Evaluating the Effect of Word Prediction and Location of Word Prediction List on Text Entry with Children with Spina Bifida and Hydrocephalus

By

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A thesis submitted in conformity with the requirements for the degree of Master of Science
Graduate Department of Rehabilitation Science
University of Toronto

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Master of Science, 2001

Graduate Department of Rehabilitation Science

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Abstract

This study which used a single-subject alternating treatments design evaluated the effect of word prediction on rate and accuracy of text entry and compared the effect of location of word prediction list on rate and accuracy of text entry. Three locations (upper right corner, following the cursor and lower middle border) were used. In addition, user’s perspectives related to the potential benefits of word prediction were explored. Three girls and one boy aged 10-12 with spina bifida and hydrocephalus participated in the study over a period of 20 days. Rates and accuracy of text entry were measured on a copy-writing task. The Canadian Occupational Performance Measure (COPM) was used to evaluate participants’ perceived performance and satisfaction with written productivity tasks. This study found that word prediction did not improve rates of text entry but did improve accuracy of text entry when the prediction list was placed in the lower middle border.
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Introduction

Health Canada estimates that spina bifida occurs in 5.6 per 10,000 total births in Canada (Health Canada, 1999). It is the second most common "birth defect," after cerebral palsy (Wills, 1993). The Canadian rates of spina bifida rank among the highest in the world. These rates have important social and economic implications with regard to the long-term treatment requirements for children born with spina bifida and hydrocephalus. The potential economic consequences for this disability group are likely to be considerable if these children are unable to function productively in society.

Many children with spina bifida and hydrocephalus experience difficulty in developing functional handwriting skills (Anderson, 1976; Cambridge & Anderson, 1979; Pearson, Carr, & Halliwell, 1988). Generally, handwriting speed in children with spina bifida and hydrocephalus is 20% slower than that of children without a disability (Anderson, 1976; Ziviani, Hayes, & Chant, 1990). Difficulties in maintaining alignment, letter formation and word spacing are the most common concerns in legibility (Anderson, 1976). When writing is a difficult task, children may try to complete a written assignment in as few words as possible, thus affecting development of language skills (Amundson & Weil, 1996). The implications of handwriting difficulties are highlighted in Briggs's studies which show that the quality of handwriting may mean the difference between passing and failing a major examination even when the quality of the content remains similar (Briggs, 1970; Briggs, 1980). A reduced handwriting speed could mean that an incomplete response would be produced in an examination, thereby lowering academic achievement (Tseng & Cermak, 1993). Furthermore, children whose writing speeds are slow often cannot finish assignments on time, and have to complete their schoolwork at home or at recess periods. This results in a reduction in playtime, which is important for children’s
social-emotional development (Morrison, Metzger, & Pratt, 1996). Increased concern about handwriting difficulties has been spurred by recent mandates in Ontario to introduce a more vigorous curriculum in writing and other subject areas. Province-wide tests have been conducted with students in Grades 3, 6 and 9 since 1997 to determine the level of achievement in the areas of reading, writing and mathematics (Ontario Ministry of Education, 2000). A literacy examination has been designed recently and will be conducted before the end of Grade 10. Students in Ontario will be required to pass the literacy examination to graduate from high school (Ontario Ministry of Education, 2000). While proficiency in a subject area is judged by the mastery of knowledge and skills, the legibility and speed of a child’s handwriting is critical to providing a medium in which to demonstrate what the child has learned about a given subject.

A problem with handwriting is one of the most common reasons for referring school-aged children to occupational therapy (Cermak, 1991; Oliver, 1990). While some children can improve their handwriting skills through remediation, other children cannot and they commonly require the use of a computer to help with text generation (Amundson & Weil, 1996; Muen & Bannister, 1997; Wills, 1993). However, with reduced finger dexterity, finger agnosia and impaired kinesthetic sensation, children with spina bifida and hydrocephalus also have difficulties developing typing skills, especially in terms of the rate of text entry (Muen & Bannister, 1997; Sandler, 1997; Ziviani et al., 1990). Therefore, use of a computer may help to improve the quality, but not necessarily the speed of written output.

Word prediction computer software programs are designed to increase the rate of text entry for individuals with physical disabilities (Heinisch & Hecht, 1992; Struck, 1996; Swiffin, Arnott, Pickering, & Newell, 1987; Woltosz, 1990). The software monitors the keys that the user types and generates a list of the most likely words and displays them in a prediction list. The user
then selects the desired word from the prediction list by pressing a designated key on the keyboard, usually a number key. By decreasing the number of keystrokes required to type a word, word prediction software has the potential to improve the rate of text entry. Another benefit of word prediction is that it reduces fatigue (Klund & Novak, 1995). This is especially important for people who have physical disabilities and for whom keyboarding can be physically taxing (Klund & Novak, 1995; Waller, Beattie, & Newell, 1990).

Word prediction is commonly recommended by occupational therapists for children with spina bifida and hydrocephalus as a tool to improve their written productivity in tasks such as journal entry, story writing and report writing. However, the effectiveness of word prediction as a strategy to meet these targeted outcomes has not been well established. The results of research into this area are equivocal. A number of clinical case studies and experimental studies suggest that use of word prediction improves the rate of text generation (Lewis, Graves, Ashton, & Kieley, 1998; Newell, Booth, & Beattie, 1991). Other studies find no difference in the rate of text entry with or without word prediction, while some researchers report lower rates with word prediction (Anson, 1993; Koester & Levine, 1994; Koester & Levine, 1996; Scull & Hill, 1988). Researchers generally agree that there is an increased demand on the visual-cognitive system associated with the use of word prediction.

The demand on visual-cognitive skills related to the use of word prediction is particularly important to consider when working with children with spina bifida because they commonly experience difficulties with oculo-motor control, perceptual and cognitive functioning (Biglan, 1990; Dennis. et al., 1981; Fletcher. Levin & Butler, 1995; Stickel. 1998; Wills. 1993). Children with spina bifida and hydrocephalus typically have difficulties with tasks requiring shifting of
eye gaze, active scanning, sequencing, planning, mental tracking, and shifting attention, or inhibiting overlearned responses (Biglan, 1990; Tew, Laurence, & Richards, 1980; Wills, 1993). They also generally take twice as long as children without disabilities to achieve the same level of accuracy in visual scanning tasks (Tew et al., 1980).

Adjusting parameters of the word prediction programs can lessen the visual-cognitive loads associated with its use. For example, Swiflin and associates (1987) suggest that a balance between saving keystrokes and minimizing visual-cognitive loads can be reached by using a five-word list. They also suggest that a vertical layout of the list reduces visual search time as it keeps the head and eye movements to a minimum. The length of words also offers visual cues to guide the search, thus further reducing the searching time. Koester and Levine (1996) suggest that searching the word prediction list after typing two letters was the most efficient searching strategy for individuals with slower visual searching abilities. Another possible parameter affecting visual search time is the placement location of the prediction list on the computer monitor (Klund & Novak, 1995; Newell, et al., 1991). The design of the Windows operating system restricts where the prediction list can be placed. The left upper corner contains the frequently used application command menu. The scroll bars will be blocked if the word list is placed at the two lower corners. Therefore, there are only three logical locations for the prediction list: upper right corner (UR), lower middle border (LM) and following the cursor (FC). To date, no empirical study has addressed the relationship between the placement location of the prediction list and the rate and accuracy of text entry.
1.1 Objectives

The purpose of this study was threefold. First, this study investigated if use of word prediction could enhance written productivity for children with spina bifida and hydrocephalus. Rate and accuracy of text entry were examined, as both are important elements of overall productivity with the use of a computer. Second, this study compared the effect of placement locations of the prediction list on rate and accuracy of text entry. The three locations that were compared included right upper corner, lower middle border and following the cursor. Third, this study explored user’s perspectives related to the potential benefits of word prediction.

Specifically, this study was designed to answer the following questions:

1. Does the use of word prediction significantly improve rate of text entry?
2. Does the use of word prediction significantly improve accuracy of text entry?
3. Is there a difference in rate of text entry when the word prediction list is placed in different locations on the computer screen?
4. Is there a difference in accuracy of text entry when the word prediction list is placed in different locations on the computer screen?
5. Does client’s perception of performance and satisfaction with written productivity tasks change after using word prediction?

1.2 Conceptual Basis and Relevance of the Study

In response to the economic climate of streamlined services and cost cutting in recent years, DeRuyter (1995) issued a wake-up call to the assistive technology community for the need to conduct outcome research. Many authors have echoed that it is imperative to demonstrate accountability and to produce evidence that application of assistive technology interventions are
producing the desired outcomes (Minkel, 1996; Petty, Treviranus, & Weiss, 1999; Scherer, 1996; Smith, 1996). However, the ability to measure the true impact of any assistive device is a very complex and challenging exercise. Recently, there is a growing interest in adopting a client-centered approach to evaluate outcomes of assistive devices (Demers, Weiss-Lambrcu, & Ska, 1996; Scherer & Galvin, 1997; Smith, 1996).

This study was conceived in the context of the Canadian Occupational Performance Model (CMOP), a model of client-centered practice (Canadian Association of Occupational Therapists [CAOT], 1997). The CMOP is based on the belief that the person is a fundamental part of the therapeutic process. It suggests that occupational performance is the result of a dynamic relationship between persons, environment, and occupation over a person’s life span. Acknowledging that an individual’s performance is affected by the complexity of environmental and personal factors, Fearing, Law and Clark (1997) suggest that evidence for outcomes should be established using objective measurements and subjective evidence obtained from the client. Using subjective evidence to establish outcomes is important because underlying client-centred practice is a recognition of the autonomy of the individual person and the recognition of client choice (Law, Polatajko, Baptiste, & Townsend, 1997). Objective evaluation of occupational performance is of value to clients because it helps them gain insight into the degree of change that has occurred (Fearing, et al., 1997).

The CMOP provides the concept and framework for this study to examine the common clinical practice of using word prediction as a rate enhancement tool for children with spina bifida and hydrocephalus. The results of this study will provide preliminary information that can be used to guide prescription and implementation of word prediction technology with children with spina bifida and hydrocephalus.
Chapter Two - Literature Review

This literature review is organized into three distinct sections. The first section summarizes current understandings of spina bifida in the literature. It includes a description of the disorder and the concomitant difficulties experienced by children. Deficits in the areas of upper limb functions, vision, cognition and language are discussed in greater depth as these deficits may affect the ability of children with spina bifida and hydrocephalus to use a computer and word prediction software effectively. The second section reviews the literature on clinical applications of word prediction and factors that may affect the effectiveness of this technology. Factors that influence keystroke savings and visual-cognitive loads associated with the use of word prediction are elaborated to provide the foundation for the study. Previous studies on effectiveness of word prediction are critiqued to identify gaps in existing knowledge. The third section summarizes theories related to perceived self-efficacy and discusses how perceived self-efficacy can influence performance. At the end of the chapter, information gained from the literature review is summarized and applied to guide the implementation of word prediction technology in this study and the development of the hypotheses.

2.1 Spina Bifida and Hydrocephalus

2.1.1 Description of Spina Bifida

The term spina bifida describes the condition in which sections of the spinal column fail to close at the midline. This can occur at any level of the spine from the cervical to the sacral region. The most common location (80%) for spina bifida is in the lumbar region (Biglan, 1990; Shaer, 1997). Myelomeningocele is the most severe form of spina bifida, in which the spinal cord protrudes through the dorsal aspect of the spinal column causing damage to the spinal cord.
The abnormal development of the spinal cord results in a lack of normal nerve function at and below the level of the defect. As a result of spinal cord dysfunction, most children with myelomeningocele require assistance with ambulation. Skin sensation may be absent or significantly reduced in areas at or below the level of the lesion (Sandler, 1997; Shaer, 1997). Fewer than 10% of children with myelomeningocele achieve independent bladder and bowel control (Lie, Lagergren, & Rasmussen, 1991). In addition, orthopaedic abnormalities such as club feet, and other deformities of the feet, knees, and hips or kyphoscoliosis are commonly found in children with myelomeningocele (Karol, 1995). In addition to being the most severe form, myelomeningocele is also the most common form of spina bifida (90%). Therefore the term “myelomeningocele” is very often simply called spina bifida by lay persons and professionals alike (Shaer, 1997). Throughout this thesis, the terms “spina bifida” and “myelomeningocele” are used interchangeably.

When a child is born with an open defect in the spinal column, surgery is done to place the underdeveloped, protruding nervous tissue back into the spinal canal and to cover it with as many of the normal tissue layers as possible. Delayed closure of the defect can lead to contamination and damages to the central nervous system. With advances in medicine, the 10-year survival rate of children with spina bifida improved from 40% in the 1950's to over 83% in 1992 (Eckstein & Macnab, 1966; Steinbook, Levine, Cochrane, & Irwin, 1992). Shunt procedures, infection control and clean catheterization techniques are among the most significant medical advancements that have allowed more babies to survive and to survive with less neurological deficits than previously reported (Harcourt, 1974; Hunt & Poulton, 1995; Wills, 1993).
2.12 Associated Abnormalities

Spina bifida is not just a condition of the spine. There are also associated abnormalities of the nervous system as a result of Arnold-Chiari II malformation and hydrocephalus (Sandler, 1997; Shaer, 1997). With the availability of magnetic resonance imaging (MRI) techniques, researchers have gained a better understanding of the changes in the central nervous systems related to spina bifida (Barkowich, 1990). The MRI techniques have also been applied to relate the pathology in the central nervous system to the clinical manifestations (Fletcher, Bohan, et al., 1996; Lennerstrand, Gallo, & Samuelson, 1990).

Samuelsson and associates (1987) reported that nearly all children with spina bifida were born with Arnold-Chiari II malformation. The Arnold-Chiari II malformation is a condition which involves abnormalities of the hindbrain and posterior fossa, including an elongated, small cerebellum and brain stem and herniation of the cerebellum and portions of the medulla and pons through an enlarged foramen magnum into the cervical spinal canal (Barkowich, 1990). This malformation can lead to dysfunction of the brainstem, the cerebellum and of some of the cranial nerves and the upper cervical nerves. Motor difficulties including vocal cord paralysis, disorders of eye movements and upper extremity weakness can result. In the severe cases, life-threatening symptoms such as apnea and disorganized swallowing can occur (Shaer, 1997).

Hydrocephalus is seen in approximately 80% of children with spina bifida, often as a result of the obstruction of the ventricular system caused by the Arnold-Chiari II malformation (Dias & McLone, 1993; Yeates, Enrile, & Loss, 1998). Hydrocephalus can cause a variety of associated brain abnormalities, including dysplasia of the corpus callosum, stretching of the periventricular white matter, disruption of myelination, damage to the optic tracts, and reduction in the thickness of the cortical mantle, especially in the posterior regions (Del Bigio, 1993;
In addition, children with hydrocephalus show reductions in overall gray matter that are more pronounced in posterior than anterior regions of both hemispheres (Fletcher, McCauley, et al., 1996).

The clinical management of hydrocephalus usually involves shunting to continuously drain the cerebral-spinal fluid (CSF) out of the ventricles. The CSF can be drained into several locations including the abdominal cavity, atrium, the gallbladder, or directly to the outside of the head (Shaer, 1997). The ventricular-peritoneal (VP) shunt, which drains the CSF to the peritoneal cavity is the most common procedure (Christoferson, 1991; Sandler, 1997). The shunt helps to keep the intracranial pressure within normal limits and prevents further damage to the brain from high pressure (Shaer, 1997). Approximately 85% of children with spina bifida and hydrocephalus have shunts inserted, most in the first year of life (Minns, 1984; Wills, 1993). Recent studies suggest that shunt treatment does not restore the brain damages caused by hydrocephalus (Del Bigio, 1993).

More than half of all new-born VP shunt recipients have no significant episodes of shunt malformation and keep the same shunt until late childhood, at which time the shunt tubing may need lengthening to accommodate increasing growth (Sandler, 1997). However, shunt failure is more common in adolescents and adults with spina bifida and hydrocephalus. The growth that occurs with puberty can pull the shunt tubing up and out of the abdominal cavity, so that the shunt does not drain normally or becomes obstructed (Sandler, 1997). The actual presence of the shunt within the body can predispose children with spina bifida and hydrocephalus to many other complications such as a reaction to the tubing, infections, tissue scarring and mechanical breakdown (Christoferson, 1991).
In addition to Arnold-Chiari II malformation and hydrocephalus, magnetic resonance imaging (MRI) studies show that complete or partial agenesis of the corpus callosum are commonly found in children with spina bifida and hydrocephalus (Barkowich, 1990). Children with spina bifida and hydrocephalus are also at increased risk for seizures, with an incidence of approximately 5% to 15%. The risk of seizures is greatest for children with a history of ventriculitis and frequent shunt revisions (Yeates et al., 1998).

The consequences of the involvement of the central nervous system in children with spina bifida and hydrocephalus include deficiencies in intelligence, language, visual perception, memory, attention and upper limb functioning (Dahl, et al., 1995; Dennis et al., 1981; Dennis, Hendrick, Hoffman, & Humphrey, 1987; Fletcher, Brookshire, 1996; Fletcher et al., 1992; Jansen et al., 1991; Tew & Lawrence, 1975; Wills, 1993). In the early years of life, parents of children with spina bifida and hydrocephalus are most concerned about survival, followed by orthopaedic problems, and bowel and bladder incontinence (Lollar, 1993). Deficits in neuropsychological functioning, language, and hand function are often not identified or addressed in these early years (Anderson & Spain, 1977). Donders and colleagues (1991) suggested that many of these deficits are subtle in nature and would not be apparent to caregivers of children under the age of eight. Anderson and Spain (1977) also observed that children with spina bifida and hydrocephalus often manage well in their first two or three years at school. However, they commonly begin to fall behind their peers when they reach grade three, when the demands and complexity of academic and writing tasks increase (Anderson & Spain, 1977; Donders, Rourke, & Canady, 1991).

Many researchers suggest that the spina bifida and hydrocephalus population is very heterogeneous because many factors affect their outcomes, especially in the area of
neuropsychological functioning (Fletcher, Dennis, & Northrup, 2000; Wills, 1993; Yeates et al., 1998). Greener and associates (1991) studied the association of race and gender with neurological levels of myelomeningocele. Overall, they found that the white to black ratio was 3.6:1 and the male to female ratio was 0.86:1. However, the proportions of thoracic level lesion increased significantly in whites and females. The level of lesion has been found to be strongly correlated with sensory, motor and neuropsychological functions. Rather than a gradual decrease in functions with higher level lesions, there appears to be a sharp dropoff in functions at the thoracic level (Donders et al., 1991; Greener, Terry, Demasi, & Herrington, 1991; Laurence & Coates, 1962; Wills, Holmbeck, Dillon, & McLone, 1990). Most reports find no correlation between the number of shunt revisions and cognitive functioning (Dennis et al., 1981; Hunt & Holmes, 1976; Tew & Lawrence, 1975). Researchers agree that children with history of infection in the central nervous system such as ventriculitis or meningitis commonly have lower intellectual function (Hunt & Holmes, 1976; McLone, Czyzewski, Raimondi, & Sommers, 1982; Shaffer, Freidrich, Shurtleff, & Wolf, 1985). Fletcher and associates (1992) showed that measures of the size of the corpus callosum were significantly and robustly correlated with nonverbal intelligence, but not with verbal intelligence. In addition, the severity of hydrocephalus, timing of shunt insertion, visual function, the child’s personality, family, social and educational arrangements are all possible factors affecting the child’s development and neuropsychological functioning (Wills, 1993).

2.13 Deficits in Spina Bifida and Hydrocephalus

Intellectual function. Intellectual functioning is commonly described using the Intelligence Quotient (Yeates et al., 1998). Early studies of children with spina bifida and
hydrocephalus. before advances in medical practice reduced the mortality rate and complications related to shunt procedures. commonly reported below average intelligence on standardized intelligence tests. Incidence of mental retardation was found to be high (Laurence & Coates. 1962; Tew. 1977). Recent studies provide a more optimistic picture. showing that children with spina bifida and hydrocephalus often have IQs in the low-average to average range (Brookshire. et al., 1995; Fletcher et al., 1992; Wills et al., 1990). Verbal abilities are usually stronger than performance skills. Verbal intelligence is usually in the average range, whereas nonverbal or performance intelligence falls below the average. (Brookshire et al., 1995; Dennis et al., 1981; Fletcher et al., 1992; Friedrich, Lovejoy, Shaffer, Shurtleff, & Beilke, 1991; Hunt & Poulton. 1995; Steinbook et al., 1992; Tew. 1991).

Memory. Relatively few studies focus on memory functioning in children with spina bifida. Children with spina bifida and hydrocephalus are often included in studies that examine memory functions of children with hydrocephalus of various etiologies (Cull & Wyke, 1984; Scott. Fletcher. et al., 1998; Yeates. Enrile. & Loss. 1995). The results from these studies suggest that children with shunted hydrocephalus exhibit a pattern of performance suggestive of encoding and retrieval deficits on both verbal and nonverbal tasks. showing a pervasive disturbance of memory processes. These children show deficits on tasks involving serial learning of unrelated items. but not on measures involving the recall of meaningful stories or pictorial stimuli. One area of disagreement remains unsettled. Scott. Fletcher et al. (1998) reported that children with shunted hydrocephalus displayed difficulties with recognition memory. On the contrary. Yeates et al. (1995) reported that children with hydrocephalus have no difficulties in tasks involving recognition. Scott and his colleagues (1998) attributed this disparity in findings
to differences in sampling characteristics. Scott et al. included a broader range of etiologies and a larger sample of children with shunted hydrocephalus in their study.

**Attention and executive functions.** Attention and executive functions are the least studied area of neuropsychological functions in children with spina bifida and hydrocephalus. Fletcher, Brookshire et al. (1996) found that children with hydrocephalus display isolated deficits on measures of focused attention and selective attention as well as problem-solving deficiencies on measures of executive functions. However, they commented that the poorer performance was in part related to motor and speed-of-processing deficits common to children with hydrocephalus. Children with hydrocephalus simply perform more slowly on tasks that measure selective attention and problem-solving skills (Fletcher, Brookshire, 1996). In 1996, Loss, Yeates and colleagues examined attention and executive functions with children with spina bifida and hydrocephalus. They adopted the attention theory proposed by Mirsky (1991) and used test batteries that measure the four elements of attention: encode, focus/execute, sustain and shift. Loss et al. (1996) found that children with spina bifida and hydrocephalus showed deficits across all four elements of attention (Loss, Yeates, & Enrile, 1996; Mirsky, Bruno, Duncan, Ahearn, & Kellam, 1991).

**Language.** Children with spina bifida and hydrocephalus often demonstrate adequate language skills, especially in form and structure (Fletcher et al., 2000). However, they often display deficits in discourse and semantic-pragmatic skills so that their language output is often lacking in substance and poorly matched to the communicative context (Dennis, Jacennik, & Barnes, 1994). Dennis and associates (1987) suggested that with increasing age, children with hydrocephalus appeared less able than children without disabilities to maintain age-appropriate performance increments in language skills. Word-finding, grammatical comprehension and
spelling are common areas of difficulty found in children with spina bifida and hydrocephalus (Dennis et al., 1987; Shaffer et al., 1985; Tew & Lawrence, 1975). Studies of school attainment have consistently shown that children with spina bifida and hydrocephalus have reading skills below their actual age (Tew, 1991). Reading recognition is usually intact but reading comprehension is relatively impaired (Anderson & Spain, 1977; Barnes & Dennis, 1992; Carr, Halliwell, & Pearson, 1981; Halliwell, Carr & Pearson, 1980).

**Visual perception.** Difficulties in visual perception are commonly reported in studies that address the neuropsychological functioning of children with hydrocephalus (Brookshire et al., 1995; Dennis et al., 1981; Fletcher et al., 1992; Tew & Lawrence, 1975; Yeates et al., 1998). Children with spina bifida and hydrocephalus have been found to be slower and less accurate than children without disabilities with respect to visual-spatial abilities (Anderson & Plewis, 1977; Brookshire et al., 1995; Yeates et al., 1998). Poor performance in tasks that involve identifying embedded figures from the background and identifying shape in its entirety have been reported (Fletcher et al., 1992; Miller & Sethi, 1971; Willoughby & Hoffman, 1979). Stickel (1998) reported that children with spina bifida and hydrocephalus are able to solve simple two-dimensional computer-based visual discrimination problems. However, they often require a longer time with visual discrimination tasks that demand more cognitive processing (Stickel, 1998).

**Vision.** Children with spina bifida and hydrocephalus frequently experience visual difficulties including ocular mobility defects, strabismus, nystagmus, and refractive errors (Biglan, 1990; Biglan, 1995; Gaston, 1985; Harcourt, 1974). Approximately 60% - 75% of children with spina bifida and hydrocephalus are diagnosed with strabismus (Caines & Dahl, 1997). A-pattern strabismus, which is also called convergent squint, is the most common type of
strabismus found in this population. Strabismus is commonly treated surgically to restore bifocal fixation (Harcourt, 1974). However, only a small number of treated individuals are able to develop normal binocular functioning (Harcourt, 1974). Nystagmus is another eye movement disorder commonly found in children with spina bifida and hydrocephalus, occurring at a rate of 25% (Biglan, 1990). Children with nystagmus experience oscillating eye movements in a particular direction, most often upon lateral gaze. Nystagmus also impedes the development of binocular vision. Children assessed for strabismus and nystagmus are sometimes found to have defective vision due to optic atrophy (Biglan, 1990). A number of researchers attribute strabismus and nystagmus to hydrocephalus, midbrain or cerebellar dysfunction, or to a combination of these mechanisms, which causes thinning of the cortex, disruption to the brainstem and the cerebellum, and traction and angulation of optic and oculomotor nerves (Clements & Kaushal, 1970; Gaston, 1985; Harcourt, 1974). These findings have been confirmed using MRI techniques in recent studies (Biglan, 1995; Lennerstrand et al., 1990). The ocular motility and acuity problems may contribute to the difficulties in visual acuity, visual accommodation, visuomotor and visuospatial tasks (Dennis et al., 1981; Hunt & Holmes, 1976; Tew, 1991). Children with spina bifida and hydrocephalus commonly experience loss of place, skipping words and slow reading speed because of oculo-motor difficulties (Biglan, 1990; Biglan, 1995; Sandler, 1997). They typically take twice as long as children without disabilities in visual scanning tasks to achieve the same level of accuracy (Tew, Laurence, & Richards, 1980).

Upper extremity function. Children with spina bifida and hydrocephalus commonly experience dysfunction in their upper extremities and their hands. They may score poorly in tests of muscle power, bilateral coordination, stereognosis, and tactile and kinesthetic sensation. Hydrocephalus and cerebellar anomalies due to Arnold-Chiari II malformation have been the
most commonly implicated cause of poor upper limb function (Jansen et al., 1991; Mazur, Aylward, Colliner, Stacy, & Menelaus, 1988; Minns, 1984; Sand, Taylor, Hill, Kosky, & Rawlings, 1974; Wallace, 1973). Muen and associates (1997) report that children with spina bifida, but without hydrocephalus, also have reduced hand function scores as compared to children of their own age and sex. They suggest that the spinal cord abnormalities might be the contributing factor to reduced hand function in children with spina bifida. A high incidence of vertebral malformations such as syringohydromyelia, hydromyelia or diastematomyelia have been identified and confirmed using MRI techniques (Azimullah, Smit, Rietveld-Knol, & Valk, 1991; Emery & Lendon, 1972; La Marca, Herman, Grant, & McLone, 1997; Samuelsson, Bergstrom, Thomas, Hemmingsson, & Wallensten, 1987). All of these pathologies are capable of considerable disruption of the spinal cord locally by their effect on the neurons in the dorsal and ventral horns, and more distally by affecting the long tracts as they pass through the affected area.

Reduced upper limb functioning, especially in terms of coordination, and tactile and kinesthetic sensation affects the abilities of children with spina bifida and hydrocephalus to write and type (Muen & Bannister, 1997; Wills, 1993). The development of writing and typing skills is compounded by the deficits in oculo-motor control, visual perception, and visual-motor integration (Anderson, 1976; Cambridge & Anderson, 1979; Pearson, Carr, & Halliwell, 1988; Wills, 1993; Ziviani et al., 1990). Generally, handwriting speed in children with spina bifida is about 20% slower than that of children with no disability (Anderson, 1976; Ziviani et al., 1990). The level of difficulty in typing has not been documented in the literature. Clinically, children with spina bifida and hydrocephalus are observed to have difficulties developing touch-typing skills. Many type with only one finger. This may be due to the difficulties in bilateral
coordination of hand movement commonly found in children with spina bifida and hydrocephalus (Muen & Bannister, 1997).

2.2 Word Prediction

2.2.1 Application of Word Prediction

Many individuals with physical disabilities find their methods of access to the computer (e.g., direct keyboarding, single-switch scanning and on-screen keyboard) too slow and tiring to serve as adequate writing tools (Scull & Hill, 1988; Soede & Foulds, 1986; Swiffin, Arnott, Pickering, & Newell, 1987). Word prediction software was developed to help them improve the rate of written communication (Klund & Novak, 1995). The software presents a list of possible words to users as they type the initial letters of a word. By selecting a word from the prediction list instead of typing the whole word, the number of keystrokes required to type a word is reduced. Additional keystroke savings are achieved with auto-spacing and auto-punctuation. Auto-spacing means that the word prediction software automatically inserts a space after the user selects a word from the prediction list. Auto-capitalization refers to the automatic capitalization of the next word after an end-of-sentence punctuation is typed. The reduction of keystrokes required for typing was hypothesized to be the main reason that word prediction can improve the rate of text entry (Swiffin et al., 1987). Typically, word prediction programs are used by individuals who type using standard or alternative keyboards (e.g., expanded or small keyboard), but the technology has also been incorporated into on-screen keyboard programs, and single-switch scanning software (Fong-Lee, 1993). In addition, word prediction programs have been regarded as a useful tool to help students with learning disabilities in the writing process.
particularly to help them with difficulties in spelling (Hunt-Berg, Ranking, & Beukelman, 1994; MacArthur, 1996).

2.22 Factors Affecting Effectiveness of Word Prediction in Rate Enhancement

Researchers have long recognized that reduction of keystrokes or motor acts does not translate into an equal amount of improvement in rate (Dabbagh & Damper, 1985; Damper, 1984; Gibler & Childress, 1982; Goodenough-Trepagnier & Rosen, 1988; Vanderheiden & Kelso, 1987). There are many factors that affect the overall rate of text entry or communication rate offered by a word prediction program. These include user characteristics, computer efficiency, keystroke savings and visual-cognitive loads (Horstmann & Levine, 1991; Newell, et al., 1992; Soede & Foulds, 1986). It is generally assumed that, with the advancement in computer technology, the factors related to computer efficiency are negligible (Soede & Foulds, 1986). User characteristics that should be considered include physical functions, motivation and visual-cognitive functions (Newell, Booth, & Beattie, 1991). Assuming that user characteristics are a relatively constant factor, the overall efficiency of a word prediction program depends on the balance between keystroke savings and the visual-cognitive loads (Koester & Levine, 1998; Soede & Foulds, 1986; Vanderheiden & Kelso, 1987).

Higginbotham (1992) conducted a systematic evaluation of keystroke savings offered by five word prediction programs. He determined that the range of keystroke savings offered by word prediction was between 31% to 48% (Higginbotham, 1992). The median range of keystroke savings reported in several case studies was in the range of 23-58% (Koester & Levine, 1996).
The cognitive processes required to use word prediction include decisions about when or whether to search the prediction list, visual searching of the prediction list, decisions about whether or not the list contains the desired word, and planning the appropriate action depending on the presence or absence of the word on the list (Koester & Levine, 1991; Treviranus & Norris, 1987; Vanderheiden & Kelso, 1987). Visually, users who are not touch-typists have to switch their eye gaze between the keyboard, the text location on the computer monitor, and the prediction list. In the case of a copy task, additional eye-gaze switching is required to and from the copy material. The switching of eye-gaze requires additional effort for the users to find their places after scanning the prediction list (Anson, 1993; Koester & Levine, 1991; Treviranus & Norris, 1987; Vanderheiden & Kelso, 1987).

Through the use of case studies, clinical observations and mathematical modeling techniques, researchers have identified a number of parameters related to word prediction programs that can affect keystroke savings and the visual-cognitive loads. These include: prediction lexicon, prediction algorithm, prediction list length, layout and order of the prediction list (Gibler & Childress, 1982; Higginbotham, Bak, Drazek, Kelly, & White, 1992; Klund & Novak, 1995; Koester & Levine, 1998; Newell et al., 1991; Swiffin et al., 1987; Vanderheiden, 1990; Vanderheiden & Kelso, 1987). In addition to changing the parameters of the word prediction program, application of search strategies and training are also recommended as important factors affecting visual-cognitive loads when using a word prediction program (Koester & Levine, 1998; Newell et al., 1992; Vanderheiden & Kelso, 1987).

The prediction algorithm determines how many keystrokes are required before a word is displayed on the prediction list: therefore, it is an important factor contributing to keystroke savings (Klund & Novak, 1995). A list of predicted words can be generated based on the
frequency of word usage in the English language, recency of use by the user, word association, grammar or topic (Higginbotham et al., 1992; Klund & Novak, 1995; Swiffin et al., 1987). The most commonly used algorithm is frequency-of-use (Vanderheiden & Kelso, 1987). However, simple word frequencies and recencies are not an accurate measure of the probability of the next word during text composition. Both syntax and context play an important part in determining how likely a particular word will occur as the next word in a sentence. Therefore, by incorporating syntax and context information into the prediction algorithm, it may be possible to increase the keystroke savings by an additional factor (Swiffin et al., 1987).

The prediction lexicon affects when and whether the desired word will appear in the prediction list. A prediction lexicon can be fixed or dynamic. A fixed lexicon does not allow any words to be added to the dictionary. A dynamic lexicon allows a user’s words to be added to the dictionary as they are typed. Higginbotham (1992) suggested that keystroke savings may be affected by individual communication style, word selection and discourse genre. A prediction lexicon that can adequately reflect the individual’s writing or communication needs in different situations will likely be most effective. To be able to reflect the user’s writing or communication style, a dynamic lexicon is recommended (Swiffin et al., 1987; Treviranus & Norris, 1987). On the other hand, a fixed lexicon helps the user to predict whether or not a word will appear on the prediction list, where it will be on the list, and thus less cognitively demanding (Vanderheiden & Kelso, 1987). A large dictionary increases the likelihood that the desired word will be included in the pre-stored lexicon, but it also tends to increase the required keystrokes before the word is displayed on the prediction list (Vanderheiden & Kelso, 1987). Smaller dictionaries of about 2,000 words are recommended as one way to increase communication rate, while keeping the visual-cognitive load to a minimum (Anson, 1993; Gibler & Childress, 1982; Klund & Novak.
Swifin (1987) suggested that using a number of context-based small dictionaries is better than using a large dictionary. However, with the improvement in prediction algorithms, the current trend in development of word prediction software is in favour of a large pre-stored lexicon (Co:Writer 4000. 2000; Tam. et al.. 1999).

Predicted words can be displayed in the prediction list according to alphabetical order, length of the word or frequency-of-use (Woltosz. 1990). The potential benefit of a frequency-of-use order is the reduction of search time by having the most frequently used words appear at the top of the list. Displaying words according to word length may assist users with visual searching, because the length of the word provides a visual cue for the search. Arranging words alphabetically is used more commonly by users with learning difficulties (Aurora. 1999).

Landauer and Nachbar (as cited in Horstmann and Levine. 1991), who examined the effect of prediction list length with mathematical modeling found that search time for a 5-word list was between 1.0-1.5 seconds, and may be expected to increase logarithmically if more items are added to the list. Using a laboratory simulation program to test the effectiveness of word prediction in rate reduction, Swifin and associates (1987) observed that a 5-word prediction list provided “a useful keysaving while keeping cognitive load and list scanning time to a minimum” (p.188). Venkatagiri (1994) conducted a study to explore the effect of the length of prediction list on communication rate. He compared prediction list lengths of 5, 10 and 15 words and concluded that a 15-word list provided the highest keystroke savings, but required the most time to search. Venkatagiri recommended a 5-word list because it offers the best compromise between keystroke savings and visual-cognitive loads.

Swifin and colleagues (1987) described their experiences in the design of PAL, a word prediction program. They found that displaying the prediction list horizontally across the screen
required a larger amount of head and eye movements from the users than a vertical display.

When the words are displayed vertically in a prediction list, the length and the shape of the words provide some clues to guide the visual search (Swiffin et al., 1987).

The placement location has been suggested as one possible factor that may affect the visual-cognitive load when using word prediction. Anecdotally, Swiffin, Arnott and others (1987) suggest that the prediction list should be kept in close proximity to the text cursor as it allows users to take in the prediction list and the cursor with one glance. Clinical experiences suggested that individuals have their own preferences for the location of the word prediction list. To date, no empirical study has been done to compare the effect of different placement locations on rate or accuracy of text entry.

The strategy used to search the word list also has an effect on the rate of text entry. To gain the maximum benefit from keystroke savings, the best strategy is to always search the list. However, this strategy usually means an increased search time (Koester & Levine, 1998).

Applying the Keystroke-Level model (Card, Moran, & Newell, 1983), a mathematical model developed for the study of human-computer interfaces, Koester and Levine (1997, 1998) built performance profiles to determine the relative performances of visual search strategies. They suggest that a good "all-purpose strategy" is to type one letter and then search the word list, but for individuals with slower visual search abilities, the recommended searching strategy is a "2-then-search" strategy meaning searching after typing two letters (Koester & Levine, 1998).

In addition to adjusting the parameters on word prediction programs to optimize the rate of text entry, appropriate training and sufficient practice can also reduce the visual-cognitive loads associated with the use of word prediction. Users should be trained to use search strategies effectively, so that the process becomes automatic (Vanderheiden, 1990). Newell and associates
(1992) recommended that an average of 1-2 hours of training is necessary to properly introduce users to word prediction. After users begin to use word prediction, anticipation of the contents in the prediction list will become more successful with practice, thus shortening visual search time (Koester & Levine, 1996). However, Koester and Levine (1996) suggested that the visual search task in using word prediction is unlikely to become truly automatic, even with extended practice, because the words in the list serve as both targets and distractors. This makes it unlikely that cognitive and perceptual loads from word prediction would become negligible in skilled users.

2.23 Previous Studies on Effectiveness of Word Prediction

Researchers studying the effectiveness of word prediction reported mixed results. The mixed results generated from previous studies could be attributed to the combination of differences in research methodologies, study populations, word prediction packages, and computer access devices used in the studies. The major shortfall in the existing body of literature is that many experimental studies on word prediction are efficacy studies conducted with able-bodied subjects in laboratory settings. Clinical information was gained mainly from case studies that were anecdotal in nature.

Two groups of researchers reported improved rates of text entry with word prediction and single-switch row-column scanning (Gibler & Childress, 1982; Koester & Levine, 1994). Both groups used software specifically written for the experiments. Three able-bodied individuals and one person with a disability participated in the study conducted by Gibler and Childress (1982). Four able-bodied individuals were involved with Koester & Levine's study (1994). Gibler et al. (1982) reported a 30% gain in the rate of text entry with word prediction. They also noted that the participant with disabilities found word prediction to be helpful in spelling and reduction of
typographical errors. Koester and Levine (1994) reported that participants, who practiced using scanning before being introduced to word prediction, experienced a gain of 8.7% in the rate of text entry with the use of word prediction.

The developers of PAL conducted a number of case studies to evaluate the benefits that PAL offered (Newell et al., 1991; Waller, Beattie, & Newell, 1990). Waller, who was a member of the PAL development team, reported her experience as a word-prediction user with physical disabilities (Waller et al., 1990). She found that her rates of typing were significantly better with the use of word prediction as compared to her previous method of access (abbreviation-expansion). Newell and associates (1991) conducted nine case studies in a classroom environment over the entire school year. The participants had a variety of diagnoses covering learning, developmental and/or physical disabilities. Newell et al. (1991) tested rates of text entry with two of the nine participants. They reported an overall gain in text entry from the participants' responses to a questionnaire and through interview with the teachers. Despite a positive response, Newell and associates suggested that only children who have problems accessing the keyboard would experience the speed advantage of PAL. Considering the time required for scanning the prediction list, they suggested that for individuals typing at or above a typing rate of approximately 10 words per minute (wpm), PAL would not increase typing rates substantially. However, Newell et al. felt that the improvements in the accuracy of the written work from using PAL outweighed this disadvantage.

Lewis and his colleagues (1998) compared the usefulness of different technology devices for students with learning disabilities. In their studies, 132 students with learning disabilities participated. Twenty-two students were assigned to the control group who continued to use handwriting as their means of written communication. One hundred and ten students were
randomly assigned to five experimental groups (i.e., word processing, keyboarding, alternative keyboard, word prediction, word prediction with speech output). All students used their assigned technology throughout the school year. Lewis et al. (1998) reported that participants in the control group had the fastest output rates. Among the technology user groups, the word prediction group was the fastest, and the group who used word prediction with speech output was the slowest. However, Lewis et al. did not provide information to demonstrate that the groups were similar in their typing rates before the study. Therefore, it is difficult to determine if the faster rates of text entry in the word prediction group were a result of the intervention. Lewis et al. (1998) also found that students in all of the technology groups made fewer spelling mistakes in post-tests, with the best accuracy achieved by the group who used word prediction with speech output. Lewis et al. (1998) interviewed the teachers of the participating students for their views on the usefulness of assistive technology. The teachers indicated that for more advanced students, word prediction was distracting and could slow down the writing process (Lewis et al., 1998).

Contrary to the support provided by the above-mentioned studies, a number of researchers reported slower or similar rates with the use of word prediction. Scull and Hill (1988) conducted a study using a single-subject alternating treatments design to explore the effect of word prediction. An adult with cerebral palsy participated in the study. Scull and Hill reported no difference in rates with and without word prediction. They noted that the time saved by reduction of keystrokes was lost by time spent searching the prediction list (Scull & Hill, 1988). Caves and colleagues (1991) reported a case study of a 20-year-old male with a C1-C2 spinal cord injury who used a single switch to access his computer. This young man discontinued the use of word prediction after using it for a short time because he felt that he could type a word in less time
than it took to locate and select it from the prediction list. Anson (1993) tested the speed benefit of word prediction with 18 able-bodied participants. Ten people were assigned to the direct-typing group, while 8 people were asked to type using an on-screen keyboard. Anson (1993) reported a drop of 42% in the typing rate for the direct-keyboarding group, but a gain of 8% for the on-screen keyboard group. Eight able-bodied individuals and six people with spinal cord injuries at levels ranging from C4 to C6 participated in a study conducted by Koester and Levine in 1994. The participants used word-prediction software specially written for the study, with a mouthstick or a typing splint. Koester and Levine (1994) reported that rates of text entry were similar with or without word prediction in the able-bodied group, but the participants with spinal cord injuries experienced a decrease in their typing rates with word prediction.

In addition to being used as a rate-enhancement tool, word prediction has been applied to help students with learning difficulties with writing. Morris, Newell, Booth, Ricketts, and Arnott (1992) conducted ten case studies but only provided detailed information on two children in their report. Both children had physical disabilities (cerebral palsy, spina bifida, and hydrocephalus) as well as learning difficulties. The authors suggested that use of word prediction improved syntax in the writing samples of one participant. The participant who has spina bifida, lost interest in the use of the software after a number of trials, therefore, no definitive result was reported on her (Morris, et al., 1992). Using single-subject designs, MacArthur studied the effects of word prediction on writing with students with learning disabilities in two studies (MacArthur, 1998; MacArthur, 1999). The students in both studies were 9 to 10 years old and had similar learning profiles. In the first study, using word prediction software with a small dictionary of 450 words, MacArthur (1998) found that word prediction had a strong effect on the legibility and spelling of written dialogue journal entries for four of the five students. However, word prediction did not
have an impact on the length of writing and rate of text entry. In his second study, a word prediction package with a dictionary of 2,000 words was used (MacArthur, 1999). No differences were found for legibility and spelling when MacArthur made comparisons between direct typing and use of word prediction. He also reported that students wrote two to three times slower with word prediction than with handwriting. Analyses of students’ use of word prediction and their spelling errors suggests that the software is difficult to use because it places substantial demands on attention and requires the initial letters of words to be spelled correctly (MacArthur, 1999).

2.3 Perceived Self-Efficacy

Self-efficacy theory stated that behaviour is cognitively mediated by the strength of a person’s perceived self-efficacy. Perceived self-efficacy is defined as an individual’s assessment of his or her ability to perform behaviours in specific situations (Bandura, 1997). Research has indicated that perceived self-efficacy is a significant behavioral determinant of actual performance (Bandura & Adams, 1977; Bandura & Wood, 1989; Toshima, Kaplan, & Ries, 1990; Wang & Richard, 1987; Wassem, 1992). Most current conceptual models of health behaviour include perceived self-efficacy as a determinant of health-promoting behaviour (Ajzen, 1985; Bandura, 1997; Pender, 1987; Rogers, 1983). It is postulated that perceived self-efficacy affect whether people consider changing their health habits, whether they can enlist the motivation and perseverance needed to succeed and how well they maintain the changes they have achieved (Pender, 1987; Bandura, 1997).

A substantial body of research conducted with adults supports that strong self-efficacy beliefs are related to a variety of health outcomes (Gecht, Connell, Sinacore & Prohaska, 1996:}
Perceived self-efficacy is a concept originally developed as part of social cognitive theory. Social cognitive theorists view human functioning as the result of triadic reciprocality: behaviour, internal personal factors in the form of cognitive, affective and biological events, and the external environment (Bandura, 1997). These three major classes of determinants interact with each other and influence one another bidirectionally. The relative influence of each of these three factors varies from situation to situation, from person to person, and from environment to environment. Therefore, perceptions of self-efficacy are not reflective of a global personality trait: rather, they vary across different behaviour domains such as physical self-efficacy and productivity self-efficacy (Bandura, 1997).

Bandura (1977) identified three parameters of perceived self-efficacy: magnitude, strength, and generality. Magnitude refers to the relative level of difficulty of the task that is being rated. Strength of perceived self-efficacy refers to the degree to which people believe they can succeed at a given level of an activity. Generality of perceived self-efficacy refers to the degree to which the person’s perceived self-efficacy for one activity transfers to other similar or different activities (Bandura, 1977).

Response efficacy is the belief that performance of a specific behaviour will result in a specific outcome (Rogers, 1983). Both perceived self-efficacy and response efficacy affect whether or not the person will elect to perform a certain activity. Bandura (1997) asserted that people may believe that they can perform an activity (i.e. high perceived self-efficacy), but they
may not believe that performing the activity can achieve the desired outcomes (i.e., low response-efficacy). Improvement in performance can only be expected if people believe that they can perform the activity and that doing so has some effect.

A strong sense of perceived self-efficacy for an activity is important to successful performance (Bandura, 1997). Feeling of mastery heightens perceived self-efficacy and provides a source of motivation. Self-discontent with comparative substandard performance lowers perceived self-efficacy and can lead to termination of the activity (Bandura, 1997). Successful performance on one activity can result in a strengthening of efficacy expectations for other activities of similar nature (Bandura, 1977).

2.4 Summary

Children with spina bifida and hydrocephalus commonly experience difficulties with written productivity. Weaknesses in oculo-motor control, visual perception, visual-motor integration and upper extremity dysfunctions are considered to be the contributing factors to their handwriting difficulties (Anderson, 1976; Pearson et al., 1988; Wills, 1993). Use of a computer for text generation is a common strategy recommended by occupational therapists to overcome the mechanical difficulties with writing (Hunt-Berg et al., 1994; Struck, 1996). However, with reduced finger dexterity, finger agnosia and impaired kinesthetic sensation, children with spina bifida often have difficulties developing functional typing skills, especially in terms of rate of text entry (Sandler, 1997).

Word prediction is often recommended by occupational therapists as a tool to enhance rates of text entry (Fong-Lee, 1993). However, the effectiveness of word prediction when used as a rate enhancement tool has not yet been established. Many published studies address this issue.
but the results are equivocal. Researchers recognize that there is a visual-cognitive load associated with the use of word prediction. Therefore the keystroke saving gained from using word prediction will not translate into an equal amount of gain in speed. The overall efficiency of word prediction is determined by the balance of keystroke savings and visual-cognitive loads (Horstmann & Levine. 1991; Newell et al. 1992; Soede & Foulds. 1986).

The demand on visual-cognitive skills in using word prediction is a particular important consideration when working with children with spina bifida as these children commonly experience difficulties with oculo-motor control, perceptual and cognitive functioning (Biglari. 1990, 1995; Dennis et al., 1981; Wills. 1993). Researchers suggest that adjusting the parameters available on word prediction software might help to lessen the visual-cognitive load. A prediction list that is presented vertically and contains five words helps to minimize visual search time (Newell et al., 1992). A fixed dictionary helps users with the visual searches as they can anticipate the location of commonly used words on the prediction list (Vanderheiden & Kelso. 1987). A small dictionary of about 2,000 words that matches the user's vocabulary may be a good compromise between keystroke savings and visual-cognitive demands (Gibler & Childress. 1982). Children with spina bifida and hydrocephalus who are typically slow with visual scanning, will benefit from the "2-then-search" strategy (i.e., they type two letters before scanning the prediction list). The location of the prediction list may also affect the visual search time, as it changes the distance for eye gaze to shift between the keyboard, the monitor and the text material being copied. Clinical experiences suggested that individuals have their own preferences for the location of the word prediction list.

Generally speaking, researchers agree that word prediction helps to improve accuracy of writing as it removes the mechanical difficulties of spelling (Lewis et al., 1998; Newell et al.,
that individuals whose typing rate is slower than 10 or 15 words per minute would benefit from using word prediction as a rate enhancement tool (Fong-Lee, 1993; Higginbotham et al., 1992; Newell et al., 1991). To date, no studies have explored the effectiveness of word prediction in improving rate and accuracy of text entry with children with spina bifida and hydrocephalus.

In addition to using objective data to demonstrate clinical outcomes, Kemper, Cassileth and Ferris (1999) recommended that a holistic approach for paediatric outcome research should include indicators such as impact on cultural identity and perceived self-efficacy. Perceived self-efficacy is defined as an individual’s assessment of his or her ability to perform behaviours in specific situations (Bandura, 1997). Efficacy beliefs affect whether people can enlist the motivation and perseverance needed to succeed and how well they maintain the changes they have achieved. Applying the self-efficacy theory to children with spina bifida and hydrocephalus suggests that success with the use of word prediction for copy-typing leads to an increase in motivation with the engagement of the activity and a sense of mastery, which can lead to an increase in perceived performance and satisfaction with performance in other typing tasks.

2.5 Hypotheses

It is hypothesized that:

1. Use of word prediction will significantly improve rate of text entry.

2. Use of word prediction will significantly improve accuracy of text entry.

3. Rate of text entry will be significantly faster when the word prediction list is placed in the participant’s preferred location.
4. Accuracy of text entry will be significantly higher when the word prediction list is placed in the participant's preferred location.

5. There will be a positive change in participants' self-perception of performance and satisfaction with performance in written productivity tasks after using word prediction.
Chapter Three – Method

A single-subject alternating treatments design (Barlow & Hayes. 1979: Ottenbacher. 1986) was used in the study. The first section of this chapter provides the rationale for using this design and the considerations in internal and external validity relating to the alternating treatments design. It also describes how the alternating treatments design was applied in this study. The latter sections describe the sampling strategy, measures, data collection procedures and data analysis methods used in the study. The last section reports results of the pilot study conducted to verify the data collection and analysis procedures.

3.1 Research Design

3.1.1 Single Subject Experimental Design

Traditionally, researchers have relied on group and statistical designs to explore treatment variables and treatment outcomes (Barlow & Hersen. 1984). The use of group designs make it possible to use the most well-known powerful designs such as the randomized control trials and associated statistical tests to evaluate the effectiveness of treatments (Hacker. 1980). However, group designs require a large enough sample from homogeneous groups of subjects to demonstrate the power of inference (Hulley. Gove. Browner. & Cummings. 1988). The limited availability of clients with similar types of disabilities makes it very difficult and often impossible to use the powerful group designs in paediatric rehabilitation research (Law. King. & Pollock. 1994). The heterogeneity in children with neurological deficits and the small sample size available were the main reasons why a group comparison approach was impractical for this study.
Single-subject experimental designs provide a valid alternative to the traditional group designs (Kazdin, 1982; Ottenbacher, 1986). These designs enable the researcher to conduct experimental investigations with one or a small number of participants. In single-subject research, the participant serves as his/her own control, therefore, it is also called a within-subject design (McReynolds & Kearns, 1983). Single-subject research is not the same as a case study. Similar to group designs, single-subject research designs demand careful control of variables, clearly delineated and reliable data collection, and the introduction and manipulation of only one intervention at a time (Backman, Harris, Chisholm, & Monette, 1997). Single-subject research is particularly suitable for clinical research. It offers some flexibility to individualize the therapeutic approach, and it offers an opportunity for in-depth exploration and documentation of a specific client under specific conditions, to the therapeutic intervention (Hacker, 1980; Law et al., 1994; McReynolds & Kearns, 1983; Ottenbacher, 1986). In this study, the use of a single-subject research design made it possible to individualize the word prediction program to suit the needs of specific participants, while allowing in-depth exploration and documentation of the effect of word prediction and the effect of locations of the prediction list on rate and accuracy of text entry.

3.12 Alternating Treatments Design

Alternating treatments design is one form of single-subject research design. It is well suited to compare the relative merits of different versions of the same intervention, while allowing comparison of treatment and no-treatment effects at the same time (Barlow & Hayes, 1979). Backman et al. (1997) suggested that the alternating treatments design is well suited to study the effects of assistive technology because use of assistive devices can produce reasonably
rapid and clear behaviour changes. In the basic form of an alternating treatments design, a baseline phase is not an absolute requirement (Ottenbacher, 1986). In a more sophisticated and powerful alternating treatments design, the baseline phase is included (Backman et al., 1997; Ottenbacher, 1986). Such a design is illustrated in Figure 1. This initial baseline phase consists of a number of measurements taken with the no-treatment conditions (Ottenbacher, 1986). The baseline information defines the extent to which the participant requires treatment. It also serves as a basis of comparison for evaluating the effectiveness of treatment (McReynolds & Kearns, 1983). In the alternating treatments phase, the participant is exposed to baseline and treatment conditions one after another in a rapidly alternating fashion. The different treatment conditions and the no-treatment condition are presented to the participant in a random order (Barlow & Hayes, 1979; Stromgren & Kolby, 1996). After the alternating treatments phase, the no-treatment data are collected. This strong design permits empirical comparisons between treatments and between treatment and no-treatment conditions (Backman et al., 1997).

3.13 Internal Validity

Variables such as history, maturation, testing, instrumentation, and statistical regression are potential threats to the internal validity of a single-subject research study (Ottenbacher, 1986). History refers to any event outside of the intervention that occurs between a set of observations or measurement such as family crises or the use of a new drug (Kazdin, 1982). Maturation may be defined as biological, physiological, or psychological changes that occur over a period of time and are due primarily to growth or adaptation (Ottenbacher, 1986). Testing refers to "any changes that can be attributed to the effects of repeated assessments" (Kazdin, 1982, p.78). Statistical regression refers to the tendency of extreme scores to move toward the
means (Kazdin, 1982). In general, internal validity threats can be controlled by the multiple application and variation or withdrawal of interventions and by the use of repeated measures (Ottenbacker, 1986). In an alternating treatments design, the subjects experience each of the rapidly alternating treatments for an equal amount of time in the same time period, therefore, variables such as history, maturation and testing would have similar impact on each of the treatment conditions (Barlow & Hayes, 1979; Stromgren & Kolby, 1996). The use of valid and reliable measures to determine outcome effects can provide adequate control over instrumentation (Ottenbacher, 1986).

3.14 External Validity

The primary disadvantage associated with alternating treatments design is the risk of multiple treatment interference (Barlow & Hayes, 1979). Multiple treatment interference refers to the fact that the two or more treatments being evaluated may interact in some fashion to produce an effect that would not be present if any of the treatments were applied in isolation. Barlow and Hayes (1979) suggest that there are two concerns related to multiple treatment interference: sequential confounding and carry-over effects.

Sequential confounding or an order effect refers to the influence of one treatment on an adjacent treatment. Counterbalancing or randomized order are common strategies used to control the order effect (Ottenbacher, 1986; Stromgren & Kolby, 1996). A carry-over effect refers to the influence on an adjacent treatment, regardless of the overall sequencing. The carry-over effect can be divided into two categories: contrast and induction. In contrast carry-over effects, the performances in the two associated conditions change in the opposite directions. In induction carry-over effects, the performances in the two associated conditions change in the same
direction (Barlow & Hayes, 1979). There are several possible ways to reduce carry-over effects, including counterbalancing or randomized order, the use of short treatment phases and providing a separation between the treatment conditions (Ottenbacher, 1986). McGonigle and colleagues (1987) studied the impact on different intercomponent interval lengths (ICI) between treatments on carry-over effects. They conclude that there is no fixed-and-fast rule as to the appropriate duration of the ICI. The treatment should be alternated rapidly enough to establish discrimination within a reasonable amount of time, and, at the same time, alternate slowly enough to avoid carry-over effects (McGonigle, Rojahn, Dixon, & Strain, 1987). Even if all these points are taken into consideration, carry-over effects can occur (Barlow & Hayes, 1979). If data show that one treatment is more effective than the other, it is desirable to implement this treatment alone in the follow-up phase. By doing so, the researcher can assess the effects of that treatment when administered in isolation. Empirically, the impact of carry-over effects has been shown to be minimal and there is no reason to believe that carry-over effects would reverse the relative position of the two treatments (Barlow & Hersen, 1984: Ottenbacher, 1986).

The major weakness of a single-subject research design is that one cannot generalize the results beyond the single individual involved in the study. Generalizability of single-subject research is established through replicating the study directly using other individuals with similar characteristics, followed by systematic replications of the study across populations, settings and time. (Barlow & Hersen, 1984: Kazdin, 1982: Ottenbacher, 1986). Barlow and Hersen (1984) offer specific guidelines for conducting a direct replication series in single-subject research. They suggest that (a) the therapist and setting remain constant across replications: (b) the behavior disorder is topographically similar across clients: (c) client background variables are as closely matched as possible: and (d) the procedure is employed uniformly across clients.
Detailed and accurate description of the participants, settings, behaviours and treatments are important to ensure successful systematic replications of the study (Wolery & Harris, 1982).

3.15 Description of Research Design Used in this Study

The research design is illustrated in Appendix A. A baseline was established with participants typing without the use of word prediction for four days. At the end of the baseline phase, word prediction was introduced to the participants in a training session. In the alternating treatments phase, the three treatment conditions (word prediction with the prediction list in three different locations: upper right corner, following the cursor and in lower middle edge of the monitor) and the no-treatment condition were presented to the participants in random order each day for 10 days. A short break of five minutes was provided between treatment conditions. These short breaks served as the intercomponent intervals (ICI). After the alternating treatment phase, baseline data were collected for four more days.

3.2 Ethics and Informed Consent

Permission to conduct the study was obtained through Bloorview MacMillan Centre. The proposal for the study was submitted to the Research Department at Bloorview MacMillan Centre for scientific review, and was presented to the Ethics Committee for ethical clearance (Appendix B). The Ethics committee approved the Consent Form (Appendix C) and the Assent Form (Appendix D), which described the study to the parents/guardian and to the participant respectively. All parents/guardian of the participants signed a Consent Form, and the participants signed an Assent Form prior to taking part in the study.
3.3 Sampling

3.3.1 Sample Size

This study includes three direct replications, bringing the total number of participants to four. Barlow and Hersen (1984) suggest that one successful experiment and three successful replications are required to establish the generality in a series of direct duplication. They felt that in the case of mixed results, continuing a direct replication series indefinitely is not a sound experimental strategy. A more efficient approach would be to stop after four or five replications followed by a functional analysis of the failures encountered. If neither the reliability nor the generality can be established, the reasons should be analyzed and recommendations should be made for future studies (Barlow & Hersen, 1984).

3.3.2 Inclusion Criteria

1. Chronological age from 10 to 14 years. The age range was selected because written productivity becomes increasingly important around the intermediate and senior grades in primary school, when the frequency of note-taking, composition and essay tests increase (Reisman, 1993).

2. A primary diagnosis of spina bifida and hydrocephalus confirmed by medical records, with the lesion at a low thoracic level (T12) or below.

3. Living in the Greater Toronto area.

4. Rate of handwriting and rate of typing slower than the average rate of handwriting for the participant's academic grade.¹

¹ Writing speeds of children (letters per minute): grade 3 (25), grade 4 (37), grade 5 (47), grade 6 (57), grade 7 (62), grade 8 (72) (Phelps et al., 1985)
5. Verbal intelligence scores of 80 or above as reported in the psychological record.

Verbal intelligence scores are considered to be better predictors for academic achievements than full scale IQ scores (Lollars, 1993; Tew, 1991; Wills et al., 1990). As this study focuses on written productivity, a score of 80 is required to make sure that participants are competitive in education (McLone, 1992; Hurley and Bell, 1994).

6. Ability to read at the minimum of grade three level as confirmed by educational assessment findings or school report.

7. English as first language.

3.33 Exclusion Criteria

1. Identified to have low vision or blindness by an ophthalmologist.

2. Currently using adaptive devices such as an on-screen keyboard or switches to control the computer.

3. Currently using word prediction.

4. Malfunctioning shunt two weeks prior to commencement of the study. The symptoms indicating shunt malfunction include persistent headache, an abnormally enlarged head, deteriorating mental function, blurred vision or brief episodes of vision loss, and an increased frequency of seizures (Sekhar, Moossy, & Guthkelch, 1982).

5. Shunt infection two weeks prior to commencement of the study.

3.34 Recruitment Strategy

All clients of the Communication and Writing Aids Service and the Spina Bifida/Spinal Cord Program at the Bloorview MacMillan Centre who met the selection criteria were invited to
participate in the study. A review of the client database generated a potential sampling pool of 15 candidates. Potential participants were randomly drawn from the pool one at a time. The investigator mailed a letter of invitation (Appendix E) to the parent/guardian of each potential participant to seek their consent and the participant’s assent to participate in the study. The Consent Form and the Assent Form were sent with the letter of invitation. The investigator called the family one week after the invitation letter was mailed to follow up and to ensure informed consent. The process was repeated until the required number of participants had been recruited. Due to a variety of reasons, many candidates could not participate in the study. All 15 candidates in the sampling pool eventually received a letter of invitation. A total of seven candidates agreed to participate in the study. Two candidates withdrew from the study a few days before the commencement of the study because of a hospital admission or illness in the family.

3.4 Computer Hardware and Software

3.4.1 Computer Hardware

A Toshiba Tecra notebook computer with a Pentium 166 MHz processor and 64MB RAM was used for the study. The display setting on the computer was set at 1024 X 768 pixels, 16 bit high colour and large fonts. A Sony SVGA 15” monitor and an AST standard 101-key keyboard were set up on the workstation at the participant’s home, but the notebook computer was not left with the participant. The monitor and the keyboard were connected to the notebook computer at the beginning of each day in the experiment.
3.42 Word Prediction Software

A feature comparison was done in the planning stage of this study (May, 1999) to identify suitable word prediction software to be used in the study. Parameters important for reducing visual-cognitive loads in the use of word prediction software were used as criteria for comparison. These criteria included support for a five-word vertical display and flexibility in placement locations of the prediction list. The four most common word prediction software packages (i.e., Aurora®, Co:Writer™, KeyREP®, TextHelp™) available on the Windows platform were compared (Aurora, 1997; Co:Writer, 1998; KeyREP, 1998; TextHelp, 1999). Details of the comparison are provided in Table 1. KeyREP was selected because it was the only product that allowed the prediction list to be placed in all of the testing locations.

In an effort to control the confounding factors that may affect the effectiveness of word prediction, suggestions in the literature with regard to minimizing the visual-cognitive loads were adopted to set the parameters on KeyREP. These include display options, customization of the prediction lexicon and searching strategy. The prediction list on KeyREP was programmed to display five words vertically. It was also modified so that no word would be displayed until after the second letter was typed. This was implemented to ensure that participants used the "2-then-search" strategy. KeyREP provides four pre-stored dictionaries: elementary, intermediate, senior and general. The dictionaries are intended to be used by individuals of different ages. The elementary dictionary is for children aged 6-8, the intermediate dictionary is for children aged 9-12, the senior dictionary is for young people aged 13-18, and the general dictionary is intended to be used by adults. A new prediction dictionary was created for the study. The dictionary

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2 Parameters important for reducing visual-cognition loads are discussed in Chapter 2, Literature Review. Refer to p. 30-32 for a summary of the discussion.

3 The possible effect of searching strategies are discussed in Chapter 2, Literature Review. Refer to p. 30-32 for a summary of the discussion.
contained all of the words in the copy material \(^4\) that was used in the study. It also matched the minimum reading level (i.e., grade 3) for the study. The dictionary was created by importing the copy material into the elementary dictionary. Originally, the elementary dictionary consisted of 1,928 words. As two-letter words were not needed in a "2-then-search" strategy, all 2-letter words were deleted leaving a total of 1,888 words. After the copy material was imported, the dictionary contained 2,245 words. Forty-five words with the lowest frequency (i.e. frequency =1) that were not in the copy material were deleted to create a 2,000-word dictionary.

Two raters independently typed with KeyREP to determine the keystroke saving ratio of KeyREP with the new dictionary. The ratio was determined by dividing the number of keystrokes required to type a paragraph with KeyREP by the number of keystrokes required with direct typing. The computed value was then subtracted from one to derive the keystroke saving ratio (Higginbotham. 1993; Venkatagiri. 1994). The copy material consisted of 50 paragraphs of text, each containing about 100 words. To determine the keystroke savings, each rater typed a random sample of 15 paragraphs (i.e., 30% of the copy material) using the "2-then-search" strategy. The average keystroke savings was found to be 37.2%, with the range between 35.2% to 41.3% (SD = 2.4). Inter-rater agreement was 98.2%. The results showed that although the "2-then-search" strategy reduced the keystroke savings, the overall keystroke savings with the new dictionary was within the average range reported in the literature (Higginbotham. 1992).

3.43 Word processing software

Measures, a simple word processing software package with built-in timing features and links to Microsoft Word 97\(^9\) and Microsoft Excel 97\(^8\), was provided by the Microcomputer

\(^4\) Copy material is described in Section 3.5, p. 45.
Application Program of Bloorview MacMillan Centre (Birch, 1999). The software began timing when the participant typed the first letter, and the software stopped accepting keystrokes at the end of five minutes. At the end of the five minutes, the software saved the keystroke count into a Microsoft Excel file, which contained formulae for calculation of the text entry rate. The typed text was automatically saved as a rich text file. The use of electronic timing and calculation is to control for potential errors in manual timing and calculation, and thus improves the reliability of the data.

3.5 Copy Material

For the copy tasks, the story entitled “Cam Jansen and the Triceratops Pops Mystery” was used (Adler, 1995). The story was classified as grade 3 reading material using Fry’s Readability Test (Fry, 1977) and Flesch-Kincaid readability information available in Microsoft Word 97®. The story was printed double-spaced in 18 point Arial font for easy reading.

3.6 Measurement

3.6.1 Kump’s Directions for Scoring Typing Tests

In 1992, Kump detailed directions for scoring typing tests on a typewriter or a computer. Kump’s scoring method applies to educational settings and is most appropriate to use with a sample population who are school-aged children.

**Gross Rate of Text Entry.** The gross rate score was obtained by determining the total number of keystrokes typed in 5 minutes. All letters, numbers, punctuation, tab keys, enter

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*K Keystroke counts and rates of text entry are counted according to Kump’s directions for scoring typing tests. Details are explained in section 3.6.1, p.45.*
keys, and spaces were counted as keystrokes. The total number of keystrokes was divided by 25 to derive the rate of text entry. The reporting unit was words per minute (wpm).

Accuracy of Text Entry. Kump (1992) provides very detailed scoring keys for marking errors in the typing samples (Appendix F). The number of correct keystrokes was derived by subtracting the number of errors from the total number of keystrokes. The percent accuracy was calculated from the number of correct keystrokes over the total number of keystrokes and multiplied by 100.

Error-Adjusted Rate of Text Entry. The total number of correct keystrokes was divided by 25 to derive the error-adjusted rate of text entry. The reporting unit, again, was wpm. The error-adjusted rate represents the true productivity with typing after correction of errors. It is therefore the rate that is commonly reported in a standard typing test (Kump, 1992).

3.62 Canadian Occupational Performance Measures (COPM)

In this study, the COPM was used as a measure of functional self-efficacy. The COPM is a standardized outcome measure with a semi-structured interview format and structured scoring method to: (1) identify and prioritize occupational performance issues in one or all three purposes of occupation: self-care, leisure and productivity, (2) evaluate self-perception of performance and satisfaction relative to identified issues, and (3) measure changes in client’s perception of his/her occupational performance over time (Law, et al., 1998). A number of studies report that the COPM demonstrates good test-retest reliability (Baptiste, et al., 1993; Law, et al., 1990) and content validity (Bosch, 1995; Law, et al., 1997; Law, et al., 1998; Pollock & Stewart, 1998). Evidence of criterion and construct validity (Chan & Lee, 19997; Law, et al., 1994; Mahurin, Bettignies & Pirozzolo, 1991: Wilcox, 1994) and responsiveness of the COPM is
also provided (Mew & Fossey, 1996; Toomey, Nicholson & Carswell, 1995; Wilcox, 1994). The COPM has been used with clients across developmental levels, with a variety of disabilities and different treatment interventions including assistive technology (McColl, Paterson, Davies, Doubt, & Law, 2000. Reid, Rigby & Ryan, 1999). The COPM uses three 10 point rating scales to rate importance, performance, and satisfaction. A score value of ‘1’ refers to a low rating, i.e. ‘not important at all’, ‘not able to do at all’, ‘not satisfied at all’. A score of value of ‘10’ refers to a high rating, i.e. ‘extremely important’, ‘able to do it extremely well’, ‘extremely satisfied’. Mean performance and satisfaction scores are derived by summing the ratings across problems and dividing by the total number of problems.

3.62 Developmental Eye Movement Test (DEM)

The DEM was used in this study as a descriptive measure. The DEM is a clinical tool designed to measure saccadic eye movements related to reading (Richman & Garzia, 1987). Information on eye movement skills is important to collect as these skills may affect participants’ abilities to use word prediction effectively (Koester & Levine, 1996). It was necessary to administer the DEM to describe the eye movement skills of the participants because this information is not readily accessible in the medical record. A number of studies provided evidence supporting the reliability and validity of the DEM (Garzia, Richman, & Nicholson, 1990; Kulp & Schmidt, 1998). Complete guidelines for administration and scoring of the DEM are contained in the DEM manual. The DEM consists of two sets of vertical column arrays of numbers (Subtest A and Subtest B: Appendix G) and a scattered array of numbers in horizontal rows (Subtest C: Appendix H). The participants were timed for speed on reading the numbers and evaluated for any errors (omissions, additions, transpositions, and substitutions). The time
score of each subtest is adjusted by the number of errors. The vertical score is the sum of the error-adjusted time score of subtest A and B. The horizontal score is the error-adjusted time score of subtest C. A ratio score was calculated by dividing the vertical score with the horizontal score. The vertical score, the horizontal score and the ratio score are used in combination to determine the presence and the type of oculo-motor deficits. Normative data for percentile score are available for children aged 6 to 13 years (Richman & Garzia, 1987). Griffin, Christenson, Wesson, & Erickson (1997) found that after age 13, only limited additional improvement can be expected in performance on the DEM test. Therefore, even though norms are not available for children older than 13, this test can be used with adolescents and adults (Scheiman, 1997).

3.64 The Children’s Handwriting Evaluation Scale (CHES)

CHES was used as a qualifying test to assess the handwriting abilities of the participants. CHES is a commonly used clinical tool, which was developed to evaluate speed and quality of handwriting (Phelps, Stempel, & Speck, 1985). Preliminary reliability and validity of CHES has been established (Phelps, Stempel, & Speck, 1984). The CHES manual provides detailed guidelines for the administration and scoring on speed and quality of handwriting (Appendix 1). Normative data on writing rate are provided for children in grades 3 through 8. Quality score is provided according to five standards: letter forms, slant, rhythm, space and general appearance. The percentile scores of writing rate and the quality scores of the participants are reported.

3.65 Behaviour Checklist

The Behaviour Checklist (Appendix J) was used to monitor behaviour during the experiment as a means of ensuring validity when interpreting results. It was developed as a result
of the pilot study indicating the need to monitor behavioural factors such as pain, attention, and motivation that may affect the rate and accuracy of text entry. The Behaviour Checklist was adapted from UAB Pain Behavior Questionnaire and Child Behavior Checklist (Richards, Nepomuceno, Riles, & Suer, 1982; Taylor, 1999). Four occupational therapists with minimum 2 years of experience in assistive technology were consulted on the initial draft of the checklist regarding the relevance and clarity of the items. As a result of these consultations, minor changes were made in content. The Behaviour Checklist was then pilot-tested with 10 children with disabilities aged between 6 to 17 (M = 12.7). They were 4 girls and 6 boys with different diagnoses including head injury, upper limb amputations, rheumatoid arthritis, cerebral palsy, pervasive developmental disorder, congenital viral infection, motor dyspraxia and attention deficit disorder. The results of the pilot test indicate that items on the Behaviour Checklist were adequate in capturing behaviour related to pain / discomfort or difficulties in attention while the children used computer technology.

3.66. Demographic Information Form

The demographic information of the participants was collected using the Demographic Information Form (Appendix K). Detailed and accurate descriptions of the participants are necessary to ensure successful replication of the study (Wolery & Harris, 1982).

3.7 Data Collection Procedures

After verbal consent for participation was received, demographic information on the participants was collected from medical records and psychological records using the Demographic Information Form.

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* The pilot study is described in Section 3.9, p. 55.
Participants were visited at home. The investigator requested all families to provide a room or a quiet area for the experiment to be conducted in the home, so that distraction would be kept to a minimum.

**Pre-baseline.** On the first day of the study, a computer workstation was set up for the participant according to ergonomic principles (Claiborne, Powell, & Reynolds-Lynch, 1999). Participants who were wheelchair dependent remained in their wheelchairs. Ambulatory participants were seated upright in a chair with their hips and knees flexed at approximately 90 degree or as allowed due to orthopaedic constraints. Participants' feet were supported on the floor or with a footstool. The monitor was positioned at a distance 12 to 20 inches from the participant's eyes. The top of the monitor was adjusted so that it was at or slightly below the eye level of the participant. The keyboard was adjusted to slightly below elbow level so that the participants could type with their elbows at about 90 degrees and their wrists in the neutral position. The copy material was placed between the monitor and the keyboard (Figure 2).

For participants whose handwriting and typing rates had not been tested in one year prior to the commencement of the study, a writing test using CHES and a typing test using Measures were administered to confirm that inclusion criteria were met. In administering CHES, the sample passage was read to the participants, then the participants were instructed to copy the sample passage. They were asked to write as they usually do, and to write as well as they could for two minutes. If the participant completed the passage before two minutes has elapsed, he/she would be asked to start from the beginning and keep copying until he/she was asked to stop. For the typing test, the participants were asked to copy type for five minutes using the Measures program.
Once inclusion criteria were confirmed, the COPM and DEM were administered. In this study, the COPM was used in a modified fashion, focusing on the domain of productivity. During the COPM interview, participants were asked to identify written productivity tasks that they were expected to do, needed to do, or wanted to do in a typical day. The participants were guided to discuss details of the tasks in order to focus on the aspects of the task that were difficult for them. Once tasks were identified, participants rated how important each task was to them using the 10-point importance rating scale. Consequently, the participants were asked to rate their current performance with each task and their satisfaction with performance on the 10-point rating scales. In administering the DEM, participants were asked to read the numbers from top to bottom, column by column in subtest A and B, and to read the numbers from left to right, row by row in subtest C. Participants were not allowed to use their fingers to guide their reading. The time required to read each subtest was recorded.

**Baseline phase.** On each of the four days in the baseline phase, participants were asked to type as they usually do and as accurately as they could for five minutes.

**Training day.** On the day following the baseline phase, training on the use of word prediction was provided. Participants were introduced to the concept of word prediction with the prediction list in the left upper corner. They were instructed to type two letters before looking at the prediction list, and to use the prediction list for completion of words as much as possible. Training was considered completed when the participants could consistently use word prediction for the completion of 10 consecutive words without the investigator providing any verbal prompts. On average, training took about an hour to complete.

**Alternating treatment phase.** On each day in the alternating treatments phase, participants were asked to type for a total of four five-minute sessions: direct typing without word prediction
and with word prediction at the three testing locations. At the beginning of each day, participants were asked to draw from an envelope a piece of paper listing one of the 24 possible arrangements of typing conditions (i.e., the total possible combinations for four treatment conditions). The three word prediction conditions and the direct typing conditions were tested in the arrangement selected. A 5-minute break was provided between each testing session. At the end of each day, participants were asked to rank the three locations for the prediction list in order of preference.

A reinforcement system was used in this phase to promote and maintain participants' performance. The reinforcement system involved giving a sticker to the participants when they demonstrated good effort in a typing session. The number of checkmarks on the Behaviour Checklist was used to define “good effort”. This number was individualized using baseline observation as a guideline to ensure that it was attainable. A variable interval schedule of reinforcement (Schunk, 1991) was used to provide rewards for good efforts. The time between the reinforcements was varied around an average of 2 days. On the reinforcement day, the participant received a MacDonald meal coupon as a reward. Participants were reinforced for their efforts in all four treatment conditions (i.e., no word prediction and the three word prediction condition) in the alternating treatment phase.

After the last session on the last day of the alternating treatments phase, the COPM was re-administered. Participants were asked to rate their performance and their satisfaction with performance on the written productivity tasks they identified in the pre-baseline day using the 10-point performance and satisfaction rating scales.

Follow-up phase. In each of these four days, the participants were asked to type for five minutes without using word prediction.
3.8 Data Analysis

Analysis of single-subject data traditionally involves visual inspection of graphed data (Wolery & Harris, 1982). Raters use visual inspection to compare the magnitude and pattern of data in the different phases and during the alternating treatments phase (Ottenbacher, 1986; Wolery & Harris, 1982). Visual inspection focuses on graphic characteristics such as trend, slope, level, percentage of overlap, and variability (Barlow & Hersen, 1984). These graphic traits are assessed singly and in combination to determine whether the intervention resulted in a significant change in outcomes (Ottenbacher, 1986). Typically, analysis of single-subject data involves first establishing the stability of the baseline. However, the stability of baseline is not a requirement for an alternating treatments design because inferences on intervention effects are made by comparing data in the alternating treatments phase. The validity of inferences is usually not threatened by an initial baseline trend or variability in baseline data in an alternating treatments design (Barlow & Hersen, 1984). The baseline data serve as references for comparison in the alternating treatments phase. Follow-up data are used for observation of no-treatment effects after all interventions are removed (Backman et al., 1997).

Researchers have identified inconsistency associated with visual analysis and recommended statistical analysis to be used as an adjunct to visual analysis (Harbst, Ottenbacher, & Harris, 1991; Kazdin, 1982; Kratochwill & Levin, 1992; Nourbakhsh & Ottenbacher, 1994). Statistical analysis is particularly useful when changes appear to be small on visual inspection (Kazdin, 1982; Ottenbacher, 1992; Wolery & Harris, 1982). Conventional parametric statistical measures such as the t and F tests assume normal distribution of the population and independent data (Pagano & Gauvreau, 1992). Single-subject data violate these two assumptions. therefore t and F tests cannot be used in single-subject research. On the contrary, randomization tests make
no assumption about the distribution or the data and are therefore recommended to be the appropriate tests to use for N=1 experiments (Kazdin. 1976; Kratochwill & Levin. 1992; Ludbrook & Dudley. 1998). Performing randomization tests involves rearranging the data and calculating the necessary statistics such as the t or the F statistic for each permutation. The proportion of the test statistics that are as large as the obtained value is the significance or probability value (P-value: Edgington. 1995). When the number of data assignments is so large that it would be impractical to calculate the test statistics for all possible permutations, a random procedure can be conducted to approximate the P-value. The minimum number of permutations required for approximation is 100, with 5,000 to 10,000 permutations being recommended for scientific reporting (Edgington. 1995).

In this study, a randomization test was performed by using a repeated-measure analysis of variance F as a test statistic to examine if there was any difference in the means of the four conditions being compared in the alternating treatments phase. The significance of F was determined by a random procedure with 5,000 permutations as the number of total permutations was over 100,000. The α level was set at 0.05. The F statistic can only be used to test if there is a significant difference among the means of the different conditions. To be able to test the specific hypotheses in the study, multiple comparison procedures had to be performed. To test Hypothesis one and two, pair-wise randomization tests were performed by using a paired t-statistic to compare the rates and accuracy of text entry without word prediction with each of the word prediction conditions. As three comparisons were made, the significance level was adjusted using the Bonferroni correction (Pagano & Gauveau. 1992). The adjusted α was 0.05/3 = 0.0167. The adjustment was necessary in order to reduce the risk of committing a Type I error. To test Hypotheses three and four, pair-wise randomization tests were performed by using a
paired t-statistic to compare the rates and accuracy of text entry between the participant’s preferred location and the other two locations. The adjusted \( \alpha \) with Bonferroni correction was \( 0.05/2 = 0.025 \). The significance of \( t \) in individual participant’s data was determined by running the paired t-tests on all of the 1.024 permutations. In analysis of the group data, a random procedure with 5,000 permutations was used as the number of total permutations was over 100,000.

To test Hypothesis five, COPM scores at the beginning of the study and at the end of the alternating treatments phase were compared to assess whether a trial of word prediction influenced the participants’ perception of their performance and satisfaction with written productivity tasks. A change score of two was considered clinically significant (Law et al., 1994). The mean COPM scores before and after introduction of word prediction were compared using randomization tests. The use of t-tests was not appropriate because of the small sample size (Ludbrook & Dudley, 1998).

The demographic information and the pre-baseline test results were compiled and reported descriptively. Statistical significance, clinical significance and the participant’s perception of the effect of word prediction were considered in the final analysis of the experimental data because an intervention is only effective if it is perceived by the participant as being important and useful (Wolery & Harris, 1982).

3.9 Pilot Study

A pilot study was conducted with one participant to test the data collection procedures and data analysis methods of the study. In order to preserve the number of candidates available for the main study, the pilot study was initially intended to be conducted with a young person.
slightly older or younger than the specified age (10-14) for the main study. Due to recruitment difficulties, the pilot participant was randomly drawn from the list of candidates for the main study.

The pilot participant took part in the study following the above-mentioned procedures, except that no reinforcement system was used. The results of the pilot study are presented in Appendix L. The findings from the pilot study supported that the data collection procedures and the data analysis methods were appropriate. The need for two additional measures were indicated when interpreting the pilot results. They were the Behaviour Checklist 7 and a Pain Scale. The Behaviour Checklist was necessary to help explain the variability in the data. The participant in the pilot study complained of pain in his neck when he used word prediction, especially when the prediction list was in the upper right corner. To be able to measure the level of pain, the Pain Scale developed by Abu-Saad in 1984 was adopted and pilot tested with 10 children (Abu-Saad, 1984). However, the Pain Scale was not used in the main study, as none of the other children experienced pain during the study.

In the pilot study, the participant appeared to lose interest in using word prediction starting around Day 6 in the alternating treatments phase. In order to promote and maintain the motivation of the participants in the main study, a token reinforcement system 8 was introduced. The token reinforcement system was designed based on learning theories, which suggest that rewards can help develop skills and interest when they are informative of one's capabilities (Schunk, 1991; Walter & Marks, 1981). Extensive research exist to support the idea that offering children rewards based on pre-defined conditions on performances during an instructional program increases self-efficiency, motivation, and skill acquisition (Devers, Bradley-Johnson, &

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7 Section 3.65, p.48.
8 Section 3.7, p.49.
Johnson, 1994; Pavchinski. Evans. & Bostow. 1989: Workman. Workman. & Maclin. 1979). The reinforcement system was only used in the alternating treatments phase. Not using the reinforcement system in the baseline and in the follow-up phase ensured that baseline performances were established, and withdrawal effects could be observed.
Chapter Four - Results

This chapter is organized into five sections. The first four sections describe each participant and his/her experiences in the study. The last section summarizes the results and presents them in relation to the hypotheses. Selected characteristics of the participants, the pre-baseline results, and the summary statistics are tabulated. The results of the study are plotted on line graphs for visual analysis. Results of statistical analyses are also reported.

4. Participant One

4.1 Background Information

Participant characteristics. Participant One (P1) was a 10-year-old girl with the diagnosis of S1 myelomeningocele, hydrocephalus with VP shunt and Strabismus. Relevant characteristics of P1 are presented in Table 2. Other deficits reported in the medical record include difficulties in maintaining attention to tasks and visual perceptual difficulties especially in the area of visual memory, form constancy and figure-ground perception. P1 had very limited access to her mother’s computer at home. At school, she only used the computers in the library for games.

Setting. P1 lived in a small apartment. The experiment took place in the dining area. The computer was set up on the dining table. P1’s mother was always present in the apartment and often talked on the telephone. Due to the small size of the apartment, the telephone conversation could be heard clearly in the dining area.

4.12 Pre-baseline Results

Pre-baseline test results are presented in Table 3. P1’s handwriting and typing skills were not assessed, because her skills had been assessed by her occupational therapist three months
prior to the experiment. Her writing and typing speeds were much slower than the average writing speed of 9.4 wpm for her grade (Phelps et al., 1985). For comfortable reading, P1 preferred 18-point font on the screen and in printed material. Her scores on the DEM suggested a Type II deficit indicating difficulties in oculomotor control (Richman & Garzia, 1987).

4.13 Preference for Placement Location of Prediction List

P1 indicated that she preferred to have the prediction list at the lower middle border of the screen (LM). She reported that having the word list following the cursor bothered her eyes.

4.14 Rates of Text Entry

**Gross rates of text entry.** Data are summarized in Table 4 and plotted on the line graph (Figure 3). On average, P1 demonstrated similar gross rates of text entry with and without the use of word prediction, with the gross rate being slightly faster with the word prediction list in the LM location. The differences among all typing conditions were not statistically significant (Table 7). P1's average gross rate of text entry without word prediction (M=5.86) in the follow-up phase was similar to the average gross rates with and without word prediction in the alternating treatment phases, but was faster than the average baseline rate (M=4.71; Figure 15).

**Error-adjusted rates of text entry.** Data are summarized in Table 5 and plotted on the line graph (Figure 7). P1 was slightly faster in error-adjusted rates of text entry with word prediction in the LM location. However, the differences among all typing conditions were not statistically significant (Table 8). Comparing P1's average error-adjusted rates of text entry across all phases in the experiment, a similar pattern to that of gross rates of text entry emerged. The average error-adjusted rate of text entry in the follow-up phase (M=5.64) was only higher than that in the
baseline phase ($M=4.16$), but similar to error-adjusted rates with and without word prediction in the alternating treatments phase (Figure 19).

4.15 Accuracy of Text Entry

Data are summarized in Table 6 and plotted on the line graph (Figure 11). P1 achieved the best accuracy of text entry with word prediction in the LM location. The difference was statistically significant when compared to the accuracy without word prediction ($P=0.001$), and with the word prediction list following the cursor (FC: $P=0.008$; Table 9), which was the least accurate. P1's average accuracy ($M=96.63$) in the follow-up phase was similar to that with or without word prediction in the alternating treatment phase, but was higher than the average accuracy in the baseline phase ($M=88.4$. Figure 23).

4.16 Perceived Performance

The important written productivity tasks identified by P1 are presented in Table 10. She rated all of the tasks to be extremely important with a rating of '10' on the 10-point importance scale. The mean performance score and mean satisfaction score after using word prediction were higher than the baseline scores (change score of 1 and 2 for performance and satisfaction respectively). As compared to baseline, P1 rated her performance to be higher in two out of three tasks (66.7%; Figure 27: Table 10). She rated her performance in one task (33.3%) to be slightly poorer following the use of word prediction. In addition, P1 rated her satisfaction with performance to be higher than the baseline ratings for all tasks (Figure 27).

4.17 Behaviour Observation

P1's performance did not appear to be affected by the presence of the distracters (e.g..
presence of younger children, telephone conversation). At times, P1 had difficulties in maintaining attention to tasks, but she responded well to the reinforcement strategy.

4.2 Participant Two

4.2.1 Background Information

Participant characteristics. Participant Two (P2) was a 12-year-old girl with the diagnosis of T12 myelomeningocele, hydrocephalus with VP shunt, thoracolumbar scoliosis, Strabismus and Nystagmus. She had a history of meningitis at the age of one and a number of shunt revisions in the early years. Relevant characteristics of P2 are presented in Table 2. Visual perceptual deficits in the area of visual memory, form constancy and figure-ground perception were reported in the medical record. P2 required corrective lens for reading. She received some keyboarding training at school and had her own computer at home.

Setting. P2 lived in a detached house. The experiment took place in the dining room. The computer was set up at a computer workstation. The environment was mostly quiet with occasional noise from the young children fussing in the family room.

4.2.2 Pre-baseline Results

Pre-baseline test results are presented in Table 3. P2 typed using both index fingers. Her writing and typing speeds were much lower than the average writing speed of 12.4 wpm for her grade (Phelps et al., 1985). For comfortable reading, P2 preferred 18-point font on the screen and in printed material. Her scores on the DEM suggested a Type IV deficit indicating difficulties in automaticity and oculomotor control (Richman & Garzia, 1987).
4.23 Preference for Placement Location of Prediction List

P2 indicated that she preferred to have the prediction list in the LM location. She felt that having the copy material and the word prediction list at a close distance to the keyboard helped her visually keep track of her location on the copy task.

4.24 Rates of Text Entry

Gross rates of text entry. Data are summarized in Table 4 and plotted on the line graph (Figure 4). On average, P2 demonstrated similar gross rates of text entry with and without the use of word prediction, with the gross rate without word prediction being slightly faster. The differences among the gross rates of all typing conditions were not statistically significant (Table 7). As shown in Figure 16, P2’s average gross rate of text entry was highest in the follow-up phase ($M=9.54$) when she typed without word prediction. The high-low chart also shows improvement of gross rate of text-entry without word prediction across all three phases (Figure 16).

Error-adjusted rates of text entry. Data are summarized in Table 5 and plotted on the line graph (Figure 8). P2’s rate of text entry after error adjustment was also similar across all four conditions, with the error-adjusted rate being slightly faster when the word prediction list was in the upper right corner (UR). However, the differences among all typing conditions were not statistically significant (Table 8). P2’s average rate of text entry after error adjustment remained much higher in the follow-up phase ($M=9.41$) as compared to the baseline level ($M=6.61$) and to the average rates with and without word prediction in the alternating treatment phase (Figure 20).
4.25 Accuracy of Text entry

Data are summarized in Table 6 and plotted on the line graph (Figure 12). P2’s accuracy of text entry was higher in all three word prediction conditions than without word prediction. The differences were statistically significant when the prediction list was in the UR (P=0.015) and LM locations (P=0.011: Table 9). The differences in accuracy were not statistically significant when the preferred location (LM) was compared to the other two locations. On average, P2’s accuracy was similar across all three phases with or without word prediction (Figure 24).

4.26 Perceived Performance

The important written productivity tasks identified by P2 are presented in Table 10. A high level of importance was associated with all of the tasks with each task rated a ‘7’ or above on the 10-point importance rating scale. The mean performance score and mean satisfaction score after using word prediction were higher than the baseline scores (change score of 0.8 and 0.4 for performance and satisfaction respectively). As compared to baseline, P2 rated her performance and satisfaction to be higher in 3 out of 5 tasks (60%), unchanged for 1 task (20%) and poorer for 1 task (20%) after using word prediction (Figure 28: Table 10).

4.27 Behaviour Observation

P2 maintained focus and was motivated throughout the experiment period. Mild signs of boredom such as yawning, were observed in the last two days of the alternating treatments phase.

4.3 Participant Three

4.31 Background Information

Participant characteristics. Participant Three (P3) was a 11-year-old boy with the diagnosis of L4 myelomeningocele, hydrocephalus with VP shunt and Nystagmus. Relevant
characteristics of P3 are presented in Table 2. Other deficits reported in the medical record include difficulties maintaining attention to tasks and visual perceptual deficits in the area of visual spatial relationship, visual memory, form constancy and figure ground perception. P3 shared the family computer with his siblings. He had access to the use of a computer for writing in the classroom.

Setting. P3 lived in a detached house. The experiment took place in the living room. The computer was set up on a desk. The environment for the experiment was mostly quiet. Occasionally, the conversation of the siblings was audible in the living room. P3 was frequently distracted by the activities outside the house such as the movement of a construction vehicle. The blind in the living room was kept drawn to reduce distraction.

4.32 Pre-baseline Results

Pre-baseline test results are presented in Table 3. P3 typed with his left index finger. His writing and typing speeds were much lower than the average writing speed of 11.4 wpm for his grade (Phelps et al., 1985). For comfortable reading, P3 preferred 20-point font on the screen and in printed material. His scores on the DEM suggested a Type II deficit indicating difficulties in oculomotor control (Richman & Garzia, 1987).

4.33 Preference for Placement Location of Prediction List

P3 indicated that he preferred to have the prediction list at the LM location. He stated that not having to move his eye gazes too far away from the copy text was helpful in keeping track of where he was on the copy material.
4.34 Rates of Text Entry

Gross rates of text entry. Data are summarized in Table 4 and plotted on the line graph (Figure 5). On average, P3 demonstrated a faster gross rate of text entry without the use of word prediction than with word prediction. The differences between the gross rate of text entry without word prediction and the gross rates with all three conditions of word prediction were statistically significant (P ≤ 0.003; Table 7). Statistically, the differences in gross rates between the preferred location (LM) and the other two locations were not significant (Table 7). Compared to the baseline level (M = 6.53) and to the average gross rates with or without word prediction in the alternating treatments phase, P3’s average gross rate of text entry was at a higher level in the follow-up phase (M = 8.43; Figure 17).

Error-adjusted rates of text entry. Data are summarized in Table 5 and plotted on the line graph (Figure 9). P3 was faster in error-adjusted rates of text entry without using word prediction. The differences between the error-adjusted rate of text entry without word prediction and the error-adjusted rates with all three conditions of word prediction were statistically significant (P ≤ 0.004; Table 8). However, the differences between the preferred location and the other two locations were not statistically significant (Table 8). P3’s average rate of text entry after error adjustment was also slightly higher in the follow-up phase (M = 7.44) as compared to the baseline level (M = 6.3) and to the average error-adjusted rate with or without word prediction (Figure 21).

4.35 Accuracy of Text Entry

Data are summarized in Table 6 and plotted on a line graph (Figure 13). P3 appeared to have highest accuracy when the word prediction list was in the LM location. However, the
differences in accuracy among all typing conditions were not statistically significant (Table 9). P3 was observed to have difficulties in maintaining his place on the copy material. In a number of typing sessions. P3 skipped from one word to the next occurrence of the same word, causing a significant drop in accuracy. This problem occurred without word prediction (2 out of 18 samples), and with word prediction when the list was in the UR location (2 out of 10 samples) and the FC location (1 out of 10 samples). Incorrect spacing and capitalization were particularly noticeable in the follow-up phase. His average accuracy was slightly higher in the baseline phase, but with the variability in the accuracy data. the differences across all three phases and with and without word prediction appeared to be insignificant (Figure 25).

4.36 Perceived Performance

The important written productivity tasks identified by P3 are presented in Table 10. A high level of importance was associated with all of the tasks with each task rated a '6' or above on the 10-point importance rating scale. The mean performance score and mean satisfaction score after using word prediction were lower than the baseline scores (change score of -2.4 and -3.0 for performance and satisfaction respectively). As compared to baseline. P3 rated his performance to be higher in 1 out of 5 tasks (20%) and poorer for 4 tasks (80%) after using word prediction (Figure 29: Table 10). Comparing satisfaction after using word prediction to baseline. P3 rated 2 tasks to be the same (40%) and 3 tasks to be poorer (60%; Figure 29: Table 10).

4.37 Behaviour Observation

P3 was easily distracted, but he responded well to the reinforcement strategy. He was initially motivated to try word prediction. On the 6th day of the alternating treatment phase, he
expressed dislike of word prediction verbally. His effort had to be maintained using the reinforcement strategy.

4.4 Participant Four

4.41 Background Information

**Participant characteristics.** Participant Four (P4) was a 10-year-old young woman with the diagnosis of L3 myelomeningocele, non-shunted hydrocephalus, congenital heart defect and S-shape thoracolumbar scoliosis. Other deficits reported in the medical record included difficulties maintaining attention to tasks, visual perceptual deficits in the area of visual spatial perception, visual sequential memory and form constancy. P4 had her own computer at home. She received keyboarding training and had regular access to a computer at school.

**Setting.** P4 lived in a detached house. The experiment took place in her study room. The computer was set up at a computer workstation. The environment was quiet and distraction free.

4.42 Pre-baseline Results

Pre-baseline test results are presented in Table 3. P4 typed with all 10 fingers on the keyboard, but she needed to look at the keyboard to locate the keys. Her writing and typing speeds were lower than the average writing speed of 9.4 wpm for her grade (Phelps et al., 1985). P3 preferred 20-point font on the screen and in printed material. Her scores on the DEM suggested a Type III deficit indicating difficulties in automaticity (Richman & Garizia, 1987).
4.43 Preference for Placement Location of Prediction List

P4 indicated that she preferred to have the prediction list in the UR location. Contrary to all the other participants, she found that having the copy material and the word list at the LM location too clustered, making it harder for her to see.

4.44 Rates of Text Entry

**Gross rates of text entry.** Data are summarized in Table 4 and plotted on a line graph (Figure 6). P4 demonstrated a much faster gross rate of text entry without the use of word prediction than with all of the word prediction conditions. The differences between the gross rate of text entry with and without word prediction were statistically significant (p=0.001). Statistically, the differences in gross rates between the preferred location (UR) and the other two locations were not significant (Table 7). P3's average gross rate of text entry in the follow-up phase ($M=12.22$) was similar to that in the alternating treatment phase, but was faster than the average baseline rate ($M=10.04$) and the average gross rates with word prediction (Figure 18).

**Error-adjusted rates of text entry.** Data are summarized in Table 5 and plotted on a line graph (Figure 10). P4 was faster in error-adjusted rates of text entry without using word prediction than with word prediction. The differences between the error-adjusted rate of text entry without word prediction and the error-adjusted rates with all three conditions of word prediction were statistically significant (P=0.001). There was no significant difference in rates of text entry between the preferred location (UR) and the other two locations (Table 8). P4's average rate of text entry after error adjustment without word prediction was also similar in the follow-up phase ($M=11.76$) and in the alternating treatment phase, but was higher than the
average error-adjusted rates with word prediction and the average baseline rate ($M=9.21$; Figure 22).

4.45 Accuracy of Text Entry

Data are summarized in Table 7 and plotted on a line graph (Figure 14). Accuracy was similar in all four conditions of typing. P4 appeared to be slightly more accurate when typing without the use of word prediction. She was similarly accurate when the word prediction list was placed in the UR and the FC locations, and was slightly less accurate in the LM location. However, the differences between the preferred location (UR) and the other two locations were not statistically significant (Table 9). Generally speaking, P4 was very accurate with her typing. She was observed to have problems similar to P3, in skipping words. This problem only occurred when P4 typed without word prediction.

4.46 Perceived Performance

The important written productivity tasks identified by P4 are presented in Table 10. P4 rated three tasks to be extremely important with a rating of '10' on the 10-point importance rating scale. She rated the importance of the remaining two tasks to be medially important (rating of 4 and 5). The mean performance score and mean satisfaction score after using word prediction were lower than the baseline scores (change score of $-1.6$ and $-1.0$ for performance and satisfaction respectively). As compared to baseline, P4 rated her performance to be higher in 2 out of 5 tasks (40%), the same for 1 task (20%) and poorer for 2 tasks (40%) after using word prediction (Figure 30). Comparing satisfaction after using word prediction to baseline, P4 rated 2 tasks to be higher (40%), 2 tasks to be the same (40%) and 1 task to be poorer (20%; Figure 30).
4.47 Behaviour Observation

Occasionally, P4 was observed to have difficulties in maintaining attention to tasks, but she could be easily re-directed back to the task with verbal reminders. P4 was motivated to participate in the study and responded well to the reinforcement strategy. Towards the end of the alternating treatment phases (starting from Day 7), she appeared to prefer typing without word prediction by showing disappointment when having to type with word prediction. However, she never expressed a dislike of word prediction verbally.

4.5 Summary and Group Results

4.51 Rates of Text Entry with and without Word Prediction

As a group, the participants in this study demonstrated a significantly faster rate of text entry (gross rates and error-adjusted rates) without the use of word prediction than with all of the word prediction conditions (P=0.000; Table 7 & 8). In examination of individual data, the rates of text entry without word prediction were significantly higher than the rates of text entry with word prediction in two participants (P3 and P4). P1 was slightly faster typing with word prediction in the LM condition. P2 was slightly faster typing without word prediction. In both cases, the differences in rates between typing with or without word prediction were not statistically significant (Table 7 & 8). When comparing the average rates of text entry across the three phases, three participants (P2, P3 and P4) demonstrated fastest rates of text entry in the follow-up phase, when they typed without word prediction. These rates were much higher than the average rates with all of the word prediction conditions. P1’s average rate in the follow-up
phase was also the highest among the three phases, but the difference was too small to be considered significant.

4.52 Accuracy of text entry with and without word prediction

Generally speaking, all participants were quite accurate in text entry. As a group, accuracy of text entry was significantly higher with word prediction in the LM location (P = 0.006), but the differences in accuracy between typing without word prediction and the other word prediction locations (UR and FC) were not significant (Table 9). P1 achieved significantly higher accuracy when using word prediction in the LM location. P2 attained significantly higher accuracy with word prediction in the LM and the UR location. For the other two participants, the differences in accuracy were not significant among all typing conditions. All participants demonstrated similar accuracy across the three phases of the experiment.

4.53 Preference on location for the word prediction list

Three participants preferred to have the word prediction list at the LM location, while 1 participant preferred the UR location.

4.54 Rates of Text Entry with the Prediction List in Participant-Preferred Location

For all the participants, there was no significant difference in gross and error-adjusted rates of text entry when the prediction list was placed in the participant’s preferred location (Table 7 & 8). No trend can be seen in the gross rates of text entry across participants, but three participants were slowest in error-adjusted rates of text entry when the word prediction list was in the FC location and one participant was slowest with the word prediction list in the UR location.
4.54 Accuracy of Text Entry with the Prediction List in Participant-Preferred Location

Statistically, there were no significant differences in accuracy when the word prediction list was placed in the participant's preferred location (Table 9). For all participants, the poorest accuracy occurred when the word prediction list was placed in the FC location. For P3, who experienced the most difficulties in keeping track of his place in the copy material, the only occasion when skipping of words did not happen was when the word list was in the LM location.

4.55 Perceived Performance

The mean performance change score before and after using word prediction ranged from -2.4 to 1.0 (Table 10: Figure 31), and from -3.0 to -2.0 (Table 10: Figure 32) for satisfaction scores. As a group, the difference in the mean performance score and the mean satisfaction score before and after using word prediction was not statistically significant (P=0.5 and P=0.75 for performance and satisfaction respectively). As compared to baseline, two participants (P1 and P2) rated their performance and satisfaction to be higher after using word prediction. The other two participants (P3 and P4) rated their performance and satisfaction to be poorer after using word prediction (Figure 31 &32). At the task level, participants rated higher performance with 1-3 tasks (20%-66.7%), same performance with 0-1 task (0-20%) and poorer performance with 1-4 tasks (20%-80%). With respect to satisfaction with performance, participants rated higher satisfaction with 0-3 tasks (0%-100%), the same with 0-2 tasks (0%-40%), and poorer with 0-3 tasks (0%-60%).
Chapter Five – Discussion

This chapter discusses the results of the current study in terms of the effect of word prediction and the location of word prediction list on rate and accuracy of text entry, and the perceived influence of word prediction on participants’ written productivity. In addition, the strengths and weaknesses of the study are reviewed, and priority areas for further studies are identified.

5.1 The Effect of Word Prediction on the Rate of Text Entry

As opposed to the hypothesized increase in rate of text entry, this study found that children with spina bifida and hydrocephalus were slower in rates of text entry with the use of word prediction. This finding is consistent with several previous studies in which the participants typed using a standard keyboard (Anson. 1993; Koester & Levine. 1994; Scull & Hill. 1988). However, other researchers report gain in rates of text entry with the use of word prediction (Lewis. et al.. 1998; Newell. et al.. 1991). In the study conducted by Newell and associates (1991) rates of text entry were measured in two participants. Methods of data collection were a questionnaire and interviews with teachers. In Lewis et al.’s study (1998), no information regarding participants’ typing rates on entry was provided. Both Newell et al.’s (1991) and Lewis et al.’s (1998) studies were conducted in school environments over a school year, therefore the reported gain in rates of text entry in the two studies might have been the result of long-term exposure to word prediction.

Researchers have recognized that there are visual-cognitive demands related to the use of word prediction (Dabbagh & Damper. 1985; Damper. 1984; Gibler & Childress. 1982; Goodenough-Trepagnier & Rosen. 1988; Vanderheiden & Kelso. 1987). The spontaneous
comments made by the participants and the observations of their performance during the study provided some information about these visual-cognitive demands. The participants of this study relied on looking at the keyboard to locate the keys. P3 and P4 reported that having to look away from the keyboard and switch their eye-gaze back and forth from the copy material to the keyboard and the monitor slowed their typing rates. P1 and P3 commented that the use of word prediction required more concentration than direct typing. In the word prediction sessions, all participants were observed to spend a considerable amount of time searching the prediction list. Often, they paused when they had to make a decision. Examples of the decisions they made include: choosing a number to pick a word from the prediction list, determining what action to take when the desired word was not on the list, and deciding which letter to type next. It was quite common for participants to forget which word they were looking for as they scanned the prediction list, especially if the desired word was not displayed the first time they looked at the list. This resulted in additional time required for the participants to switch their eye gaze back to the copy material and scan the copy material for the desired word, before returning to the task of searching the prediction list for the appropriate word. The visual-cognitive processes the participants were observed to use for word prediction were similar to those processes described in the literature (Horstmann & Levine, 1991; Treviranus & Norris, 1987; Vanderheiden & Kelso, 1987). The time that the visual-cognitive activities required might have significantly offsetted any timesaving gained from reduced keystrokes offered by word prediction.

At the simplest level, using word prediction is a visual detection task. Research has demonstrated that individuals with difficulties in perceptual ability, visual scanning ability, visual spatial skills, and eye movement control have poor performance in visual detection tasks, both in terms of accuracy and efficiency (Gale, 1993; Sergeant, 1996). Use of word prediction
involves higher level cognitive skills than what may be required for a simple visual detection task. A certain level of language ability is also necessary in order to be able to recognize the words in the prediction list. The participants of the current study had below average to low average intelligence. They also demonstrated difficulties in oculo-motor control, visual perception, attention and memory (Table 3 and 4). It is possible that the constellation of difficulties in the area of visual-cognitive functioning may have contributed to the reduced rate of text entry with the use of word prediction. This hypothesis is strengthened by the observation that P3 and P4, who had the lower scores in intelligence, memory and reading and the most difficulties keeping track of their place on the copy material, recorded significantly slower rates of text entry with word prediction than without word prediction. In comparison, P1 and P2 who function at a slightly higher level in the area of visual-cognitive skills, recorded insignificant differences in rates of text entry with and without the use of word prediction.

P2’s rates of text entry without word prediction declined toward the end of the alternating treatment phase. She was observed to be spending time looking for the prediction list when she was supposed to be typing without it. Her accuracy with direct typing also suffered because she often omitted spaces between words. These observations suggest that there might be a multiple treatment effect. The application of different typing conditions on the same day during the alternating treatment phases might have affected P2’s performances when typing without word prediction. Barlow and Hayes (1979) recommend that if there is evidence suggesting multiple treatment effect, the follow-up information should be used as a reference in the interpretation of the results. P2’s average rate of text entry without word prediction was slightly higher than the average rates of all of the word prediction conditions. Statistically, the differences were not significant. However, P2’s average rate of text entry without word prediction in the follow-up
phase (i.e., 9.41 wpm: Table 5) was much higher than the rates of text entry with word prediction (average rates with word prediction ranged from 7.27 – 7.48 wpm: Table 5). It is possible that P2’s rates of text entry without word prediction would have been much higher than the rates with word prediction in the alternating treatments phase if there was no interference effect from application of multiple treatments.

Visual inspection reveals an upward trend and variability in the data of rates of text entry with and without the use of word prediction. With all of the participants, the variability is higher with word prediction than it was without word prediction, especially in the second half of the alternating treatments phase. Decreased motivation and reduced attention may be the reasons contributing to the variability. With the exception of P1, all the other participants continued to improve their rates of text entry without word prediction in the follow-up phase. This observation suggests a practice effect. With the presence of an upward trend, there remains a possibility that the participants may have gained faster rates of text entry with the use of word prediction if the alternating treatments phase was extended. However, two of the participants (P3 and P4) expressed dislike of word prediction around Day 6 and Day 7 in the alternating treatments phase. P1 and P2 also showed signs of boredom such as playing with objects around the computer and frequent yawning toward the end of the alternating treatments phase. From a practical standpoint, it would be unrealistic to add more sessions to the present study. The existence of a practice effect and the issues of reduced motivation and decreased attention are not considered a threat to the internal validity of the study. The issue of decreased motivation/attention occurred in all of the word prediction sessions and without word prediction. It was also controlled using the reinforcement strategy. The practice effect would have a similar
impact on each of the treatments and on the no-treatment condition in the alternating treatments phase (Barlow & Hayes, 1979; Stromgren & Kolby, 1996).

The constant switching of eye gaze required in the copy task might have made additional visual demand on the participants. Consistent with Anson's report in 1993, participants were observed having to locate their place on the copy material every time they looked away from it. In the word prediction sessions, participants needed to check back and forth between the copy material and the word prediction list when they forget the words that they were looking for. It is possible that this increased frequency in eye gaze switching required in the copy task may have contributed to the reduced rate of text entry with word prediction.

The overall efficiency of word prediction is determined by the content of the prediction dictionary, the prediction algorithm and the text to be generated (Higginbotham, 1993; Koester & Levine, 1998; Newell et al., 1991; Swifin, et al., 1987; Vanderheiden & Kelso, 1987). In the present study, the keystroke savings offered using KeyREP with the custom dictionary created for the study was determined to be 37.2% ⁹. A story considered to be grade 3 reading material was used for copying and creation of the prediction dictionary ¹⁰. This was selected to make sure that participants were able to read all of the words displayed on the prediction list, but this reading level may have had an impact on keystroke saving. The average length of the words in the copy material was 4.30 not including the spaces, and 5.33 with spaces. This word length is shorter than the average of 4.74 without space (5.74 with spaces) in standard English text (Damper, 1984). Shorter words mean that less keystrokes are saved. The adoption of the “2-then-search” strategy in this study may be another factor that affected the efficiency of word

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⁹ Section 3.42, p. 43.
¹⁰ Section 3.5, p. 45.
prediction. The "2-then-search" strategy was adopted to minimize the visual-cognitive load but the application of this strategy meant that at least three keystrokes were required to type a word. The "2-then-search" strategy limited the keystroke savings because many of the words used in the study were 4-5 letters in length. The prediction list in KeyREP was generated by frequency alone. In many cases, especially in the case of content words, participants had to type 3 to 4 letters before the desired word was displayed on the prediction list. The application of a more advanced prediction algorithm, such as an application of natural language processing techniques could potentially improve the keystroke savings and reduce the visual-cognitive load (Langer & Hickey, 1999). It is possible that the effect of word prediction on rates of text entry would be different with the word prediction software applying advanced prediction algorithms.

5.2 The Effect of Word Prediction on the Accuracy of Text Entry

Generally speaking, all participants typed with high accuracy with or without the use of word prediction. Statistically, their accuracy was significantly higher with word prediction in the LM location. The improvement in accuracy was mainly in spacing and capitalization. Clinically, these improvements are not very significant because it is likely that the participants can learn to do proper spacing and capitalization from keyboarding training.

The most severe drop in accuracy occurred when participants skipped many words as they copied from the source material. The problem of skipping words seemed to appear randomly and it was noted in sessions with or without word prediction. It is likely that the problem of skipping words is related to the use of copy task in this study. The findings in accuracy of text entry may differ if participants were asked to type from dictated tapes or to do free composition.

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11 Section 2.3, p. 29.
Another common problem in accuracy for all of the participants was that additional spaces were inserted after a word when they used word prediction. This was more noticeable with P4, who was the best-trained typist in the group. The problem occurred as a result of the auto-spacing feature in KeyREP (i.e., a space was automatically inserted after a word that was selected from the prediction list). The benefit of auto-spacing is the saving of one additional keystroke for every word selected from the prediction list. However, a well-trained typist such as P4 automatically pressed the spacebar at the end of each word. This resulted in a double space being inserted thereby creating an error and decreased accuracy. P4, who had learnt to monitor her own typing, often tried to fix the double spacing problem. This meant that additional time was spent and resulted in slower rates of text entry. However, it is possible that with further practice the participants may be able to adapt to the automatic spacing when using word prediction.

Interestingly, when P4 was introduced to the use of word prediction on the training day, she started to read aloud the words that she was copying. P4 continued to do this throughout the alternating treatments phase, more so when she had to use word prediction, but also at times in the typing sessions without word prediction. This self-echoing stopped towards the end of the follow-up phase. When the accuracy data were examined, it could be seen that the accuracy was worse in the baseline (91.5%) and in the follow-up phase (96.2%), compared to the range of 97.7% to 98.96% in the alternating treatments phase (Table 6). The problem with accuracy for P4 was related to skipping words. It is possible that the echoing of words helped P4 remember where she was on the copy material. The combination of word prediction with auditory feedback is not new. In fact, it is a standard feature that is available on all shipping versions of word prediction software. The choice of not including auditory feedback in the current study was to
isolate the effect of word prediction. Anecdotally, the combination of auditory feedback and word prediction was felt to help users locate the targeted word on the prediction list (Hunt-Berg, Ranking, & Beukelman, 1994; MacArthur, 1996). Lewis and colleagues (1998) found that word prediction in combination with auditory feedback was more effective in the reduction of spelling errors than using word prediction alone, but the rate of text entry was slower than when word prediction was used without auditory feedback (Lewis, et al., 1998).

5.3 The Effect of the Location of Prediction List

Quantitative data analysis comparing the rates and accuracy of text entry between the preferred location and the other two locations revealed no significant difference. However, the accuracy of text entry with word prediction in the LM location was significantly higher than that of typing without word prediction. Subjectively, three participants (P1, P2 and P3) preferred to have the prediction list in the LM location, and P4 preferred to have the prediction list in the UR location. The location of the word prediction list does not appear to have an effect on rate of text entry. However, the preferred location of the participants was consistent with the location where participants achieved the best accuracy score. The small sample in this study may be one reason why a significant difference among the locations was not detected in analysis of the group results.

The FC location was not a favorite location for any of the participants. It is also where all of the participants recorded the lowest accuracy score, and where three of the participants registered lowest error-adjusted rates. P2 specifically commented that having the prediction list following the text cursor bothered her eyes. The observation that the FC location was not a favorite location for the participants is a particularly important finding to note because it is a
common belief among the software developers that having the prediction list following the cursor reduces eye movements related to using word prediction (Newell et al., 1992; Swil'fin et al., 1987). In May of 1999, KeyREP and Co:Writer were the only two software packages that allowed the prediction list to follow the cursor. The FC location remains the default location in the current version of Co:Writer (Co:Writer 4000, 2000). Recently, other software developers have begun to support the placement of the prediction list in the FC location. For example, the FC location is the default location used in WriteAway 2000 (WriteAway, 1999). The new version of TextHelp (TextHelp! Read and Write 4, 2000) also provides the option for the word prediction list to follow the cursor.

The use of a copy task with the copy material being placed between the keyboard and the monitor in this study may have influenced the preference for having the prediction list at the LM location. It would be interesting to compare the preferences for the location of the prediction list when the copy material is placed in different locations (e.g., either side of the monitor). The type of writing task used is another possible factor that may affect the choice of location. When an user performs a novel writing task, his/her visual focus is constantly on the text cursor. It is possible that during this type of task the FC location may be preferable.

Another factor to consider in relation to the location of the word prediction list is eye dominance. Gur (1975) suggested that an individual's tendency to gaze either to the left or to the right is determined by his/her characteristic preference for use of a certain hemisphere (Gur, 1975). His theory was supported by the evidence of a strong association between eye preference and handedness (Dellatolas, Curt, Dargent-Pare, & De Agostini, 1998). An individual’s eye dominance is important to consider in the placement of the prediction list as it can affect the reference point for visual localization (Porac & Coren, 1986). In the current study, the left-sided
placement of the prediction list was not tested because of the limitation set by the Windows operating system. If future technology allows the prediction list to be placed on the left hand side of the screen without compromising the efficiency or the size of text viewing area, then it will be important to compare the effect of location of the prediction list according to eye preferences.

5.4 Perceived Influence of Word Prediction on Written Productivity

The participants in the study appeared to have different perception of change in written productivity after using word prediction. The direction of change appears to parallel the changes in rates and accuracy of text entry recorded in the experiment. P1 and P2 recorded faster rate of text entry and/or higher accuracy with text entry with word prediction than without word prediction. Their mean performance and satisfaction scores after using word prediction were higher than baseline. P3 and P4 registered lower rate of text entry and insignificant change in accuracy of text entry with word prediction than without word prediction. Their mean performance and satisfaction scores after word prediction were lower than baseline. This finding agrees with the self-efficacy theory, which suggested that feeling of mastery heightens perceived self-efficacy (Bandura, 1997).

Prior research indicates that change scores of two or more points on the COPM are clinically significant (Law, et al., 1998). Analysis of individual participant’s data revealed that participant’s perception of change in performance and satisfaction after using word prediction varied with the writing tasks. The variability in ratings with different tasks means that the average performance and satisfaction change scores may not be the best indicators for change. After examining individual participant’s COPM scores, significant changes were noted at the task level. P1 rated her performance to be higher in 2 tasks (66.7%) and satisfaction to be higher
in all three tasks (100%) after using word prediction. For the 2 tasks rated with higher performance and satisfaction, the change scores are between 2 to 3. P2 rated her performance and satisfaction with 3 tasks (60%) to be higher after using word prediction, the change scores in 2 of these 3 tasks were in the range of 2-3. P3 rated his performance and satisfaction to be lower in four tasks (80%). The change scores in performance in three out of these four tasks were between –2 and -5. P4 rated her performance and satisfaction to be lower in two tasks (40%). The change scores in performance and satisfaction in these two tasks were between –4 and -8.

Participants’ perception of written productivity at baseline can affect the magnitude of changes in their performance and satisfaction after using word prediction. At baseline, P2 rated her performance and satisfaction to be at a relatively high level with the rating of ‘7’ or above for four tasks (80%) on a 10-point scale. After using word prediction, she rated her performance and satisfaction at ‘6’ or higher for all tasks. With a relatively high initial rating for most of the tasks, it is probably not surprising that the perceived overall changes (0.8 for performance and 0.4 for satisfaction) after using word prediction were not clinically significant.

During the experiment, P1 and P4 offered comments suggesting that use of word prediction might be helpful for spelling because instead of having to type the whole word they could select the desired word from the prediction list. However, P3 commented that use of word prediction might not help him with spelling because the use of word prediction required him to spell at least the first one or two letters of a word. His feeling was consistent with the results reported by MacArthur (1999) in a study conducted with students with learning disabilities. In this study, MacArthur raised concerns about basic spelling skills, word recognition skills, attention and memory required in the use of word prediction. However, other studies have supported the effectiveness of using word prediction to help with spelling (Lewis et al., 1998;
Newell, et al., 1991). As suggested by MacArthur (1999), the disagreement in findings in previous studies regarding the effect of word prediction on spelling accuracy may be related to differences in word prediction software in terms of prediction algorithms, size and content of the prediction dictionaries, and writing tasks used for the studies.

5.5 Strengths and Limitations of the Study

Four methodological strengths were identified in this study. First, the protocol was of a reasonable length to maintain compliance. Second, inclusion of a reinforcement strategy controlled for the possibility of reduced motivation and decreased attention affecting the results. Third, increased objectivity was achieved through the use of electronic monitoring and calculation of rates and inclusion of inter-rater comparison in the scoring of accuracy. Fourth, inclusion of baseline and follow-up phases, randomized order of treatment applications, and application of intercomponent intervals controlled for order and carry-over effects.

Conducting the study in the home environment appears to be both a strength and a limitation. Higginbotham (1993) suggests that the functional aspects of technology should be assessed under realistic conditions. This study provided information on the effect of word prediction in the home setting. However, conducting the experiments in the home environment made it impossible to standardize environmental factors such as noise, workstation, and presence of distracters.

The primary limitation of this study is the limited generalizability of the results. The present study consists of four direct replications. Interpretation of the results from the present study should be limited to children with spina bifida and hydrocephalus who have similar
characteristics as the participants in this study and to the specific word prediction software used in the study.

The use of copy task in this study was to control for the time required for idea generation and organization of thoughts in a novel writing task. However, the use of copy task imposes a limitation in generalizability of the findings of this study to free composition, which accounts for majority of the writing tasks required of school-aged children.

Other limitations of the study include limited reliability and validity of the Behaviour Checklist used to monitor behavior during the experiment, the small sample size in the study and limited reliability in sampling information gathered from medical records.

5.6 Direction for Future Research

Further research in four main areas is merited. First, with the availability of new word prediction software that adopts advanced prediction algorithms developed from natural language processing research, studies are needed to evaluate the effect of this new software on rate and accuracy of text entry. This information is necessary to guide the prescription of word prediction. A single-subject repeated measures ABA design may be an effective method to gather clinically relevant information (Ottenbacher, 1986).

Second, research is needed to evaluate the long-term use effect of word prediction with different writing tasks such as story writing, note taking and report writing that are typical for school-aged children. This study focused on the effect of word prediction on rates and accuracy of text entry, but prior research and anecdotal information suggests that word prediction may also be helpful in reducing fatigue, improving spelling and promoting the development of written language (Hunt-Berg et al., 1994; Klund & Novak, 1995; Lewis et al., 1998; Newell, et al.,
1991). The use of longitudinal studies may be able to capture the overall benefits of using word prediction with the different writing tasks in home and/or school settings.

Third, research is needed to further explore the location of word prediction list as a factor contributing to the effectiveness of word prediction. This study demonstrated that the location of the prediction list might affect the accuracy of text entry and the ease of use of word prediction. The finding of this study challenged the common belief that having the word prediction list following the cursor is a favorable location. Information on the effect of location of word prediction list is important for clinical implementation of word prediction technology. It is also important information for software developers in further development of the technology. The use of randomized block design with a large enough sample size to demonstrate power of inference may be a suitable design for this purpose. The recommendation of using randomized block design instead of a more powerful randomized controlled trial is based on limited availability of homogenous samples in pediatric rehabilitation research (Law, et al., 1994).

Fourth, research is needed to explore the effectiveness of word prediction when it is used with different computer access systems such as on-screen keyboard and switch access. Different computer access systems present different challenges and benefits in terms of the user interface. For example, when using an on-screen keyboard, the user’s visual focus is constantly on the computer screen. It is possible that elimination of the need to switch eye gaze in this situation would make word prediction a more effective tool for rate enhancement. Single-subject repeated measures ABA design should be considered. In a single-subject research, the participant serves as his/her own control, therefore the design allows customization of the access system to suit individual participant’s needs. The flexibility in experimental setup is important because
individuals requiring the use of on-screen keyboard or switch access are generally more physically challenged and would require the computer system to be set up in a specific manner.

5.7 Conclusion and Clinical Implications

In the present study conducted with children with spina bifida and hydrocephalus, it was found that word prediction did not improve rate of text entry, but it did improve accuracy of text entry when the word prediction list was placed in the lower middle border of the computer screen. Considering the limitations stated above, this finding is considered to be preliminary. Further study is necessary before a definitive conclusion can be made.

Contributions. To date, only a few clinical studies have addressed the effectiveness of word prediction. This study provides much needed clinical information on the effect of word prediction on rates and accuracy of text entry for children with spina bifida and hydrocephalus. It is the first study to explore the effect of location of the prediction list on rate and accuracy of text entry in this population. This study is also the first to explore the user’s perspectives on the potential influence of word prediction.

Clinical implications. This study supports the client-centered approach to assessment and recommendation of word prediction. Clinicians should explore the demands of different writing tasks from the client’s perspective and keep in mind that the benefits of word prediction are probably not restricted to improvement of rate and accuracy of text entry. The possible effect of location of the word prediction list on rate and accuracy of text entry is worth exploring with individual client in clinical evaluation to ensure that the word prediction list is placed in an appropriate location for the client.
References


http://www.hc-sc.gc.ca/hpb/lcdc/brcIdmeauin~mu~e~e.html


Table 1

Comparison of Word Prediction Software (May, 1999)

<table>
<thead>
<tr>
<th></th>
<th>Aurora™</th>
<th>Co:Writer™</th>
<th>KeyREP™</th>
<th>TextHelp™</th>
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<tr>
<td>5-word display</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<td>Vertical display</td>
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<td>Yes</td>
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<td>Placement locations:</td>
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<td></td>
<td></td>
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<td>Upper right (UR)</td>
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<td>Following the cursor (FC)</td>
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<td>Lower middle (LM)</td>
<td>Yes</td>
<td>No</td>
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### Participant Characteristics

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<th>P3</th>
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<td>10</td>
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<td>Reduced fine motor control (OT informal testing)</td>
<td>&lt;Age norm (Subtest 7, Bruininks-Oseretsky)</td>
<td>&lt;10th percentile (Purdue)</td>
</tr>
</tbody>
</table>

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12 Standford Diagnostic Reading Test, Fourth Edition (Karlsen & Gardner, 1995)
14 Wide Range Assessment of Memory and Learning, Story Memory (Immediate; Sheslow & Adams, 1990).
15 Purdue Pegboard Test (Purdue Pegboard., 2000)
16 Bruininks-Oseretsky Test of Upper Extremity functions (Bruininks, 1978)
Table 3

Results of Pre-baseline Tests

<table>
<thead>
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<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
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<td>5&lt;sup&gt;th&lt;/sup&gt; percentile</td>
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<td>IV</td>
<td>II</td>
<td>III</td>
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<td>&lt;0.2 percentile</td>
<td>12&lt;sup&gt;th&lt;/sup&gt; percentile</td>
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<td>Fair (Basal test)&lt;sup&gt;17&lt;/sup&gt;</td>
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<td>Fair (CHES)</td>
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<td>6.48 wpm</td>
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<sup>17</sup> Basal Test is a non-standardized clinical tool with its own indicators for speed for students Grade 1-8.
Table 4

Means and Standard Deviations of Gross Rates of Text Entry

<table>
<thead>
<tr>
<th>Participant</th>
<th>Phase</th>
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<tbody>
<tr>
<td>P1</td>
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### Table 5

**Means and Standard Deviations of Error-Adjusted Rates of Text Entry**

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<th>Participant</th>
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<th>SD</th>
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Table 6

Means and Standard Deviations of Accuracy of Text Entry

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Table 7

**Comparison of Mean Gross Rates of Text Entry**

<table>
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<tr>
<th></th>
<th>Randomization tests with repeated measure F-statistic</th>
<th>Randomization tests with paired t-statistic</th>
<th>P value (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>F = 1.161, P = 0.327</td>
<td>Multiple comparison procedures were not performed because of the insignificant F.</td>
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<tr>
<td>Participant 2</td>
<td>F = 0.387, P = 0.751</td>
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<td></td>
</tr>
<tr>
<td>Participant 3</td>
<td>F = 8.964, P = 0.001*</td>
<td>NWP – UR</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>NWP – FC</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NWP – LM</td>
<td>0.003**</td>
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<td>LM – UR</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>LM – FC</td>
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<td>Participant 4</td>
<td>F = 20.247, P = 0.000*</td>
<td>NWP – UR</td>
<td>0.001**</td>
</tr>
<tr>
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<td>NWP – FC</td>
<td>0.001**</td>
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<tr>
<td></td>
<td></td>
<td>NWP – LM</td>
<td>0.001**</td>
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<td>UR – FC</td>
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<td>Group</td>
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<td>0.000**</td>
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<tr>
<td></td>
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<td>NWP – FC</td>
<td>0.000**</td>
</tr>
<tr>
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<td></td>
<td>NWP – LM</td>
<td>0.000**</td>
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<td>LM – FC</td>
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*α=0.05

**α=0.0167 after Bonferroni adjustment**
### Table 8

**Comparison of Mean Error-Adjusted Rates of Text Entry**

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<tr>
<th></th>
<th>Randomization tests with repeated measure F-statistic</th>
<th>Randomization tests with paired t-statistic</th>
<th>P value (one-tailed)</th>
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</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>$F=1.346, \ P=0.263$</td>
<td>Multiple comparison procedures were not performed because of the insignificant F.</td>
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<td>Participant 2</td>
<td>$F=0.160, \ P=0.912$</td>
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</tr>
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<td>Participant 3</td>
<td>$F^2=5.754, \ P=0.004^*$</td>
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<tr>
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<td></td>
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<td>NWP – FC</td>
<td>0.001**</td>
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<tr>
<td></td>
<td></td>
<td>NWP – LM</td>
<td>0.001**</td>
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<td>NWP – FC</td>
<td>0.000**</td>
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<tr>
<td></td>
<td></td>
<td>NWP – LM</td>
<td>0.000**</td>
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* $\alpha=0.05$

** $\alpha=0.0167$ after Bonferroni adjustment
## Table 9

### Comparison of Mean Accuracy of Text Entry

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<th></th>
<th>Randomization tests with repeated measure F-statistic</th>
<th>Randomization tests with paired t-statistic</th>
<th>P value (one-tailed)</th>
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<td>NWP - UR</td>
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<td></td>
<td></td>
<td>NWP - LM</td>
<td>0.001***</td>
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<td>LM - UR</td>
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<td></td>
<td>LM - FC</td>
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<td>NWP - LM</td>
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<td>Participant 4</td>
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<td></td>
</tr>
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<td>NWP - FC</td>
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<td>NWP - LM</td>
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*α=0.05

**α=0.0167 after Bonferroni adjustment

***α=0.025 after Bonferroni adjustment
### Table 10

**Occupational Performance Tasks and COPM Scores**

<table>
<thead>
<tr>
<th>Participant</th>
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<th>Importance</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a) Completing homework better and faster</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>b) Writing better reports for projects</td>
<td>10</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>c) Completing school assignments better and faster</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td><em>(5.0)</em></td>
<td><em>(6.0)</em></td>
<td><em>(4.3)</em></td>
<td><em>(6.3)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>a) Completing homework assignments better</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>b) Writing test within the allowed time</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>c) Keeping a personal diary</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>d) Writing letters to friends and relatives</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>e) Coping notes from the board</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>(7.2)</em></td>
<td><em>(8.0)</em></td>
<td><em>(7.4)</em></td>
<td><em>(8.4)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>a) Completing homework assignments faster</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>b) Story-writing</td>
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<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>c) Copying notes from the board</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>d) Writing test within the allowed time</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>e) Completing in-class assignments within class time</td>
<td>6</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
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<td></td>
<td></td>
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<tr>
<td></td>
<td><em>(5.6)</em></td>
<td><em>(3.2)</em></td>
<td><em>(6.0)</em></td>
<td><em>(3.0)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>a) Writing better reports or speeches</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>b) Keeping a personal journal</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>c) Writing test within the allowed time</td>
<td>4</td>
<td>10</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>d) Story writing</td>
<td>10</td>
<td>9</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>e) Copying notes from the board</td>
<td>10</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>6</td>
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</tr>
<tr>
<td></td>
<td><em>(6.4)</em></td>
<td><em>(4.8)</em></td>
<td><em>(4.2)</em></td>
<td><em>(3.6)</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(Means)*
Figure 1. Illustration of Alternating Treatments Design Using Hypothetical Data
This picture illustrates the proposed computer workstation set-up. The actual set-up for individual participant varied slightly because of environmental and individual factors.
Figure 3. P1: Gross Rates of Text Entry

![Graph showing rates of text entry over days for different conditions.]

- Baseline
- Alternating Treatments Phase
- Follow-Up

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor

Figure 4. P2: Gross Rates of Text Entry

![Graph showing rates of text entry over days for different conditions.]

- Baseline
- Alternating Treatments Phase
- Follow-Up
Figure 5. P3: Gross Rates of Text Entry

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 7. P1: Error Adjusted Rates of Text Entry

Figure 8. P2: Error Adjusted Rates of Text Entry

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 9.  P3: Error Adjusted Rates of Text Entry

Figure 10.  P4: Error Adjusted Rates of Text Entry

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 11. P1: Accuracy of Text Entry

![Graph showing accuracy of text entry with different word prediction types over days.]

Figure 12. P2: Accuracy of Text Entry

![Graph showing accuracy of text entry with different word prediction types over days.]

NWP = No word prediction  
WP-UR = Word prediction list at the upper right corner  
WP-FC = Word prediction list following the cursor  
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 13. P3: Accuracy of Text Entry

Figure 14. P4: Accuracy of Text Entry

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 15. P1: Mean Gross Rates of Text Entry Across three Phases

Figure 16. P2: Mean Gross Rates of Text Entry Across three Phases

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 17. P3: Mean Gross Rates of Text Entry Across three Phases

Figure 18. P4: Mean Gross rates of Text Entry Across three Phases

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 21. P3: Mean Error-Adjusted Rates of Text Entry Across Three Phases

Figure 22. P4: Mean Error-Adjusted Rates of Text Entry Across Three Phases

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 21. P3: Mean Error-Adjusted Rates of Text Entry Across Three Phases

![Graph showing error-adjusted rates of text entry across three phases.]

Figure 22. P4: Mean Error-Adjusted Rates of Text Entry Across Three Phases

![Graph showing error-adjusted rates of text entry across three phases.]

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 23. P1: Mean Accuracy of Text Entry Across three Phases

Figure 24. P2: Mean Accuracy of Text Entry Across three Phases

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
**Figure 25.** P3: Mean Accuracy of Text Entry Across three Phases

NWP = No word prediction  
WP-UR = Word prediction list at the upper right corner  
WP-FC = Word prediction list following the cursor  
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 27. P1: COPM Performance and Satisfaction Scores for Three Tasks

![Graph showing COPM Performance and Satisfaction Scores for Three Tasks](image)

Figure 28. P2: COPM Performance and Satisfaction Scores for Five Tasks

![Graph showing COPM Performance and Satisfaction Scores for Five Tasks](image)
Figure 29. P3: COPM Performance and Satisfaction Scores for Five Tasks

Figure 30. P4: COPM Performance and Satisfaction Scores for Five Tasks
Appendix A

Illustration of Research Design

1. Pre-baseline Session (Day 1): Workstation set-up
   CHES and typing test as required
   COPM and DEM.

2. Baseline Phase (4 days)
   Treatment condition: NWP-No word prediction
   Measures: Rate of text entry (wpm)
   Accuracy (%)

<table>
<thead>
<tr>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
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</thead>
<tbody>
<tr>
<td>Treatment Condition</td>
<td>NWP</td>
<td>NWP</td>
<td>NWP</td>
</tr>
</tbody>
</table>

3. Training Session (Day 6)

4. Alternating Treatment Phase (10 days)
   Treatment conditions: NWP-No word prediction
   UR-Word prediction list on the upper right corner of the monitor
   FC-Word prediction list following the cursor
   LM-Word prediction list on the lower middle edge of the monitor
   Measures: Rate of text entry (wpm)
   Accuracy (%)

<table>
<thead>
<tr>
<th>Day 7</th>
<th>Day 8</th>
<th>Day 9</th>
<th>Day 10</th>
<th>Day 11</th>
<th>Day 12</th>
<th>Day 13</th>
<th>Day 14</th>
<th>Day 15</th>
<th>Day 16</th>
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</thead>
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<tr>
<td>Treatment Conditions*</td>
<td>NWP</td>
<td>NWP</td>
<td>NWP</td>
<td>FC</td>
<td>FC</td>
<td>LM</td>
<td>UR</td>
<td>UR</td>
<td>UR</td>
</tr>
<tr>
<td></td>
<td>LM</td>
<td>FC</td>
<td>UR</td>
<td>UR</td>
<td>NWP</td>
<td>FC</td>
<td>NWP</td>
<td>LM</td>
<td>LM</td>
</tr>
<tr>
<td></td>
<td>FC</td>
<td>LM</td>
<td>FC</td>
<td>NWP</td>
<td>UR</td>
<td>NWP</td>
<td>LM</td>
<td>FC</td>
<td>FC</td>
</tr>
<tr>
<td></td>
<td>UR</td>
<td>UR</td>
<td>LM</td>
<td>LM</td>
<td>LM</td>
<td>UR</td>
<td>FC</td>
<td>NWP</td>
<td>NWP</td>
</tr>
</tbody>
</table>

* An example of a random draw of 10 from the possible 24 combinations of treatment conditions

4. Follow-up Phase (4 days)
   Treatment condition: NWP-No word prediction
   Measures: Rate of text entry (wpm)
   Accuracy (%)

<table>
<thead>
<tr>
<th>Day 17</th>
<th>Day 18</th>
<th>Day 19</th>
<th>Day 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Condition</td>
<td>NWP</td>
<td>NWP</td>
<td>NWP</td>
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</tbody>
</table>
Appendix B

Ethics Approval

October 7, 1999

ETTICAL CLEARANCE

This is to certify that a Review Committee consisting of:

Doug Biggar, M.D., FRCP(C) - Chair
Linda LaRocque, School Principal
Darryn Gill, Parent
Jeff Jutai, Ph.D., C.Psych.
Peter Rosenbaum, M.D., FRCP(C)
Cathy Steele, Ph.D.
Alan Wolfish, B.A., LL.B., Q.C.

(*) Meeting may not have been attended by all members.

has examined the proposal "A comparison of placement locations of word prediction list for functional text entry with children with spina bifida and hydrocephalus". P.I.: Cynthia Tam, including materials relating to information and consent forms, and finds it to be ethically acceptable.

Doug Biggar, MD, FRCP(C)
Appendix C

Consent Form

Title of Study: Evaluating the effect of word prediction and location of prediction list for functional text entry with children with spina bifida and hydrocephalus

Investigator: Cynthia Tam
Occupational Therapist
Bloorview MacMillan Centre
(416) 425-6220 ext.3622

Supervisor: Denise Reid, Ph.D., University of Toronto, (416) 978-5937

Purpose of the Study:
Many children with spina bifida have difficulty with writing. They will use a computer for their written work. Very often, children with spina bifida also find their typing to be slow. They may benefit from using word prediction, a computer program to help improve their typing speeds and accuracy. KeyREP is the name of the program I will be using in this study. KeyREP provides a word list based on the letter typed by your son/daughter. He/she selects the desired word from the word list. By decreasing the number of keystrokes required to type a word, word prediction programs can improve typing rates. In this study, I want to know if KeyREP will improve your son/daughter's typing skills. I also want to know if the location of KeyREP on the screen will affect his/her typing skills.

Description of the Study:
I will visit you and your son/daughter at your house for 20 days, for a short period each day. On the first day (Day 1), I will set up the computer for your son/daughter. If he/she has not had his/her handwriting and typing skills tested in the past year, I will ask him/her to do a two-minute writing test and a five-minute typing test. This is to make sure that he/she needs to use word prediction. After that, I will have an interview with your son/daughter to understand what he/she thinks about written work. I will also do an eye movement test with your son/daughter. This test requires that he/she reads some numbers out loud.

Day 2 to Day 5. On each of these four days I will ask your son/daughter to type as he/she normally does for five minutes.

Day 6. I will show your son/daughter how to use word prediction. He/she can practice typing with word prediction until he/she knows how to use it.

Day 7 to Day 16. On these ten days I will ask your son/daughter to type for four five-minute sessions. He/she will be typing with KeyREP in three different locations on the screen and without using KeyREP. A five-minute break will be provided between each session. On the last day of this period, I will interview your son/daughter again to see if he/she think KeyREP had an impact on his/her typing skills.

Day 15 to Day 18. In the last four days of the study, I will ask your son/daughter to type for five minutes, without using KeyREP.
Potential harms (inconvenience):

There are no known risks to this study. There will be a total of 20 study sessions. Each lasts between 10 and 40 minutes. These sessions will hopefully be scheduled consecutively over four weeks. As much as possible, the sessions will be scheduled at a time that is most convenient to you and your son/daughter. I will bring a portable computer with me. A monitor and a keyboard will be left at your house during the study period.

Potential Benefits:

This study does have the potential to benefit your son/daughter directly. There is a good chance KeyREP can improve your son/daughter’s typing skills. If KeyREP is shown to be beneficial, I can help you procure the program. With your consent, I can send the findings from the research project to an occupational therapist at Communication and Writing Aids Service, Bloorview MacMillan Centre. Your son/daughter will not be placed on the waiting list for assessment. The occupational therapist will contact you directly to set up a meeting with you and your son/daughter. She will discuss the possibility of funding assistance from the Assistive Devices Program of Ministry of Health with you. This study will also increase our knowledge in the use of word prediction for children who have spina bifida, and provide a basis for us to examine its use with other population.

Confidentiality:

All the information that I collect about your son/daughter will be kept confidential. This information will be protected in the same way as a person’s medical chart. No information about your son/daughter will be given out to anyone without your written permission, unless this information is required by law. For example there is the legal duty to report particular infections that could spread to others. It is the law that professionals must report a suspicion of child abuse.

If I need to publish information that could identify your son/daughter, we will ask for your written consent again. You have the choice of giving or not giving this consent.

Research information is normally destroyed after the research is done. If it is important to keep research information longer, we will ask for your written consent. You have the choice of giving or not giving this consent.

The original of this consent form will be filed in your son/daughter’s medical chart. One photocopy of the consent form will be filed in your son/daughter’s research file. You will be given a photocopy of this consent form for your own records.

Participation

Participation in this study is voluntary. You have the right to decide not to allow your son/daughter to be a part of this study. You also have the right to withdraw your son/daughter from this study anytime. If you do not want to participate or if you choose to withdraw later, you and your family will continue to have access to services at Bloorview MacMillan Centre.

For questions and further information

Please do not hesitate to contact Cynthia Tam at (416) 425-6220 ext. 3622 or Denise Reid at 978-5937 with any questions or concerns you may have about this study, Monday to Friday, 8:30 am-4:30 pm. If you reach voice mail, please leave your name and phone number. We will call you as soon as we can.
Please complete the consent portion of this form below.

I have taken part in research at this Centre in the past. Yes_______ No ______

I am currently participating in another research study at this Centre. Yes_______ No ______

The name of this study is Evaluating the Effect of Word Prediction and Location of Word Prediction List on Text Entry with Children with Spina Bifida and Hydrocephalus.

I have received an explanation of the study, as described in this form, by the investigator named below. I understand that I may refuse to participate or withdraw my child from the study at any time without any penalties of any kind.

I hereby consent to let my son/daughter participate in this study.

Printed Name __________________________ Signature __________________________ Date _____________

Investigator’s Name __________________________ Signature __________________________


Appendix D

Assent Form

**TITLE OF STUDY:** To test if a computer program called KeyREP helps you with your typing skill on the computer.

**INVESTIGATOR:** Cynthia Tam
Occupational Therapist
Bloorview MacMillan Centre
(416) 425-6220 ext. 3622

**SUPERVISOR:** Denise Reid, Ph.D., University of Toronto
(416) 978-5937

**Why am I doing this study?**

Many young persons with spina bifida may not be able to finish their work at school. KeyREP is a computer program. It can help you type faster. When you type a letter, KeyREP shows you a list of words. You then pick the word you want from the list. You don't have to type out the whole word. In this study, I want to know if KeyREP helps you type faster and better. I also want to know if the location of KeyREP will affect your typing.

**What will happen to you during this study?**

I will visit you at home. I will come for 4 weeks, on Monday to Friday each week. On my first visit, I will set up a computer for you. I may ask you to write for two minutes and to type for five minutes. I will ask you to read some numbers out loud. I also like to discuss with you on what you think about written work (handwriting and typing).

In the next four days, I will ask you to type for five minutes each day. You will type as you normally do. I will show you how to use KeyREP on the fifth day.

Everyday in the following ten days, I will ask you to type with KeyREP. I will put KeyREP in three different spots on the screen. I will also ask you to type as you normally do. You will type for a total of 20 minutes. After typing for 5 minutes, you will have a break. On the last day of these ten days, I will speak with you again to find out what you think about KeyREP.
In the last four days of the study, I will ask you to type for five minutes each
day, without using KeyREP.

Are there good things and bad things about the study?

As far as I know, there are no bad things about this study. There will be a
total of 20 visits. Each last between 15 and 40 minutes. I will visit you at a time
when it is best for you and your parents. I will bring a portable computer with me.
I will leave the monitor and the keyboard in your house.

There is one good thing about this study. KeyREP may help you type faster
and better. If you and your parents want to keep using KeyREP, I will put you in
contact with an occupational therapist at Communication and Writing Aids
Service, Bloorview MacMillan Centre. She will help you get the program.

Who will know about what you did in this study?

Only people who do this study will know what you did in the study. I will
not tell anyone what you and your parents told me about yourself and the results of
your tests. When I talk about the study to anyone, I will not say or print your name.

Can I decide if I want to be in the study?

If you do not want to be a part of this study that is O.K. No one will be mad
or disappointed. If you say yes now but change your mind later, you can still say
no and that will be O.K. Your parents are also reading some information about this
study. They will talk to you about it. Ask them questions if you do not understand
what you have read or what people have told you. They will help you to
understand better. Please ask me any questions that you have. I can help you
understand the study.
I/You give me your permission, please sign here.

I want to be in this study.

__________________________
Name of young person and age

__________________________
Signature

__________________________
Name of person who obtained assent

__________________________
Signature

__________________________
Date

I was present when ________________________ read this form and gave his/her verbal assent.
Appendix E

Letter of Invitation*

January 1, 2000

Mr. and Mrs. Smith
350 Rumsey Road
Toronto, ON M4G 1R8

Dear Mr. And Mrs. Smith,

I wish to invite Johnny to participate in a research study. In this study, I want to find out if word prediction computer program will help children with spina bifida with their typing skills. KeyREP is the name of the program I will use in this study. You can find more information about this research study in the attached Consent Form and Assent Form. The Consent Form is prepared for you, and the Assent Form is for Johnny to read.

If you agree to have Johnny participate in the study, I will be visiting you at home for 20 days. On these visits, I will do typing practices with Johnny with or without the use of KeyREP. I will also interview Johnny at the beginning and at the end of the study to understand what he thinks about written work. In addition, I will complete an eye movements test, a handwriting test and a typing test with Johnny. All the information gained from this study will be kept confidential.

If Johnny does not want to participate in this study, it will not affect services that he receives at Bloorview MacMillan Centre or the Communication and Writing Aids Service. If you consent for Johnny to participate in this study but wish to withdraw later, you are free to do so.

I will call you in about two weeks to ask you about your decision to participate. If you agree to participate, we can then arrange suitable time for me to visit you and Johnny at home. If you do not want to participate and do not wish to receive a phone call, please call me at 416-425-6220 X 3622.

Sincerely,

Cynthia Tam, B.Sc.OT
Project Investigator

Cc. D. Reid, Ph.D. (Supervisor)

*In order to personalize the letter for each of the participants, the original letter of invitation was prepared using mail merge features on Microsoft Word®. This is a sample of a merged letter using counterfeit name and address. The letters sent to the participants were printed on Bloorview MacMillan letterhead.
Appendix F

Sample of Kump's Scoring Instructions for Accuracy of Text Entry

Words copied incorrectly = 1 error each time this occurs.  

* accrued property in Adams County. If you have pains to * 

* facilities of the local area ** (considered one misspelled word) 

* hope to have the pleasure of * 

(considered one misspelled word)

Incorrect spacing between letters within a word, resulting in excess space between letters = 1 error each time this occurs. (This includes words which are partially typed, then typed again.) 

* development of your property, you will be interested * 

* to hear that you (ar are)** pleased with the referral * 

** (considered one misspelled word)

* There is a problem with the typed material but no error is counted.  

1 error is counted
Appendix G

Sample of Subtest A and B of Developmental Eye Movement Test

<p>| | |</p>
<table>
<thead>
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<td>7</td>
<td>5</td>
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<td>7</td>
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<td>2</td>
<td>5</td>
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</tbody>
</table>
Appendix H

Sample of Subtest C of Developmental Eye Movement Test

<p>| | | | | |</p>
<table>
<thead>
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<td>4</td>
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<td>1</td>
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</tbody>
</table>
Appendix 1

Sample of Scoring Instructions on Children Handwriting Evaluation Scale

Scoring keys for calculation of rate of writing:

A boy named Jack lost a foot race home quickly to be comforted by his will not race again if I can not win. can not win if you do not race. Whatever you do, do with all you

Scoring instructions for quality of writing:

GENERAL APPEARANCE

Copy should be free of excessive strikeovers or erasures. Letters should not be so small or so large that the passage cannot be easily read. Age and grade level should be considered when judging sample.

Count off for: 1) Messy look, too many erasures or strikeovers
2) Too small writing
3) Too large writing
4) Age and grade should be considered when judging sample

A boy named Jack lost a foot race at the school picnic. He ran home quickly to be comforted by his mother, "Melly," he said. "I will not race again if I can not win." Don said, "His mother, you cannot win if you do not race." What ever you do, do with all your might.

A boy named Jack lost a foot race at the school picnic. He ran home quickly to be comforted by his mother, "Melly," he said. "I will not race again if I can not win." Don said, "His mother, you cannot win if you do not race." What ever you do, do with all your might.
Appendix J

Behaviour Checklist

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>...</th>
<th>...</th>
<th>...</th>
<th>...</th>
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<th>...</th>
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<td>Complaint of pain or discomfort</td>
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<td>Complaint of sickness</td>
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<td>Shaking hand</td>
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<td>Use hand to support head</td>
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<tr>
<td>Playing with objects around the computer</td>
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<td>Slump posture</td>
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<td>Distraction from people</td>
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Appendix K

Demographic Information Form

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<td>Date of Birth</td>
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<tr>
<td>Gender</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Medical diagnosis</td>
<td></td>
</tr>
<tr>
<td>Shunt malfunctions</td>
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</tr>
<tr>
<td>infection</td>
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<tr>
<td>Seizure</td>
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<tr>
<td>Level of lesion</td>
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<tr>
<td>Visual diagnosis</td>
<td></td>
</tr>
<tr>
<td>Vision</td>
<td></td>
</tr>
<tr>
<td>Visual perception</td>
<td></td>
</tr>
<tr>
<td>Neck movements</td>
<td></td>
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<td>Ambulatory status</td>
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<td>Upper limb functions</td>
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<td>IQ scores</td>
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<td>Verbal Performance</td>
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<td>Overall</td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td></td>
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<tr>
<td>Language spoken at</td>
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</tr>
<tr>
<td>home</td>
<td></td>
</tr>
<tr>
<td>Language instructions</td>
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<tr>
<td>at school</td>
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<tr>
<td>Reading</td>
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<tr>
<td>Writing /Keyboarding</td>
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<tr>
<td>Language skills</td>
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Appendix L

Result of Pilot Study

L.1 Background Information

Participant characteristics. The participant in the pilot study (PP) was a 12-year-old boy with the diagnosis of L5 myelomeningocele, Arnold-Chiari II malformation, hydrocephalus with right occipital VP shunt, tethered cord and Nystagmus. PP had a short stature. He was of average height of an 8-year-old boy. PP was a grade 6 student in a local primary school. Review of medical record showed that PP’s verbal intelligence score was 96 on WISC-III. On WRAML, his score was 25 indicating average memory skill. On the Stanford Diagnostic Reading Test, PP’s scores placed his reading level at grade 6. Other deficits reported in the medical record included reduced grip strength and difficulties in fine motor skills and eye-hand coordination. PP had access to a computer at home, and had a computer designated for his use at school.

Setting. PP lived in a semi-detached house. The experiment took place in the dining room. The computer was set up on the dining table. With his short stature, PP needed to put one phonebook on the chair, and had his feet supported by boxes. The environment for the experiment was mostly quiet except for when there were visitors in the house.

L.2 Pre-baseline Results

PP’s handwriting speed as assessed with CHES was in the 3.2 percentile for students at his grade. The quality of his writing was considered to be good (Phelps, et al., 1984). PP typed with two index fingers. On the DEM, PP recorded below the 1st percentile for the vertical score, the horizontal score and the ratio scores. These scores suggested a Type IV deficit indicating difficulties in automaticity and oculomotor control (Richman & Garzia, 1987).
L.3 Preference for Placement Location of Prediction List

PP indicated that having the prediction list at the LM location (LM) was easier for him to see. However, he has no strong preference for placement location of the prediction list.

L.4 Rates of Text Entry

**Gross rates of text entry.** Data are summarized in Table 11 and plotted on the line graph (Figure 33). At the end of the first session in the baseline phase, PP requested the text display on screen and on print be enlarged to 20 points. He also requested that the copy material be printed in double spaced format for later sessions. Therefore, the first data point was not included in data analysis. On average, P3 demonstrated a faster gross rate of text entry without the use of word prediction than with word prediction. The differences between the gross rate of text entry without word prediction and the gross rates with the word prediction list at the UR and FC locations were statistically significant ($P \leq 0.003$, Table 12). Statistically, the differences in gross rates between the preferred location (LM) and the other two locations are not significant (Table 12). As shown in Figure 36, PP’s average gross rate of text entry was highest in the follow-up phase ($M=9.61$) when he typed without word prediction. The high-low chart also shows improvement of gross rates of text-entry without word prediction across all three phases (Figure 36).

**Error-adjusted rates of text entry.** Data are summarized in Table 11 and plotted on the line graph (Figure 34). PP was slightly faster in error-adjusted rates of text entry without word prediction than with word prediction. However, the differences among the error-adjusted rates of all typing conditions were not statistically significant (Table 12). PP’s average error-adjusted rates of text entry remained higher in the follow-up phase ($M=8.70$) as compared to the baseline
level ($M=6.59$) and to the average rates with and without word prediction in the alternating treatment phases. (Figure 37).

L.5 Accuracy of Text Entry

Data are summarized in Table 11 and plotted on a line graph (Figure 35). PP appeared to have slightly higher accuracy when the word prediction list was in the LM location. However, the differences in accuracy among all typing conditions were not statistically significant (Table 12). PP was observed to have the problem of skipping words. This problem occurred without word prediction, and with word prediction in the UR and FC locations. The word-skipping problem started to appear at the alternating treatment phase, and continued into the follow-up phase; therefore, the baseline accuracy was highest among the three phases ($M=97.17$; Figure 38).

L.6 Perceived Performance

The important written productivity tasks identified by PP are presented in Table 13. A high level of importance was associated with all of the tasks with each task rated a '8' or above on the 10-point importance rating scale. The mean performance score and mean satisfaction score after using word prediction were lower than the baseline scores (change score of $-2.25$ and $-2.75$ for performance and satisfaction respectively). As compared to baseline, PP rated his performance to be higher in 1 out of 4 tasks (25%) and poorer for 3 tasks (75%) after using word prediction (Figure 39: Table 13). Comparing satisfaction after using word prediction to baseline, PP rated 1 task to be the same (25%) and 3 tasks to be poorer (75%: Figure 39: Table 13).
L.7 Behaviour Observation

PP maintained focus and was motivated throughout the experiment period. He became discouraged with the use of word prediction on the 7th day in the alternating treatments phase. Carelessness, slow movements and yawning were noticed while he typed with word prediction in the last four days. He also needed verbal prompt to continue using word prediction.

Signs of eye strain were observed during the alternating treatments phase. At the end of the first day in this phase, PP reported severe eye strain and headache. Consequently, he was asked to close his eyes briefly during the five-minute break between treatment conditions. This strategy appeared to alleviate the fatigue on the eyes. Yet PP was observed to be rubbing his eyes at the end of each day in the alternating treatments phase.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Means</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross rates of text entry</strong></td>
<td></td>
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</tr>
<tr>
<td>Baseline Phase (NWP)</td>
<td>6.59</td>
<td>0.10</td>
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<td>Alternating Treatments Phase</td>
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<tr>
<td>NWP</td>
<td>8.16</td>
<td>0.73</td>
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<td>WP-UR</td>
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<td>0.86</td>
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<td>WP-FC</td>
<td>6.81</td>
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<td>WP-LM</td>
<td>7.11</td>
<td>1.08</td>
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<td>Follow-up Phase (NWP)</td>
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<td>0.58</td>
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<tr>
<td><strong>Error-adjusted rates of text entry</strong></td>
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<tr>
<td>Baseline Phase (NWP)</td>
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<td>0.11</td>
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<td>Alternating Treatments Phase</td>
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<td>WP-UR</td>
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<td>WP-FC</td>
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<td>WP-LM</td>
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<td>Follow-up Phase (NWP)</td>
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<td><strong>Accuracy of text entry</strong></td>
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<td>Baseline Phase (NWP)</td>
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<td>Follow-up Phase (NWP)</td>
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Table 12

**PP: Comparison of Mean Rates and Accuracy of Text Entry**

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<th></th>
<th>Randomization tests with repeated measure F-statistic</th>
<th>Randomization tests with paired t-statistic</th>
<th>P value (one-tailed)</th>
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<td><strong>Gross rates</strong></td>
<td>F=8.018, P=0.002*</td>
<td>NWP – UR</td>
<td>0.008**</td>
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<td>NWP – FC</td>
<td>0.003**</td>
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<td>LM – UR</td>
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<td>LM – FC</td>
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<td><strong>Error-adjusted rates</strong></td>
<td>F=1.059, P=0.365</td>
<td>Based on the insignificant finding in the repeated measure F, multiple comparison procedures were not performed.</td>
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<td><strong>Accuracy</strong></td>
<td>F=1.031, P=0.378</td>
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*α=0.05
**α=0.0167 after Bonferroni adjustment
Table 13

PP: Occupational Performance Tasks and COPM Scores

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<th>Performance Pre</th>
<th>Performance Post</th>
<th>Satisfaction Pre</th>
<th>Satisfaction Post</th>
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<td>(1) Completing school assignments within school time</td>
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<td>(2) Completing homework better and faster</td>
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<td>(3) Copying notes from the board</td>
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<td>(4) Write a story faster</td>
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<td></td>
<td></td>
<td>(5.25)*</td>
<td>(3.00)</td>
<td>(5.25)</td>
<td>(2.75)</td>
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</tbody>
</table>

*(Means)*
Figure 33. PP: Gross Rates of Text Entry

Figure 34. PP: Error-Adjusted Rates of Text Entry

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 35. PP: Accuracy of Text Entry

![Graph showing accuracy of text entry across different phases.]

Figure 36. PP: Mean Gross Rates of Text Entry Across Three Phases

![Graph showing mean gross rates of text entry across different phases.]

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 37. PP: Mean Error-Adjusted Rates of Text Entry Across Three Phases

Figure 38. PP: Mean Accuracy of Text Entry Across Three Phases

NWP = No word prediction
WP-UR = Word prediction list at the upper right corner
WP-FC = Word prediction list following the cursor
WP-LM = Word prediction list at the lower middle edge of the monitor
Figure 39. PP: COPM Performance and Satisfaction Scores for Four Tasks