the question of differences in progression of strong and weak spellers on data related and on cognitive control related operations for June to February, February to May, and June to May, the relative frequency of each operation at the beginning of the interval was subtracted from the relative frequency of the operation at the end of the interval for both ability groups. The difference in progression between groups was obtained by subtracting the progression of the weak group from the progression of the strong group, and signifying which ability group made the greater change by placing a S (strong) or a W (weak) in front of the numerical difference obtained. Because operations coded sometimes increased in frequency with development over time and sometimes decreased in frequency with development over time, this form of reporting avoided the complexities in interpretation produced by double negatives. An asterisk following the alphabetic/numeric value was used to highlight patterns of differences of 25% or greater between ability groups. The calculations of differences in progression by ability on data related operations and on cognitive control related operations are reported in Appendices K and L respectively. Discussion of differences in progression by ability on data related operations will be followed by discussion of differences in progression by ability in cognitive control related operations.

Data Related Operations

The differences in progression by ability calculated in Appendix K are summarized for June to February, February to May, and June to May in Table 16. The relative frequency of use of data related operations by strong and weak spellers at June 93 is included as a baseline for the reader. Again, patterns of difference are frequent during the

Table 16

Relative Frequency Differences in Progression in Data Related Operations by Ability Over Time

Operation	June 93		Difference in Progression by Ability		
	Strong	Weak	June-Feb	Feb-May	June-May
Letter Form					
Writes capital letters only (10)	37	21	S 17	W 1	S16
Writes mix of capital and lower case letters (10)	48	71	W33*	S21	W12
Writes lower case letters only (10)	16	4	W 22	S23	S 1
Writes reversed letter(s) (10)	1	26	W13	S 5	W18
Writes inverted letter(s) (10)	0	4	W 1	W 3	W 4
Consonants					
Writes letter string(s) (10)	0	47	W25*	W16	W41*
Writes phonetically related initial consonant (8)	100	40	W32*	W17	W49*
Writes correct initial consonant (8)	95	44	W14	W19	W33*
Writes phonetically related final consonant (10)	80	13	W40*	W 7	W47*
Writes correct final consonant (10)	70	11	W28*	W20	W48*
Writes phonetically related medial consonant (9)	73	11	W30*	W 6	W36*
Writes correct medial consonant (9)	71	7	W33*	W 1	W34*
Writes phonetically related 2-consonant blend (4)	58	3	W17	S12	W 5
Writes correct initial 2-consonant blend (4)	53	0	W12	S 9	W 3
Writes correct consonant nasal (2)	44	6	S30*	W 6	S24
Writes correct initial 3-consonant blend (1)	30	0	S18	W 2	S16

(Table continues . . .)

Table 16 (cont'd)

Operation	June 93		Difference in Progression by Ability		
	Strong	Weak	Feb-June	May-Feb	May-June
Vowels					
Writes with all syllables represented (10)	98	47	W33*	W 9	W42*
Writes vowel/vowel substitution (10)	35	10	W30*	W 5	W35*
Writes phonetically related initial vowel (2)	60	11	W30*	S27*	W 3
Writes correct initial vowel (2)	55	6	W18	S 5	W13
Writes phonetically related cvc pattern (6)	85	6	W53*	S 9	W44*
Writes correct cvc pattern (6)	32	4	S 10	W 4	S 6
Writes phonetically related cvcc pattern (5)	38	4	S 1	S12	S13
Writes correct cvcc pattern (5)	32	2	W 1	S17	S16
Writes phonetically related long vowel pattern (4)	28	11	S20	S12	S32*
Writes correct long vowel pattern (4)	10	0	S31*	S18	S49*
Writes phonetically related vowel followed by r (1)	90	11	W76*	S20	W56*
Writes correct vowel followed by r pattern (1)	10	0	S50*	0	S50*
Phonetically related intervocalic tap (1)	0	0	W 2	S22	S20
Correct intervocalic tap (1)	0	0	W11	S11	0
Meaning					
Writes correct -ing ending (1)	30	0	S26*	W22	S 4
Writes correct -ed ending (1)	0	0	S10	S39*	S49*

Note. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing frequency of occurrences of operation by product of the number in the group and the number in parentheses ( )

* indicates a pattern of change in progression discerned where there is a relative frequency difference of 25% or more between ability groups. S preceding the number indicates greater change by the strong group, W preceding the number indicates greater change by the weak group.

June to February interval, and sparse during the February to May interval. Patterns located in the June to May interval are similar, but not identical to those of the June to February interval.

In discussing the **letter form** category, references will be made to calculations reported in Appendix K in order to demonstrate the derivation of information summarized in Table 16. In the ensuing categories, discussion will evolve primarily from the table.

As shown in Table 16, a pattern of difference in progression between ability groups emerged on only one letter form operation, writes mix of capital and lower case letters, and from June to February only. From Appendix K, it is evident that the strong ability group wrote a mix of capital and lower case letters in June 93, February 94, and May 94 with relative frequencies of 48%, 54%, and 37% respectively. The weak ability group wrote a mix of capital and lower case letters in June 93, February 94, and May 94 with relative frequencies of 71%, 44%, and 48% respectively. Change over time for the strong group was 6% from June to February, -17% from February to May, and -11% from June to May. Change over time for the weak group was -27% from June to February, 4% from February to May, and -23% from June to May. The difference in progression between groups, calculated by subtracting the progression of the weak group from the progression of the strong group, was 33% favouring the weak group (W33) over the June to February interval, 21% favouring the strong group (S21) over the February to May interval, and 12% favouring the weak group (W12) from June to May. These results suggest a pattern of difference in progression by ability only for the June to February interval, with the pattern favouring the weak group. The strong group approached but did not reach a pattern of difference in progression in the February to May interval (S21).

Differences approached but failed to reach the designation for pattern on writing in lower case letters for both June to February (W22%) and February to May (S23%). From Appendix K, this shift between ability groups in growth over time can be comprehended. The strong ability group wrote only in lower case letters in June 93, February 94, and May

94 with relative frequencies of 16%, 46%, and 64% respectively. The weak ability group wrote only in lower case letters in June 93, February 94, and May 94 with relative frequencies of 4%, 56%, and 51% respectively. The change for the strong group was 30% from June to February, 18% from February to May, and 48% from June to May. The change for the weak group was 52% from June to February, -5% from February to May, and 47% from June to May. The differences in progression between groups, calculated by subtracting the progression of the weak group from the progression of the strong group, was 22% favouring the weak group (W22) over the June to February interval, 23% favouring the strong group (S23) over the February to May interval, and 1% favouring the strong group (S1) from June to May.

Patterns of difference in progression by ability emerged for 7 of the 11 **consonant** strategy operations from June to February, for 0 operations from February to May, and for 7 operations from June to May. Of the 7 patterns June to May, 6 displayed patterns also in the June to February interval. Differences favouring the weak group on all 6 of these patterns were augmented in the year long period. The pattern of difference in progression on the correct consonant nasal operation during the first interval (S30%), was eliminated as a pattern (S24%) over the year long interval because weak spellers showed a greater difference in progression from February to May. Over the June to May interval, a pattern was added for correct initial consonants (W33%).

Weak subjects produced patterns of greater difference over time on most consonant operations. Strong subjects produced patterns of greater difference over time only on a developmentally advanced operation, the consonant nasal.

A somewhat similar profile was exhibited on **vowel** operations. Of 14 operations, patterns of difference between strong and weak ability spellers emerged on 7 operations from June to February, on 1 operation from February to May, and on 7 operations from June to May. Six (6) of the 7 patterns which emerged during the first interval continued during the full-year interval, with patterns favouring the weak group on 4 operations and the strong group on 2 operations. As revealed by Appendix K, the weak group regressed in production of phonetically related initial vowels during the second interval (February, 56%; May, 44%), while the strong ability group progressed somewhat (February, 75%; May, 90%). Therefore, a pattern of difference in progression favoured the strong group (S27) from February to May, and no pattern emerged for the June to May interval. An additional pattern of difference in progression favouring the strong group emerged on writing phonetically related long vowel patterns for the June to May interval.

Patterns favouring weak spellers were influenced by a saturation effect limiting strong spellers at first data collection. Weak subjects made greater progress because they had more growing to do and because they were developmentally ready for a major increase in representing sound/letter approximations of vowel patterns. From February to May, it appears that weak spellers reached a plateau in development in Case's (1991) substages while strong spellers, having consolidated their vowel operations, experienced a period of minor growth toward Stage 3 in Henderson's developmental stages of word knowledge.

In the **meaning** related category, a pattern of difference in progression favoured the strong ability group for the -ing ending during the June to February interval. Differences in progression favouring the weak group fell just short of discerning a pattern during the second term, resulting in no pattern of difference for the year long interval. The -ed ending, produced too infrequently to discern a pattern during the first interval, produced a pattern of difference from February to May and June to May. These differences were influenced by the minimal production of the -ed operation by weak ability pupils who were faced with tasks beyond the limits of their cognitive development.

<u>Cognitive Control Related Operations</u>

The relative frequency of differences in progression of strong and weak spellers on cognitive control related operations are summarized for June to February, February to May, and June to May in Table 17. The relative frequency of cognitive control related operations

Table 17

Relative Frequency Differences in Progression on Cognitive Control Related Operations by Ability Over Time

Operation	June 93		Difference in Progression by Ability		
	Strong	Weak	June-Feb	Feb-May	June-May
Automatic Production					
Automatic production of letters	100	26	W56*	0	W56*
Automatic production of letter patterns	63	2	W18	W 6	W24
Automatic production of words	9	0	S 26*	S 3	S 29*
Memory					
Touches	1	9	W 7	W 1	W 8
Copies	4	74	W38*	W10	W48*
Repeats target word	52	62	S 34*	W17	S 17
Visual images	53	91	S 6	W 2	S 4
Says letter sounds	62	69	S 62*	W10	S 52*
Says letter names	16	53	W19	S 2	W17
Refers to previous knowledge/ experience	1	1	W 5	S 6	S 1
Knows target word in retrospect	99	58	W28*	W 5	W33*
Articulation of Plan					
Goal setting	100	87	W 4	W 9	W13
Patterned sequencing	100	57	W23	W 8	W31*
Self-monitoring	99	63	W13	W13	W26*
Self-correcting	10	3	W 4	W 5	W 9
Rationale evident	100	46	W31*	W4	W35*
Focus of Attention					
Selectively attends to detail	99	76	W 6	W 7	W13
Attends to the entire task	94	19	W53*	W 2	W55*
Uninterrupted concentration on task	97	63	W17	W 1	W18
Response Style					
Orthodox movement	51	24	W26*	S10	W16
Uninterrupted dictation	79	63	S 9	S 6	S 15
Responds rhythmically	75	22	S 7	W21	W14
Responds thoughtfully	100	61	W22	W 6	W28*
Displays confidence	96	33	W21	W13	W34*

<u>Note</u>. * denotes a patterns of change in progression where there is a relative frequency difference of 25% or more between ability groups.
S preceding a number indicates greater change by the strong group, W preceding a number indicates greater change by the weak group.

by strong and weak spellers at June 93 are included as a baseline for the reader. The calculations from which this summary was abstracted can be found in Appendix L. Again, patterns of difference in progression between strong and weak groups were frequent during the June to February interval and sparse during the February to May interval. Also, patterns located for June to May are similar, but not identical, to patterns located from June to February.

In the **automatic production** category, patterns of difference in progression favouring the weak group emerged for both June to February and June to May intervals on automatic production of letters. Patterns of difference in progression favouring strong spellers emerged for the same intervals on automatic production of words. Although no pattern emerged on automatic production of letter patterns, difference in progression favouring the weak group approached the level designated for pattern during the June to May interval.

Patterns of difference in progression emerged on four **memory** operations from June to February, no operations from February to May, and three operations from June to May. During the first interval, patterns favouring the weak group on copying and on knowing target word in retrospect were augmented when the June to May interval was considered. Patterns which emerged on repeating the target word and sounding out favouring the strong group during the June to February interval, were reduced when the year long interval was considered because weak spellers made greater progress on these operations from February to May. This resulted in no pattern of difference in progression on repeating the target word during the June to May interval.

In the **articulation of a plan** category, all 4 patterns produced favoured weak spellers. From June to February, an ability pattern of difference in progression emerged on rationale evident. Patterned sequencing (W23) approached the level designated to discern a pattern. During the June to May interval, patterns of difference in progression were found for patterned sequencing, self-monitoring, and rationale evident. Clearly, goal setting, patterned sequencing, self-monitoring, and evidence of a rationale operations were firmly entrenched in the thinking of strong spellers by June of the kindergarten year. Weak spellers developed these planning operations throughout Grade 1.

In the **focus of attention** category, only the attention to the entire task operation, infrequent in the writing of weak spellers at the June data collection, produced a pattern of difference in progression favouring the weak group during the first interval. This pattern of difference increased minimally during the June to May interval. Again, the high level of performance of strong spellers at June 93 made their growth potential negligible. Although weak spellers were less efficient in their use of selective attention to detail and uninterrupted concentration on task operations, it appears that their growth spurt was underway on these operations at June 93. Only moderate changes in progression followed.

Patterns of difference in progression over time emerged on three operations in **response style**--orthodox movement, responds thoughtfully, and displays confidence. For each operation, the pattern favoured the weak group and was displayed for only one interval. The pattern of difference for use of orthodox movement appeared during the June to February interval, but was not maintained over the year because the strong group made greater progress during the second interval. No patterns were discerned during the February to May interval, although the weak group approached a pattern for greater progress on rhythmic response. Over the year long interval, patterns emerged on responding thoughtfully and displaying confidence--operations that had approached, but had not reached the difference required to discern a pattern during the first interval. From June to February patterns emerged on 9 cognitive control operations, 6 favouring weak spellers, 3 favouring the strong spellers. From February to May no differences were found. Again, operations which produced patterns over the full year were similar, but not identical, to operations which produced patterns in the June to February interval.

Case (1991) has suggested that development in cognitive processes is accomplished by goal setting, experimenting, evaluating, and restructuring to closer approximations of the goal objective. From the application of the coding grids to both data related and cognitive control related operations, the way in which learning of specific data is constrained by the functioning of the cognitive control system be..me evident. It appeared that data related information cannot be received and managed until the learner has reached the stage or substage of thought required to process information at that level of complexity. Cognitive growth occurs not all-of-a-piece, but through a number of specific changes that occur within a general systemic constraint. When a new stage or substage is entered, the cognitive control system is prepared to receive data of a more complex nature. Then, through practice and experience, through trial-and-error, and with appropriate feedback, the learners make sense of the new more complex information and organize this information within their cognitive processing systems so that it can be retrieved when required (Hall, Gerber, and Stricker, 1989).

Growth of data related operations is contingent upon thought development. As soon as a new stage or substage is reached within the "mind's staircase", there is a consequent growth spurt in use of the data related operations which can now be accommodated within the cognitive structure. Independent practice is required to review, reuse, and consolidate thought patterns recently acquired before the learner is prepared for the next stage. Guided experience reaching just beyond the current level of thought into the learning zone of proximal development (Vygotsky, 1978) gently stretches the learner toward new limits in thinking. When there has been movement to a new stage of thought by only one ability group in a time interval, a pattern of difference in progression is likely to occur. If there is no change during a time interval in stages or substages of thought by either group, or a change by both groups, differences are modest.

It was both enlightening and rewarding to discover the extent of growth made by weak ability subjects in the course of the grade one year. When only products were considered, weak ability pupils appeared to fall short of expectations, when, in fact, the extent of progress they exhibited while writing their "mis-spellings" was outstanding.

Summary of Differences by Ability

Are there differences in progression of operations between strong spellers and weak spellers over time? There was no difference found in the order in which operations emerged, but there were large observed differences in the number of operations performed during the research period. Weak spellers progressed on more data related operations than strong spellers, while, at the same time, continuing to develop the response style, focus of attention, and articulation of planning operations. This difference was due largely to the fact that strong spellers were already functioning efficiently on both data related and cognitive control related operations. Weak spellers developed automaticity in the production of letters, then letter patterns, while strong spellers developed automaticity in production of whole words. Weak spellers made greater progress on copying and retention of target word memory operations, while strong spellers made greater progress on sounding out and repetition of target word operations. Weak spellers continued to develop articulation of planning operations and focus of attention operations, while these were performed automatically by strong spellers. In addition, weak spellers lagged behind strong spellers in response style operations throughout the research period. Weak spellers were observed developing the same operations already exhibited by strong spellers, but developing more operations identified for coding than the strong group. From end of kindergarten to end of Grade 1, the overall progress in development of operations was greater for weak spellers than for strong spellers.

Weak subjects outperformed strong subjects in data related growth over time by 12 patterns to 4 patterns during the first interval. The 2 patterns of difference in change over time identified during the second interval favoured the strong group. Patterns favouring the strong group were produced on operations not yet performed by weak subjects. A growth spurt during the first interval appeared to be followed by a period of consolidation during the second interval. Weak subjects outperformed strong subjects 6 patterns to 3 patterns in differences in progression over time on cognitive control related operations over the first interval. Again, no patterns were discerned during the second interval.

A new question then arises, "Had the target words of the developmental spelling test addressed within word pattern and syllable juncture (Stages 3 and 4 of Henderson's word knowledge), would the strong spellers have exhibited greater progress over time than they did on the 10- word DST used in this research?"

In this section the differences in progression of operations between strong and weak spellers have been examined. The focus of the next section will be operational differences by gender. The final research question will be addressed: Do the operations of boys differ from the operations of girls over time?

Differences in Progression of Operations by Gender

To examine the question of differences in progression on data related and cognitive control related operations by gender, relative frequencies were calculated at the June, February, and May data collections. Differences between data collections were determined for June to February, February to May, and June to May intervals for each gender. The smaller difference was subtracted from the larger difference, and the gender obtaining the larger difference was identified by placing a G (girls) or a B (boys) in front of the numerical difference. An asterisk following the alphabetic/numeric response was used to highlight patterns of difference between gender groups.

Data Related Differences

The relative frequencies of data related operations of girls and boys at June 93 and the differences in progression by gender as calculated for June to February, February to May, and June to May are presented in Table 18. The detailed calculations of relative frequency differences in progression by girls and boys on data related operations are

Table 18

Relative Frequency Differences in Progression in Data Related Operations by Gender Over Time

Operation	June 93		Difference in Progression by Gender		
	Girls	Boys	June-Feb	Feb-May	June-May
Letter Form					
Writes capital letters only (10)	18	45	B26*	B 1	B27*
Writes mix of capital and lower case letters (10)	65	51	G 4	G 6	G10
Writes lower case letters only (10)	17	1	B26*	G 6	B20
Writes reversed letter(s) (10)	15	9	G 3	G 2	G 5
Writes inverted letter(s) (10)	4	0	G 1	G 3	G 4
Consonants					
Writes letter string(s) (10)	22	23	0	B 6	B 6
Writes phonetically related initial consonant (8)	78	63	B 1	B15	B16
Writes correct initial consonant (8)	72	70	B 5	G 4	B 1
Writes phonetically related final consonant (10)	47	50	G 2	B 5	B 3
Writes correct final consonant (10)	43	41	B 6	B 2	B 8
Writes phonetically related medial consonant (9)	42	46	G 2	0	G 2
Writes correct medial consonant (9)	39	43	G19	B20	B 1
Writes phonetically related 2-consonant blend (4)	23	47	G 4	G11	G15
Writes correct initial 2-consonant blend (4)	20	38	B 3	G12	G 9
Writes correct consonant nasal (2)	18	31	G27*	B19	G 8
Writes correct initial 3-consonant blend (1)	9	25	B32*	G37*	G 5

(Table continues . . .)

Table 18 (cont'd)

Operation	June 93 Girls	June 93 Boys	Difference in Progression by Gender June-Feb	Feb-May	June-May
Vowels					
Writes with all syllables represented (10)	73	75	B 3	0	B 3
Writes vowel/vowel substitution (10)	20	28	B16	G 7	B 9
Writes phonetically related initial vowel (2)	27	50	G18	B 6	G12
Writes correct initial vowel (2)	27	38	B 3	G 4	G 1
Writes phonetically related cvc pattern (6)	45	54	G 7	B 9	B 2
Writes correct cvc pattern (6)	18	19	B 6	G 5	B 1
Writes phonetically related cvcc pattern (5)	20	25	G 4	G 1	G 5
Writes correct cvcc pattern (5)	7	8	B 5	G 1	B 4
Writes phonetically related long vowel pattern (4)	16	25	G 4	B 9	B 5
Writes correct long vowel pattern (4)	0	13	G 9	G 4	G13
Writes phonetically related vowel followed by <u>r</u> (1)	45	63	G 7	G18	G25*
Writes correct vowel followed by <u>r</u> pattern (1)	9	0	B 41*	0	B41*
Phonetically related intervocalic tap (1)	0	0	B 7	G25*	G18
Correct intervocalic tap (1)	0	0	G 9	B 9	0
Meaning					
Writes correct -ing ending	27	0	B29*	G21	B 8
Writes correct -ed ending	0	0	B13	G11	B 2

Note. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing frequency of occurrence of operation by product of number in group and number in ( ).
* indicates that a patterns of change in progression has been discerned because there is a relative frequency difference of 25% or more between gender groups.
G preceding a number indicates greater change by girls, B preceding a number indicates greater change by boys.

included as Appendix M. Although the quantitative overview revealed no statistical difference in DST results by gender, a few patterns of difference were revealed when the coding grid was applied. These patterns will be discussed within category of coding.

In the **letter form** category, all 3 patterns of difference between gender groups favoured boys. Patterns were discerned in the June to February interval for writing in capital letters and writing in lower case letters. The pattern of difference in growth was maintained from June to May for capital letters, but the difference in progress between gender groups on the lower case operation dropped below the standard designated to discern pattern for the June to May interval.

Patterns emerged on only the two most developmentally advanced operations in the **consonant** category. Girls displayed a pattern of greater progress on initial consonant nasals from June to February. Because boys made greater progress from February to May, no pattern of difference was discerned for the full year. The outcome was reversed when the three-consonant blend was studied. Boys outperformed girls from June to February and girls outperformed boys from February to May. As a result, no pattern of difference in progression by gender was evident for the June to May interval.

Patterns of difference in progression were found on three developmentally advanced **vowel** operations--phonetically related vowel followed by r (June to May for girls), correct vowel followed by r (June to February and June to May for boys), and phonetically related intervocalic tap (February to May). Overall, patterns of difference in progression on vowel operations were balanced between gender groups-- two vowel patterns favoured girls and two favoured boys.

In the **meaning** category, the -ed ending was used too infrequently to discern a pattern of difference in any of the 3 intervals. The correct -ing ending, the earlier developing operation, produced a pattern of difference in progression from June to February for boys and approached pattern level from February to May for girls. As a result, there was no pattern of difference for June to May. Boys progressed earlier; girls progressed later.

Cognitive Control Related Differences

Relative frequencies of cognitive control operations of girls and boys groups at June 93 and the differences in progression by gender as calculated for June to February, February to May, and June to May are summarized in Table 19. The detailed calculations are included as Appendix N. There were no patterns of difference in progression over time for any operations in **automatic production**, **articulation of a plan**, and **focus of attention** categories. However, patterns by gender were discerned on three back-up operations in the **memory** category and one operation in the **response style** category. In all instances, patterns endured only one interval. Two of the three patterns in the memory category favoured girls. One memory pattern, and the response style pattern favoured boys.

On the repetition of the target word operation, a pattern favouring girls was discerned for the February to May interval, following a difference in progression during the June to February that approached a pattern favouring boys. As a result, there was no pattern of difference over the year. On the sounding out operation, a pattern favouring boys emerged for June to February. A 9% greater difference in progression by girls from February to May negated pattern possibilities for the June to May interval. A pattern for letter naming emerged favouring girls only from June to May. One additional back-up operation, visual images, approached without reaching pattern during the June to May interval (B24%). All other operations produced differences in progression between genders of less than 15%.

In an attempt to understand why pattern differences occurred for one interval only, the profile of relative frequencies at each data collection was examined (Appendix N). For each of the three operations on which patterns were located--repeats target word, says letter

Table 19

Relative Frequency Differences in Progression in Cognitive Control Related Operations by Gender Over Time

Operation	June 93 Girls	June 93 Boys	Difference in Progression by Gender June-Feb	Feb-May	June-May
Automatic Production					
Automatic production of letters	65	64	G 6	B 9	B 3
Automatic production of letter patterns	33	36	B 8	G 5	B 3
Automatic production of words	5	4	B 7	B 1	B 8
Memory					
Touches	1	10	B10	G 1	B 9
Copies	35	40	B14	B 4	B18
Repeats target word	55	60	B24	G37*	G13
Visual images	72	70	B 4	B20	B24
Says letter sounds	54	69	B33*	G 9	B24
Says letter names	44	20	G23	G 5	G28*
Refers to previous knowledge/ experience	1	1	B 6	B 7	B13
Knows target word in retrospect	75	85	G 8	B 1	G 7
Articulation of Plan					
Goal setting	92	96	G 9	B 5	G 4
Patterned sequencing	76	84	G 9	B 7	G 2
Self-monitoring	84	80	B 6	B 8	B14
Self-correcting	4	11	G10	B 2	G 8
Rationale evident	74	75	G 1	B 5	B 4
Focus of Attention					
Selectively attends to detail	85	91	G 4	B 4	0
Attends to the entire task	56	61	B 4	B 1	B 5
Uninterrupted concentration on task	83	79	B 7	B 6	B13
Response Style					
Orthodox movement	44	31	G 7	B 6	G 1
Uninterrupted dictation	72	71	B27*	G23	B 4
Responds rhythmically	45	56	B 5	G11	G 6
Responds thoughtfully	84	79	B 8	B 4	B12
Displays confidence	82	66	B12	B 4	B16

Note. * indicates a pattern of change in progression that is discerned where there is a relative frequency difference of 25% or more between gender groups.
G preceding a number indicates greater change by girls, B preceding a number indicates greater change by boys.

sound, says letter name--there was a gradual reduction over the three intervals in use of operations by girls, and a rapid reduction from June to February, followed by a moderate increase from February to May in use of operations by boys. The "peaks and valleys" in the profiles reflect experimentation with back-up operations as subjects attempt to select the most successful. When these profiles were compared with those of operations on which no patterns emerged, "peaks and valleys" were evident on only one other operation, visual images, which approached a pattern of difference. The girls group displayed variability in use of visual imaging, while the boys group displayed a gradual reduction. It is possible, therefore, that these patterns of difference in progression over time are to a large extent the result of experimentation with back-up memory operations.

In the **response style** category, uninterrupted dictation discerned a pattern of difference favouring boys over the June to February interval, and approached a pattern favouring girls in the February to May interval. Again, the frequency of use of the operation by girls decreased, then increased over the three data collection points. Boys increased, then decreased over the three data collection points. Of the operations that approached, but did not quite reach pattern, boys achieved a 24% greater difference in progression on three operations, while girls achieved a 23% greater difference on two operations. The patterns of difference were equally balanced between girls and boys.

Summary of Differences by Gender

There were more patterns from June to February than from February to May or from June to May. On data related operations, 6 patterns of difference by gender emerged from June to February, 2 patterns emerged from February to May, and 3 patterns emerged from June to May. Boys made 25% or greater progress on use of capital letters (June to February and June to May), lower case letters (June to February), three-consonant blends (June to February), correct vowel followed by *r* pattern (June to February and June to May), and correct -ing ending (June to February). Girls made greater progress on consonant nasals (June to February), on the initial three-consonant blend (February to May), on phonetically related vowel followed by r (June to May), and on phonetically related intervocalic tap (February to May).

On cognitive control related operations, 2 patterns of difference in progression by gender emerged from June to February, 1 pattern emerged from February to May, and 1 pattern emerged from June to May. The few differences in progression over time by gender were believed to be primarily on frequently used back-up operations, illustrating the experimentation by trial and error in the development of cognitive processes described by Case's (1991).

Do the operations of boys differ from the operations of girls over time? Differences in changes by gender over time appear to be of little consequence for both data related and cognitive control related operations.

CHAPTER 6

DISCUSSION AND IMPLICATIONS

The primary objective of this investigation was to explore the inventing spelling processes of young school aged children for possible indicators of problem-solving strategies. Henderson's (1990) developmental stages of word knowledge were examined within Case's (1991) cognitive developmental framework.

Through error analysis, previous researchers had established (a) that spelling is an orthographic problem-solving process (Hall, 1984), (b) that learning disabled poor spellers lack sufficient skills or strategies to direct and to control the data related information they possess while problem-solving (Gerber, 1984a, 1985, 1987), (c) that learning disabled poor spellers follow the same pattern of development as their normally achieving peers (Gerber, 1985), (d) that spelling productions of LD student resemble those of normally achieving children in younger age groups (Gerber, 1985, 1987; Hall, Gerber, & Stricker, 1989), (e) that slowness in deciding which letter or letter pattern corresponds to the particular sound that the problem-solver wishes to represent begins a downward spiral (Gerber, 1985, 1987), and (f) that problem-solving deficiencies can be improved with appropriate teaching (Gerber, 1987, Hall, Gerber, & Stricker, 1989; Hall & Gerber, 1990). It appeared appropriate, therefore, to examine the earliest invented spelling processes of young school aged children during word writing as potential indicators of their problem-solving strategies. If the operations used could be differentiated by ability and gender, an avenue for improving deficiencies in problem-solving might be opened before a downward spiral begins.

The lack of an appropriate instrument to rate early invented spellings qualitatively and precisely at kindergarten and Grade 1 and of a methodology to identify and observe problem-solving strategies in written productions had been deterring factors for studying invented spellings as indicators of differential problem-solving strategies at this early school age. A developmental spelling test designed to rate the quality of invented spelling of kindergarten and Grade 1 children (Tangel, 1991) and the creation of the Dionne Observation Table (Hayes, 1993; Schael, 1994) offered an avenue to undertake such a study. In her pilot study, the researcher had found that by using the observation table spelling strategies could be recorded, and that, from repeated replay, the specific operations performed by kindergarten and Grade 1 subjects during strategy construction could be observed and analyzed. The Dionne table was used to collect simultaneously visual protocols, verbal protocols, and the invented spelling test word in production at three data collection points over a calendar year. These three forms of data were analyzed for two types of operations--data related and cognitive control related--using coding grids (vocabulary for defining operations, with examples of instances and non-instances of the operation where possible) developed by the researcher and based on the literature and on content of the protocols collected. Verbal and non-verbal activities were stated in operational terms and organized into four data related categories (letter form, consonants, vowels, and meaning) and five cognitive control related categories (automatic production, memory, articulation of a plan, focus of attention, and response style). The information was condensed to abbreviated form and consolidated to a single page Data Analysis Form (Appendix E-1) and a single page Cognitive Control Analysis Form (Appendix F-1) on which all operations identified in the coding process were recorded as existing or non-existing in the writing process for each word written by each subject at each data collection. The coding grid was used to tally the frequency of each operation.

To differentiate operational use by gender and ability, a difference of 25% in relative frequency between groups was selected by the researcher to represent a large observed difference. The operations which differentiated by ability and gender, and which produced changes in progression over time for all subjects, for subjects by ability, and for subjects by gender were highlighted. The implications of these results for further research and to the classroom milieu will be addressed. Suggestions for refining the data collection procedure will follow.

Overview of Operations Identified

The results of applying the data related and the cognitive control related coding grids to the corpus of data have been presented and discussed in detail for all operations in Chapter 5. The intent here is to highlight only operations which produced large observed differences by ability and gender between groups, and to comment from observations made during the invented spelling process on the relationship between the two data types.

Data Related Operations Which Differentiated by Ability and Gender

The data related operations which produced patterns of difference by ability and gender between strong and weak girl and boy spellers (Table 10) are highlighted in Table 20. Only operations on which patterns emerged are included in the table. The groups for which a pattern was discerned are marked with an x. Because there was no pattern of difference for any of the five letter form operations, this category does not appear in the table. All consonant and meaning operations and 11 of the 14 vowel operations produced ability patterns. One operation differentiated by gender for the weak group only; one operation differentiated by gender for the strong group only.

Based on the information in the table, the following general statements can be made concerning invented spelling as indicators of differential data related operations used the invented spelling process:

1. Consonant, vowel, and meaning operations differentiate by ability;
2. Data related operations rarely differentiate by gender;
3. Ability is a better differentiating variable than gender of data related operations in the invented spelling process.

Table 20

Data Related Operations Which Differentiate Kindergarten and Grade 1 Spellers by Ability and Gender

Operation	Ability		Gender	
	Girls	Boys	Strong	Weak
Consonants				
Writes letter strings		x		
Writes phonetically related initial consonant	x	x		
Writes correct initial consonant	x	x		
Writes phonetically related final consonant	x	x		
Writes correct final consonant	x	x		
Writes phonetically related medial consonant	x	x		
Writes correct medial consonant	x	x		
Writes phonetically related 2-consonant blend	x	x		
Writes correct 2-consonant blend	x	x		
Writes correct consonant nasal	x	x		
Writes correct 3-consonant blend	x			x
Vowels				
Writes with all syllables represented	x	x		
Writes phonetically related initial vowels	x	x		
Writes correct initial vowels	x	x		
Writes phonetically related cvc patterns	x	x		
Writes correct cvc patterns	x	x		
Writes phonetically related cvcc patterns	x	x		
Writes correct cvcc patterns	x			
Writes phonetically related long vowel pattern	x	x		
Writes correct long vowel pattern	x	x		
Writes phonetically related vowel followed by r		x		
Writes correct vowel followed by r	x	x		
Meaning				
Writes correct -ing ending	x	x	x	
Writes correct -ed ending		x		

Note. x marks patterns of 25% or greater difference between ability/gender groups.

Cognitive Control Operations Which Differentiated by Ability and Gender

The cognitive control operations which produced patterns of difference between strong and weak girl and boy spellers (Table 11) are reviewed in Table 21. Only 15 of the 24 operations monitored are highlighted because only operations on which patterns emerged are included in the table. The ability and/or gender groups for whom patterns were discerned are marked with an x for each operation.

Based on the information in the table, the following general statements can be made concerning invented spellings as indicators of differential cognitive control related operations in the invented spelling process:

1. Some operations in each of the cognitive control related categories differentiated by ability between strong and weak girl spellers and between strong and weak boy spellers;

2. No cognitive control operation differentiated by gender between strong girls and strong boys nor between weak girls and weak boys;

3. Ability is a better differentiating variable than gender of cognitive control related operations in the invented spelling process.

Conclusions Concerning Operation Identification.

Clearly, it was possible by using the Dionne Observation Table to identify from invented spellings produced for Developmental Spelling Test words the operations performed by kindergarten and Grade 1 pupils. The researcher was able to achieve an in-depth understanding of both **what** was written (data related operations) and **how** the subjects made their decisions concerning what to write (cognitive control related operations). While it is true that in many instances data related knowledge could be interpreted by error analysis of the words written, in some instances the operations in progress (the visual and verbal protocols) were required to understand the subjects' perceptions of the data related information they produced. On several occasions, observing

Table 21

Cognitive Control Operations Which Differentiate Kindergarten and Grade 1 Spellers by Ability and Gender

Operation	Ability		Gender	
	Girls	Boys	Strong	Weak
Automatic Production				
Automatic production of letters	x			
Automatic production of patterns	x	x		
Automatic production of words	x			
Memory				
Copies	x	x		
Repeats target word		x		
Visual images	x	x		
Says letter sounds	x	x		
Says letter names		x		
Articulation of a Plan				
Patterned sequencing	x	x		
Self-monitoring		x		
Rationale evident	x	x		
Focus of Attention				
Attends to entire task	x	x		
Response Style				
Responds rhythmically	x	x		
Responds thoughtfully		x		
Displays confidence	x	x		

Note. x marks pattern of 25% or more difference between ability or gender groups how the data was produced altered the judges' understanding of what the subjects believed they had written. For example, when Ann (Protocol 9) invented a spelling for train, all three judges initially believe that she had written the correct initial consonant followed with a letter string (thRu). From an in-depth analysis of the protocols, it became clear that Ann had a minor speech impediment (a tongue thrust) which altered her pronunciation of the initial sound in train to the TH digraph and that lack of experience with appropriate feedback affected the presentation of the final letter N. Ann "felt" she was making the letter N. She talked about the letter N (Protocol 9, 51). She made the shape of the lower case letter "n" in appropriate flow and sequence, but, because she began at bottom right instead of top left, she produced the letter U. While at surface level Ann appeared to be in transition from the letter strings productions of Preliterate Stage 1 in word development to Letter Name Stage 2, she clearly had already developed concept of word, of correct initial, final and medial consonants, and could represent a two letter blend in a phonetically related form. She was well advanced in Stage 2 and beginning to show signs of readiness for Within Word Pattern Stage 3. The Dionne table was essential to the observation, analysis, and interpretation of the nuances of data related operations, as well as to the identification of cognitive control operations in word writing.

What are the operations by gender of strong and weak spellers? These data related and cognitive control related operations which differentiated by ability and gender have been highlighted in Tables 20 and 21 respectively, and a brief discussion has followed on the interaction of these specific and globally related operations as hypothesized by Case (1991) and observed from analyzing the data collected at the Dionne Observation Table. From analyzing the details of work in progress, it became clear that both types of operations are of importance simultaneously and interactively in the invented spelling development.

By studying the growth over time of data related and cognitive control related operations, the researcher was able to elaborate the interactive relationship. Highlights from the results of the three questions addressing growth over time will be capsulated next, followed by a discussion of the researcher's perceptions of how data related and cognitive control related operations interacted over time in the invented spelling processes of kindergarten and Grade 1 subjects.

Changes in Use of Operations Over Time

In the discussion of the three questions addressing growth over time in Chapter 5, the results of applying the coding grids to determine changes in data related and cognitive control related operations have been presented and elaborated for each operation coded. The intent here is to highlight only operations which produced patterns of change in data related and cognitive control related operations.

Changes in Data Related Operations Over Time

The patterns of change over time in data related operations are consolidated in Table 22. Operations that produced a pattern of difference for any or all of the three questions addressing a) all 19 subjects, b) subjects by ability, and c) subjects by gender are presented together to culminate how operations change over time. From this tabular overview, operations on which patterns were discerned will be highlighted for each of the questions.

Changes in progression over time for all subjects.

When all 57 protocols were considered as one group, patterns of change over time which emerged during the production of data related operations can be identified as follows:

1. Capital letters only and lower case letters only;
2. Final consonants, medial consonants, consonant blends, and consonant nasals;
3. Initial vowels and vowel patterns (except the intervocalic tap);

Table 22

Data Related Operations Discerning Patterns of Change Over Time by All Subjects, by Ability, and by Gender

Operations	All Subjects			Ability			Gender		
	J-F	F-M	J-M	J-F	F-M	J-M	J-F	F-M	J-M
Letter Form									
Writes in capital letters	x		x				B		B
Writes mix of capital and lower case letters				W					
Writes lower case letters	x		x				B		
Consonants									
Writes letter strings				W		W			
Writes phonetically related initial consonant				W		W			
Writes correct initial consonant						W			
Writes phonetically related final consonant	x		x	W		W			
Writes correct final consonant	x		x	W		W			
Writes phonetically related medial consonant	x		x	W		W			
Writes correct medial consonant	x		x	W		W			
Writes phonetically related 2-consonant blend	x		x						
Writes correct 2-consonant blend	x		x						
Writes correct consonant nasal	x		x	S			G		
Writes correct 3-consonant blend	x		x				B	G	

(Table continues . . .)

Table 22 (cont'd)

Operation	All Subjects			Ability			Gender		
	J-F	F-M	J-M	J-F	F-M	J-M	J-F	F-M	J-M
Vowels									
Writes with all syllables represented				W		W			
Writes vowel/vowel substitutions				W		W			
Writes phonetically related initial vowels	x		x	W	S				
Writes correct initial vowels	x		x						
Writes phonetically related cvc patterns			x	W		W			
Writes correct cvc patterns	x		x						
Writes phonetically related cvcc patterns	x		x						
Writes correct cvcc patterns			x						
Writes phonetically related long vowel pattern	x		x			S			
Writes correct long vowel pattern	x		x	S		S			
Writes phonetically related vowel followed by r			x	W		W			G
Writes correct vowel followed by r	x		x	S		S	B		B
Writes phonetically related intervocalic tap								G	
Meaning									
Writes correct -ing ending	x		x	S			B		
Writes correct -ed ending		x	x		S	S			

Note. x indicates pattern of 25% or greater difference between intervals
S= Strong spellers made 25% of more progress than weak spellers.
W= Weak spellers made 25% of more progress than strong spellers.
B= Boys made 25% or greater progress than girls.
G= Girls made 25% or greater progress than boys.

4. Meaning related inflectional endings (-ed and -ing);

Also, it is clear that most data related growth took place during the June to February interval. Only one pattern of change was discerned during the second interval.

Changes in progression over time between ability groups.

In summarizing the patterns of change in progression over time between strong and weak spellers, the following general conclusions were drawn:

1. Weak spellers produced patterns of change over time on developmentally early operations and strong spellers produced patterns of change over time on developmentally advanced operations;

2. There were more patterns of change by ability favouring weak spellers than patterns favouring strong spellers;

3. There were more patterns of change by ability during the June to February interval than during the February to May interval;

Changes in progression over time between gender groups.

When patterns of change in progression over time between girls and boys were summarized the following general conclusions were drawn:

1. Boys improved more than girls in letter formation (a category of operations which did not differentiate spellers by ability);

2. Patterns of difference in progression over time favoured boys (5 : 1) during the June-February interval;

3. Patterns of difference in progression over time favoured girls (2 : 0) during the February-May interval;

4. The few patterns of difference in progression by gender were of little consequence to the invented spelling process.

Did boys make greater progress than girls during the first half of Grade 1 because they lagged developmentally at the end of kindergarten? Did boys make greater progress than girls because boys had just entered the period of major reworking resulting from a change in cognitive stage while girls were either in a pre- or post- major stage change? Did boys receive more of the attention they required than girls in their interactions with significant others? Girls were favoured on the only two patterns of difference by gender produced during the second interval. These patterns emerged on the most sophisticated consonant operation and on the most sophisticated vowel operation. Does this finding suggest that girls were developmentally advanced on data related operations? Did girls receive more of the attention they required than boys in their interactions with significant others during the second interval? Do differences between genders in physical structure underlie the minimal functional differences? Although differences by gender appeared to be of little consequence to data related and cognitive control related operations observed during the research, they have raised questions worthy of further investigation in kindergarten and Grade 1 classrooms.

Changes in Cognitive Control Related Operations Over Time

Patterns of change over time in cognitive control related operations are consolidated in Table 23. Again, operations that produced a pattern of difference for any or all of the questions addressing a) all 19 subjects, b) subjects by ability, and c) subjects by gender are presented together in the table to culminate how operations change over time. From this global overview, operations on which patterns were discerned will be highlighted for each of the three questions.

Changes in progression of all subjects over time.

When all 57 protocols were considered as a whole, patterns of change over time emerged on the following cognitive control related operations:

Table 23

Cognitive Control Operations Discerning Patterns of Change Over Time by All Subjects, by Ability, and by Gender

Operations	All Subjects			Ability			Gender		
	J-F	F-M	J-M	J-F	F-M	J-M	J-F	F-M	J-M
Automatic Production									
Automatic production of letters	x		x	W		W			
Automatic production of letter patterns	x		x						
Automatic production of words			x	S		S			
Memory									
Copies			x	W		W			
Repeats target word	x			S				G	
Visual images	x								
Says letter sounds				S		S	B		
Says letter names	x								
Knows target word in retrospect				W		W			G
Articulation of a Plan									
Patterned sequencing						W			
Self-monitoring						W			
Rationale evident				W		W			
Focus of Attention									
Attends to entire task	x		x	W		W			
Response Style									
Orthodox movement	x		x	W					
Uninterrupted dictation							B		
Responds thoughtfully						W			
Displays confidence						W			

Note. x indicates pattern of 25% or more difference between intervals over time.
S= Strong spellers made 25% of more progress than weak spellers.
W= Weak spellers made 25% of more progress than strong spellers.
B= Boys made 25% or greater progress than girls.
G= Girls made 25% or greater progress than boys.

1. Automatic production of letters, letter patterns and words:

2. Copying, repeating the target word, visual imaging, and letter naming (back-up memory operations);

3. Attending to the entire task (a focus of attention operation);

4. Orthodox movement (a response style operation).

Again, it was clear that most cognitive control related growth took place by mid Grade 1. No patterns of change over time emerged during the second interval.

Changes in progression between ability groups over time.

The following conclusions have been reached concerning patterns of change in progression over time between strong and weak spellers on cognitive control related operations:

1. Patterns of change in progression favoured weak spellers on automatic production of letters and strong spellers on automatic production of words;

2. Patterns of change in progression favoured weak spellers on copying and knowing the target word in retrospect and strong spellers on repeating the target word and sounding out;

3. Patterns of change in progression favoured weak spellers on patterned sequencing, self-monitoring, and evidence of a rational for choices;

4. A pattern of change in progression favoured weak spellers on attending to the entire task;

5. Patterns of change in progression favoured weak spellers on orthodox movement, responding thoughtfully, and displaying confidence;

6. There were more patterns of change favouring weak spellers than favouring strong spellers;

7. There were several patterns of change in progression between ability groups during the first interval and no pattern during the second interval.

Changes in progression over time between gender groups.

The following conclusions have been drawn concerning changes in progression over time between girls and boys on cognitive control related operations:

1. The number of patterns was equally distributed between girls and boys;

2. Boys displayed patterns of change during the first interval on sounding out (a back-up memory operation) and uninterrupted dictation (response style operation);

3. Girls displayed a pattern of change in progression during the second interval on repetition of the target word (a back-up memory operation) and during the year long interval on knowing the target word in retrospect (retrieval memory operation);

4. Patterns of change in progression over time were few and of little consequence to the invented spelling process;

Conclusions Concerning Change Over Time

In summarizing the patterns in progression over time, the following conclusions have been drawn:

1. Patterns of change in progression over time emerged on some operation(s) in each of the five cognitive control related categories;

2. Change in invented spelling processes was greater by ability than by gender;

3. Weak spellers made greater change than strong spellers;

4.. Change in the invented spelling process by gender was minimal;

5. The major shift in thought processes was made by the first week of February of Grade 1. Progress in invented spelling from beginning of February to the end of May was comparatively limited. Most progress on operations identified for writing the 10 target words over the June to May interval had taken place by beginning February.

Interaction of Data Related and Cognitive Control Related Operations

The extent to which subjects progressed on data related operations was contingent upon the extent to which their cognitive control related operations had developed. The development of control structures appeared to be hierarchical. Rudimentary psychomotor responses and the ability to focus attention and articulate a plan appear to be prerequisites to efficient memory and, in turn, to automatic production. From the coding process, it became evident that strong spellers produced most response style, focus of attention, and articulation of plan operations with facility. Until weak spellers were able to demonstrate focus of attention and articulation of planning operations regularly, they used multiple back-up strategies in an attempt to "hold on" to the overwhelming influx of unrelated incoming data. The generation of back-up operations consumed available working memory space, thereby short circuiting organization and integration of in-coming information. Once subjects had learned to focus attention and to develop and effect an organizational plan, use of back-up strategies was reduced, "freeing up" executive processing space for organization and integration of in-coming information into existing memory structures. When focus of attention and articulation of a plan operations were observed regularly, data related operations appropriate to the cognitive developmental stage emerged, transferred to similar examples during guided practice, and integrated into the thought schema with independent practice and experience. Fluidity within and among the three lower controls in the hierarchical control system formed the framework for controlled thinking through which efficient memory could extend and elaborate information to be learned. As memory controls were sharpened, automatic production followed. The data related operations were the substance of the thought development process. The organization of control operations provided the structuring of thinking to facilitate data organization and elaboration.

Further Research Considerations

From the literature reviewed, from observations made by the researcher during the coding process, and from interpretation of the results the following conclusions are advanced:

1. The Dionne Observation Table is "a window to cognition". It offers the possibility of tapping operations used in strategy construction during writing. Using this apparatus, it is possible to analyze and interpret both specific content learning and how learners process the content being learned.

2. The Dionne methodology is a valuable supplement to verbal protocols as a means of interpreting cognitive processes of learners at any stage or substage of thought, but holds greatest promise for analysis and interpretation of operational use for subjects in the interrelational and early dimensional stages of thinking when cognitive developmental limitations affect verbal protocol productions.

3. Focus of attention and articulation of a plan are necessary precursors to efficient memory functioning. Until operations within these strategies are observed with regularity in performance of goal tasks, back-up strategies are evoked to the degree that they may consume working memory, leaving little or no operating space to connect the known and the unknown in the problem-solving process. As a result, growth to increased complexity of thought (e.g., from unifocal to bifocal thinking) is impeded.

4. Most strong kindergarten and Grade 1 subjects learn intrinsically from interaction with significant others over time to efficiently organize memory. Many weak subjects at kindergarten and Grade 1 require demonstration, guided practice, and on-going feedback to develop efficient cognitive processing strategies. Weak spellers need to be shown what they are doing correctly, where they are going astray, and how to detect and correct the deficiencies they exhibit. Weak spellers at kindergarten and Grade 1 can be taught the problem-solving strategies they lack. With practice, experience, and continuing

monitoring with feedback, over time many weak subjects can develop automaticity in the production at increasingly more complex stages and substages of thought development.

5. Weak spellers made greater progress than strong spellers during the research year. In many instances, the progress of strong spellers was limited by a saturation effect. Weak spellers were required to write DST words at least one stage beyond their levels of cognitive development. Research should be conducted using test words at least one spelling stage beyond the current developmental stages of each the weak ability group and of the strong ability group so that differences in progress in use of data related and cognitive control related operations could be compared when goal tasks are beyond the zones of proximal development of both groups.

Contributions of the Study to Educational Practice

The Dionne "window to cognition" could become a valuable tool for assessment of cognitive processing for educators of young children. The researcher has demonstrated that it is possible within regular primary schools to use the Dionne table to assess the invented spelling strategies of weak ability kindergarten and Grade 1 pupils. A "cognitive control detection and correction program" for those pupils identified by their teachers to be experiencing difficulty could be designed to improve the learner's situation.

No later than mid Grade 1, the data related and cognitive control related operations of pupils who are identified by their teachers as weak spellers could be analyzed at the Dionne table to detect possible deficiencies in data related and/or cognitive control related strategies as outlined in this research. Then, a correction program addressing the deficiencies detected could be designed to meet the needs of the individual learner and effected to remediate the early detected difficulties before a downward spiral further complicates possibilities of learning. Beginning with an example at the learner's stage of word knowledge, the teacher could model the most basic control operation in the hierarchy requiring correction, verbalizing her thought processes during the demonstration. Guided practice, with appropriate constructive feedback, should follow, in individualized session within the realm of the learner's attention span, until the learner has acquired the control operation under construction. Independent practice of related examples should continue until automaticity evolves. The teacher should then proceed to the next control operation in the hierarchy, using data related operations of the same cognitive developmental stage of word knowledge as content. Remediation using demonstration, guided practice, then independent practice should be continued until the control operations are operating on a regular basis. Operations should then be tracked at the next stage of word knowledge to insure that control structures continue to operate at a level of greater complexity. If so, regular remedial assistance may be interrupted, with periodic maintenance check-ups provided. If not, remedial assistance should be continued until the objective is achieved. By providing assistance early, the emerging speller will learn to activate new schemes and to organize (chunk) these in working memory, rather than attempting to use several back-up operations simultaneously to maintain the in-coming information in a "bottle-neck" to memory and then become discouraged from lack of success. Investment of resources during the Grade 1 year to insure that the major restructuring of thought identified by Case (1991) occurs, would advance learning outcomes throughout the dimensional stage of thought.

Case (1991, p. 33-34) has identified instruction as a specific aspect of development presumed to account for considerable variability from one child, task, and context to another. If pupils are to be provided with the best possible opportunities to develop cognitively, teachers at kindergarten and Grade 1 must be versed in cognitive processing and cognitive development. They must have a working knowledge of stages of word knowledge and content appropriate for learning at each stage. In the present study, Wayne's teacher was well versed in this regard. Her approach to written language development was reflected by her enthusiasm for immediate feedback concerning the performance of her pupils, through increases in pupils' use of response style, focus of attention, and articulation of plan operations, and through the gains in quality of production of both weak and strong spelling subjects over the three intervals as indicated by their DST scores.

Ann's teacher displayed neither knowledge nor interest in this regard. In her interactions with the researcher, she displayed a genuine appreciation of Ann's productions as expressions of her youthful idiosyncrasies, but did not view the rudimentary conventions and phonetically related approximations of conventions in her pupils' invented spellings as opportunities on which to build by gradually refining conventions of written language. Her "laissez faire" belief in the development of spelling within a whole language approach was reflected in the data and cognitive control analysis summary forms of her pupils, and by the comparatively modest changes in DST scores over the June, February, and May data collections.

Teacher educators, supervisors, and evaluators must ensure that a system is in place to educate and maintain a level of knowledge in accord with current and developing physiological, cognitive processing, and language development research affecting learning. The recent Report of the Royal Commission on Learning of the Ontario Ministry of Education (1995) has recognized and addressed the need for the professionalization and continuing development of teachers throughout their careers. Teacher development is cited as one of the four engines of change. A vehicle is identified to ensure that teaching practitioners establish and maintain current professional knowledge.

Ideally, all teachers of emerging and developing writers should be knowledgeable of stages of cognitive growth and development, stages of word knowledge, and of how cognitive processing unfolds within a cognitive developmental framework. During the time lapse required to effect this change through staff education, individualized assistance tailored to meet the learner's cognitive developmental needs can make a difference. In Hannah's school, regular classroom teachers were not versed in cognitive and word knowledge development. However, some remedial support was provided by a resource teacher who expressed enthusiasm for learning about the developmental nature of word knowledge within a cognitive developmental framework, and who sought assistance in developing an appropriate programme for students for whom she provided resource help. Developmental Spelling Test results at the June, February, and May data collections for the two subjects with whom the resource teacher worked from November onward were 11, 39, 42 and 11, 42, 46 (maximum DST score- 60). The parent of an additional subject who continued to be a non-reader into the spring term finally agreed to remedial assistance for her son early in April. His DST scores reflect the change in progression that resulted--June, 2; February, 4; May, 26.

To improve spelling and problem-solving skills, a "cognitive control detection and correction program" produced and effected by teachers educated in cognitive processing and cognitive development could be beneficial as an interim to the long range goal of all teachers of emerging and developing writers as cognitive processing and cognitive development experts.

Considerations and Suggestions for Improvements in Methodology

The Dionne Table was critical to data collection and analysis of cognitive strategy construction. The suggestions which follow are worthy of consideration if attempting to replicate the procedure used:

1. A pilot study is critical. With the number of components requiring management and monitoring simultaneously, prior practice with the Dionne apparatus is required.

2. During the pilot, a patterned sequence of operations to be conducted should be established in order to ensure that the video camera, the two tape recorders, the tie clip microphone, the sequence of acetates, the markers, and the puppet are in place and ready to function simultaneously when needed. A single oversight or malfunction can add hours to

the transcription and analysis processes. The sequence of operations provided in this research will require adaption to the idiosyncrasies of the machines being used.

3. The geometric shapes on the DST acetate should be either removed entirely or relocated in smaller size to the top right hand corner of the acetate (depending on the skill level of the subjects to be studied). The shapes, as produced on the acetates used in this research, in several instances blocked the view of facial movements and expressions, making the analysis and interpretation tedious. The original purpose of the shapes in Tangel's kindergarten data collection was to ensure that subjects could identify the correct page on which to write in their DST test booklets. Since the researcher controls the presentation and removal of each acetate, there is little danger of being unable to establish which target word has been represented in even the most imaginative letter strings produced in early writings if the researcher has established and followed a pattern for acetate organization.

4. The cognitive control coding grid and analysis forms should be reordered so that the categories are placed into hierarchical developmental sequence. This has already been done in the case of the data related operation material, for which the researcher drew extensively from the developmental sequence of word knowledge established by Henderson (1990) and Tangel (1991) as a framework to the grid development. In developing the cognitive control categories, the researcher relied primarily on the protocols for operation identification and categorization. As a consequence, categories are currently ordered in the sequence in which they were identified from the videotapes--from the surface structure of the productions to the deeper level of thoughts of the child. The flow in presentation is from "end product" to "earliest thought process". In hindsight, it appears more reasonable to sequence both data related and cognitive control related forms in developmental sequence.

In Conclusion

It is possible to identify data related and cognitive control related operations used by kindergarten and Grade 1 girls and boys of strong and weak abilities, and from these to examine patterns of difference in operational use by ability and gender. Patterns of differences by ability were frequent; patterns of difference by gender were inconsequential. Response style, focus of attention and articulation of a plan operations were found to differentiate by ability the extent to which processing of new information was possible within the executive control structures (working memory), and consequently, the rate at which automatic production was achieved. When attentional focus and articulation of a plan operations were not functioning efficiently, emerging spellers consumed an inordinate amount of working memory space when activating back-up memory operations. There was little space remaining for integration.

The control structures of strong spellers were found to be operating efficiently. Strong spellers selected appropriate information for processing and attended to the task until completed. If interrupted by an external source, they returned to the task without reminder. From the information selected, they were able to establish a goal, develop a sequenced procedure to explore the goal, and monitor the way in which they effected their planning. Once these operations were activated, the major restructuring of thought was followed by a rapid increase in data related operations performed. Until restructuring occurred, no major surge in data related operations was forthcoming.

Weak subjects took longer to develop attention and planning operations. They attempted to compensate by introducing back-up operations to retain in-coming information while attempting to organize the new information being "held" for integration into existing thought structures. The activation of additional back-up operations reduced the space available for organizing and integrating new learning into existing structures. When working memory became occupied by back-up strategies, integration was "blocked". When blockage occurs, intervention is required.

The Dionne Observation Table was critical to the analysis and interpretation of cognitive control operational use. As such, it offers promise both as a research tool and as a diagnostic tool for classroom use. Although the apparatus might initially appear intimidating, the effort of the researcher, a novice operator of audio-visual equipment when the research began, has demonstrated that the expertize required to manage the equipment can be acquired through articulation of a working plan and minimal practice in a pilot study.

REFERENCES

Allred, R. A. (1990). Gender differences in spelling achievement in grades 1 through 6. Journal of Educational Research, 83 (4), 187- 193.

Anderson, J. R. (1983). The architecture of cognition. Cambridge, MA: Harvard University Press.

Anderson, J. R. (1987). Methodologies for studying human knowledge. Behavioural and Brain Science, 10, 467-505.

Anderson, J. R., Greeno, J. G., Kline, P. J., & Neves, D. M. (1981). Acquisition of problem-solving skill. In J. R. Anderson (Ed.), Cognitive skills and their acquisition. Hillsdale, NJ: Lawrence Erlbaum Associates.

Ball, E. & Blachman, B. (1988). Phoneme segmentation training: Effect on reading readiness. Annals of Dyslexia, 38, 208-225.

Ball E. & Blachman, B. (1991). Does phoneme awareness training in kindergarten make a difference? Reading Research Quarterly, 26(1), 49-66.

Beers, J. (1974). First and second grade children's concepts of tense and lax vowels. Unpublished doctoral dissertation, University of Virginia. Dissertations Abstracts International, 35, 4972. (University Microfilms No.74-04698).

Beers, J., Beers, C., & Grant, K. (1977). The logic behind children's spelling. Elementary School Journal, 3, 238-242.

Beers, J. & Henderson, E. (1977). A study of developing orthographic concepts among first graders. Research in Teaching English, 11, 133-148.

Bissex, G. (1980). GYNS AT WRK: A child learns to write and read. Cambridge, MA: Harvard University Press.

Blanchet, A. (1981). Étude génétique des signification et des modèles utilisés par l'enfant lors de la résolution de problèmes. Thèse de doctorat (No. 102), Université de Genève, Faculté de psychologie et des sciences de l'éducation, Impremerie Nationale.

Broderius, B. W. (1985). Achievement gains of fifth grade pupils taught by teachers using the essentials of instruction: A pilot study. Paper presented at the Annual Meeting of the Northern Rocky Mountain Educational Research Association, Jackson Hole, Wyoming, October 10- 12.

Bruchkowsky, M. M. (1991). The development of empathic cognition in early and middle childhood. In R. Case, The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge (p.153-170). Hillsdale, NJ: Lawrence Erlbaum and Associates.

Burns, J. & Richgels, D. (1989). An investigation of task requirements associated with invented spellings of 4-year-olds with above average intelligence. Journal of Reading Behavior, 21(1), 1-14.

Butler, J. M. & Handley, H. M. (1989). Differences in achievement for first grade students taught in small classes. Paper presented at the Annual Meeting of the American Educational Researcher Association, San Francisco, CA, March 27-31.

Carey, S. (1985). Conceptual change in childhood. Cambridge, MA: MIT Press.

Carey, S. (1988). Reorganization of knowledge in the course of acquisition. In S. Strauss (Ed.), Ontogeny, phylogeny, and historical development (pp. 1 - 27). New York: Ablex.

Case, R. (1978). A developmentally based theory and technology of instruction. Review of Educational Research, 48 (3), 439-463.

Case, R. (1984a). From behaviorism to cognitive behaviorism to cognitive development: Steps in the evolution of instructional design. Instructional Science, 13 (2), 141-158.

Case, R. (1984b). The process of stage transition: A neo-Piagetian view. In R. J. Sternberg (Ed.), Mechanisms of cognitive development (21-44), New York: W. H. Freeman.

Case, R. (1985). Intellectual development: Birth to adulthood. Toronto: Academic Press, Inc.

Case, R. (1991). The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge. Hillsdale NJ: Lawrence Erlbaum Associates.

Case R. & Bereiter, C. (1984). From behaviorism to cognitive behaviorism to cognitive development: Steps in the evolution of instructional design. Instructional. Science, 13 (2), 141-158.

Case R. & Griffin, S. (1989). Child cognitive development: The role of central conceptual structure in the development of scientific and social thought. In C. A. Hauert (Ed.), Advances in psychology (pp.193-230), Amsterdam: North Holland (Elsevier).

Case, R., Hayward, S., Lewis, M. & Hurst, P. (1987). Toward a neo-Piagetian theory of cognitive and emotional development. Developmental Review, 8, 35.

Chase, W. G. & Ericsson, K. A. (1981). In J. R. Anderson (Ed.), Cognitive skills and their acquisition (pp. 141-189). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chipman, S. F., Segal, J. W., & Glaser, R. (1985). Thinking and learning skills, Vol. 2: Research and open questions. Hillsdale, NJ: Lawrence Erlbaum & Associates.

Chomsky, C. (1971, March). Write first, read later. Childhood Education, 296-299.

Chomsky, C. (1979). Approaching reading through invented spelling. In L. B. Resnick and P. A. Weaver (Eds.), Theory and practice of early reading: Vol. 2. Hillsdale, N.J.: Erlbaum.

Clay, M. (1972). Sand- the concepts about print test. Auckland, New Zealand: Heinemann Publishers.

Clay, M. (1975). What did I write? Exeter, NH: Heinnemann Educational Books.

Clay, M. (1993). Reading recovery: A guidebook for teachers in training. Portsmouth, NH: Heinnemann Educational Books.

Cone, T. E., Wilson, L. R., Bradley, C. M., & Reese, J. H. (1985). Characteristics of LD students in Iowa: An empirical investigation. Learning Disabilities Quarterly, 8, 211-220.

Crammond, J. (1991). Analyzing the basic cognitive-developmental processes of children with specific types of learning disability. In R. Case, The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge (p. 285-302). Hillsdale, NJ: Lawrence Erlbaum Associates.

Damon, W. (1973). The child's conception of justice as related to logical thought. Unpublished doctoral dissertation, University of California, Berkley. Dissertation Abstracts International, 35, 2400. (University Microfilms No. 74- 24631).

Dangel, H. L. (1989). The use of student-directed spelling strategies. Academic Therapy., 25 (1), 43-51.

Demersseman, S. L. (1976). A developmental investigation of children's moral reasoning and behaviour in hypothetical and practical situations. Unpublished doctoral dissertation. University of California, Berkley. Dissertation Abstracts International, 37, 4643. (University Microfilms No. 77-04435).

Dyson, A. H. (1984). Learning to write/ learning to do school: Emergent writers' interpretation of school tasks. Research in the Teaching of English, 18 (3), 233-264.

Ericsson, K. A. & Crutcher, R. J. (1991). Introspection and verbal reports on cognitive processes--two approaches to the study of thought processes: A response to Howe. New Ideas in Psychology, 9, 57-71.

Ericsson, K. A. & Simon, H. A. (1980). Verbal reports as data. Psychological Review, 87, 215-251.

Ericsson, K. A. & Simon, H. A. (1985). Protocol analysis. In T. A. van Dijk (Ed.), Handbook of discourse analysis, Vol. 2. London: Academic Press.

Ericsson, K. A. & Simon, H. A. (1987). Verbal reports on thinking. In C. Faerch & G. Kasper (Eds.), Introspective methods in second-language acquisition research (24-53), Clevedon, UK: Multilingual Matters.

Ericsson, K. A. & Simon, H. A. (1993). Protocol analysis: Verbal reports as data. Cambridge, MA: The MIT Press.

Fischer, K. W. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. Psychological Review, 87, 477 - 531.

Fodor, J. (1982). The modularity of mind. Cambridge, MA: MIT Press.

Gardner, H. (1983). Frames of mind: The theory of multiple intelligences. New York: Basic Books.

Garner, R. (1988). Verbal report data on cognitive and metacognitive strategies. In C. E. Weinstein, E. T. Goetz, & P. A. Alexander, (Eds.), Learning and study strategies: Issues in assessment, instruction, and evaluation, (pp. 63-76). San Diago, CA: Academic Press.

Gentry, J. R. (1977). A study of the orhtographic strategies of beginning readers. Unpublished doctoral dissertation, University of Virginia. Dissertation Abstracts International., 39, 4017. (University Microfilms No. 79-01152).

Gentry, J. R. & Henderson, E. H. (1978). Three steps to teaching beginning readers to spell. Reading Teacher, 31,(1), 632-637.

Gelzheiser, L. M. (1991). Learning sound/symbol correspondences: Transfer effects of pattern detection and phonics instruction. Applied Cognitive Psychology, 5, 361-371.

Gerber, M. M. (1984a). Orthographic problem-solving ability of learning disabled and normally achieving students. Learning Disabilities Quarterly, 7, 157-164.

Gerber, M. M. (1984b). Techniques to teach generalizable spelling skills. Academic Therapy, 20(1), 49-58.

Gerber, M. M. (1985). Spelling as concept governed problem-solving: Learning disabled and normally achieving students. In B. Hutson (Ed.), Advances in reading/language research (Vol. 3, pp. 39-75). Greenwich, CT: JAI Press.

Gerber, M. M. (1986). Cognitive behavioral training in the curriculum: Time, slow learners, and basic skills. Focus on Exceptional Children, 18(6), 1-12.

Gerber, M. M. (1987). Applications of cognitive behavioral training methods to teaching basic skills to mildly handicapped elementary school students. In M. C. Wang & H. J. Walberg (Eds.), Handbook of special education: Research and practice (Vol. 1): Learner characteristics and adaptive education (167-186), Oxford, England: Pergamon Press.

Gerber M. M. & Hall, R. J. (1982). Development of spelling in learning disabled and normally achieving children. Unpublished monograph, University of California, Santa Barbara.

Gerber M. M. & Hall, R. J. (1987). Information processing approaches to studying spelling deficiencies. Journal of Learning Disabilities, 20 (1), 34-42.

Gerber, M. M. & Hall, R. J. (1989). Cognitive behavioral training in spelling for learning handicapped students. Learning Disabilities Quarterly, 12(3), 159-171.

Halford, G. S. (1982). The development of thought. Hillsdale, NJ: Lawrence Erlbaum Associates.

Halford, G. S. (1989). Reflections on 25 years of Piagetian cognitive developmental psychology, 1963 - 1988. Human Development, 32, 325 - 357.

Hall, R. J. (1984). Orthographic problem-solving. Academic Therapy, 20(1), 67-75.

Hall, R. J., Gerber, M. M., & Stricker, A. G. (1989). Cognitive training: Implications for spelling instruction. In J. N. Hughes & R. J. Hall (Eds.), Cognitive behavioral psychology in the schools: A comprehensive handbook (347- 388). New York: Guilford Press.

Harste, J., Woodward, V. & Burke, C. (1984). Language lessons and literacy lessons. Portsmouth, NH: Heinemann Educational Books.

Hayes, U. (1993). Invented spelling: An indicator of problem-solving strategies? Unpublished manuscript, University of Ottawa.

Healy, J. M. & Aram, D. M. (1986). Hyperlexia and dyslexia. Anals of Dyslexia, 36 , 237- 252.

Henderson, E. H. (1981). Teaching children to read and spell. Dekalb, IL: Northern Illinois University Press.

Henderson, E. H. (1984). Teaching children to spell English. Boston, MA: Houghton Mifflin.

Henderson, E. H. (1986). Understanding children's knowledge of written language. In David B. Yaden and Shane Templeton (Eds.) . Metalinguistic awareness of beginning literacy. Portsmouth, NH: Heinnemann Educational Books.

Henderson, E. H. (1990). Teaching spelling. Boston, MA: Houghton Mifflin.

Henderson, E. H. & Beers, J. W. (1980). Developmental and cognitive aspects of learning to spell: A reflection of word knowledge . Newark, DE: International Reading Association.

Henderson, E. H., Estes, T. H., & Stonecash, S. (1972). An exploratory study of word acquisition among first graders at mid-year in a language experience approach. Journal of Reading Behavior, 4, 21-30.

Henderson, E. H. & Templeman, S. (1986). A developmental perspective of formal spelling instruction through alphabet, pattern, and meaning. Elementary School Journal, 86(3), 1-13.

Holland, H. J., Holyoak, K. J., Nisbett, R. E., & Thagard, P. R. (1986). Induction: Processes on inference, learning, and discovery. Cambridge, MA: MIT Press.

Hunt, B. C. (1985, April). A Leprechaun in King Arthur's Court: Topic, theme, and mode in the writing of first graders using invented spelling. Paper presented at the Annual Meeting of the Massachusetts Reading Association, Sturbridge, MA.

Inhelder, B. & Piaget, J. (1958). The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures. New York: Basic Books.

Javal, E. (1878). Essaie sur la physiologie de la lecture. Annales d'oculistique, 79, 97. In R. S. Siegler, Children's thinking, (p.125), Englewood Cliffs: NJ: Prentice-Hall.

Johansen, K. (1991). Diagnosing dyslexia: The screening of auditory laterality. (Research Report No. CS 010 344). Copenhagen, Denmark: (ERIC Document Reproduction Services No. ED 326 845)

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. Psychological Review, 87, 329-354.

Kail, R. (1984). The development of memory in children (2nd ed.). New York: Freeman.

Keating, D. P. & Bobbitt, B. L. (1978). Individual and developmental differences in cognitive processing components of mental ability. Child Development, 49, 155-167.

Kimura, D. (1992). Sex differences in the brain. Scientific American, 267 (3), 118-125.

Leahy, P. E. (1991). Results of a multi-year formative evaluation for the "Writing to Read" program in a mid-sized suburban school district. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, April 3- 7.

Liberman, I., Rubin, H., Duques, S., & Carlisle, J. (1985). Linguistic abilities and spelling proficiency in kindergarteners and adult poor spellers. In D. Gray & J. Kavanagh (Eds.). Behavioral measures of dyslexia. Parkton, MD: York Press.

Leunenberger, J. & Morris, M. (1990). Analysis of spelling errors by learning disabled and normal college students. Learning Disabilities Focus, 5 (2), 103- 118.

Lydiatt, S. (1984). Error detection and correction in spelling. Academic Therapy, 20(1), 33-40.

Mann, V., Tobin, P., & Wilson, R. (1987). Measuring phonological awareness through the invented spellings of kindergarten children. Merrill Palmer Quarterly, 33, 365-391.

Maratsos, M. P. (1983). Some current issues in the study of the acquisition of grammar. In J. H. Flavell & E. Markman (Eds.), Handbook of child psychology (Vol. 3, pp. 707-786). New York: Wiley.

Marini, Z. & Case, R. (1989). Parallels in the development of preschoolers knowledge about their physical and social worlds. Merrill Palmer Quarterly, 35(1), 63-88.

McKenna, M., Stahl, S., & Reinking, D. (1994). A critical commentary on research, politics, and whole language. Journal of Reading Behavior, 26, (2), 211-233.

Metz, K. E. (1985). The development of children's problem-solving in a gears task: A problem space perspective. Cognitive Science, 9, 431-471.

Ministry of Education and Training of Ontario. (1994). For the love of learning: Report of the Royal Commission on Learning. Toronto, Ontario: Queen's Printer for Ontario.

Morton, L. L. (1985). Educational implications of preinstructional spelling proficiency at the grade four level. Canadian Journal for Exceptional Children, 2(1), 25-29.

Morris, D. (1983). Concept of word and phoneme awareness in the beginning reader. Research in the Teaching of English, 17 (4), 359-373.

Morris, D. (1989). Developmental spelling theory revisited. Reading Psychology, 10(3), iii-x.

Morris, D., Nelson, L., & Pierney, J. (1986). Exploring the concept of spelling "instructional level" through the analysis of error types. Elementary School Journal, 87, 181-200.

Morris, D. & Perney, J. (1984). Developmental spelling as a predictor of first grade reading achievement. Elementary School Journal, 84(4), 440-457.

Newall, A. & Simon, H. A. (1972). Human Problem-solving. Englewood Cliffs, NJ: Prentice-Hall.

Nisbett, R. & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. Psychological Review, 84, 231-259.

Noelting, G. (1982). Le développement cognitif et le méchanisms de l'éqilibration. Chicoutimi, QC: Gaetan Morin.

Novelli, J. (1993). Strategies for spelling successes. Instructor, May/June, 41-47.

Pascual-Leone, J. (1988). Organismic processes for neo-Piagetian theories: A dialectical causal account of cognitive development. In A. Demetriou (Ed.), The neo-Piagetian theories of cognitive development: Towards an integration (pp. 25 -65). Amsterdam: North Holland (Elsevier).

Pascual-Leone, J., & Goodman, D. (1979). Intelligence and experience: A neo-Piagetian approach. Instructional Science, 8, 301 - 367.

Paul, R. (1976). Invented spelling in kindergarten. Young Children, 21(3), 195-200.

Payne, J. W. (1976). Task complexity and contingent processing in decision making: An information search and protocol analysis. Organizational Behavior and Human Performance, 16, 366-387.

Polya, G. (1957). How to solve it. Garden City, NY: Doubleday-Anchor.

Porath, M. (1991). Stages and structure in development of children with various types of giftedness. In R. Case, The mind's staircase: Exploring conceptual underpinnings of children's thought and knowledge (p. 303-318). Hillsdale, NJ: Laurence Erlbaum Associates.

Read, C. (1971). Preschool children's knowledge of English phonology. Harvard Educational Review, 41, 1-34.

Read, C. (1975). Children's categorizations of speech sounds in English. Urbana, Ill.: National Council of Teachers of English.

Read, C. (1981). Writing is not the inverse of reading for young children. In C. Frederiksen & J. F. Dominic, Writing: The nature, development, and teaching of written communication. N. J.: Erlbaum.

Read, C. (1986). Children's creative spellings. London: Routledge & Kegan Paul.

Reder, L. (1987). Strategy selection in question answering. Cognitive Psychology, 19, 90-138.

Reed, S. K., Ernst, G. W., & Banerji, R. (1974). The role of analogy in transfer between similar problem states. Cognitive Psychology, 6, 436-450.

Richgels, D. (1995). Invented spelling ability and printed word learning in kindergarten. Reading Research Quarterly, 30 (1), 96-109.

Riding, R. J. and Tempest, J. (1986). Spelling and learning style in children. Educational Psychology, 6 (4), 313- 320.

Routman, R. (1993). The uses and abuses of invented spelling. Instructor, May/June, 35-39.

Schauble, L. (1989). Processes of constructive learning and inference in children: Understanding the causal structure of a microworld. Unpublished manuscript.

Schlagel, R. (1982). A qualitative inventory of word knowledge: A developmental study of spelling, grades one through six. Unpublished doctoral dissertation, University of Virginia, Charlottesville.

Schlagel, R. C. (1989). Constancy and change in spelling development. Reading Psychology, 10, 207-232.

Schlagel, R. C. (1986). Informal and qualitative assessment of spelling. Pointer, 30(2), 37-41.

Schael, J. G. (1994). La nature et la fonction des graphismes produits lors de la résolution de problèmes en mathématique `a niveau intermédiaire. Unpublished doctoral dissertation, University of Ottawa, Ottawa.

Scott, R. (1993). Spelling: Sharing the secrets. Toronto: Gage Educational Publishing.

Shultz, T. R., Fisher, G. W., Pratt, C.C., & Rulf, S. (1986). Selection of causal rules. Child Development, 57, 143-152.

Siegler, R. S. (1976). Three aspects of cognitive development. Cognitive Psychology, 8, 481-520.

Siegler, R. S. (1978). The origins of scientific reasoning. In R. S. Siegler (Ed.), Children's thinking: What develops? Hillsdale, NJ: Lawrence Erlbaum Associates.

Siegler, R. S. (1981). Developmental sequence within and between concepts. Monographs of the Society for Research in Child Development, 46, (Whole No. 189).

Siegler, R. S. (1983). Five generalizations about cognitive development. American Psychologist, 38, 263-277.

Siegler, R. S. (1986a). Children's thinking. Hillsdale, NJ: Prentice-Hall.

Siegler, R. S. (1986b). Unities in strategy choice across domains. In M. Perlmutter (Ed.), Minnesota symposium on child development, (Vol. 19, pp. 1-48). Hillsdale, NJ: Lawrence Erlbaum Associates.

Siegler, R. S. (1987a). Strategy choices in subtraction. In J. Sloboda and D. Rogers (Eds.), Cognitive process in mathematics, (pp. 81-106). Oxford: Oxford University Press.

Siegler, R. S. (1987b). The perils of averaging data over strategy: An example from children's addition. Journal of Experimental Psychology, 116, 250-264.

Siegler, R. S. (1988a). Strategy choice procedures and the development of multiplication skill. Journal of Experimental Psychology, 117, 258-275.

Siegler, R. S. (1988b). Individual differences in strategy choices: Good students, not-so-good students, and perfectionists. Child Development, 59, 833-851.

Siegler, R. S. (1991). Strategy choice and strategy development. Learning and instruction, (Vol. 1, pp. 89-102). Great Britain: Pergamon Press.

Siegler R. & Jenkins, E. (1989). How children discover new strategies. Hillsdale, NH: Lawrence Erlbaum Associates.

Siegler , R. S. & McGilly, K. (1989). Strategy choices in children's telling time. In I. Levin & D. Zakay (Eds.), Psychological Time: A life span perspective. Elsvier: The Netherlands.

Siegler , R. S.& Richards, D. (1979). Development of time, speed, and distance concepts. Developmental Psychology, 15, 288-298.

Siegler, R. S. & Robinson, M. (1982). The development of numerical understandings. In H. W. Reese & L. P. Lipsett (Eds.), Advances in child development and behaviour. New York: Academic Press.

Siegler R. S. & Shrager, J. (1984). Strategy choices in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), Origins of cognitive skills. Hillsdale, NJ: Lawrence Erlbaum Associates.

Simon, H. A. & Hayes, J. R. (1976) Understanding complex task instructions. In D. Khlar (Ed.), Cognition and instruction, (pp. 269-285). Hillsdale, NJ: Lawrence Erlbaum Associates.

Simon, D. P. & Simon, H. A. (1978). Individual differences in solving physics problems. In R. S. Siegler (Ed.), Children's thinking: What develops? (325-348). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stanley, J. C. (1987). Study of mathematically precocious youth. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, DC, April 20- 24.

Tangel, D. (1991). Effect of phoneme awareness training on kindergarten and first grade children's invented spelling. Unpublished doctoral dissertation, Syracuse University.

Tangel, D. & Blachman, B. (1991). Effects of phoneme awareness training on kindergarten children's invented spelling. Research paper presented at the American Educational Research Association Conference, Chicago, April 5.

Taylor, K. L. (1992). University Professors' and Students' Knowledge of the Executive Control Strategies Applied in the Solving of Ill-structured Problems. Unpublished doctoral dissertation, University of Ottawa, Ottawa.

Vogel, S. A. (1990). Gender differences in intelligence, language, visual-motor abilities, and academic achievement in students with learning disabilities: A review of the literature. Journal of Learning Disabilities, 23 (1), 44- 52.

Vygotsky, L. S. (1962). Thought and language. Cambridge , MA: M.I.T.

Vygotsky, L. S. (1978). Mind in Society. Cambridge, MA: Harvard University Press.

Weber, W. R.& Henderson, E. H. (1989). A computer-based program of word study: Effects on reading and spelling. Reading Psychology , 10 (3), 157-172.

Whorton, J. E. (1985). Comparing ability and achievement in three academic areas for upper elementary gifted students. Journal for the Education of the Gifted, 8 (2), 149- 154.

Zutell, J. (1980). Children's spelling strategies and their cognitive development. In E. Henderson & J. Beers (Eds.), Developmental and cognitive aspects of learning to spell: A reflection of word knowledge. Newark, DE: International Reading Association.

APPENDIX A

Directions for Administration of 10-Word Developmental Spelling Test

Directions for Administration of 10-Word DST

"You are going to be given some words and I want you to write each of them on an acetate that looks like this one.

Across the top of each acetate you will see the letters of the alphabet. There will be a line towards the center. Your task is to write the word that the tape recorder tells you on the line.

The tape recorder will say the word, then read a sentence with the word in it, then say the word again. I will give you a new acetate for each word. Here is the acetate for the first word."

1. lap . . . . The baby was on her mother's lap . . . . lap
2. sick . . . . The child was too sick to go to school. . . . . sick
3. pretty . . . . . . The girl had on a pretty dress . . . . pretty
4. elephant . . . . . We saw an elephant at the zoo. . . . . zoo
5. train. . . . . . . We took the train to our grandmother's house . . . train
6. hunt . . . . On Easter, we hunt for eggs . . . . hunt
7. street . . . . . . It is dangerous to play in the street . . . . street
8. kissed . . . . . . The boy kissed his mother goodnight . . . . kissed
9. order. . . . . . . Please order me a hamburger . . . . order
10. snowing . . . . When it is snowing, we wear our boots . . . . . snowing

Encourage each child to put something down for each word.
Prompts can include: . . . . . . Just do the best you can
. . . . I like how hard you are trying.

Adapted from Effects of Phoneme Awareness Training on Kindergarten and First Grade Children's Invented Spelling, (p. 200) by Darlene M. Tangel, 1991. Unpublished doctoral dissertation. University of Syracuse, Syracuse, NY.

APPENDIX B

Rating Scale for 10-Word Developmental Spelling Test

Scoring Criteria: Lap, Sick

0 A random string of letters

---

1 The initial phoneme represented with a phonetically related letter. May be followed by a random string.
e.g., lap r
or
Single letter response that represents some part of the word other than the initial phoneme. May be followed by a random string.

e.g.,	lap	p
	sick	c, k

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabetic string.

e.g.,	lap	lmnop
	sick	stuv, slh

---

3 More tham one phoneme but not all. Must be represented with phonetically related or conventional letters. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.

e.g.,	lap	ltp, lpa
	sick	cit, soc, sak

or
Every phoneme must be represented, but not all with phonetically related letters.

e.g.,	lap	fab, eap
	sick	cit, soc, sak

---

4 Every phoneme represented with a mix of phonetically related and conventional letters. May include intrusions.

e.g.,	lap	labt, rap, lape
	sick	siack, sec, sek, sike

---

5 All consonant phonemes with conventional letters and the correct short vowel.

e.g.,	lap	lapp
	sick	sic, cik, sik, scik

---

6 The correct spelling.

Scoring Criteria: Pretty

0 A random string of letters.

---

1 One phonetically related letter. May be followed by a random string.
e.g., b

or

Single letter response that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., e, t, r, d

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabet string.
e.g., pqrst, psmtfls, p

---

3 Two or three phonemes from the first syllable, with conventional or phonetically related letters. The initial blend is absent.
e.g., pd, pi, ptt, pit, ped, pid

or

The initial blend correctly represented or represented with a vowel between it. May be followed by a random string.
e.g., pr, prmtzsa, par, pir

or

The first and last syllable represented, but the blend is absent.
e.g., pte, pie, pe

---

4 Everv phoneme of the first syllable including the initial blend and appropriate vowel with conventional or phonetically related letters.
e.g., pret, pred, prit

or

Both syllables represented, first syllable vowel present, but blend absent or both syllables represented, blend present, but first syllable vowel absent.
e.g., pidy, petee, prte, prdy

---

5 All consonant phonemes of the first syllable, including the initial blend, with phonetically related or conventional letters, plus a vowel in the second syllable.
e.g., predy, prete, prite, prity, prittie

---

6 The correct spelling.

Scoring Criteria: Elephant

0 A random string of letters.

---

1 A single letter that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., l, f, t

---

2 The initial syllable represented by e or el. May be followed by a random string.

or

Any two phonemes from the word (must be in proper sequence) and may be followed by a random string. The initial syllable (the schwa) may be represented with any vowel.
e.g., ltfnoa, efl, lolot, le

or

ll, al, or el plus any one phoneme.
e.g., alfThe initial syllable represented with, elf

---

3 One or two letters from the initial syllable (e, l, el, al, ll) plus two phonemes from the third syllable.
e.g., eft, lfax, alft, llft

or

The initial syllable represented with el, al, e, or l, a vowel to represent the middle syllable, and one or two phonemes from the third syllable.
e.g., lot, elof, elovt, lyfe, eeft

or

The initial syllable represented by l, al, el, e, plus three phonemes from the third syllable.
e.g., efanl, elfit, alfate, elfnt

---

4 The initial syllable represented with e, l, al, or el, a vowel to represent the middle syllable, and three or more phonemes from the last syllable.
e.g., lefan, lifit, elufit, alafinte, elapint

or

The initial syllable represented with el, al, l, the final syllable represented with four conventional phonemes, including the consonant nasal, but no vowel to represent the middle syllable.
e.g., elfent, alfint, llfent

---

5 The initial syllable represented, a vowel for the middle syllable, and four conventional or phonetically related phonemes from the third syllable.
e.g., elufint, alufint, alefint

---

6 The correct spelling.

Scoring Criteria: Train

0 A random string of letters.

---

1 The initial phoneme represented with a phonetically related letter. May be followed by a random string.
e.g., j, g, ch, h

or

Single letter response that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., r, a, n

---

2 The correct initial phoneme of the word. May be followed by a random string.
e.g., t, toonum

---

3 More than one phoneme but not all. Must be represented with phonetically related or conventional letters. May include intrusions. When the intrusion is removed, the rest of the letters should be in a proper sequence.
e.g., tam, jra, tan, cran

---

4 Every phoneme, including the blend, represented with a mix of phonetically related or conventional letters. The long vowel may or may not be marked.
e.g., tren, chran, thran, shran, jran, chrane

or

The long vowel is marked, but only part of the blend is given.
e.g., chane, jane, tain

---

5 All consonant phonemes, including the blend, represented with conventional letters. The vowel is marked.
e.g., trane, trayn, traen, traiyn

---

6 The correct spelling.

Scoring Criteria: Hunt

0 A random string of letters.

---

1 A single letter response that represents some salient part of the word other than the initial phomene. May be followed by a random string.
e.g., t

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabet string.
e.g., h, hmtsv

---

3 More than one phoneme but not all. Must be represented with phonetically related or conventional letters. May include some intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., th, hu, hat, hit, hout, hot

---

4 Every phoneme including the preconsonant nasal. Either a single incorrect vowel or an incorrectly marked vowel is present. May include intrusions.
e.g., huint, hunte, honte, hent, hint, hant

or

Every phoneme with correct letters except the preconsonant nasal
e.g., hut

or

Every phoneme with conventional letters except the short vowel.
e.g., hnt

---

5 All consonant phonemes, including the preconsonant nasal, with conventional or phonetically related letters.
e.g., hont

---

6 The correect spelling.

Scoring Criteria: Street

0 A random string of letters.

---

1 A single letter response that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., tlamtlvu, e, r

---

2 The correct initial phoneme.May be followed by a random string or an alphabet string.
e.g., stuvw

---

3 More than one phoneme but not all. May be represented with phonetically related or conventional letters. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., swet, stot, jret

or

Two letters from the blend, plus at least one other phoneme. May include intrusions.
e.g., stee, sret

or

The entire blend plus one or two phonemes. May include intrusions.
e.g., strt, strit, strite

---

4 Every phoneme including the blend (in proper sequence), represented with a mix of phonetically related and conventional letters. May include intrusions.
e.g., stret, sttret, shrete, stareet

or

Two letters of the blend, the correct vowel, and an attempt to mark the vowel. May include intrusions.
e.g., strete, steat, shreat

---

5 All consonant phonemes, including the initial blend, with conventional letters, and an attempt to mark the vowel. May not include intrusions.
e.g., strete, streat

---

6 The correct spelling.

Scoring Criteria: Kissed

0 A random string of letters.

---

1 A single letter response that represents some salient part of the word. May be followed by a letter string.
e.g., <u>s</u>umr, t

The initial phoneme represented with a phonetically related letter. May be followed by a random string.
e.g., c

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabet string
e.g., <u>k</u>rmts

---

3 More than one phoneme. but not all. Must be represented with phonetically related or conventional letters. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., cis, kee, c<u>l</u>t

or

Two or more phonemes represented with phonetically related or conventional letters. The -<u>ed</u> is represented with a -<u>t</u> or -<u>ed</u>.
e.g., kst, cit, cest, cised

---

4 Every phoneme represented with a mix of phonetically related or conventional letters. The initial phoneme is correct, and the -<u>ed</u> is represented. May include intrusions. When the intrusion is removed, the rest of the letters are in proper sequence.
e.g., kiss<u>e</u>t, kest, kisted

or

<u>Kiss</u> spelled correctly.

---

5 Every phoneme of <u>kiss</u> represented with conventional letters and the -<u>ed</u> represented. May <u>not</u> include intrusions.
e.g., kised, kist

---

6 The correct spelling.

Scoring Criteria: Order

0 A random string of letters.

---

1 Single letter response that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., d, r, t

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabet string.
e.g., omstb

---

3 More than one phoneme, but not all. Must be represented with phonetically related or conventional letters. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., ord, odre, odr, rdr, wrd

---

4 Representation of four phonemes with a mix of phonetically related and conventional letters. May include intrusions.
e.g., oder, ordr, ortre, orde

---

5 Representation of all consonant phonemes with a mix of phonetically related and conventional letters. Each -r is preceded by a vowel.
e.g., orter, ordor

---

6 The correct spelling.

Scoring Criteria: Snowing

0 A random string of letters.

---

1 Single letter response that represents some salient part of the word other than the initial phoneme. May be followed by a random string.
e.g., omstrb

---

2 The correct initial phoneme of the word. May be followed by a random string or an alphabet string.
e.g., srfzxo, stuvw

---

3 Two of three phonemes from the first syllable, with conventional or phonetically related letters. The initial blend is absent. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., so, sowe, son

or

The initial blend is correctly represented. May be followed by a random string.
e.g., sn, snarn

---

4 The first syllable represented by at least three phonemes.
e.g., snow, snowe, sno

or

Both syllables represented, first syllable vowel and blend present. May include intrusions. When the intrusion is removed, the rest of the letters should be in proper sequence.
e.g., stnoin,snowig, snoinge

or

Both syllables represented with euther first syllable vowel present but blend absent or blend present and first syllable vowel absent.m Complete -ing ending present.
e.g., sowing, soing, snwing

---

5 All consonant phonemes, including the initial blend, with conventional letters, the correct vowel, but the vowel is either not marked or marked incorrectly.
e.g., snoing, snoweing

---

6 The correct spelling.

APPENDIX C

Consent Forms

Una Poole Hayes
Graduate Student
Faculty of Education
University of Ottawa
Box 91, 145 Jean-Jacques Lussier
Ottawa, Ontario KIN 6N5

Telephone: 458-2450 or 729-5397

Dear

I am an elementary school principal with a keen interest in how children learn to spell. The Pontiac Administration Committee of the Western Quebec School Board has granted me permission to request your cooperation in a study to be conducted under the direction of my research advisor, Dr. J. P. Dionne.

The purpose of the research is to explore the problem-solving strategies used by kindergarten and grade one children as they "sound out" and "invent" their own spellings to dictated words. Your child has been nomimated by his/her teacher as a potential candidate. Participation is voluntary with the right to withdraw at any time. Withdrawal from the project will not affect grades.

All work will be done at McDowell School in three or four sessions interspersed over a 12-month period. During each of the meetings, after a brief warm-up, children will be invited to teach a puppet how they decide what to write when dictated ten words. They will be audiotaped and videotaped as they work. Each session should require approximately 30 minutes. Children will be able to "see themselves" on the T.V. monitor as they write. Your child's teacher will be invited to review the tapes and writing. Parents will be able to have a copy of the global results if they so wish.

Children's "invented spellings", verbalizations, movements, and gestures will be analyzed to determine the cognitive strategies used. Information will be kept strictly confidential and will not appear in any school records. Your child's name will not be published. Pseudo-names will be attached to any data from the study. Results collected will be used only for research and professional development purposes.

If you have any questions, please call the researcher at the numbers given at the top of this letter or discuss them with your child's teacher who has already spoken with you about this project.

I would be grateful for your cooperation. Whether or not you wish to allow your child to participate, please complete the form below and return it to the school by ________________. If you give your permission, please complete the Permission to Quote form on the reverse side of this sheet.

Yours truly

Una Poole Hayes

CONSENT TO PARTICIPATE

I hereby _____ give permission
_____ do not give permission

for my child ________________________ to participate in the study "Invented Spelling as an Indicator of Problem-solving Strategies" as described above.

__________ ____________________________ ______________________________

Date Signature of parent or guardian Signature of child participant

Permission to Quote

I hereby grant permission to Una Poole Hayes to use anonymously (with no mention of child's name at any time) for research and professional development purposes, the audio and video recordings of my child, ________________________, during the taping of the "Invented Spelling as an Indicator of Problem-solving Strategies" research project at McDowell School outlined on the reverse side of this letter.

________	____________________	____________________
Date	Signature of Parent or Guardian	Signature of Child

APPENDIX D

Examples of Verbal Prococols of a Strong Speller and a Weak Speller

Appendix D-1

Verbal Protocol of a Strong Speller at February Data Collection

T: #1. Lap . . . The baby was on her mother's lap . . . . . lap.
S: Should I put a small L or a big L ?
E: As you choose.
S: OK. . . . .
E: Can you explain to Wrinkles why you chose those letters?
S: Um-mm . . . . Because . . . like . . . I was . . trying to spell out the words . . . so , . . . like, I made out the sound of L and A and P -- and it made lap.
E: Great ! Got that, Wrinkles ? . . . .

T: #2. Sick . . . The child was too sick to go to school . . . . . sick.
S: . . . .
E: Tell Wrinkles how you chose those letters?
S: Like the tape recorder said sick, like, and then I just putted out what I sounded. . . . .
E: Show him how you sounded it. He likes to be shown.
S: First I made the sound of S and I , and then C , and then K.
E: And how did you sound it . . . show him.
S: S-s-s- i-i-i- ck.
E: Great ! . . . . Very good . You're teaching him very well.

T: 3. Pretty. . . . The girl had on a pretty dress . . . . . pretty.
S: . . . .
E: Tell Wrinkles how.
S: I made the sound of pretty , like puh r-r-r-r- i-i-i-ih tuh tuh ee-ee-ee-.
E: And the word was . . . .
S: Pretty
E: Pretty. . . . .

T: #4. Elephant . . . We saw an elephant at the zoo. . . . . elephant.
S: . . . .
E: My goodness ! You've done a terrific job with elephant. Tell Wrinkles how you made all those choices.
S: Like, I kinda sounded them out . Um-mm, like, e- L e- fuh- i-i-i- in- tuh.
E: What's this?
S: But, but, I put the P in, because some words like phone , start with P H.

E: So that's why you put that PH in there. Terrific ! . . . . . . And you explained it well to Wrinkles, too. . . . .

T: #5. Train . . . We took the train to our grandmother's house . . . . . train.
S: . . . .
E: Tell Wrinkles.
S: Um-mm, I picked out the like the T R I A N N because , like, I just thought it was how you spelled train.
E: Um-hmm. . . . .

T: #6. Hunt . . . On Easter, we hunt for eggs . . . . . . hunt.
S: . . . .
E: Well, there's another one to tell Wrinkles about.
S: . . . . I picked those letters because I thought it spelled how you spelt hunt, and . . . .um-mm . . . . . .um-mm . . . .
E: You did it very well. I hope Wrinkles can do it as well. . . . .
T: #7. Stret . . . It is dangerous to play in the street . . . . . street.
S: . . . .
E: Tell Wrinkles about that. You certainly wrote that down fast.
S: Um-mm. I picked the letters S T R E E T because um-mm E in some words, like in the middle or something, um-mm there's 2 E's to make the sound instead of like . . . I R.
E: And what did you hear in front of the 2 E's? . . . . You've done an excellent job . . . . What all did you hear in front of the 2 E's?
S: You mean here.
E: Um-m hmm.
S: Like, it's kind of like train, also, the beginning of train.
E: It is ! It is ! Except it's got an S at the front, hasn't it.
S: Um-hmm.
E: Great !

T: #8. Kissed . . . The boy kissed his mother goodnight . . . . . kissed.
S: . . . .
E: How did you choose those letters?
S: Because, . . .um-mm . . . . you could put C or K in kissed. But I choosed because that's how I thought it was spelled.
E: Um-hmm. Did you know how to spell it, or did you just think it was spelled that way.
S: I don't really know.
E: You don't really know . . . Well, I think you've done an excellent job. Tell me about the ending.

S: The ending is kind of like street also.
E: Um-hmm. . . . What was the word you were writing.
S: Street. . Um-mm, kissed.
E: Kissed . um-hmm. . . . . . .

T: #9. Order . . . Please order me a hamburger . . . . .
order.
S: . . . .
E: Another excellent job. Teach Wrinkles about it.
S: . . . . Um-mm. The reason I picked . . . . . O R D E
and R is because . . .um-mm I wanted to pick them ,
because I thought that's how you spelled order.
E: Well, that's great. . . . .

T: #10. Snowing . . . When it is snowing, we wear our
boots . . . . . snowing.
S: . . . .
.
E: Tell us about that one?
S: It's kind of like a compound word. . . . . but -ing , it
isn't really, it isn't a compound word . . . but sometimes,
like, you put -ing on the end of the word.
E: Why would you put --ing on the end?
S: To make the sound -ing.
E: -ing. What about the first part of the word? Tell me about
it. The part before the -ing.
S: Oh, um-mm. It's kind of like snow, like snow.
E: Snow. And how did you know how to write snow?
S: Because when we were learning about snow, Miss M.
taught us how to spell snow.
E: And you just remember now. That's just great !

Appendix D-2

Verbal Protocol of a Weak Speller at February Data Collection

T: #1. Lap. . . The baby was on her mother's lap. . . . . lap

S: . . . . .D . . . .

E: Talk to Wrinkles about what you're thinking.

S: . . . . . . b--b--b . . . . . .

E: That's all.

S: Well, because O . .. ..is . . . . . I use it for a lot of things . . . . and . . . . P . . . is one of the best words that I like.

E: Which one is P?

S: This one . . . . . . and A . . . .

E: Touch the A for Wrinkles.

S: A . . . . is . . . . . .well . . . .

E: And the word is . . . .

S: LAP

E: LAP. Good try! This time would you try to tell Wrinkles the letters as you're doing them.

T: #2. Sick. . . . The child was too sick to go to school. . . . . . sick

S:. . . . uh! . . . . Sick is for C

E: Are you watching, Wrinkles?

S:. . . . . and . . . . .K- sick . . . . and it has a K in it because . . . . . . k--k . . . . and the next letter is . . . . O . . . and O . . .is . . .for . . . well . . . . . . to sick to go to school . . . . .That's the way it's spelled, eh Wrinkles?

E: Thank you for showing Wrinkles all about that.

T: #3. Pretty, ... The girl had on a pretty dress . . . . . pretty.

S: pr- . . .pr- pr- . .e . .ty

E: Tell Wrinkles what you're thinking.

S: . . . . . uh . . . I've got the C . . .see that Wrinkles, see that? . . . . . . R . . . . is . . . . you use it for things like . . . . . something like . . . . A . . . . V . . .for another . . . . U . . . all the time . . . . .and O. I already told you about that, eh Wrinkles. . . . . But . . . . O . . . . cause . . . . . I put it because . . . . it fits.

E: And that's it?

S: Uh-huh.

E: Great! We're doing very well.

T: #4. Elephant . . . . We saw an elephant at the zoo. . . . . . elephant

S:. . . . . D . . . . I know it's D because . . . . . uh- . . . . elephant begins with D . . . . I did my soundings and one of them was D.

E: Um-hum!

S: Right, Wrinkles? . . . . (sniffs) . . . . uh . . . L . . . . like in my brother's name . . . . Look here, eh Wrinkles . . . . . and this is kind of . . . . . people use it for a lot of things . . . . . . can't say . . . . let's see . . . it can be . . . . let's see . . . .

E: What kinds of things do they use it for?

S: Well . . . if you're saying like . . . . how about . . . . someone said "Yes" and . . . . . . there we go. . . . .

E: What did you make there?

S: A 'Z" . . . .

E: Can you tell Wrinkles why you made the Z?

S: Because . . . . it . . . . and . . . . I . . . . really like Z.

E: Um-humm . . . . Is there any more?

S: Not that I know .

E: Well then, that's enough . . . .

T: #5. Train . . . . Web took the train to our grandmother's house . . . . . train.

S: . . . tr . . . . tr . . . . This one, the first one, ... because I like it . . . . It goes like this . . . . . this . . . and it's gucky . . . . . in (Says his name) . . . . I already told you it's in my name . . . . . and . . . . . and . . . this one here . . . you can mean it for glass . . . . . and I think that's about it.

E: And what's the word?

S: Uh?

E: Wrinkles has forgotten the word. Can you tell him what it is?

S: I am going on the train to my grandma's.

E: And which one of those words did you write?

S: Uh . . . . . . uh . . . .

E: Train . . . . . train

S: Train

T: #6. Hunt . . . . On Easter, we hunt for eggs . . . . . hunt

S: . . . . C is for . . . . . uh . . . .a lot of things . . . . like you can use it for words . . . . carpet . . . . and K you use it in radio and . . . . .B is for . . . . . . B is for . . . . let's see . . . .

E: And the word is . . .?

S: Uh . . . .

E: Hunt . . . . hunt

S: Hunt . . .

T: #7. Street . . . It is dangerous to play in the street . . . . . street.

S:. . . . A . . . . first you put A . . . . . uh . . . . .uh . . . .

E: And what did you make next?

S: Uh . . . . .uh . . . . uh . . . . L is for my brother's . . . . my brother . . . . . and X . . . . . . X because you use it for . . . . oh, lots. . . . .

E: Is there any more?

S: Not that I know.

E: And what's the word?

S: What's the word?

E: Um-humm. . . . . Street.

S: Street

E: Street. . . . Listen for the next word.

T: #8. Kissed . . . The boy kissed his grandmother goodnight . . . . . kissed.

S:. . . . . Well, there it is . . . . . . I'm done this one . . .

E: Can you tell Wrinkles how you chose those letters?

S: Because . . . because . . . . C . . .C . . . . C has my name in it, and this one . . . . and this one . . . . . and this one because it goes like . . . . . like if you're going to shut . . . . . . and O . . . . . I forgot about that word there . . . .

E: Do you not want it there?

S: Eh?

E: Do you not want it there?

S: And this one here . . . . . and it . . . . it is good to use . . . for stuff.

E: Any more letters?

S: No, that's all.

E: What's the word?

S: Kissed

E: Great! Here comes #9. We're almost finished!

T: #9. Order . . . Please order me a hamburger . . . . . order

S:. . . . . . . Order . . . . .like, this one . . . . . for tuh- tuh- . . . . . . and this one . . . . use it for money . . . . cause it's the last letter in my name . . . . and this one for my brother.

E: You told us about that one before, didn't you?

S: Um- hummmm

E: Here's the very last one.

T: #10. Snowing . . . When it is snowing, we wear our boots . . . . . snowing

S: I . . . . I always go in about that word. . . . . . S .
. . .cause you need it for . . . . like if
you say . . . ."Let's go to buy a hamburger" and
use . . . . like to buy it like . . . . that's all
I know
E: And the word is . . .?
S: The word is . . . . can't think.

APPENDIX E

Coding Grid and Analysis Form for Data Related Operations

Appendix E

Coding Grid for Data Related Operations

Code	Operation	Operational Definition
	LETTER FORM	**The way in which the letters are formed and presented on the page.** Note: For letters in which shape in capital and lower case form differs, shape supercedes size. When capital and lower case forms are the same, size relative to other letters in the word indicates case.
C	Writes capital (upper case) letter(s) only .	Instances: LAP, SICK, ELFT, HUT, SNOG Non-instances: LAp, eLfT, OrT, GHijK, ghik
L	Writes lower case letter(s) only.	Instances: sick, tran, elft, snoig Non-instances: LAP, siC, prTy
M	Writes mix of capital and lower case letters.	Instances: Lap, SIc, prTy, elfT, JnoPQr Non-instances: LTT, odr, STRET, hont. Note: In the event of uncertainty, use code M.
R	Writes reversed letters.	A letter is flipped from left to right and rests in mirror image.
I	Writes inversed letters.	A letter is flipped from top to bottom.
	CONSONANTS	
LS	Writes letter string(s).	A letter or series of letters and/or symbols that have no sound/ letter correspondence with the target word. Instances: JFLSTE (lap), xovHemp (street), Cdvmwyz (pretty),eM (order). Non-instances: LP (lap), RDR (order), pte (pretty).
CI	Writes correct initial consonant.	Only the correct consonant in a word that begins with a consonant is coded here. The spelling of the entire word need not be word perfect. There may be errors in the rest of the word. Instances: Kist (kissed), PTE (pretty), tan (train), soing (snowing). Non-instances: LphT (elephant), rDr (order), jran (train).
PI	Writes phonetically correct initial consonant.	A sound/ letter match that is phonetically correct, even if imcorrectly used. A word coded CI is also coded PI.
CF	Writes correct final consonant.	Only the correct final consonant in the conventional spelling of the target word is coded. There may be other miscues in the invented word. A correct or incorrect vowel may follow the final consonant, or the final vowel in the conventional spelling of the target word may be missing. Instances: seck sek (sick), pret ptety (pretty), elft (elephant), tranc (train), hut (hunt), sRT (street), KSD kised (kissed), snog snoing (snowing, odR (order). Non-instances: sic (sick), prde (pretty), kist (kissed), ELFN (elephant), hettmo (hunt).
PF	Writes phonetically correct final consonant.	Any proximity to a sound letter match in final consonant sound position is coded. An unnecessary final "e" may follow without annulling the PF code. Instances: sec sike (sick), kist kiste (kissed), ordr (order), LP lape (lap), snog (snowing), pret (pretty). Non-instances: Hutm (hunt), snon (snowing)

(Appendix E continues . . .)

Appendix E (continued)

Coding Grid for Data Related Operations

Code	Operation	Operational Definition
CM	Writes correct medial consonant(s).	There is one or more consonants between the initial and the final consonant sounds in the target word and this (these) consonant(s) is (are) represented in conventional form. There may be other errors or intrusions. Instances: LPHET (elephant), Sn STcT (street), Ptc prty (pretty), ODR (order), train tran (train), Hont (hunt), Kist (kissed. Non-instances: LFT elefat (elephant), oTr (order)
PM	Writes phonetically correct medial consonant(s).	There is one or more consonants between the initial and final sound in a target word, and at least one of these consonants is represented by a phonetically appropriate letter or letter combination. There may be other errors or intrusions in the invented word. Words coded CM are also coded PM. Instances: LFT (elephant), PRt (pretty), kist (kissed), rtr ORtr (order), CHRan (train). Non-instances: lap, sic, SET (street)
CCB	Writes correct two consonant initial blend.	Both of the correct consonants must be represented in correct sequence without intrusion. There may be errors or intrusions elsewhere in the invented word. Instances: prtc (pretty), tran (train), street stet (street), sno (snoing). Non-instances: purtty (pretty), Chran (train),sreet (street), soning (snowing).
PCB	Writes phonetically correct two consonant initial blend.	Both letters in the initial blend are represented in correct sequence without intrusion in a phonetically plausible manner. There may be errors or intrusions elsewhere in the invented word All CCBs are coded also PCB. Instances: chrin chrane jran (train), prittee (pretty), shret (street) Non-instances: Churane chirn (train), puritty pirritty (pretty), sherete (street).
CCN	Writes correct consonant nasal.	The "nt" consonant nasal is presented in correct sequence without intrusion. There may be errors elsewhere in the invented spelling. Instances: Hont honte (hunt), clefnt alfnt (elephant) Non-instances: hunit (hunt), lefnot (elephant).
TLB	Writes correct three letter consonant blend.	All three consonants are present in correct sequence without intrusion. There may be other errors and intrusions in the invented word. Instances: street, strete, streat Non-instances: terrain (train), shreet (street), chrane (train), prtee (pretty), shnowing (snowing), elfnt (elephant)
	VOWELS	**A E I O U and Y in final position.**
ASR	Writes with all syllables represented.	All syllables are represented by a phonetically correct letter(s). Letter srings are not coded ASR. Instances: LP LTUV (lap), C cik (sick), PT (pretty), ELUFT (elephant), KIST (kissed), ord (order), sing (snowing). Non-instances: LTUVRS (hunt), snow (snowing), kis (kissed), elphenat (elephant), pri (pretty).
VVS	Writes vowel/ vowel substitution	A vowel is substituted for another vowel. Instances: hont hot (hunt), prete (pretty), Kest (kissed). Non-instances: ordr (order), ELFANT (elephant), strete (street).
Ccvc	Writes correct consonant/ vowel/ consonant vowel pattern	Consonants and vowels within the pattern must be conventional without intrusion. Errors or intrusions may appear in other parts of the word. Instances: pretee, prety, lap. Non-instances: hut, kised, order, sic, sik, ordeer, snowing.

(Appendix E continues . . .)

Appendix E (continued)

Coding Grid for Data Related Operations

Code	Operation	Operational Definition
Pcvc	Writes phonetically correct consonant/ vowel/ consonant vowel pattern.	There may be a vowel/ vowel substitution or a consonant/ consonant substitution within the pattern as long as these substitutions are phonetically appropriate. Errors or intrusions may appear in other parts of the word. Words with correct cvc pattern are coded also Pcvc. Instances: lap, lap, hut, hat, sic, sek, sik, pritty, prity, kised Non-instances: tran, chran, chrin, kist, hunt, snowing, clufit, clufint, elephant, order, sike.
Ccvcc	Writes correct consonant/ vowel/ consonant/ consonant vowel pattern	All letters within the Ccvcc pattern must be conventional without intrusion. Errors or intrusions may appear in other parts of the word. Instances: hunt, hunte, kisst, kiss, alaphant, pretty, prettee. Non-instances: clufint, clufant, trann, pritty, strett.
Pcvcc	Writes phonetically correct consonant/ vowel/ consonant/ consonant vowel pattern	Letters within the pattern may be substituted for phonetically correct letters as long as the pattern is maintained. Errors or intrusions may appear in other parts of the word. Correct cvcc patterns are coded also Pcvcc. Instances: clufint, alafunt, elefant, Lfant, cluphint, hont, kist, kest, kissed, kisst, pritte, pritty, sick, seck. Non-instances: hetm (hunt), snowing, pirt, alaphit, sonw.
CLVP	Writes correct long vowel pattern.	The long vowel pattern is written in conventional form. All vowels and consonants in that pattern are correct. Errors or intrusions may be present in other parts of the word. Instances: train, tain, sreet, streeth, pritty. Non-instances: stret, streat, prite, trian, traen.
PLVP	Writes phonetically correct long vowel pattern.	The long vowel pattern invented is phonetically correct. Errors or intrusions may appear in other parts of the word. Words coded CLVP are coded also PLVP. Instances: trane, traen, prettee, streat, strete. Non-instances: stret, pret.
CIVS	Writes correct initial vowel schwa.	Only the correct two letter schwa (vowel plus consonant into which it is "swallowed") in a word that begins with a vowel is coded here. Errors or intrusions may appear in the remainder of the word. Instances: ordr, orter, elft, elepht, elapetn, ellafet, eleanpnt, elafnt. Non-instances: alifit, alfit, ilafit, lafit, urdr, ardur, rdr.
PIVS	Writes partially correct initial vowel schwa.	The correct initial vowel is followed with an incorrect letter, or the correct consonant is preceded by an incorrect vowel, or the correct two letters in the schwa are separated by an intrusion. Instances: oder, otr, oudoor, oerder, urdr, arder, efnt, eait, alfit, ilafit. Non-instances: rdr, rder, dr, left, lafit, lft.
CVFR	Writes correct vowel followed by r pattern.	Applies only to target word "order". Both or and er in "order" must be correct to be coded CVFR. There may be other inaccuracies in the invented spelling. Instances: order orter Non-instances: ordor, rter, ordr.
PVFR	Writes partially correct vowel followed by r pattern.	The vowel in the pattern may be substituted for another vowel or the pattern may be substituted with a phonetically correct blend. At least one vowel followed by r pattern must be correct or phonetically correct. Words coded CVFR are coded also PVFR. Instances: order, oder, ordr, rter, ordir, ordur, urdr. Non-instances: odr, rdr, rtr.

(Table continues . . .)

Appendix E (continued)

Coding Grid for Data Related Operations

Code	Operation	Operational Definition
CIVT	Writes correct intervocalic tap between two vowels.	Applies only to target word "pretty". Both vowels and the doubled consonant must be conventional. Only the "etty" combination is accepted as correct. There may be errors or intrusions in the preceding letters of the word. Instance: pretty, petty, puretty Non-instances: prette, pett, pretee
PIVT	Writes phonetically correct intervocalic tap between two vowels.	A phonetically correct consonant must be doubled between two vowels. There may be other errors or intrusions in the invented word. CIVT is coded also PIVT Instances: pretty, prette, prettee, pritte, pritty, pitty, pitte, predde. Non-instances: prety, pretey, pty, pte, ptite.
	MEANING	**The inflections "ed" anding" are used as word endings to indicate tense, rather than as a direct match of letter to sound.**
ED	Writes correct -ed ending.	The ending, -ed, is correctly represented. There may be errors or intrusions in the base word. Instances: kissed, kised, cised. Non-instances: kisd, kisst, kissing
ING	Writes correct -ing ending	The "-ing" ending is correctly represented. There may be errors or intrusions in the base word. Instances: snowing, snoing, sowing, sing, sonwing Non-instances: soiwng, song, clingint, snowig.

Notes:
1. Reversed, inverted, or poorly formed letters are accepted throughout the data analysis grid. Their existence is relevant only in the LETTER FORM section.
2. Correct sound and letter patterns are coded also as phonetically correct throughout the grid.

Appendix E-1 DST DATA ANALYSIS FORM

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C										
	L										
	M										
	R										
	I										
Consonants	LS										
	CI										
	PI										
	CF										
	PF										
	CM										
	PM										
	CCB										
	PCB										
	CCN										
	TBL										
Vowels	ASR										
	VVS										
	Ccvc										
	Pcvc										
	Ccvcc										
	Pcvcc										
	CLVP										
	PLVP										
	CIVS										
	PIVS										
	CVFR										
	PVFR										
	CIVT										
	PIVT										
Meaning	ED										
	ING										

APPENDIX F

Cognitive Control Related Coding Grid and Analysis Form

Appendix F

Coding Grid for Cognitive Control Related Operations

Code	Operation	Operational Definition
	AUTOMATIC PRODUCTION	**The way in which the subject produces immediate automatic responses to the dictation of the target word.**
AL	Automatic production of letters.	All the letters in the word are formed without copying from the alphabet line or from an external source.
AP	Automatic production of sound/ letter pattern.	A within word letter pattern is produced in a single piece or "chunk" (a blend, a vowel stem, a base word, an ending, a little word within the target word etc.).
AW	Automatic production of target word.	The entire word is produced automatically, in conventional spelling, and in one piece (without hesitation between letters or letter patterns).
	MEMORY	**The way in which the subject constructs images, holds them over time, and relates them to perceptions of current information.**
TOU	Touches.	Touches, traces over, or points at a letter on the alphabet line <u>during the writing</u> of the target word.
COP	Copies.	Copies a letter or letters from the alphabet line or from any other location when inventing a spelling. Any eye contact to the alphabet line is copying.
RTW	Repeats target word.	The target word is repeated, or a sequence of sounds from the word in production is vocalized or subvocalized <u>before of during</u> the writing.
VIM	Visual images.	Conjures up a visual image before producing a letter, a letter pattern, or a target word (closes eyes, rolls eyes upward, glances toward a selected letter on the alphabet line, stares momentarily into space, focuses momentarily on the writing line of the acetate, etc.).
SLS	Says letter sounds.	Vocalizes or sub-vocalizes a letter sound <u>before or during the writing</u> of letters, letter patterns, or target words.
SLN	Says letter names.	Vocalizes or sub-vocalizes letter name <u>before or during the writing</u> of letters, letter patterns, or target words.
PKE	Makes reference to prior knowledge and/ or experience.	<u>During the writing episode</u> or <u>in retrospective debriefing</u> , makes verbal reference to how the letter, letter pattern, or word being written is similar to, or built upon, something learned, experienced, or written earlier. Information given may be inaccurate. (Examples re word <u>snowing</u>: - " L L. Cause the teacher said every time you hear the word snow- ing - ing , it's two L's, cause we learned a letter that starts with snow -ing -ing, and it was L" (Protocol # 47, ll.) --"Because when we were um-m . . . . . . when it was winter, that was our secret passage word (Protocol #44, ll. 61-62).
WIR	Knows word in retrospect.	Retains target word in memory throughout the writing episode. This may be concluded from the following: --- The word is written conventionally, or with sufficient phonetic accuracy to demonstrate memory of the target word. -- The subject uses the target word in retrospect debriefing. -- The subject recalls the target word when asked.

(Table continues . . .)

Appendix F (continued)

Coding Grid for Cognitive Control Operations

Code	Operation	Operational Definition
	ARTICULATION OF PLAN	**The way in which the subject responds to the dictation of the target word and distinguishes what is relevant from what is irrelevant.**
GS	Goal setting.	Demonstrates awareness that the goal is to invent a spelling for the target word dictated. Evidence of goal setting includes: - repeating the target word - vocalizing or subvocalizing sufficiently during the writing episode to demonstrate that the target word is being processed - producing the target word correctly, or with sufficient phonetic detail to indicate an invented spelling of the target word dictated.
PS	Planned sequencing.	Demonstrates an awareness that the word to be written is composed of a sequence of sound/ letter correspondences and that the task is to plan and produce relevant letters in this sequence.
SM	Self-monitoring	Demonstrates ability to focus without reminder on the task of inventing a spelling for the target word dictated .
SC	Self-correcting	Notes of own volition a response that requires correction.
RE	Relevant rationale evident	Provides, through concurrent verbal protocol or in retrospective debriefing, sufficient data related information to demonstrate the rationale underlying the choices made. The information provided must be data related. Personal preferences for letters, their occurence in the names of family and friends, etc. are not considered relevant choices.
	FOCUS OF ATTENTION	**The way in which the subject attends to the task of inventing a spelling for the target word.**
SAD	Selectively attends to detail.	Attends to detail that is relevant to the target word while selecting component letters and letter patterns. Attention is focused on producing appropriate letters or letter patterns to represent the target word in writing.
AET	Attends to the entire task.	Attends to all syllables of the word and produces, in correct sequence, a representation for each syllable.
UCT	Uninterrupted concentration on the task.	Directs body movements and verbalizations,during the word writing to inventing a spelling. Neither unrelated activity nor unrelated topics are generated. If outside interruption breaks concentration, the subject returns to the completion of the task without reminder.
	RESPONSE STYLE	**The way in which body movement is regulated in the production of invented spelling.**
OM	Orthodox movement	Demonstrates orthodox movements in letter making including - vertical strokes from top to bottom; horizontal strokes from left to right - within letter movements in conventional sequence/ direction - circular movements in even flow - marker held in orthodox hand grip for writing
UD	Uninterrupted dictation	Does not interrupt the taped dictation to vocalize / subvocalize.
RR	Responds rhythmically.	Produces written responses in rhythmic tempo. No definite pauses to collect information, to decide what comes next, or to attend to external stimuli.
RT	Responds thoughtfully.	Demonstrates through verbal responses and non-verbal actions reflective, thoughtful consideration rather than impulsive whim.
DC	Displays confidence.	Communicates through verbarizations, body posturing, and facial expression confidence in ability to invent a spelling for target word dictated. Minimal verbalization does not necessarily indicate lack of confidence during writing

Appendix F-1: DST CONTROL STRUCTURES ANALYSIS FORM

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL										
	AP										
	AW										
Memory	TOU										
	COP										
	RTW										
	VIM										
	SLS										
	SLN										
	PKE										
	WIR										
Articulation of plan	SG										
	PS										
	SM										
	SC										
	RE										
Focus of Attention	SAD										
	AET										
	UCT										
Response Style	OM										
	UD										
	RR										
	RT										
	DC										

APPENDIX G

Examples of Coded Data Analysis Forms of a Strong Speller and a Weak Speller at June 93, February 94, and May 94

Appendix G-1

Data Related Operations of a Strong Speller in June 93

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C	✓	—	—	—	✓	✓	✓	—	✓	✓
	L	—	—	—	—	—	—	—	—	—	—
	M	—	✓	✓	✓	—	—	—	✓	—	—
	R	—	—	—	—	—	—	—	—	—	—
	I	—	—	—	—	—	—	—	—	—	—
Consonants	LS	—	—	—	—	—	—	—	—	—	—
	CI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	PI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	CF	✓	—	✓	✓	✓	✓	✓	—	✓	✓
	PF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CM	—	✓	✓	—	✓	—	✓	✓	✓	✓
	PM	—	✓	✓	✓	✓	—	✓	✓	✓	✓
	CCB	—	—	—	—	—	—	—	—	—	—
	PCB	—	—	✓	—	✓	—	✓	—	—	✓
	CCN	—	—	—	✓	—	—	—	—	—	—
	TBL	—	—	—	—	—	—	—	—	—	—
Vowels	ASR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	✓	✓	—	—	—	—	—	✓	—	—
	Pcvc	✓	✓	✓	✓	—	✓	—	✓	—	—
	Ccvcc	—	—	—	—	—	✓	—	✓	—	—
	Pcvcc	—	—	—	✓	—	✓	—	✓	—	—
	CLVP	—	—	✓	—	—	—	—	—	—	—
	PLVP	—	—	✓	—	—	—	—	—	—	✓
	CIVS	—	—	—	—	—	—	—	—	—	—
	PIVS	—	—	—	—	—	—	—	—	—	—
	CVFR	—	—	—	—	—	—	—	—	—	—
	PVFR	—	—	—	—	—	—	—	—	—	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	—	—	—
	ING	—	—	—	—	—	—	—	—	—	—

Data Related Operations of a Strong Speller in February 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C	—	—	—	—	—	—	—	—	—	—
	L	✓	—	✓	✓	✓	✓	✓	—	✓	—
	M	—	✓	—	—	—	—	—	✓	—	✓
	R	—	—	—	—	—	—	—	—	—	—
	I	—	—	—	—	—	—	—	—	—	—
Consonants	LS	—	—	—	—	—	—	—	—	—	—
	CI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	PI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	CF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CM	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PM	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CCB	—	—	✓	—	✓	—	✓	—	—	✓
	PCB	—	—	✓	—	✓	—	✓	—	—	✓
	CCN	—	—	—	✓	—	✓	—	—	—	—
	TBL	—	—	—	—	—	—	✓	—	—	—
Vowels	ASR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	✓	✓	—	✓	—	✓	—	✓	—	—
	Pcvc	✓	✓	—	✓	—	✓	—	✓	—	—
	Ccvcc	—	✓	—	✓	—	✓	—	✓	—	—
	Pcvcc	—	✓	—	✓	—	✓	—	✓	—	—
	CLVP	—	—	✓	—	✓	—	✓	—	—	✓
	PLVP	—	—	✓	—	✓	—	✓	—	—	✓
	CIVS	—	—	—	✓	—	—	—	—	✓	—
	PIVS	—	—	—	✓	—	—	—	—	✓	—
	CVFR	—	—	—	—	—	—	—	—	✓	—
	PVFR	—	—	—	—	—	—	—	—	✓	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	✓	—	✓
	ING	—	—	—	—	—	—	—	✓	—	✓

Data Related Operations of a Strong Speller in May 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C	—	—	—	—	—	—	—	—	—	—
	L	✓	✓	✓	✓	✓	—	✓	✓	—	✓
	M	—	—	—	—	—	✓	—	—	✓	—
	R	—	—	—	—	—	—	—	—	—	—
	I	—	—	—	—	—	—	—	—	—	—
Consonants	LS	—	—	—	—	—	—	—	—	—	—
	CI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	PI	✓	✓	✓	—	✓	✓	✓	✓	—	✓
	CF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CM	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PM	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CCB	—	—	✓	—	✓	—	✓	—	—	✓
	PCB	—	—	✓	—	✓	—	✓	—	—	✓
	CCN	—	—	—	✓	—	✓	—	—	—	—
	TBL	—	—	—	—	—	—	✓	—	—	—
Vowels	ASR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	✓	✓	✓	✓	—	✓	—	✓	—	—
	Pcvc	✓	✓	✓	✓	—	✓	—	✓	—	—
	Ccvcc	—	✓	—	✓	—	✓	—	✓	—	—
	Pcvcc	—	✓	—	✓	—	✓	—	✓	—	—
	CLVP	—	—	✓	—	✓	—	✓	—	—	✓
	PLVP	—	—	✓	—	✓	—	✓	—	—	✓
	CIVS	—	—	—	✓	—	—	—	—	✓	—
	PIVS	—	—	—	✓	—	—	—	—	✓	—
	CVFR	—	—	—	—	—	—	—	—	✓	—
	PVFR	—	—	—	—	—	—	—	—	✓	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	✓	—	✓
	ING	—	—	—	—	—	—	—	✓	—	✓

Appendix G-2

Cognitive Control Related Operations of a Strong Speller in June 93

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AP	—	—	—	—	—	—	—	—	—	—
	AW	—	—	—	—	—	—	—	—	—	—
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	—	—	—	—	—	—	—	—	—	—
	RTW	—	—	—	—	—	—	—	—	—	—
	VIM	—	—	✓	✓	✓	✓	✓	✓	✓	✓
	SLS	—	—	✓	—	—	—	✓	✓	✓	✓
	SLN	—	—	—	—	—	—	—	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Articulation of plan	SG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SC	—	—	—	—	—	—	—	—	—	—
	RE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Focus of Attention	SAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AET	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UCT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Response Style	OM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	DC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Cognitive Control Related Operations of a Strong Speller in February 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AW	✓	✓	—	—	✓	—	✓	✓	✓	✓
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	—	—	—	—	—	—	—	—	—	—
	RTW	—	—	—	—	—	—	—	—	—	—
	VIM	—	—	✓	✓	✓	✓	—	—	✓	—
	SLS	—	—	—	—	—	—	—	—	—	—
	SLN	—	—	—	—	—	—	—	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Articulation of plan	SG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SC	—	—	—	—	—	—	—	—	—	—
	RE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Focus of Attention	SAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AET	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UCT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Response Style	OM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RR	✓	✓	✓	—	✓	—	✓	✓	✓	✓
	RT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	DC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Cognitive Control Related Operations of a Strong Speller in May 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production -	AL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	—	—	—	—	—	—	—	—	—	—
	RTW	—	—	—	—	—	—	—	—	—	—
	VIM	—	—	—	—	—	—	✓	—	—	—
	SLS	—	—	—	—	—	—	—	—	—	—
	SLN	—	—	—	—	—	—	—	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Articulation of plan	SG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SC	—	—	—	—	—	—	—	—	—	—
	RE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Focus of Attention	SAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	AET	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UCT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Response Style	OM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RR	✓	✓	—	✓	✓	✓	✓	✓	✓	✓
	RT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	DC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Appendix G-3

Data Related Operations of a Weak Speller in June 93

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form*	C	—	—	—	—	—	—	—	—	—	—
	L	—	—	—	—	—	—	—	—	—	—
	M	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	R	✓	✓	✓	✓	✓	✓	✓	✓	—	✓
	I	—	—	—	—	—	—	—	—	—	—
Consonants	LS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CI	—	✓	—	—	—	—	✓	—	—	—
	PI	—	✓	—	—	—	—	✓	—	—	—
	CF	—	—	—	—	—	—	—	—	—	—
	PF	—	—	—	—	—	—	—	—	—	—
	CM	—	—	—	—	—	—	—	—	—	—
	PM	—	—	—	—	—	—	—	—	—	—
	CCB	—	—	—	—	—	—	—	—	—	—
	PCB	—	—	—	—	—	—	—	—	—	—
	CCN	—	—	—	—	—	—	—	—	—	—
	TBL	—	—	—	—	—	—	—	—	—	—
Vowels	ASR	—	—	—	—	—	—	—	—	—	—
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	—	—	—	—	—	—	—	—	—	—
	Pcvc	—	—	—	—	—	—	—	—	—	—
	Ccvcc	—	—	—	—	—	—	—	—	—	—
	Pcvcc	—	—	—	—	—	—	—	—	—	—
	CLVP	—	—	—	—	—	—	—	—	—	—
	PLVP	—	—	—	—	—	—	—	—	—	—
	CIVS	—	—	—	—	—	—	—	—	—	—
	PIVS	—	—	—	—	—	—	—	—	—	—
	CVFR	—	—	—	—	—	—	—	—	—	—
	PVFR	—	—	—	—	—	—	—	—	—	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	—	—	—
	ING	—	—	—	—	—	—	—	—	—	—

Data Related Operations of a Weak Speller in February 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C	—	—	—	—	—	—	—	—	—	—
	L	—	—	—	—	—	—	—	✓	—	—
	M	✓	✓	✓	✓	✓	✓	✓	—	✓	✓
	R	✓	✓	✓	—	—	✓	✓	—	✓	✓
	I	✓	—	✓	—	—	—	—	—	—	—
Consonants	LS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	CI	—	✓	✓	—	—	—	—	—	—	—
	PI	—	✓	✓	—	—	—	—	—	—	—
	CF	—	—	—	—	—	—	—	—	—	—
	PF	—	—	—	—	—	—	—	—	—	—
	CM	—	—	—	—	—	—	—	—	—	—
	PM	—	—	—	—	—	—	—	—	—	—
	CCB	—	—	—	—	—	—	—	—	—	—
	PCB	—	—	—	—	—	—	—	—	—	—
	CCN	—	—	—	—	—	—	—	—	—	—
	TBL	—	—	—	—	—	—	—	—	—	—
Vowels	ASR	—	—	—	—	—	—	—	—	—	—
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	—	—	—	—	—	—	—	—	—	—
	Pcvc	—	—	—	—	—	—	—	—	—	—
	Ccvcc	—	—	—	—	—	—	—	—	—	—
	Pcvcc	—	—	—	—	—	—	—	—	—	—
	CLVP	—	—	—	—	—	—	—	—	—	—
	PLVP	—	—	—	—	—	—	—	—	—	—
	CIVS	—	—	—	—	—	—	—	—	—	—
	PIVS	—	—	—	—	—	—	—	—	—	—
	CVFR	—	—	—	—	—	—	—	—	—	—
	PVFR	—	—	—	—	—	—	—	—	—	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	—	—	—
	ING	—	—	—	—	—	—	—	—	—	—

Data Related Operations of a Weak Speller in May 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C	—	—	—	—	—	—	—	—	—	—
	L	—	—	✓	—	✓	✓	—	—	—	—
	M	✓	✓	—	✓	—	—	✓	✓	✓	✓
	R	✓	—	✓	—	—	—	—	✓	—	—
	I	—	—	—	—	—	—	—	—	—	—
Consonants	LS	✓	—	✓	—	✓	—	✓	—	✓	—
	CI	—	✓	—	—	—	✓	—	✓	—	✓
	PI	—	✓	—	✓	—	✓	—	✓	—	✓
	CF	—	—	—	—	—	—	—	—	—	—
	PF	—	—	—	—	—	—	—	—	—	—
	CM	—	—	—	—	—	—	—	—	—	—
	PM	—	—	—	—	—	—	—	—	—	—
	CCB	—	—	—	—	—	—	—	—	—	—
	PCB	—	—	—	—	—	—	—	—	—	—
	CCN	—	—	—	—	—	—	—	—	—	—
	TBL	—	—	—	—	—	—	—	—	—	—
Vowels	ASR	—	✓	—	✓	—	✓	—	✓	—	—
	VVS	—	—	—	—	—	—	—	—	—	—
	Ccvc	—	—	—	—	—	—	—	—	—	—
	Pcvc	—	—	—	—	—	—	—	—	—	—
	Ccvcc	—	—	—	—	—	—	—	—	—	—
	Pcvcc	—	—	—	—	—	—	—	—	—	—
	CLVP	—	—	—	—	—	—	—	—	—	—
	PLVP	—	—	—	—	—	—	—	—	—	—
	CIVS	—	—	—	—	—	—	—	—	—	—
	PIVS	—	—	—	—	—	—	—	—	—	—
	CVFR	—	—	—	—	—	—	—	—	—	—
	PVFR	—	—	—	—	—	—	—	—	—	—
	CIVT	—	—	—	—	—	—	—	—	—	—
	PIVT	—	—	—	—	—	—	—	—	—	—
Meaning	ED	—	—	—	—	—	—	—	—	—	—
	ING	—	—	—	—	—	—	—	—	—	—

Appendix G-4

Cognitive Control Related Operations of a Weak Speller in June 93

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL	—	—	—	—	—	—	—	—	—	—
	AP	—	—	—	—	—	—	—	—	—	—
	AW	—	—	—	—	—	—	—	—	—	—
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	✓	✓	✓	✓	✓	✓	✓	✓	✓	—
	RTW	✓	✓	✓	—	✓	✓	—	—	✓	—
	VIM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SLS	—	—	—	—	—	—	—	—	—	—
	SLN	—	—	—	—	—	—	—	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	—	—	—	—	✓	—	—	—	—	—
Articulation of plan	SG	✓	✓	✓	—	✓	✓	—	✓	✓	—
	PS	—	—	—	—	—	—	—	—	—	—
	SM	—	—	—	—	—	—	—	—	—	—
	SC	—	—	—	—	—	—	—	—	—	—
	RE	—	—	—	—	—	—	—	—	—	—
Focus of Attention	SAD	—	—	—	—	—	—	—	—	—	—
	AET	—	—	—	—	—	—	—	—	—	—
	UCT	—	—	—	—	—	—	—	—	—	—
Response Style	OM	—	—	—	—	—	—	—	—	—	—
	UD	—	✓	✓	—	—	—	✓	—	—	✓
	RR	—	—	—	—	—	—	—	—	—	—
	RT	—	—	—	—	—	—	—	—	—	—
	DC	—	✓	✓	—	—	—	—	—	—	—

Cognitive Control Related Operations of a Weak Speller in February 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL	—	—	—	—	—	—	—	—	—	—
	AP	—	—	—	—	—	—	—	—	—	—
	AW	—	—	—	—	—	—	—	—	—	—
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	—	✓	✓	✓	✓	—	✓	✓	✓	✓
	RTW	—	✓	✓	✓	—	—	—	—	✓	—
	VIM	✓	✓	✓	✓	✓	—	✓	✓	✓	✓
	SLS	✓	✓	✓	—	✓	—	—	—	—	—
	SLN	—	✓	✓	✓	✓	✓	✓	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	✓	✓	✓	✓	—	—	—	✓	✓	—
Articulation of plan	SG	—	✓	✓	✓	—	—	—	—	✓	—
	PS	—	✓	✓	—	—	—	—	—	—	—
	SM	—	✓	✓	—	—	—	—	—	—	—
	SC	—	—	—	—	—	—	—	—	—	—
	RE	—	✓	✓	—	—	—	—	—	—	—
Focus of Attention	SAD	—	✓	—	—	—	—	—	—	—	—
	AET	—	✓	✓	✓	—	—	✓	—	—	—
	UCT	✓	✓	✓	—	—	✓	—	—	—	✓
Response Style	OM	—	—	—	—	—	—	—	—	—	—
	UD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RR	—	—	—	—	—	—	—	—	—	—
	RT	✓	✓	✓	✓	✓	—	—	—	—	—
	DC	—	—	—	—	—	—	—	—	—	—

Cognitive Control Related Operations of a Weak Speller in May 94

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production *	AL	✓	✓	✓	✓	—	—	—	—	—	✓
	AP	—	—	—	—	—	—	—	—	—	—
	AW	—	—	—	—	—	—	—	—	—	—
Memory	TOU	—	—	—	—	—	—	—	—	—	—
	COP	—	—	—	—	✓	✓	—	—	—	—
	RTW	✓	✓	—	—	—	✓	✓	✓	✓	✓
	VIM	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SLS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SLN	—	—	✓	—	—	✓	—	—	—	—
	PKE	—	—	—	—	—	—	—	—	—	—
	WIR	✓	✓	✓	✓	✓	✓	✓	✓	✓	—
Articulation of plan	SG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PS	✓	—	✓	✓	✓	✓	—	✓	✓	✓
	SM	✓	—	—	✓	✓	✓	✓	✓	✓	✓
	SC	—	✓	✓	—	—	✓	✓	—	—	—
	RE	✓	—	—	✓	✓	✓	—	—	—	—
Focus of Attention	SAD	✓	✓	✓	✓	✓	✓	—	✓	✓	✓
	AET	✓	—	—	✓	—	✓	✓	✓	✓	✓
	UCT	✓	—	—	✓	✓	✓	✓	✓	✓	✓
Response Style	OM	—	—	—	—	—	—	—	—	—	—
	UD	—	✓	—	✓	✓	✓	—	✓	✓	✓
	RR	—	—	—	—	—	—	—	—	—	—
	RT	✓	—	✓	✓	✓	✓	✓	✓	✓	✓
	DC	—	—	—	—	—	—	—	—	—	—

APPENDIX H

Examples of One-page Summaries of Operations While Spelling Developmental Spelling Test Words

Appendix H-1: Strong Speller

G/S	S#13(J93)	S#25(F94)	S#19(M94)
DST results	36	52	59J

Data Related Behaviours

Letter Form:
- lower case letters or mix of capital and lower case letters throughout; -one reversal J93(p in lap)

Consonants:
- correct and phonetically correct initial consonants (8): J93- 7; F94- 8; M94- 8
- correct final consonants throughout except ed ending in J93 and F94
- phonetically correct final consonants throughout
- correct and phonetically correct medial consonant (9): J93- 4; F94- 9; M94- 9
- correct and phonetically correct initial 2-consonant blends (4):J93- 0; F94- 3; M94- 4
- 3-consonant blend- M94 only
- correct consonant nasals (2): J93- 0; F94- 2; M94- 2

Vowels:
- all syllables represented throughout; vowel/vowel substitutions (10): J93- 4; F94- 3; M94- 0
- correct consonant/vowel/consonant pattern (6): J93- 2; F94- 4; M94- 6
- phonetically correct consonant/vowel/consonant pattern (6): J93- 2; F94- 6; M94- 6
- correct consonant/vowel/consonant/consonant patterns (4): J93- 1; F94-1; M94- 4
- phonetically correct consonant/vowel/consonant/consonant: J93- 1; F94- 4; M94- 4
- correct long vowel patterns(4): J93- 0; F94- 2; M94- 4
- phonetically correct long vowel patterns (4): J93- 0; F94- 4; M94- 4
- correct and phonetically correct initial vowel schwa (2): J93- 0; F94- 2; M94-2
- correct and phonetically correct vowel followed by r (1): J93- 0; F94- 1; M94- 1

Meaning:
- correct use of-ed: M94 only; correct use of -ing: F94 and M94

Data Related Changes Over Time:
- medial consonants emerging J93,established F94, and maintained M94
- blends emerging throughout grade one year; consonant nasals correct by F94 -maintained M94
- vowel/vowel substitutions reduced from 40% to 30% to 0%
- correct use of short and long vowel patterns established by M94
- initial vowel schwa and vowels followed by r correct by F94
- emergence of meaning: -ing by F94 and maintained M94; -ed by M94 only

---

Cognitive Control Related Behaviours

Automatic Production
- of letters by J93; of letter patterns by F94; of words- emerging (10): J93- 2; F94- 4; M94- 7

Memory:
- repeated target words (10): J93- 10; F94- 5; M94-0
- sounded out words (10): J93- 10; F94- 5; M94-3
- said letter names (10): J93- 10; F94- 0; M94- 0
- visual imaging (10): J93- 8; F94- 0; M94- 2
- retained all 10 words in immediate retrospect throughout

Articulation of Plan:
- goal setting, patterned sequencing, self-monitoring, and rationale evident throughout
- self-corrected : J93- 1word; F94- 1; M94- 2

Focus of Attention:
- selective attention, attention to entire task, and uninterrupted concentration on task throughout

Response Style
- orthodox movement by J93 and maintained throughout F94 and M94
- rhythmic response: J93- 4; F94- 10; M94- 7
- responded thoughtfully throughout; displayed confidence: J93- 7 words; F94- 10; M94- 10

Changes Over Time:
- automaticity developing with data knowledge and experience
- use of memory strategies decreasing from every word to "tough spots" - increase in display of confidence
- rhythmic response style peaked in F94 and varied with focus of visual imaging memory strategy

---

Appendix H-2: Weak Speller

G/W	S#30(J93)	S#47(F94)	S#54(M94)
DST results	11	39	42

Data Related Behaviours

Letter Form:

- J93-capitals only , lower case only, andmix of both; F94 M94- lower case only and mix of capital and lower case letters - reversals: J93- 1; F94- 1; M94- 1

Consonants:

- letter strings (10): J93- 10; F94-0; M94- 0
- correct initial consonants (8) : J93- 2; F94-8; M94- 7 -phonetically correct:J93- 6; F94-8; M94- 8
- correct final consonants: J93- 0; F94-6; M94- 8 -phonetically correct: J93-0; F94-8; M94-9
- correct medial consonant (9): J93-0; F94-6; M94-8 -phonetically correct J93-0; F94-7; M94-8
- correct and phonetically correct initial 2 letter blends (4): J93- 0; F94- 4; M94- 4
- correct consonant nasals (2): J93- 0; F94- 0; M94- 1

Vowels:

- all syllables rep: J93-0; F94-10; M94-10; vowel/vowel substitutions (10): J93- 0; F94- 3; M94- 2
- correct cons/vow/con pattern (6): J93- 0; F94- 2; M94- 2;phon. correct : J93- 0; F94- 4; M94- 5
- correct con/vow/cons/cons (4): J93- 0; F94- 0; M94- 1- phonet. correct :J93- 0; F94- 1; M94- 2
- correct long vowel pattern(4): J93- 0; F94-0; M94- 1 - phonetically correct :J93- 0; F94- 0; M94- 2
- correct initial vowel schwa (2): J93- 0; F94- 0; M94-1 - correct vowel followed by r (1) cr only M94

Meaning: - correct use of neither -ing nor -ed evident

Data Related Changes Over Time:

- caps only letter form replaced by lower case only; mix of both forms throughout
- correct and phonetically correct initial consonants by F94 with 1 miscue M94
- initial, medial, final consonants emerging gradually throughout - nasals not evident yet
- 2-letter blends by F94 and maintained M94; 3-letter blends not yet evident
- correct vowel patterns emerging F94 and M94 - meaning patterns --ing M94; - ed not yet

---

Cognitive Control Related Behaviours

Automatic Production:

- of letters by F94; of letter patterns emerging (J93- 0 F94- 3; M94-7)

Memory:

- copied: J93- 8; F94- 2; M94- 0 - repeated target word: J93- 9; F94- 10; M94- 4
- visual imaging: J93- 10; F94- 5; M94- 5 - sounded out: J93- 6; F94- 9 ; M94- 10
- letter naming: J93- 10; F94- 3; M94-1 -previous knowledge & experience: J93- 1; F94-0; M94- 3
- retained words in retrospect : J93- 6; F94- 9; M94- 10

Articulation of Plan:

- goal set throughout
- patterned sequence: J93- 2; F94-10; M94- 0; self-monitoring J93-10; F94-7; M94-10
- self-corrected: J93-1; F94-2; M94-0 - rationale evident: J93- 9; F94- 8; M94- 10

Focus of Attention:

- selective attention: J93- 8; F94- 10; M94- 10 - attention to entire task: J93- 0; F94- 10; M94- 9
- uninterrupted concentration on task: J93- 6; F94- 3; M94- 9

Response Style

- orthodox movement: J93- 1; F94- 6; M94-7 -uninterrupted dictation:J93- 7; F94- 1; M94-5
- rhythmic response: J93- 8; F94- 1; M94-5 -- responded thoughtfully: J93- 1; F94- 10; M94- 10
- displayed confidence: J93- 10; F94- 1; M94-10

Changes Over Time:

- automaticity emerging slowly with increased data knowledge and experience
- increase in use of sounding out and retention of word in retrospect
- decrease in copying , repeating target word, visual imaging, and letter naming
- improvement in selective attention and attention to entire task J93 to F94 maintained M94
- self-correcting J93 and F94 - dip in uninterrupted concentration on task F94
- dip in uninterrupted dictation F94 to use sounding out and repetition of word behaviours
- orthodox movement and thoughtful response surged F94 and maintained M94
- rhythmic response and display of confidence dipped F94

APPENDIX I

ANOVA With Repeated Measures

Appendix I

ANOVA With Repeated Measures

Source of Variation	SS	df	MS	F	p
Between groups					
Gender (G)	12.46	1	12.46	.05	.830
Ability (A)	5811.75	1	5811.75	22.14	.000*
G x A	1.79	1	1.79	.01	.935
Between subjects	3936.67	15	262.44		
Within groups					
Time (T)	3510.18	2	1755.09	70.25	.000*
G x T	67.56	2	33.78	1.35	.274
A x T	291.17	2	145.59	5.83	.007*
G x A x T	147.12	2	73.56	2.94	.068
Within subjects	749.53	30	24.98		

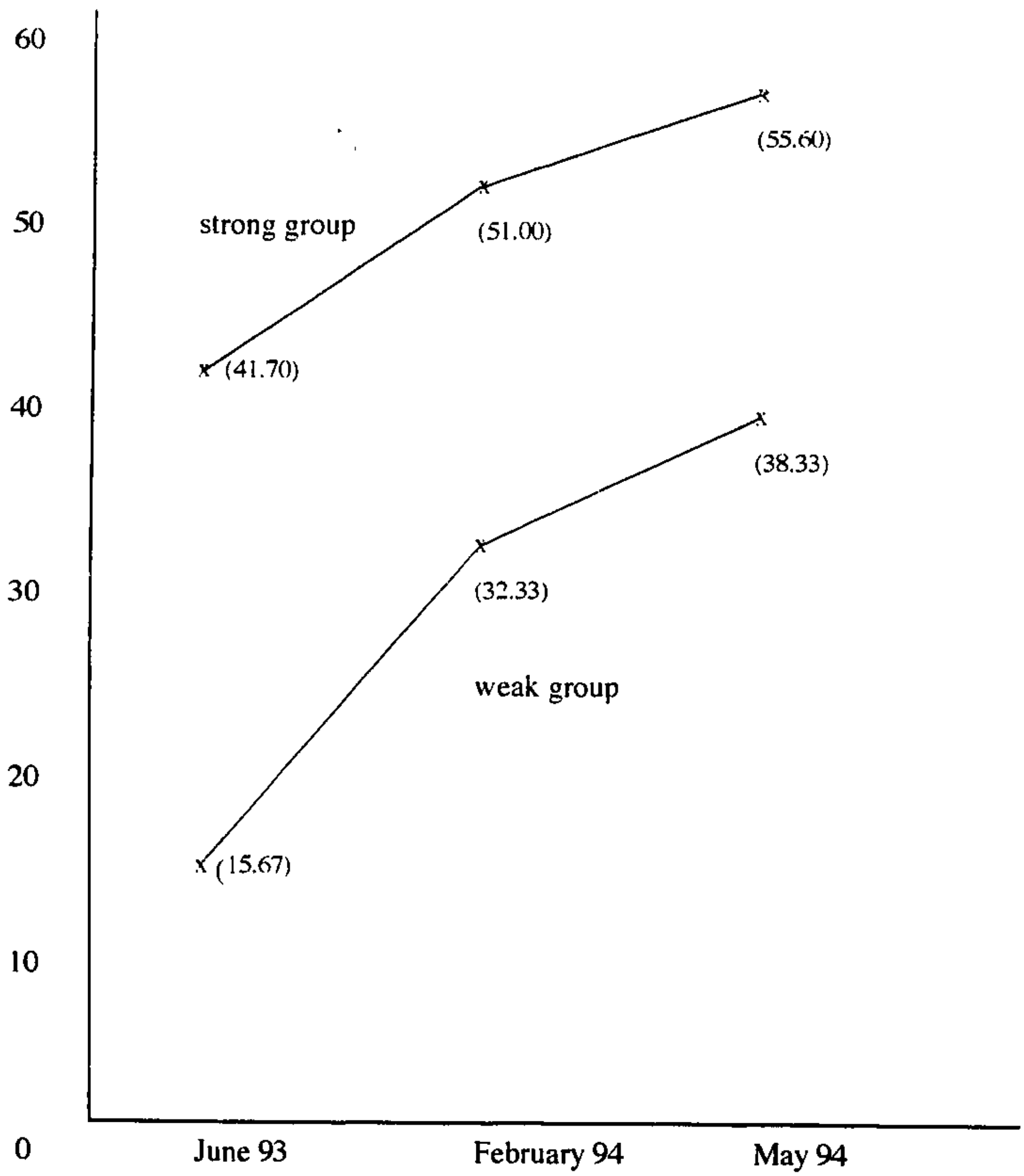
*$p < 0.05$

APPENDIX J

Interaction Effect for Ability and Time for Developmental Spelling Test Score Means

Appendix J

Interaction Effect for Time and Ability for Developmental Spelling Test Score Means



APPENDIX K

Relative Frequency Differences in Progression between Strong and Weak Spellers on Data Related Operations

Appendix K

Relative Frequency Differences in Progression Between Strong and Weak Spellers on Data Related Operations

Operation	Strong Group (N = 100 ops.)			Weak Group (N = 90 ops.)			Progression (S)			Progression (W)			Difference in Progression (S - W)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Letter Form															
Writes capital letters only	37	0	0	21	1	0	- 37*	0	- 37*	- 20	- 1	- 21	S 17	W 1	S16
Writes mix of capital and lower case letters	48	54	37	71	44	48	6	- 17	- 11	- 27*	4	- 23	W33*	S 21	W12
Writes lower case letters only	16	46	64	4	56	51	30*	18	48*	52*	- 5	47*	W22	S23	S 1
Writes reversed letter(s)	1	0	1	26	12	8	- 1	1	0	- 14	- 4	- 18	W13	W 5	W18
Writes inverted letter(s)	0	0	0	4	3	0	0	0	0	- 1	- 3	- 4	W 1	W 3	W 4
Consonants															
Writes letter string(s)	0	0	0	47	22	6	0	0	0	- 25*	- 16	- 41*	W25*	W16	W41*
Writes phonetically related initial consonant	100	100	100	40	72	89	0	0	0	32*	17	49*	W32*	W17	W49*
Writes correct initial consonant	95	100	100	44	63	82	5	0	5	19	19	38*	W14	W19	W33*
Writes phonetically related final consonant	80	97	100	13	70	80	17	3	20	57*	10	67*	W40*	W 7	W47*
Writes correct final consonant	70	91	97	11	60	86	21	6	27*	49*	26*	75*	W28*	W20	W48*
Writes phonetically related medial consonant	73	96	99	11	64	73	23	3	26*	53*	9	62*	W30*	W 6	W36*
Writes correct medial consonant	71	93	99	7	62	69	22	6	28*	55*	7	62*	W33*	W 1	W34*
Writes phonetically related two consonant blend	58	88	100	3	50	50	30*	12	42*	47*	0	47*	W 17	S 12	W 5
Writes correct initial two consonant blend	53	85	100	0	44	50	32*	15	47*	44*	6	50*	W 12	S 9	W 3
Writes correct consonant nasal	44	90	95	6	22	33	46*	5	51*	16	11	27*	S 30*	W 6	S24
Writes correct initial three consonant blend	30	70	90	0	22	44	40*	20	60*	22	22	44*	S18	W 2	S16

Appendix K (cont'd)

Appendix K (cont'd)

Operation	Strong Group (N = 100 ops.)			Weak Group (N = 90 ops.)			Progression (S)			Progression (W)			Difference in Progression (S - W)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Vowels															
Writes with all syllables represented	98	97	99	47	79	90	- 1	2	1	32*	11	43*	W33*	W 9	W42*
Writes vowel/vowel substitution	35	18	11	10	23	21	- 17	- 7	- 24	13	- 2	11	W30*	W 5	W35*
Writes phonetically related initial vowel	60	75	90	11	56	44	15	15	30*	45*	- 12	33*	W30*	S27*	W 3
Writes correct initial vowel	55	75	80	6	44	44	20	5	25*	38*	0	38*	W18	S 5	W13
Writes phonetically related cvc pattern	85	80	100	6	54	65	- 5	20	15*	48*	11	59*	W53*	S 9	W44*
Writes correct cvc pattern	32	62	73	4	24	39	30*	11	41*	20	15	35*	S10	W4	S 6
Writes phonetically related cvcc pattern	38	66	80	4	31	33	28*	14	42*	27*	2	29*	S 1	S12	S13
Writes correct cvcc pattern	32	40	64	2	11	18	8	24	32*	9	7	16	W 1	S17	S16
Writes phonetically related long vowel pattern	28	68	93	11	31	44	40*	25*	65*	20	13	33*	S20	S12	S32*
Writes correct long vowel pattern	10	55	78	0	14	19	45*	23	68*	14	5	19	S31*	S18*	S49*
Writes phonetically related vowel followed by r	90	70	90	11	67	67	- 20	20	0	56*	0	56*	W76*	S 20	W56*
Writes correct vowel followed by r pattern	10	60	60	0	0	0	50*	0	50*	0	0	0	S 50*	0	S 50*
Phonetically related intervocalic tap	0	20	20	0	22	0	20	0	20	22	- 22	0	W 2	S22	S 20
Correct intervocalic tap	0	0	0	0	11	0	0	0	0	11	- 11	0	W 11	S11	0

Appendix continues . . .

Appendix K (cont'd)

Operation	Strong Group (N = 100 ops.)			Weak Group (N = 90 ops.)			Progression (S)			Progression (W)			Difference in Progression (S - W)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Meaning															
Writes correct -ing ending	30	100	90	0	44	56	70*	- 10	60*	44*	12	56*	S26*	W 22	S 4
Writes correct -ed ending	0	10	60	0	0	11	10	50*	60*	0	11	11	S10	S39*	S49*

Legend: (N = 100 ops.) = number of operations performed by 10 strong ability subjects on 10 DST target words
(N = 90 ops.) = number of operations performed by 9 weak ability subjects on 10 DST target words
J - F = progression from June 93 to February 94; F - M = progression from February 94 to May 94
J - F= progression from June 93 to May 94
* = relative frequency difference of 15% or more between intervals or groups

APPENDIX L

Relative Frequency of Differences in Progression Between Strong and Weak Spellers on Cognitive Control Related Operations

Appendix L

Relative Frequency of Differences in Progression of Strong and Weak Spellers on Cognitive Control Related Operations

Operation	Strong Groups			Weak Groups			Progression (S)			Progression (W)			Difference in Progression (S - W)		
	Jun	Feb	May	Jun	Feb	May	J - K	F - M	J - M	J - K	F - M	J - M	J - K	F - M	J - M
Automatic Production															
Automatic production of letters	100	100	100	26	82	82	0	0	0	56*	0	56*	W56*	0	W56*
Automatic production of letter patterns	63	98	100	2	55	63	35*	2	37*	53*	8	61*	W18	W6	W24*
Automatic production of words	9	36	49	0	1	11	27*	13	40*	1	10	11	S26*	S 3	S29*
Memory															
Touches	1	0	0	9	1	0	- 1	0	- 1	- 8	- 1	- 9	W 7	W 1	W 8
Copies	4	0	0	74	32	22	- 4	0	- 4	- 42*	- 10	- 52*	W38*	W10	W48*
Repeats target word	52	9	22	62	53	49	- 43*	13	- 30*	- 9	- 4	- 13	S34*	W17*	S17*
Visual images	53	23	38	91	67	80	- 30*	15	- 15	- 24	13	- 11	S 6	W 2	S 4
Says letter sounds	62	8	13	69	77	72	- 54*	5	- 49*	8	- 5	3	S62*	W10	S 52*
Says letter names	16	0	1	53	18	21	- 16	1	- 15	- 35*	3	- 32*	W19	S 2	W17
Refers to previous knowledge/ experience	1	4	14	1	9	13	3	10	13	8	4	12	W 5	S 6	S 1
Knows target word in retrospect	99	100	100	58	87	92	1	0	1	29*	5	34*	W28*	W 5	W33*

Appendix continues . . .

Appendix L (cont'd)

Operation	Strong Group (N = 100 ops.)			Weak Group (N = 90 ops.)			Progression (S) F			Progression (W) F			Difference in Progression (S - W) F		
	Jun	Feb	May	Jun	Feb	May	J - K	F - M	J - M	J - K	F - M	J - M	J - K	F - M	J - M
Articulation of Plan															
Goal setting	100	100	100	87	91	100	0	0	0	4	9	13	W 4	W 9	W13
Patterned sequencing	100	100	100	57	80	88	0	0	0	23*	8	31*	W23	W 8	W31*
Self monitoring	99	100	100	63	77	90	1	0	1	14	13	27*	W13	W13	W26*
Self correcting	10	11	9	3	8	11	1	- 2	- 1	5	3	8	W 4	W 5	W 9
Rationale evident	100	99	100	46	76	81	- 1	1	0	30*	5	35*	W31*	W 4	W35*
Focus of Attention															
Selectively attends to detail	99	100	100	76	83	90	1	0	1	7	7	14	W 6	W 7	W13
Attends to the entire task	94	98	99	19	76	79	4	1	5	57*	3	60*	W53*	W 2	W55*
Uninterrupted concentration on task	97	100	100	63	83	84	3	0	3	20	1	21	W17	W 1	W18
Response Style															
Orthodox movement	51	72	72	24	71	61	21	0	21	47*	- 10	37*	W26*	S10	W16
Uninterrupted dictation	79	92	94	63	67	63	13	2	15	4	- 4	0	S 9	S 6	S15
Responds rhythmically	75	87	87	22	27	48	12	0	12	5	21	26*	S 7	W21	W14
Responds thoughtfully	100	100	100	61	83	89	0	0	0	22	6	28*	W22	W 6	W28*
Displays confidence	96	100	100	33	58	71	4	0	4	25*	13	38*	W21	W13	W34*

Legend: 100 ops. = number of operations performed by 10 strong ability subjects on 10 DST target words
90 ops. = number of operations performed by 9 weak ability subjects on 10 DST target words
J - F = growth from June 93 to beginning of February 94
F - M = growth from beginning of February 94 to end of May 94
J - M = growth from June 93 to end of May 94
* = relative frequency difference of 25% or more between intervals or groups

APPENDIX M

Relative Frequency Differences in Progression Between Girls and Boys on Data Related Operations

Appendix M

Relative Frequency Differences in Progression by Girls and Boys on Data Related Operations

Operation	Girls' Group (N = 110 ops.)			Boys' Group (N = 80 ops.)			Progression (G)			Progression (B)			Difference in Progression (G-B)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Letter Form															
Writes capital letters only	18	0	0	45	1	0	- 18	0	- 18	- 44*	- 1	- 45*	B26*	B 1	B27*
Writes mix of capital and lower case letters	65	54	44	51	44	40	- 11	- 10	- 21	- 7	- 4	- 11	G 4	G 6	G 10
Writes lower case letters only	17	46	56	1	56	60	29*	10	39*	55*	4	59*	B26*	G 6	B20
Writes reversed letter(s)	15	7	5	9	4	4	- 8	- 2	- 10	- 5	0	- 5	G 3	G 2	G 5
Writes inverted letter(s)	4	3	0	0	0	0	- 1	- 3	- 4	0	0	0	G 1	G 3	G 4
Consonants															
Writes letter string(s)	22	10	5	23	11	0	- 12	- 5	- 17	- 12	- 11	- 23	0	B 6	B 6
Writes phonetically related initial consonant	78	85	94	63	71	95	7	9	16	8	24	32*	B 1	B15	B16
Writes correct initial consonant	72	81	92	70	84	91	9	11	20	14	7	21	B 5	G 4	B 1
Writes phonetically related final consonant	47	84	88	50	85	94	37*	4	41*	35*	9	44*	G 2	B 5	B 3
Writes correct final consonant	43	75	84	41	79	90	32*	9	41*	38*	11	49*	B 6	B 2	B 8
Writes phonetically related medial consonant	42	80	86	46	82	88	38*	6	44*	36*	6	42*	G 2	0	G 2
Writes correct medial consonant	39	78	83	43	63	88	39*	5	44*	20	25*	45*	G19	B20	B 1
Writes phonetically related 2-consonant blend	23	61	75	47	81	84	38*	14	52*	34*	3	37*	G 4	G11	G15
Writes correct initial 2-consonant blend	20	57	75	38	78	84	37*	18	55*	40*	6	46*	B 3	G12	G 9
Writes correct consonant nasal	18	64	64	31	50	69	46*	0	46*	19	19	38*	G27*	B19	G 8
Writes correct initial three consonant blend	9	27	64	25	75	75	18*	37*	55*	50*	0	50*	B32*	G37*	G 5

Appendix continues . . .

Appendix M (cont'd)

Operation	Girls' Group (N = 110 ops.)			Boys' Group (N = 80 ops.)			Progression (G)			Progression (B)			Difference in Progression (G-B)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F -M	J - M	J - F	F - M	J - M
Vowels															
Writes with all syllables represented	73	86	93	75	91	98	13	7	20	16	7	23*	B 3	0	B 3
Writes vowel/vowel substitution	20	24	16	28	16	15	4	- 8	- 4	- 12	- 1	- 13	B16	G 7	B 9
Writes phonetically related initial vowel	27	64	64	50	69	75	37*	0	37*	19	6	25*	G18	B 6	G12
Writes correct initial vowel	27	55	59	38	69	69	28*	4	32*	31*	0	31*	B 3	G 4	G 1
Writes phonetically related cvc pattern	45	67	79	54	69	90	22*	12	34*	15	21	36*	G 7	B 9	B 2
Writes correct cvc pattern	18	41	56	19	48	58	23*	15	38*	29*	10	39*	B 6	G 5	B 1
Writes phonetically related cvcc pattern	20	49	58	25	50	58	29*	9	38*	25*	8	33*	G 4	G 1	G 5
Writes correct cvcc pattern	7	24	40	8	30	45	17	16	33*	22	15	37*	B 5	G 1	B 4
Writes phonetically related long vowel pattern	16	48	64	25	53	78	32*	16	48*	28*	25*	53*	G4	B 9	B 5
Writes correct long vowel pattern	0	34	50	13	38	50	34*	16	50*	25*	12	37*	G 9	G 4	G13
Writes phonetically related vowel followed by r	45	64	82	63	75	75	19	18	37*	12	0	12	G 7	G18	G25*
Writes correct vowel followed by r pattern	9	18	18	0	50	50	9	0	9	50*	0	50*	B41*	0	B41*
Phonetically related intervocalic tap	0	18	18	0	25	0	18	0	18	25*	- 25*	0	B 7	G25*	G18
Correct intervocalic tap	0	9	0	0	0	0	9	- 9	0	0	0	0	G 9	B 9	0

(Appendix continues . . .)

Appendix M (cont'd)

Operation	Girls' Group (N = 110 ops.)			Boys' Group (N = 80 ops.)			Progression (G)			Progression (B)			Difference in Progression (G-B)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F -M	J - M	J - F	F - M	J - M
Meaning															
Writes correct -ing ending	27	73	82	0	75	63	46*	9	55*	75*	- 12	63*	B29*	G21	B 8
Writes correct -ed ending	0	0	36	0	13	38	0	36*	36*	13	25*	38*	B13	G11	B 2

Legend:
(N = 100 ops.) = number of operations performed by 10 strong ability subjects on 10 DST target words
(N = 90 ops.) = number of operations performed by 9 weak ability subjects on 10 DST target words
J - F = progression from June 93 to February 94; F - M = progression from February 94 to May 94
J - M = progression from June 93 to May 94
* = relative frequency difference of 25% or more between intervals or groups

APPENDIX N

Relative Frequency Differences in Progression Between Girls and Boys on Cognitive Control Related Operations

Appendix N

Relative Frequency Differences in Progression between Girls and Boys on Cognitive Control Related Operations

Operation	Girls' Group (N = 110 ops.)			Boys' Group (N = 80 ops.)			Progression (G)			Progression (B)			Difference in Progression (G-B)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Automatic Production															
Automatic production of letters	65	95	91	64	88	93	30*	- 4	26*	24	5	29*	G 6	B 9	B 3
Automatic production of letter patterns	33	74	80	36	85	86	41*	6	47*	49*	1	50*	B 8	G 5	B 3
Automatic production of words	5	17	28	4	23	35	12	11	23	19	12	31*	B7	B 1	B 8
Memory															
Touches	1	1	0	10	0	0	0	- 1	- 1	- 10	0	- 10	B10	G 1	B 9
Copies	35	19	16	40	10	3	- 16	- 3	- 19	- 30*	- 7	- 37*	B14	B 4	B18
Repeats target word	55	38	27	60	19	45	- 17	- 11	- 28*	- 41*	26*	- 15	B24	G37*	G13
Visual images	72	46	64	70	40	38	- 26*	18	- 8	- 30*	- 2	- 32*	B 4	B20	B24
Says letter sounds	54	48	45	69	30	36	- 6	- 3	- 9	- 39*	6	- 33*	B33*	G 9	B24
Says letter names	44	9	9	20	8	13	- 35*	0	- 35*	- 12	5	- 7	G23	G 5	G28*
Refers to previous knowledge/ experience	1	4	8	1	10	21	3	4	7	9	11	20	B 6	B 7	B13
Knows target word in retrospect	75	93	95	85	95	98	18	2	20	10	3	13	G 8	B 1	G 7

(Appendix continues . . .)

Appendix N (cont'd)

Operation	Girls' Group (N = 110 ops.)			Boys' Group (N = 80 ops.)			Progression (G)			Progression (B)			Difference in Progression (G-B)		
	Jun	Feb	May	Jun	Feb	May	J - F	F - M	J - M	J - F	F - M	J - M	J - F	F - M	J - M
Articulation of Plan															
Goal setting	92	98	100	96	93	100	6	2	8	-3	7	4	G 9	B 5	G 4
Patterned sequencing	76	91	92	84	90	98	15	1	16	6	8	14	G 9	B 7	G 2
Self monitoring	84	88	88	80	90	98	4	0	4	10	8	18	B 6	B 8	B14
Self correcting	4	11	11	11	8	10	7	0	7	-3	2	-1	G10	B 2	G 8
Rationale evident	74	88	89	75	88	94	14	1	15	13	6	19	G 1	B 5	B 4
Focus of Attention															
Selectively attends to detail	85	92	93	91	94	99	7	1	8	3	5	8	G 4	B 4	0
Attends to the entire task	56	84	85	61	93	95	28*	1	29*	32*	2	34*	B 4	B 1	B 5
Uninterrupted concentration on task	83	91	89	79	94	98	8	-2	6	15	4	19	B 7	B 6	B13
Response Style															
Orthodox movement	44	80	72	31	60	58	36*	-8	28*	29*	-2	27*	G 7	B 6	G 1
Uninterrupted dictation	72	69	78	71	95	81	-3	7	6	24	-14	10	B27*	G 21	B 4
Responds rhythmically	45	52	66	56	68	71	7	14	21	12	3	15	B 5	G11	G 6
Responds thoughtfully	84	91	92	79	94	99	7	1	8	15	5	20	B 8	B 4	B12
Displays confidence	82	82	86	66	78	86	0	4	4	12	8	20	B12	B 4	B16

Legend:
(N = 100 ops.) = number of operations performed by 10 strong ability subjects on 10 DST target words
(N = 90 ops.) = number of operations performed by 9 weak ability subjects on 10 DST target words
J - F = progression from June 93 to February 94; F - M = progression from February 94 to May 94
J - M= progression from June 93 to May 94
* = relative frequency difference of 25% or more between intervals or groups