

**SPELLING: PROCESSES AND STRATEGIES IN PRINT AND COMPUTER
FORMATS**

by

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Abstract

Research addressing the role of format on spellers' abilities to recognize and correct errors has neglected to incorporate the variables of error type and strategic engagement in their studies. Thus, the three experiments in this dissertation examined the abilities of various types of spellers (above average, average, below average, and second language) across print and computer formats. The experiments introduced the role of attention as a factor in error blindness (i.e., inability to detect mistakes) for spelling recognition tasks, and the role of working memory in the graded quality of mental representations for spelling production tasks (i.e., correction of misspellings). In each experiment, spellers were randomly assigned to one of four counterbalanced groups. Spellers were asked to detect and correct misspelling for two essays in print and computer formats, identifying the spelling strategies applied. The studies compared word knowledge levels to error detection and correction abilities; attentional and working memory processes accounted for the influence of the type of error and format on spelling performance. Findings demonstrated inherent processing differences between spelling recognition and production processes and the masking effects of the application of strategies on spelling accuracy. Effects of error type in terms of saliency and clarity were found as phonological errors were easier to detect and correct, but morphological errors were more prone to error blindness regardless of the format. Spellers' quality of mental representations remained equally accessible due to their grounding in orthography. Format alone did not have an effect on accuracy, but did have an effect on strategic engagement. Format evidenced higher cognitive demands in the computer format and when spellers switched work from computer to print. These changes were explained by

the operations of a modulatory mechanism that inhibits the kind of information to be processed in the graphemic buffer. It is concluded that language processing models (e.g., Owen & Borowsky, 2003) can account for these findings by including the function of lexical strategies in reading and spelling tasks.

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CHAPTER 1

Spelling Recognition and Production in Print and Computer Formats

Switching between printed and computer versions of documents is a common reading practice, especially when writing essays or reports. For example, university students often have books or articles beside the computer as they write their essays. Some students also print off their penultimate draft and proofread this document at the same time they edit their soft copy (i.e., computer document). Thus, the investigation into the cognitive processes involved in attending to written information becomes relevant for the quality of academic and non-academic writing. Current research suggests there are mental costs associated with managing and structuring written information when one reads and writes. Moreover, processing written information imposes higher processing loads, demands faster processing speed, and creates more interference effects than simply reciting letters (Bourdin & Fayol, 2002; Ruz, Worden, Tudela & McCandliss, 2005; Tiu, Thompson, & Lewis, 2003). As such, it is essential for researchers to determine if the cognitive costs involved in proofreading and editing texts are similar when one reads an essay in printed or computer formats.

The processes of detecting and correcting errors are especially important at the proofreading stage of writing, but still many errors go undetected. People rarely produce error-free texts, even with the aid of spell-checker programs. At times, readers seem unable to see even common misspellings. Other times, writers are unable to produce the correct spelling of a word they know is incorrectly spelled. It appears that the strategies used by spellers are not entirely useful or adequate for them to produce a flawless document. Thus exploring the complexities of spelling becomes a challenge for cognitive

researchers. To comprehend the dynamics and further extend the knowledge of spelling sub-processes, this dissertation will examine the cognitive mechanisms and strategic engagement involved in the recognition and production sub-processes of spelling.

Understanding the integration of detection and correction processes in spelling elicits a theoretical discussion of the main explanations regarding the cognitive processes involved in spelling. To address the general cognitive processes supporting spelling and the derived models used to explain it, the first section of this chapter reviews the similarities and interactions that reading, writing, and spelling share. The first section contains three subsections: (a) the relationship between reading, writing, and spelling; (b) the general cognitive processes underlying these three language processes; and (c) the theoretical models used to explain them. The second section of the chapter describes the development of spelling skills, considering that although spelling recognition and production processes are distinct, they also have essential qualities that get cognitively integrated over time. The third section addresses the key factors affecting the detection and correction of misspellings: (a) the graded nature of the mental representations of words in the lexicon (i.e., not all words can be spelled with the same degree of ease) and the proneness of failing to detect an error (or error blindness); (b) types of spelling errors (i.e., phonological, orthographic, and morphological); (c) the cognitive strategies used by people when engaged in detecting and correcting errors; and (d) the influence of the format (i.e., print vs. computer) for performing spelling tasks.

A General Introduction to Reading, Writing, and Spelling

Reading and writing depend on knowledge representation at various linguistic levels. At the superordinate level they share a communicative function and are ruled by

universal language attributes (e.g., pragmatics, semantics, phonology, and syntactics; Fitzgerald & Shanahan, 2000). At the core structural level, these language processes share not only more specific language knowledge (i.e., phonemic awareness, decoding, listening comprehension, and processing rate of written symbols; Neuhaus, Roldan, Boulware-Gooden, & Swank, 2006), but also basic cognitive processes such as attention (Ehri, 2000; Kamhi & Hinton, 2000; Treiman, 1997) and memory (Commodari & Guarnera, 2005; Steffler, 2001). As reading and writing, spelling recognition and spelling production rely on the phonetic, orthographic, and morphemic features of the words and syllables in order to access, identify, and reproduce the mental representations of words stored in one's lexicon (Kamhi & Hinton, 2000; Seidenberg, 2005; Treiman, 1997).

In particular, the unique features of spelling provide an excellent opportunity to explore language and word processing mechanisms. Associations between spoken language and the spelling of written words allow the examination of the reproduction of units of sound and their matching graphemic characters presented in organized and meaningful letter sequences (Ehri, 2000; Kamhi & Hinton, 2000). The reproduction of sounds and letters is possible by accessing the mental representations of syllables and words already stored in long-term memory. In reading, such mental representations are accessed via the visual features of the individual letters and their sequences (graphemes) and linked to the appropriate morpho-phonetic unit(s) of a language. Conversely, in writing, the mental representations are accessed via the phonetic units, which are matched to the appropriate grapheme(s) to convey unit(s) of meaning (Ehri, 2000).

Relationships between reading, writing, and spelling. Reading and writing are not inverse processes (Reed, 1981); instead, they rely on analogous mental processes and

isomorphic knowledge. However, they are also separable processes (i.e., amount of covariance between reading and writing is about .50; Fitzgerald & Shanahan, 2000). One of the common categories shared between reading and writing is graphophonemics (i.e., letter-sound correspondences). Berninger, Abbott, Abbott, Graham, and Richards (2002) provided evidence for some unidirectional or asymmetrical relationships between specific components of reading and writing (e.g., word recognition to spelling, and handwriting to word recognition). The connections with reading were more bidirectional for the spelling component than for the handwriting component (i.e., a transcription system that translates those internal mental representations into visible text). Asymmetries were observed within the writing system depending upon the connection activated via reading to writing or writing to reading. Borowsky, Owen, and Fonos (1999) also reported the facilitation-dominant influence of graphemic processing on phonemic processing and a biasing influence of phoneme contexts on graphemic processing. Owen and Borowsky (2003) extended this finding to the word level, showing that orthography had a facilitation-dominant influence on phonology, and that phonology biased orthographic processing.

Spelling, reading, and writing are language-based activities that draw on shared knowledge. The same phonological processes that underlie reading ability also play an important role in spelling. It is generally agreed that the integration of phonological and orthographic knowledge is necessary for good spelling. All theories of spelling acquisition include a dominant role for phonology (Frith, 1980; Snowling, 1994). Evidence for the role of phonology in spelling comes from two sources: the high correlation between phonological awareness and spelling skill and the fact that spelling errors are generally phonetically accurate (e.g., 'wonc' for 'once'; Kamhi & Hinton,

2000). Also, the importance of orthographic knowledge for spelling has always been recognized given that knowledge about specific letter sequences of a word is essentially a definition of spelling. However, theories differ concerning how and when phonological and orthographic knowledge are integrated with each other into memory (Ehri, 1992, Frith, 1980). To such effect, research on reading, writing, and spelling continue to contribute to an emerging theoretical model.

Cognitive processes underlying the language processes of reading, writing and spelling. As mentioned previously, reading, writing, and spelling rely on similar cognitive processes, such as attention (Rees & Russel, 1999) and memory (Commodari & Guarnera, 2005; Steffler, 2001). In order to rapidly discriminate a correct letter sequence within a word, good spellers and proofreaders require extensive word knowledge. Extensive word knowledge relies on possessing a large number of quality representations and on rapid processing (Compton, DeFries & Olson, 2001; Neuhaus & Swank, 2002; Wile & Borowsky, 2004). Again, word knowledge and efficiency in processing greatly depend on attention and memory. Despite the substantial research on these cognitive processes, current models describing the operations of attention and memory continue to evolve (Dehaene & Changeux, 2005; Egner & Hirsch, 2005; Kilmer, 2001; Lavie, 2006; Posner & Rothbart, 2005; Szabo, Almedia, Deco & Stetter, 2004; Todd, Fougne & Marois, 2005).

As a general construct, attention is conceived as a filtering-enhancing mechanism for cognitive processing (Posner, 1992) by which people are able to direct cognitive resources to the processing of ongoing events (Szabo et al., 2004) while monitoring for errors (Dehaene & Changeux, 2005). Attention works concurrently with other cognitive

processes such as memory. These concurrent processes are observable not only in reading and writing, but also through the two sub-processes that form spelling: spelling recognition and spelling production. Spelling reflects the integrated coordination of memory and attention processes as the visual characters of words and syllables need to be associated with previously stored sounds and meanings (i.e., mental representations).

Although some studies address the importance of attention in the processing of meaningful written words (Rees & Russell, 1999), other studies have shown that words and syllables can be processed as visual-spatial tasks without reference to their verbal content (Voyer & Boudreau, 2003). Focusing on spelling processes, these findings help to explain people's inability to recognize misspellings despite possessing the necessary word knowledge for detecting spelling errors. Nonetheless, the fact that readers have an automatic sensitivity to subtly misspelled words (e.g., *faoture* for *fracture*; McConkie & Zola, 1981) provides a practical example of the integrated functioning of attention and memory in quotidian spelling tasks.

In spelling recognition tasks requiring one to *detect* misspelled words, the speller must attend to the visual characters of the misspelled word and notice (implicitly or explicitly) if the spelled word matches the mental representations of how the word should be spelled (Posner, 2005). Identifying a mismatch between a mental representation stored in the lexicon and the representation of a word being processed requires coordinated access between phonological (i.e., mental representations of what words sound like), orthographic (i.e., mental representations of what words look like), and semantic (i.e., mental representations of a word's meanings) qualities of words already stored in memory (for additional information on word representation models see Coltheart, 2006;

Owen & Borowsky, 2003; Seidenberg, 2005). These mental representations are contrasted with one another until the speller identifies the mismatched characters and either corrects or does not correct the spelling of the target word. In spelling production tasks requiring one to *correct* a misspelled word, memory continues working closely with attention to modify the letters or their sequence in order to produce the correct spelling. In other words, to determine if a word is spelled correctly one needs to read the word and compare it to the one stored in the mental lexicon; to produce a correct spelling of a word one needs to write the word, at least overtly, but one can easily do this covertly in order to reflect the one stored in the mental lexicon. The associations between the different word qualities and the related processing mechanisms have been addressed by reading and spelling models, which provide an important theoretical framework for any spelling recognition and production study.

The models of reading and spelling. Reading models propose that reading is composed of two sub-skills: word recognition and reading comprehension. Reading models recognize the relevance of other cognitive processes associated with word recognition and reading comprehension. Such cognitive processes are: decoding (i.e., matching graphemic codes to phonemic codes), linguistic comprehension (i.e., ability to understand and relate spoken language), processing speed (i.e., efficiency in coding, recognizing, accessing, and retrieving written symbols and their associations), and memory (i.e., storing capacity and stored information in phonological, visual and semantic codes) (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; Neuhaus et al., 2006; Plaut, McClelland, Seidenberg & Patterson, 1996; Tiu et al., 2003). Each of these

four aspects is found to be a source of variability in the processing of words, thus impacting both reading and writing.

There are two basic approaches to explaining the processing of words, the connectionist models (i.e., words are represented in numerous and highly interconnected units that are activated in parallel; Plaut et al., 1996) and the dual processing models (i.e., word representations are accessed via lexical, whole word, or non-lexical, sub-word procedures; Coltheart et al., 2001). Despite their differences, both models converge on the idea that our mental lexicons contain at least three kinds of information about words: phonological, orthographic, and semantic. In reading models, one assumes an associative mechanism that allows access to a mental representation of words via print to speech. Moreover, the representation of a word in memory can also be extracted via speech to print (Owen & Borowsky, 2003). Connectionist and dual-processing models also postulate that the characteristics of a word (e.g., regularity) affect the strength of the representations and processing speed (i.e., length of time required to encode and connect the different features of the mental representations of a word, such as orthography and phonology; Neuhaus et al., 2006). Individuals with an extensive set of quality mental representations in terms of orthography, phonology, and semantics can reduce their attentional resources for other tasks, such as attending to meaning, and cognitive monitoring for skilled spelling.

The spelling models differ in their conceptualization of the organization of and access to the stored mental representations. Nonetheless, all models converge on the idea that new and old mental representations are incorporated into the lexicon in a multiple representational form. The models explain that while new mental representations are

continuously formed, previously acquired representations are gradually re-described, thus enhancing knowledge and the understanding of words. Recent spelling models are extending their reach by addressing the unsystematic progression of spelling skills and the developmental patterns of misspellings. For instance, a study on spelling development by Critten, Pine, and Steffler (2007) examines the progression from phonologically based spelling to the regular use of orthographic rules until the morphological understanding of words is attained. These authors conclude that skilled spelling relies on multiple and multileveled cognitive representations of words stored in one's mental lexicon.

The relationships between spelling, reading, and writing are clearly strong. In fact, many research studies have demonstrated that reading ability is generally used as the best predictor of spelling ability (see Kamhi & Hinton, 2000 for a review). Although reading, writing, and spelling share essential elements of language processing, research should still consider theories and findings from each of these three fields of knowledge as each aspect of language processing possess a unique set of qualities. However, an integrative view of these language processes is perhaps the most appropriate way to investigate and explain the puzzling discrepancies presented between reading and spelling tasks. In this way, researchers are able to enrich their studies with an in-depth understanding of the acquisition of language and its features. The following review of the development of spelling skills provides an opportunity to observe the uneven acquisition of word knowledge. It is perhaps this unevenness in the development of spelling skills that motivates numerous cognitive scientists to study the puzzling processing of language.

Spelling: Skills and Development

Spelling can be referred to as a recapitulation of letter sequences that produce a familiar word-sound relationships fitting within the rules of orthography and morphology of a language (Radford, Atkinson, Britain, Clahsen, & Spencer, 1999). The major task in learning to spell is to become sufficiently familiar with the sequence of letters in words so that the information about the words retained in memory enables the speller to read and write them easily (Ehri, 2000). Thus, spellers need to acquire two types of knowledge about the written words: spelling regularities (i.e., phoneme-grapheme units, spelling patterns, and morphographs that symbolize syllabic units, root words, and affixes), and spelling of exception words (i.e., words that are not spelled as they sound, such as *said* or *yacht*; Coltheart, 2006; Ehri, 2000). Spelling abilities are commonly measured by two sub-skills: spelling recognition (e.g., which item is correctly spelled: *rane* - *rain*) and production (e.g., provide the correct spelling for *körs* = course).

Spelling is a complex activity, particularly in English, because the phoneme-grapheme-phoneme correspondences (i.e., associations between sounds and letters) are not isomorphic (see Cronnell, 1978). Good spellers use morphographs (i.e., irreducible units of meaning consisting of affixes and roots words) in addition to phonemes and graphemes to guide their spelling. Morphographs provide the spellers with cued graphophonemic units. These cued units help the speller to remember how to read and write words. By facilitating the decoding of words, these cued units reduce the memory load in the spelling tasks, consequently allowing spellers to operate more efficiently. To correctly spell regular words (i.e., words that follow the phoneme-grapheme correspondence rules of English such as *mint* or *cave*), writers can rely on a rule-based

phoneme-grapheme association. However, with exception words, the same phoneme-grapheme associations lead to predictable errors. Thus, to correctly spell exception words, writers must rely on a richer context of information, including the orthographic representation of whole words (Coltheart, 2004; Tiu et al., 2003), or the use of morphographs (Treiman & Bourassa, 2000a). Providing two or more types of feedback activation such as phonology and semantics facilitates efficient learning and promotes quality in the representations (Seidenberg, 2005). This multi-feedback process is usually associated with the development of skilled spelling.

Theoretically, the development of spelling skills has been linked to the variables of age, exposure, reading and writing proficiency, and experience (e.g., Burt & Butterworth, 1996; Frith, 1985; Treiman & Bourassa, 2000a). Additionally, individual processing speed is said to also reflect global processing efficiency in reading (Kail, Hall & Caskey, 1999), and spelling processes (Neuhaus, Foorman, Francis & Carlson, 2001). As noted, the ability to process words is associated with other cognitive processes (e.g., memory, attention) and with executive functioning (Denckla & Cutting, 1999).

Researchers have shown that spelling skills are acquired in an unsystematic manner (see Nunes, Bindman & Bryant, 1997). Traditional approaches to spelling development describe how, at first, the associations between sounds and letters are formed, and then, the orthographic rules are learned, and finally, knowledge and understanding of morphological relations are acquired (Treiman & Bourassa, 2000a). Given that words convey meaning, the semantic characteristics of words are also simultaneously incorporated in the word's mental representations (Treiman & Bourassa, 2000a). Thus, spellers require access to phonological, orthographic, and morphological

representations of words (i.e., knowledge of the internal structures of the word and word formation, including the meaning that different morphemes add to the word or the way that these morphemes modify the meaning of words; e.g., *unhelpful* = *un-* [negative] + *help* [meaning of word] + *-ful* [adjective meaning]). As the different representations of words (i.e., phonological, orthographic, morphological) accumulate, the semantic representation of words simultaneously fuse in memory so that word recognition is no longer attention demanding, and thus such fusion enhances automatic word recognition processes as required for efficient spelling (Neuhaus et al., 2006).

Over the course of development, children gradually acquire the morphological aspects of written language and apply these to the words they know. The unique ways in which orthographic, phonological, and morphological information gets integrated in early language development produces individual differences in spelling abilities and performance (see Nunes et al., 1997; Steffler, 2001). Analysis of misspelling in children shows that the types of errors that children make reflects their understanding of spelling knowledge (Steffler, Varnhagen, Friesen & Treiman, 1998). As an understanding of nouns and verbs deepens over time, their spelling skills transition from being phonological to morphologically-based (Critten, Pine, & Steffler, 2007). Overall, spelling researchers conclude that a child's understanding of spelling relies on multiple cognitive representations of words in his or her mental lexicon; and that words can be represented at different levels of explicitation within the cognitive system (i.e., multilevel representations for different types of words; Critten et al., 2007; Steffler, 2001).

As mental representations are formed and stored in long-term memory, they build up and become part of one's mental lexicon. Such mental representations are regularly

and continuously accessed and retrieved during reading and writing. To access mental representations, spellers make use of spelling strategies (e.g., phonetic, mnemonic) to facilitate the process. Research has shown that spelling strategies are acquired simultaneously with the development of the mental representations of words (e.g., early spelling relies on phonetic strategies; Treiman, 1993); hence, strategies are associated with developmental patterns. Spelling strategies seem to be congruent with the nature of the mental representations accessed (i.e., phonetic strategy is used to access phonological representation of words; Sénéchal, Basque & Leclaire, 2006), and to specific word features or complexity (e.g., morphology). It is also common that individuals report using more than one strategy for certain words and in different situations (Treiman & Barry, 2000). Thus, spellers may use different spelling strategies that vary in terms of efficiency. For instance, research reports that direct memory retrieval (i.e., mnemonic strategy) is the most efficient strategy (Kwong & Varnhagen, 2005); guessing, on the contrary, is reported as the most inefficient strategy for spelling (Ehri, 2000). As such, spellers can adjust their use of strategies to task difficulty and the efficiency of the strategy (Rittle-Johnson & Siegler, 1999).

Factors Affecting Spelling Performance

Research on spelling processes emphasizes that word knowledge is both necessary and sufficient to detect and correct spelling errors (Figueredo & Varnhagen, 2004; Hacker, Plumb, Butterfield, Quatham, & Heineken, 1994). However, it has been found that spellers' detection rates differed significantly from their correction rates (Plumb, Butterfield, Hacker, & Dunlosky, 1994). This difference was particularly observed in the case of morphological errors, but not observed in the case of

phonological errors (Figueredo & Varnhagen, 2004). For example, Figueredo and Varnhagen (2004) noted that it was easier for spellers to correct morphological errors (e.g., *extention*) than to detect such errors. Thus, failure to use correction knowledge for the detection of misspellings has been linked to the difference between types of spelling errors. One explanation for these findings suggests that spellers are able to deduce the correct spelling of words that they have been told are misspelled beforehand via mechanisms that process phonological information and even guess the spelling of words (i.e., processing deficit hypothesis; Figueredo & Varnhagen, 2004). Conversely, other researchers provide evidence that detection and correction of misspellings are different processes and require different skill sets (Fitzgerald, 1987), probably associated with development (e.g., increased phonemic awareness, Treiman, 1991).

Studies on spelling verification, as necessary for detection tasks, suggest that assembled phonology (i.e., sublexical activation route via grapheme-phoneme representations) plays an important role in the detection of written errors (Bosman & Groot, 1996). Similarly, spelling production, as necessary for correction tasks, is strongly associated to phonemic awareness, specifically to an ability in analyzing syllables containing consonant clusters into their component phonemes (Treiman, 1991). Therefore, not only precisely defined mental representations of words are important for detection and correction of misspellings, but also the efficiency of the processing mechanisms (e.g., attention) and the strategies (e.g., orthographic analysis) used to access the appropriate quality representations (Holmes & Castles, 2001).

Quality of mental representations. Research studies on mental representations have reported a gradation in the quality of the representations (e.g., differing degrees of

representational completeness and strength). Differential gradation implies that phonetic or graphemic features of words, letters, or syllables vary in quality and strength. Mental representations can be well defined (i.e., clear, distinct, unambiguous, precise) or degraded (i.e., imprecise, blurred, with unclear boundaries or noisy qualities; Seidenberg, 2005). Incomplete representations of words are noted in studies regarding reading difficulties (e.g., Kamhi & Hinton, 2000). Researchers have shown that some of the word representations are fragile (Ehri, 2000), incomplete (Cassar & Treiman, 1997), and susceptible to graded deterioration (Brown, 1988). Underdeveloped representations or representations that have not reached an optimal level of sharpness, precision or clarity are considered weak or incomplete mental representations (Munakata, 2001). For instance, Cassar and Treiman (1997) attribute children's early spelling errors to the ability to perceive and capture subtle discriminatory differences in sounds. The authors state that children's first sound-based spellings are incomplete representations of the sounds of words. Examples of these incomplete mental representations are the substitution of letters to represent the sounds of the name of a letter (e.g., *cr* for *car*, *bt* for *beat*), omission of sounds difficult to conceptualize as separate units (e.g., /m/ of *bump*, /n/ of *want*), and the inability to discriminate subtle differences in sounds (e.g., *dragon* as *jragn*; Treiman, 1993). Researchers postulate that degraded mental representations impair the learning process of acquiring new knowledge, and interfere with the generalization of acquired knowledge (Seidenberg, 2005).

The view that knowledge is graded in nature explains the incongruousness in knowledge and performance in both spelling tasks (Munakata, 2001). Variability in the strength or quality of mental representations also suggests an activation-strength

difference between the representations of exception words and the representations of regular words (Harm & Seidenberg, 1999, 2004). Failures to retrieve the mental representations of words and the commission of errors allude to the weakness of the representations in memory and to the deficits in accessing these representations. Degraded or weak representations account for lower decoding skills, variability in word recognition skills, and individual spelling abilities. Conceptualizing one's word knowledge as essentially graded can also help explaining the developmental transitions in spelling skills. Nonetheless, despite the relevance of the above mentioned constructs, to our knowledge, there is a lack of studies contrasting the gradation of the representations of reading with those of writing, as well as a lack of studies analyzing the compound effects of attention and quality of representations in average adult spellers. Similarly, studies addressing the impact of work that alternates between print and computer formats, as well as the gradation of word representations on spelling is absent in the literature.

Error type and spelling. The graded nature of the mental representations of words is observed at the word feature level (i.e., phonetic, orthographic, and morphemic) and is reflected in the recognition of misspellings and the production of correct spellings via the different types of errors encountered in texts. As such, one can find phonologically based errors (i.e., phonologically legal sequences with an unconventional appearance such as *incredibul*), orthographic errors (i.e., orthographic sequence very similar to the conventional spelling such as *eligeble*), and morphologically based errors (i.e., misspellings representing the incorrect morpheme such as *defensible*). Because error categories are not necessarily mutually exclusive they are viewed as operating on a continuum of orthographic sophistication (Figueredo & Varnhagen, 2004; Varnhagen,

McCallum & Burstow, 1997). It is precisely the orthographic error category that contains misspellings that are most similar to the conventional spellings of the words.

Quotidian verification and production tasks are unique events in the sense that one cannot clearly establish or predict the misspellings contained within different texts (Fitzgerald, 1987). Every time that a spelling verification task is conducted, one is required to access the word representation database in one's lexicon. An average proofreader broadly looks for errors lacking of specificity in the target (i.e., searches broadly to identify an incorrect letter, word, prefix, suffix, etc; Butterfield, Hacker, & Albertson, 1996). If the proofreader is also required to correct the errors, s(he) engages in the parallel and purposeful activity of writing (spelling production or the reproduction of the correct letter, syllable, or word in a suitable graphemic form; Fitzgerald, 1987). The nature of the error must be determined before the correction task takes place (Hacker, Plumb, Butterfield, Quathamer, & Heineken, 1994). To accurately write specific words, spelling demands access, retrieval, and correct reproduction of the appropriate features of the words (Berninger et al., 1998b). Nevertheless, lack of attention (Figueredo & Varnhagen, 2004, 2006), or error blindness, and/or low degree of clarity in the mental representations accessed can also disrupt either access or retrieval of the word's representations. In this case, spelling as a general process is disrupted and the discrepancies between the three types of errors become less pronounced (Butterfield, et al., 1996).

While reviewers may not have an overt spelling problem to search for, they generally approach the document with a certain method and general expectations (Fitzgerald, 1987; Flower et al., 1986). Since people naturally anticipate that more-

complex words give writers a greater challenge with regard to orthography (Hacker, et al., 1994), editors, reviewers, and/or proofreaders tend to analyze these complex words more closely than they do simple words (e.g., *the*). People are also aware that there are certain rules such as ‘*i* before *e* except after *c*’ and that there are exceptions to these rules. Reviewers also tend to focus more on content words or words originating from lack of lexical knowledge, as opposed to functional words such as *the*, *but*, *because*, or commonly used words such as *I*, or words containing accidental mechanical errors (Butterfield, et al., 1996). In the literature, researchers refer to these practices as spelling strategies.

Spelling strategies. In recent years, the analysis of strategies has played an important role in elucidating cognitive processes (e.g., Campbell & Timm, 2000; Geary & Wiley, 1991; Hetch, 2002; LeFevre, Sadesky, & Bisanz, 1996; Roussel, Fayol, & Barrouillet, 2002; Varnhagen, 1995). The cognitive strategies that one applies relate to the processes that one uses when accessing mental representations and to the nature of the representations being accessed. As such, in order to examine the activity of the processes engaged, as well as the nature of the representations activated during the spelling tasks, it is imperative to investigate the cognitive strategies engaged in recognition and production sub-processes.

With respect to spelling, strategies are broadly categorized into mnemonic, phonological, orthographic, and morphological strategies (Varnhagen, 1995). Two main theories explain the role of strategies for the detection and correction of spelling errors: the lexical hypothesis (i.e., spelling is produced by accessing word-specific graphemic information) and the rule hypothesis (i.e., spelling is produced by relying on rules of

phoneme to grapheme correspondence); however, some researchers have argued that both memory and rules need to be integrated to properly account for spelling processes, a concept captured by the simultaneous processing or integrative hypothesis (Kreiner & Gough, 1990; Rittle-Johnson & Siegler, 1999).

Research on the efficiency of spelling strategies demonstrates that direct retrieval from memory (i.e., fast and accurate retrieval of words in their entirety or spelling patterns from long-term memory or mnemonic strategy; Ellis, 1993; Kwong & Varnhagen, 2005), is the most efficient and advanced strategy for accessing stored representations for words (Ehri, 2005; Treiman, Berch, & Weatherston, 1993). Direct retrieval owes its efficiency to the reduced processing load that underlies the retrieval; that is, because it does not presuppose a conscious awareness of the underlying processes used during retrieval, the processing is fast and automatic (Sénéchal et al., 2006). This efficiency of the direct retrieval strategy is the core concept of the lexical or knowledge hypothesis. Conversely, back up strategies (i.e., sublexical assembly routes of spelling whereby the orthography of a word is assembled by using some system of converting rules such as those of phonology, orthography, and morphology; Ellis, 1993; Kwong & Varnhagen, 2005) require a deliberate and conscious effort that can compromise accuracy (Rittle-Johnson & Siegler, 1999). The use of rules and the associated converting systems are concepts encapsulated by the rule or processing hypothesis. Nonetheless, studies reveal that using a particular strategy increases spelling accuracy only for words with the same type of error (e.g., using a phonetic strategy for phonological errors; Sénéchal et al., 2006). The efficient parallelism between strategy and error type is the underlying concept of the strategy matching hypothesis.

Most studies have demonstrated that people utilize both direct retrieval and back-up processing strategies in spelling. Researchers have also argued that the use of strategies varies with the individual (e.g., simultaneous processing or integrative hypothesis) as identification and correction of errors depends on an individuals' accessibility to the strategies and to their strategic efficiency (i.e., use faster and effortless strategies for simple problems, and use a combination of strategies for more complex problems; Rittle-Johnson & Siegler, 1999). Interestingly, spelling researchers also report the use of an inefficient alternative strategy for spelling: the inventing of spellings for unfamiliar words (Ehri, 2000; Sterling, Ertubey, Brownfield, O'Reilly & Noyce, 2004). Spelling by invention is achieved by stretching out pronunciations, detecting sound units, and applying knowledge of the alphabetic system to generate plausible letter sequences for sounds (i.e., guessing). Given the diversity of the language and the speller's abilities, achieving a successful spelling of words using this strategy is subject to great variability (Ehri, 2000). In brief, four hypotheses encapsulate the use of spelling strategies: the lexical or knowledge hypothesis; the rule or processing hypothesis; the simultaneous processing or integrative hypothesis; and the strategy matching hypothesis.

Spelling across formats. The extensive use of word processing programs and childhood exposure to computers has raised interesting questions for cognitive scientists. Some have suggested that this change in activity (from handwriting to computer keyboarding) is likely to modify high-level cognitive functions of these children, such as the perception of the written language (Longcamp, Zerbato-Poudou & Velay, 2005). The main concerns regarding the influence of format (task response modality such as paper-pencil and handwriting, or microcomputer and keyboarding) on spelling tasks are based

on two factors: lexical representation and cognitive processing. The question is whether the lexical representation is linked to a motor component (i.e., the movements of the hands as letters are formed), and, whether the transcription through a keyboard interferes with spelling processes (Masterson & Apel, 2006).

It has been established that handwriting movements used to acquire letter knowledge are determinant for engraving graphemic information about letter, and word representations in long-term memory (Hulme, Monk & Ives, 1987; Longcamp et al, 2005; Treiman & Bourassa, 2000b). Debates over the quality of word representations acquired via typing or keyboarding are longstanding but supported by controversial findings (see Berninger et al., 1998; Logan, 1999; Vaughn, Schumm, & Gordon, 1992, 1993). Research on the methods children use to acquire alphabetic and word knowledge (handwriting and printing vs. typing and keyboarding) has uncovered variations in spelling skills associated with age (younger vs. older spellers; Longcamp et al., 2005), word complexity (single vs. multiple letter-sound correspondences, and low vs. high predictability; Berninger et al., 1998), and learning ability (detection and correction of spelling errors in learning disabled students vs. average students; McNaughton, Hughes, & Clark, 1997). On the other hand, teaching methods support the use of computers as tools to avoid frustration with motoric activity and lessen the cognitive demands for spelling production tasks (Cunningham & Stanovich, 1990). Thus, the question that remains unanswered is whether the format (i.e., print, computer) used in spelling tasks is indeed relevant for spelling performance in later years.

Numerous research findings advocate for the relevancy of handwriting over typing or keyboarding in forming quality word mental representations (see Berninger et

al., 2006; Cunningham & Stanovich, 1990; Longcamp et al., 2005; Treiman & Bourassa, 2000b), and thus for a way to become a more skilled speller. Handwriting training has exhibited superiority as far as letter recognition (Longcamp et al., 2005), and word recognition is concerned (Treiman & Bourassa, 2000b), and has proven to be useful for improving error detection skills in college students with learning disabilities (McNaughton et al., 1997). It is noted that handwriting establishes a unique correspondence between the printed letter or word, and the movement (temporo-visuo-spatial and motor connections) necessary to create (and re-create) such symbols. This special mapping contributes to stimulating deeper levels of word processing and stronger mental representations (Berninger, Abbott, Abbot, Graham, & Richards, 2001; Cunningham & Stanovich, 1999; Longcamp et al., 2005). The literature reports a significant advantage for those who use written spellings, which suggests that children represent word letter sequences more accurately when the word sequences have been learned in a handwritten, static, permanent form (Treiman & Bourassa, 2000b). Handwriting requires a set of detailed and organized movements to define a letter's graphic contour and to build a clear internal model of the letter's characteristics, providing on-line signals from several sources, including vision, motor commands, and kinesthetic feedback, which are closely linked and simultaneously distributed in time (Longcamp et al., 2005). Visual-motor connections, which upon writing a word, are transformed and integrated as a unitary word form in long-term memory, strengthen the central process required for skilled spelling (Berninger et al., 2006; Longcamp et al., 2005). Spelling, as part of an interactive language system, relies on all these sources of

information (e.g., visual, phonetic, grapho-motor) to build up a functional system to support reading and writing (Berninger et al., 2001).

Some researchers (Berninger et al., 1998; Longcamp et al., 2005) maintain that using a computer keyboard instead of hand-printing increases a writer's spelling accuracy. They explain that keyboarding requires less attention to detailed spatial-motor movements and graphemic information, but relies on visual discrimination for key selection; therefore, people are able to allocate greater attentional resources to the letter sequence necessary to spell a word correctly because less attention is directed toward the crafting of written letters. As such, accessing of the mental representations of words in this format is also hypothesized to affect spelling recognition (detection) and production (correction) tasks.

Other researchers debate the relevance of format for spelling tasks. Masterson and Apel (2006) contrast spelling abilities in print and computer, and conclude that spelling knowledge draws from modality-free, lexical representations stored in long-term memory. Berninger et al. (2006) indicate that spelling is not merely a motor or visual skill, but involves a coordinated and integrated network among phonological, orthographic, and morphological word features contributing to mental representations of words forms. In other words, using print or computer formats for spelling tasks would not have a significant impact on the mental representations of words or generate any observable difference in spelling performance. To this effect, Logan (1999) indicates that above and beyond format, phonology plays a crucial role in spelling. However, for Hartley (1998) the implication of format in spelling is only a question of personal preference. Furthermore, Berninger et al. (2006) explain that any variation in spelling performance

across print and computer formats may only reflect individual differences, and general cognitive processes such as attention, memory, and executive functions (inhibition/switching) rather than the format of the spelling tasks. Surprisingly, despite their assertion, the authors also note that typing or keyboarding should not be used to replace handwriting training in learning the spelling of words. In brief, there are three lines of thought regarding the impact of format on spelling recognition and production tasks. One states that there are no differences in spelling performance; another emphasizes the differences; and the last one proposes that format is an issue of personal preference that sometimes has an impact on spelling tasks.

The issue of format is further complicated by other word processing technologies. Using spelling support technology (spell-checkers) is now a tool widely used to alleviate some of the spelling problems faced by many people. Knowing that detection of a misspelling is required for correction and that spellers often fail to apply their spelling knowledge in detection tasks, Figueredo and Varnhagen (2004) advocate for the use of spell-checkers. These authors suggest that using spell-checkers impacts positively on a student's spelling abilities because the automatic detection of error warns the students of a need for correction. Alternatively, Holmes and Castles (2001) take a different stand by indicating that the use of spellcheckers fills a momentary need, and is thus, a less efficient strategy than being able to scan, monitor, and revise one's own spelling. The later authors advocate for people to become active spellers (i.e., augment normal reading experience by conscious deliberation about the identity and order of letters) to develop detailed monitoring reading practices (avoid reading words via partial cues), and to

construct precise orthographic representations of words via practice (reduce use of spell-checkers).

To identify the ways in which spelling knowledge and skill are potentially impacted by format changes is extremely relevant for the development of cognitive theories supporting educational training programs. Understanding how the two sub-processes of spelling (i.e., recognition and production) interact with each other illustrates how spelling impacts other language processes such as reading or writing. Research of this nature provides data on lexical representations and underlying cognitive processes that can accommodate findings from special populations and further influence instructional methods to facilitate learning and promote efficiency in reading and writing.

In summation, spelling recognition and production do not only depend solely on the individual's spelling knowledge (quality of mental representations), but are also affected by other variables inherent to the process as such. Besides a person's word knowledge, factors influencing spelling are: the attention given to the task (spelling), the nature of the task (detection, correction), the type of spelling error encountered within the text (phonological, orthographic, or morphological), the efficiency of the strategy used for the task (visual, phonetic, direct retrieval), and/or the format in which the spelling task (word or text) is presented (print, computer).

The Present Study

Because of the controversies found in the literature about the processing of language, it was of interest to analyze the factors that impact spelling performance, such as quality of mental representation and error blindness. As the literature reports, recognizing and correcting errors is affected by the type of spelling error and the spelling

strategy used for spelling. Additionally, as investigating the effects of computer use on cognitive processing is still a relatively new area of study, it was of interest to explore the impact of format (paper print vs. computer screen) on spelling. According to the advocates of the superiority of handwriting in constructing precise mental representations of words, it was expected that spelling recognition and production tasks would be more accurate if the spelling tasks were conducted in a printed format. According to those who claim that typing and keyboarding reduce the cognitive load and increase attention in spelling tasks (at least for the morphological units in the words), it was expected that spelling recognition and production tasks would be more accurate if the tasks were conducted in a computer format. Also, according to those authors advocating for a unified mental representation of words, in which spelling format was considered irrelevant, it was expected that accuracy for spelling recognition and production tasks would not vary with format.

This dissertation study brings together, and expands on the findings of previous research studies in the field of spelling, that is, for recognition and production processes. The study integrates analyses of quality mental representations and error blindness as potential variables that, together with the types of spelling error and use of spelling strategies, can affect spelling. Moreover, this study further incorporates the effects of format and the varying increases of cognitive load into the study of spelling sub-processes. In this way, this dissertation intends to detail the processing mechanisms involved in the two sub-processes that compose spelling: recognition and production. The study aims to clarify the involvement of the general cognitive processes (e.g., memory, attention) supporting all spelling activity. This will be accomplished through the analysis

of types of misspellings (e.g., orthographic, morphological) that spellers identify and correct accurately, as well as the effectiveness of the spelling strategy (e.g., visual, phonetic) they apply toward each task and format. By reporting on the cognitive activity that takes place when spellers switch between formats, it is expected that this will be a contribution to the understanding of the spelling recognition and production processes when cognitive load is increased. To this end, three studies were conducted that examined the above mentioned sub-processes in different types of spellers (i.e., average, above average, below average, and second language spellers) and two formats (i.e., print and computer). Chapter 2 examines the ability of average spellers to detect and correct different types of spelling errors (i.e., phonological, orthographic, morphological) and looks at the spelling strategies (i.e., visual, phonetic, direct retrieval) that they used for each task (detection, correction) and format (print, computer). The study also incorporates an analysis of error blindness and an analysis of the graded quality of the mental representations of words. Chapter 3 analyzes the processing mechanism associated with an increase in cognitive load in above average spellers. This study explores the accuracy of above average spellers and the various strategies (strategic engagement) they use as they switch between formats. Chapter 4 focuses on exploring the differences in spelling accuracy and strategic efficiency in three groups of spellers: native English spellers, second-language spellers, and below average spellers. Findings of all three studies are integrated and discussed in Chapter 5.

CHAPTER 2

Accuracy and Strategic Engagement in Two Formats in Average Spellers

Producing an error-free written text requires monitoring one's spelling and reading performance. Studying one's ability to detect and correct misspellings also provides a way to investigate mental lexical access. Current models of mental lexical access and reading demonstrate the assumption that skilled visual word recognition can be accomplished via multiple processes (Owen & Borowsky, 2003). These cognitive processes demand that the subject accesses knowledge of what words look like (i.e., orthography), what words sound like (i.e., phonology), and what words mean (i.e., semantics). Skilled readers often rely on some combination of all three processes for their spelling (Treiman & Barry, 2000). Moreover, research has also shown that mastery of spelling is inversely related to deficits in knowledge and/or the processing of information (Ashcraft, 2002; Geary, Homson, & Hoard, 2000).

An inability to detect and then correct errors in textual material emerging as a result of a deficiency in orthographic, phonological, or semantic knowledge (i.e., weak knowledge representations), or from attentional deficits (i.e., error blindness), may be exacerbated by the processing demands from the task at hand (e.g., switching between two or more sources or formats). The present study was developed to examine these issues and to explore the cognitive processes involved in detection and correction abilities as a function of format and error type. Previous research has focused on the analyses of spelling errors in one format (print), whereas this study includes the analysis of the cognitive processes across formats (i.e., print and computer).

The debate over the importance of motor conditions when learning to read and write is an issue of ongoing deliberation among researchers (see Berninger et al., 2006; Cunningham & Stanovich, 1990; Masterson & Apel, 2006; Treiman & Bourassa, 2000b; Vaughn et al., 2002). Cognitive researchers question whether learning how to write helps people to learn how to read (Longcamp, 2005). Even so, teaching educational institutions are increasingly employing a wide range of computer devices to extend their academic reach and promote efficient use of resources (e.g., virtual classrooms, online courses, blackboard tools, online debates, electronic submission of documents). Even learning centers are now providing online tutoring services to assist students with their reading and writing assignments. Furthermore, university services for students with disabilities grant such students computer access to write exams or take notes in classes as legal accommodations mandated by a disability (e.g., language disorder, motoric conditions).

There are vigorous controversies generated by studies advocating for the superiority of handwriting over computer methods for betterment of reading, writing, and spelling (see Cunningham & Stanovich, 1990; Longcamp, et al., 2005; Treiman & Bourassa, 2000b). A group of research studies demonstrates no differences in the acquisition of those skills (i.e., reading, writing, spelling) when computer formats are used as opposed to writing formats (Hartley, 1998; Masterson & Apel, 2006; Vaughn et al., 2002, 2003). Another group of studies concludes that other factors, such as phonology and inner speech (Logan 1999), or the integration of word features (i.e., reflective sub-word connections between phonology, orthography, morphology; Berninger et al., 2006; Steffler, 2001), but not the motoric conditions (i.e., handwriting or typing), are primarily

responsible for the learning of those skills; however, these studies also state that typing or keyboarding should not be used to replace handwriting (Berninger et al., 2006).

Such controversial findings lead one to search for ways to determine whether working in print or computer documents plays a role in adults' spelling accuracy, or if the format is irrelevant to the task and is therefore, only a question of personal preference (Hartley, 1998). Additionally, because the integration of word features is central to spelling (Berninger et al., 2006), and mastery of spelling evolves from a phonological to a morphological basis (Treiman & Bourassa, 2000a), it becomes pertinent to explore whether spellers are able to detect and correct misspellings according to the different types of errors. Efficient detection and correction processes also require the application of spelling strategies such as direct retrieval (Ellis, 1993; Kwong & Varnhagen, 2005), back-up strategies (Ellis, 1993; Kwong & Varnhagen, 2005) or some combination of both (Kreiner & Gough, 1990; Rittle-Johnson & Siegler, 1999). Thus it needs to be determined if there is a change in the strategies used across formats. Finally, recognizing misspellings and (re)producing the correct spelling of words are said to be analogous but asymmetric sub-processes drawing on the same knowledge as reading and writing (Abbot et al., 2002). Therefore, to understand the mechanisms that operate during the recognition and production processes, an analysis of the compound effects of the variables mentioned above (e.g., spelling strategy, format) is granted.

The aims of this first study were to examine: the abilities to detect and correct orthographic, phonological, and morphological errors, the strategies used to detect and correct spelling errors, and whether the speller abilities and use of strategies vary with format. To achieve these goals the present study adopted the materials and the tasks from

a study by Figueredo and Varnhagen (2004); however this research incorporated the variables of format and the spellers' strategic engagement, thus adjusting the experimental conditions, and consequently extending their findings. In the present study, average spellers were asked to detect and correct spellings for two equivalent essays each in a different, as well as to identify the proofreading strategies that they used in each task. It was hypothesized that: 1) a difference in spelling performance (detection and correction of misspellings) between the print and computer formats should indicate superiority of one of those formats in regards to spelling, 2) detection and correction rates would differ in relation to error type and task, 3) use of spelling strategies would vary as a function of task and format, and that 4) scores from the standardized spelling tests would have a linear relationship with detection and correction rates.

The research presented here examines one of the practical and quotidian ways in which spelling processes and spelling abilities are expressed. The uniqueness of the study resides in the analysis of the cognitive activity involved in automatic and controlled access to mental representations of words through the application of spelling strategies (strategic engagement). Additionally, the study looks at error blindness and the quality of the mental representation of words as expressions of attention and memory in spelling recognition and production processes. The findings of this study will form a base to further explore the processes taking place when people switch between different formats when they proofread written work.

Method

Participants

Twenty-seven undergraduate students from the University of Northern British Columbia participated in this study for bonus course credit. Three students were removed from the sample because they did not fit the criteria (i.e., two participants were second language speakers and one participant disclosed a diagnosed learning disability). All remaining participants were native English speakers and reported normal or corrected-to-normal vision. The participants' average age was 23 years, 7 months ($SD = 6$ years, 8 months). Participants rated their writing skills as moderate (spelling skill $M = 4.92$, $SD = 1.56$; proofreading skill $M = 5.08$, $SD = 1.72$). In general, their reading ($M = 108.33$, $SD = 9.21$) and spelling scores ($M = 104.25$, $SD = 11.11$) were within the average range, as measured by the Wide Range Achievement Test-3 (Wilkinson, 1993). Subjects' visual ($M = 99.25$, $SD = 6.68$) and phonetic word recognition scores ($M = 104.33$, $SD = 6.95$), in addition to their visual spelling recognition scores ($M = 107.21$, $SD = 8.48$) were within the average range, as measured by the Diagnostic Spelling Potential Test (Arena, 1982).

Apparatus and Materials

Participants were assessed on academic skills with two standardized instruments (see Appendices A & B), the Wide Range Achievement Test-3 (WRAT-3; Wilkinson, 1993) and the Diagnostic Spelling Potential Test (DSPT; Arena, 1982). A Likert-type scale adapted from LeFevre, Kulark, and Heymans (1992) rated students' interests in academics and related activities (see Appendix C).

The experimental spelling task consisted of two parallel essays (i.e., Essay 1: Violence in Film; and Essay 2: Anorexia Nervosa) presented in two formats, a printed

version and a computer version (see Appendix D). Figueredo and Varnhagen (2004) developed these essays for their study and included six examples of each error type (i.e., phonological, orthographic, morphological). The errors were compiled from several lists of commonly misspelled words and modified in their suffixes (see Figueredo & Varnhagen). The two essays had a statistically equivalent level of difficulty and contained the same misspellings (i.e., there were no significant differences in detection or correction rates across text versions, nor there were significant differences in detection or correction performance between male and female participants; see Figueredo & Varnhagen). Readability statistics were obtained for the two essays using Flesh-Kincaid Scores (tool available from Microsoft Office Word Version 11.0.8202.0). The essays were measured on Reading Ease (i.e., the ease with which a document can be understood) and Grade Level Scores (i.e., rate of a text on a level of understanding according to a school grade level). The Flesh-Kincaid Reading Ease was 52.1 for Essay 1, and 39.5 for Essay 2. The Flesh-Kincaid Grade level was 9.8 for Essay 1, and 11.1 for Essay 2. Because the participants were all university students, it was assumed that they would not have difficulties understanding either essay, concluding that both essays were appropriate for this study. The participants were asked to detect (highlight) and correct (write/type out) spelling errors in each of the essays and to identify the strategy they used to detect or correct each error.

Both tasks (i.e., detection and correction) were conducted in two formats, print and computer. For the detection tasks, participants were asked to highlight the misspelled words they encountered in the texts (i.e., using a highlighter pen in the case of a printed copy or using the highlighting function in the computer version). For the correction tasks,

participants were asked to write out the correct spelling of the words already highlighted for them by the experimenters in the text essays (i.e., the corrections were handwritten in print and typed out in the computer format). All participants were exposed to both formats and both essays.

The printed tasks were presented on a white sheet of bond paper in identical formatting characteristics to the computer tasks. The computer tasks were presented on a colour VGA monitor driven by a Pentium-class microcomputer running the word-processing software Microsoft Office Word Version 11 (1983-2003). The spellchecking function was turned off for the computer tasks.

Procedure

Participants attended individual sessions. Prior to the session, participants were randomly assigned to one of four counterbalanced conditions (i.e., Latin Square Design) created by crossing the format presentation of the essays (computer vs. printed), and the sequence of format presentation in the detection and correction tasks (e.g., first detection in print – first correction in computer). Upon their arrival at the lab, subjects received a general explanation of the study, followed by the experimental session (e.g., essays, questionnaires). All participants started with a detection task according to the group they had been assigned (e.g., Essay 1 print). The WRAT-3 arithmetic subtest was introduced as a verification task, followed by the DSPT word recognition subtest. Then, the second detection task was presented (e.g., Essay 2 computer). Immediately after the second detection task, participants completed the first correction task (e.g., Essay 1 print). Two subtests were then administered subsequently, DSPT visual recognition subtest and the WRAT-3 reading subtest; the academic interest questionnaire was presented next. In

cases where participants did not feel comfortable answering any of the questions of the questionnaire of academic background and interests, they were told to leave those questions blank. The second correction task followed (e.g., Essay 2 computer), and concluding the session with the WRAT-3 spelling subtest.

For the experimental tasks, participants were given instructions to detect, in the detection tasks, or correct, in the correction task, any misspelled words. For the detection task they highlighted the misspelled words. Participants were instructed to immediately record the strategy they used to identify each misspelling. For the correction task, participants were given a marked copy of one essay and were asked to write down the correct spelling of the words highlighted in boldface. Following each correction participants were required to record the strategy they used to correct the error. In cases when participants were not sure about their spelling strategies, the experimenter used prompting questions (see also Figueredo & Varnhagen, 2004).

Scoring

In the detection and correction tasks, the number of accurate error detections and corrections were calculated for each participant. For each task, the number of accurately identified and corrected misspellings constituted the detection and correction measures, respectively. The maximum score for each measure was 18. The strategies used to detect and correct errors were also scored in single units by category: visual, auditory, direct retrieval, a combination of more than one strategy and other (guessing). The interrater reliability score for the use of strategies was .89. Standardized instruments (WRAT-3, DSPT) were coded according to the specific guidelines for each test; the results were presented in standardized scores.

Research Design

Using a Latin Square research design, the primary manipulations in the present study were the presentation format (print vs. computer) for each task (detection and correction). This manipulation required that participants were assigned randomly to one of four groups before the experiment was carried out. The statistical design for the analyses of this experiment was a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) within-subjects design.

Results

The results of this study are presented in several sections. The first section includes general data on the materials and tasks used in the study. The second section reports data on spelling performance in detection and correction tasks as a function of format (print vs. computer) and error type. The third section examines the spelling strategies used in each task and format. The fourth section presents an analysis of the correlations between standardized tests scores, and the types of errors, and spelling strategies in each task and format. Unless noted, all effects were statistically significant at the $p < .05$.

General Data on Materials and Tasks Used in the Study

Essay Equivalence. To ensure that the two versions of the essays used in this experiment were indeed equivalent, a 2 (Essay: Violence, Anorexia) x 2 (Task: detection, correction) two-factor repeated measures Analysis of Variance (ANOVA) was conducted. Results showed no significant main effects for essay, $F(1,23) < 1$, $MSE = 1.20$, $p = .783$. No significant interaction was found for essay and task, $F(1,23) < 1$, $MSE = 1.72$, $p = .40$.

These results indicated that there were no differences between the total number of errors detected in essay 1 ($M = 12.17$, $SD = 2.81$) and essay 2 ($M = 12.00$, $SD = 2.67$). Nor were significant differences found between the total number of errors corrected in Essay 1 ($M = 11.17$, $SD = 3.55$) and Essay 2 ($M = 11.46$, $SD = 3.68$). Because the results indicated that the detection and correction rates across essays were the same (see Appendix E, Table E1), essay was ignored as a factor for the remainder of the analyses.

Learning Effects. To eliminate the possibility that any of the analyses could be influenced by task repetition effects (i.e., participants were exposed twice to the same types of errors in each task), and to prevent misinterpreting possible learning effects as presentation effects, or adding a confounding variable to this study, a 2 (Presentation: first, second) x 2 (Task: detection, correction) two-factor repeated measures ANOVA analysis was carried out. Results showed no main effects by presentation order, $F(1,23) < 1$, $MSE = 1.50$, $p = .87$, or task, $F(1,23) = 1.45$, $MSE = 5.62$, $p = .24$. No significant interaction was found between presentation order and task, $F(1,23) = 1.02$, $MSE = 4.10$, $p = .32$. These results indicate that there were no learning effects associated with the repeated exposure to the same misspellings in either of the tasks (see Appendix E, Table E2).

General Detection and Correction Rates. To quantify any difference between tasks and formats, a 2 (Task: detection, correction) x 2 (Format: print, computer) two-factor repeated measures ANOVA analysis was carried out. Results showed no main effects by task, $F(1,23) = 1.28$, $MSE = 11.52$, $p = .27$, or format, $F(1,23) = 1.09$, $MSE = 1.15$, $p = .306$, and no interaction between task and format, $F(1,23) = 1.404$, $MSE = 1.67$, $p = .25$. The results indicated that average spellers detected and corrected the same

number of errors in print as they did on computer. In print, average spellers detected and corrected misspellings in similar numbers. In computer, average spellers also detected and corrected misspellings at similar rate (see Appendix E, Table E3). As in Figueredo and Varnhagen (2004), this finding indicated that average spellers corrected everything they detected.

Spelling Performance as a Function of Error Type in Each Task and Format

To compare spelling detection and correction rates associated with the different types of errors and formats, a 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Error type: phonological, orthographic, morphological) three-factor repeated measures ANOVA was conducted. Then paired *t*-test comparisons were utilized to determine any significant differences between the spelling detection and correction rate in each format in relation to each error type. Conducting more than one *t*-test analysis increases the chances of Type I error. As such, adjusting the alpha level accounts for falsely significant findings with a Bonferroni correction¹, and results in an adjusted $\alpha = .0167$. As advocated in Dunlop, Cortina, Vaslow, and Burke (1996), pooled standard deviations to obtain measures of effect size were calculated using the original standard deviation of the scores to prevent an overestimation of the actual effect size, which can occur if one uses *t* values in the calculations.

The repeated measures ANOVA showed a main effect of error type in spelling, $F(2,46) = 33.26$, $MSE = 1.70$, $\eta^2 = .591$ (see Table 1). Paired *t*-test comparisons with Bonferroni corrections between the different types of errors showed significant

¹ A conservative multiple testing method such as Bonferroni was chosen above others (e.g., Bonferroni Holm method) because it accounts for false positive results (Type I error). The trade-off of a stringent multiple testing correction method is that reduces power, increasing the chances of a Type II error (i.e., higher rates of false negatives).

differences in all three types of errors. As such, there were significant differences between phonological and orthographic errors, $t(23) = 4.32$, $SEM = .810$, $d = .910$, between orthographic and morphological errors, $t(23) = 4.79$, $SEM = .548$, $d = .616$, and between phonological and morphological errors, $t(23) = 7.084$, $SEM = .865$, $d = 1.51$. These results indicate that this group of average spellers tend to be more accurate with phonological errors than either orthographic or morphological errors, and further, that they were more accurate with orthographic than morphological errors (see Table 2).

Table 1

Average Speller's Accuracy in Relation to Error Type in Each Task and Format

<i>Error Type</i>	<i>Format and Task</i>							
	<i>Print</i>				<i>Computer</i>			
	<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Phonological	5.46	.72	4.04	1.60	5.38	.58	3.92	1.59
Orthographic	4.17	1.31	3.71	1.30	4.0	1.35	3.42	1.53
Morphological	2.42	1.53	3.83	1.27	2.75	1.62	3.67	1.47

Also an interaction between task and error type was observed, $F(2,46) = 30.14$, $MSE = 1.39$, $\eta^2 = .567$. Paired t -test comparisons with Bonferroni corrections across detection and correction tasks in each error type showed significant differences in all but orthographic errors. As such, there were significant differences between detection and correction of phonological errors, $t(23) = 4.79$, $SEM = .600$, $d = 1.24$, with higher detection than correction rates. There was also a significant difference between detection

and correction of morphological errors, $t(23) = -3.65$, $SEM = .639$, $d = -.852$; however, in this case, correction rates were higher than detection rates. There was not a significant difference between the detection and correction of orthographic errors, $t(23) = 1.88$, $SEM = .553$, $d = .425$ (see Table 3). These results indicate that detection and correction abilities are subject to greater variability when phonological and morphological errors are encountered in texts; however, when texts contain orthographic errors, spelling detection and correction skills of average spellers are more equivalent.

Table 2

Average Spellers' Accuracy According to Error Type

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
18.79	3.60	15.29	4.08	12.67	4.48

In each detection and correction task, paired t -test comparisons with Bonferroni corrections for the rate that the three types of errors were detected or corrected were conducted separately. The results showed significant differences between all three types of errors in detection but not in correction tasks. As such, the detection rate of phonological errors was significantly different than both the detection rate of orthographic, $t(23) = 5.83$, $SEM = .457$, $d = 1.48$ and morphological errors, $t(23) = 9.94$, $SEM = .570$, $d = 2.5$; also the detection rate of orthographic errors was significantly different than the detection rate of morphological errors, $t(23) = 6.54$, $SEM = .458$, $d = 1.15$. The correction rate of phonological errors was not significantly different than either

the correction rate of orthographic, $t(23) = 1.42$, $SEM = .586$, $p = .17$, $d = 0.291$ or morphological errors, $t(23) = .781$, $SEM = .587$, $p = .443$, $d = .164$; the correction rate of orthographic errors was not significantly different than the correction rate of morphological errors, $t(23) = -1.11$, $SEM = .340$, $p = .28$, $d = -.143$ (see Table 6). These results show an inherent difference between detection and correction tasks in relation to the types of misspelling encountered in texts. Thus, the types of spelling errors impacted spelling performance in detection tasks, while performance in correction tasks was more consistent despite the types of spelling errors contained in the texts. These results are comparable to those of Figueredo and Varnhagen (2004).

Table 3

Average Spellers' Accuracy by Error Type in Each Task

<i>Task</i>	<i>Error Type</i>					
	<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	10.83	1.20	8.17	2.24	5.17	2.93
Correction	7.96	3.06	7.13	2.64	7.50	2.52

Note. Data represents the overall average number of words detected and corrected in the two formats (max cell score = 12).

No main effects were found by task, $F(1,23) = 1.37$, $MSE = 3.67$, $p = .25$, or format, $F(1,23) = 1.30$, $MSE = .384$, $p = .27$. There was no significant interaction by task and format, $F(1,23) = 1.60$, $MSE = .556$, $p = .22$, nor by error type and format, $F(2,46) <$

1, $MSE = .597$, $p = .39$. No significant three way interaction by task, error type, and format was found, $F(2,46) < 1$, $MSE = .622$, $p = .57$. These results show that task or format did not have an impact on spelling abilities.

The analyses presented in this section show that different levels of spelling accuracy are associated to each error category. Average spellers were more sensitive to phonological than to orthographic or morphological errors. In addition, spelling accuracy across detection and correction tasks varied with the type of spelling error. Detection and correction skills were more equivalent in the presence of orthographic errors. However, discrepancies in the accuracy across the tasks were evident with phonological and morphological errors. Furthermore, different levels of accuracy related to the error category were found within detection tasks but not in the correction tasks.

Strategies Used Across Tasks and Formats

To measure the strategies used by participants in detection and correction tasks according to format, a 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Strategy: visual, phonetic, direct retrieval) three-factor repeated measures ANOVA was conducted. Because the observations were low in two categories (i.e., guessing and combination of strategies) they were eliminated from the analysis. Descriptive statistics are included in Table 4.

The repeated measures ANOVA showed a main effect of the use of strategies, $F(2,46) = 11.15$, $MSE = 27.07$, $\eta^2 = .326$. Paired t -test comparisons with Bonferroni corrections between the strategies used for spelling showed significant differences between the use of visual and phonetic strategies, $t(23) = 5.78$, $SEM = 2.55$, $d = 1.72$. No significant differences were found between either the use of direct retrieval and phonetic

strategies, $t(23) = -2.24$, $SEM = 3.09$, $p = .03$, $d = -.712$; or between the use of direct retrieval and visual strategies, $t(23) = 2.07$, $SEM = 3.79$, $p = .05$, $d = .687$. These results indicate that this group of average spellers used mainly the visual strategy to guide their spelling. For spelling tasks, average spellers used the phonetic strategy the least out of all the strategies (see Table 5).

Table 4

Application of Spelling Strategies According to Task and Format by Average Spellers

<i>Strategies</i>	<i>Format and Task</i>							
	<i>Print</i>				<i>Computer</i>			
	<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Visual	6.29	3.5	4.17	3.6	6.42	3.7	4.50	3.9
Phonetic	1.71	1.9	1.71	1.9	1.92	1.8	1.88	2.3
Direct Retrieval	3.04	3.7	4.42	4.6	2.75	3.2	3.46	3.6
Other (guessing)	.04	.20	.13	.45	.13	.34	.17	.48
Combination (2 +)	.96	2.54	1.25	2.7	.88	2.4	1.04	2.0

The results also revealed a marginally significant interaction between task and strategy, $F(2,46) = 2.91$, $MSE = 19.96$, $p = .06$, $\eta^2 = .112$. Paired t -test comparisons with Bonferroni corrections were conducted to identify the use of strategies across detection and correction tasks. The results showed no significant differences in the use of strategies between detection and correction tasks with regards to visual, $t(23) = 2.20$, $SEM = 1.96$, $p = .04$, $d = .604$, or phonetic, $t(23) = .371$, $SEM = .786$, $p = .71$, $d = .080$; or direct retrieval

strategies, $t(23) = -1.623$, $SEM = 1.57$, $p = .12$, $d = -.351$. The lack of differences between the strategies used across tasks reveals that this group of average spellers tends to have a preferred and consistent strategy for guiding their spelling across tasks (see Table 6).

Another way to assess the significant interaction between strategy and task is to compare strategy use for each task. To compare the use of strategies in each task, paired t -test comparisons with Bonferroni corrections between the strategies used in task were conducted separately. Results of the comparisons in the detection tasks showed significant differences between the use of both visual and phonetic strategies, $t(23) = 5.61$, $SEM = 1.67$, $d = 1.68$, and visual and direct retrieval strategies, $t(23) = 3.16$, $SEM = 2.32$, $d = 1.08$. No significant differences were found between the use of phonetic and direct retrieval strategies, $t(23) = -1.24$, $SEM = 1.65$, $p = .23$, $d = -.388$. Results of the comparisons in the correction tasks showed significant differences between the use of phonetic and visual strategies, $t(23) = 3.03$, $SEM = 1.77$, $d = .948$, and between the phonetic and direct retrieval strategies, $t(23) = -2.57$, $SEM = 1.90$, $d = -.797$. There were no significant differences found between the use of visual and direct retrieval strategies, $t(23) = .194$, $SEM = 2.58$, $p = .85$, $d = .067$. The results show that visual strategies were used predominately for detection tasks; and that both, visual and direct retrieval strategies were used for correction tasks. Overall, phonological strategies were the least utilized in both tasks. Finally, the interaction between task and strategy suggest that the use of a phonetic strategy is generally reduced in both spelling tasks. Nevertheless, although the use of direct retrieval strategy does not seem to be affected by either task, the results need to be taken with caution. A close look at the data indicates that the use of direct retrieval as a spelling strategy is associated to the phonetic strategy in the detection tasks, but also

to the visual strategy in the correction task; this association might be an indicator of a simultaneous use of strategies to process word features.

The results also showed a marginally significant interaction between format and strategy, $F(2,46) = 2.98$, $MSE = 1.87$, $p = .061$, $\eta^2 = .115$. Paired t -test comparisons with Bonferroni corrections between the strategies used across formats showed no significant differences. As such, there was no significant differences between the use of strategies across print and computer formats regarding the visual, $t(23) = -.402$, $SEM = .518$, $p = .69$, $d = -.038$, or phonetic, $t(23) = -.371$, $SEM = .337$, $p = .71$, $d = -.0378$, or direct retrieval strategies, $t(23) = 1.41$, $SEM = 2.75$, $p = .17$, $d = .125$ (see Table 7). These results indicate that this group of average spellers tends to use the same strategy across formats and at the same rate.

To compare the strategies used in each format, paired t -test comparisons with Bonferroni corrections between the strategies applied in print and computer formats were conducted separately. The results showed only one significant difference in both formats. As such, in print, there was a significant difference between the use of visual and phonetic strategies, $t(23) = 5.24$, $SEM = 1.40$, $d = 1.57$. No significant differences were found between either the phonetic and direct retrieval strategies, $t(23) = -2.32$, $SEM = 1.69$, $p = .03$, $d = -.636$, or the visual and direct retrieval strategies, $t(23) = 1.63$, $SEM = 2.09$, $p = .12$, $d = .541$. Regarding the use of strategies in computer, there was a significant difference between the use of visual and phonetic strategies, $t(23) = 5.88$, $SEM = 1.26$, $d = 1.79$. A marginally significant difference was found between the visual and direct retrieval strategies, $t(23) = 2.52$, $SEM = 1.75$, $p = .019$, $d = .825$.

Table 5

Frequency with which Each Spelling Strategy was Used by Average Spellers

<i>Strategies</i>									
<i>Visual²</i>		<i>Phonetic³</i>		<i>Direct Retrieval⁴</i>		<i>Other (guessing)</i>		<i>Combination</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
21.63	10.48	6.88	6.12	13.79	12.27	.38	.924	4.17	8.04

Note. Data represents the overall average number of strategies used in the study (max cell score = 72).

² Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = 2.24$, $p = .23$. The analysis derived therefore can be considered valid.

³ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = .953$, $p = .59$. The analysis derived therefore can be considered valid.

⁴ Levene's Test of homogeneity variance was significant, $F(4,19) = 9.50$, $p = .02$. Follow-up tests to evaluate pairwise differences among the strategies used by the subjects were conducted.

Table 6

Spelling Strategies Used by Average Spellers in Each Task

<i>Task</i>	<i>Strategies</i>									
	<i>Visual</i>		<i>Phonetic</i>		<i>Direct Retrieval</i>		<i>Other (guessing)</i>		<i>Combination</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection ⁵	12.96	7.04	3.58	3.60	5.63	6.55	.13	.338	1.83	4.61
Correction ⁶	8.67	7.15	3.29	3.63	8.17	7.86	.25	.737	2.33	4.19

Note. Data represents the overall average number of strategies used in each task (max cell score = 36).

⁵ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = 3.93$, $p = .09$. The analysis derived therefore can be considered valid

⁶ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = 3.93$, $p = .09$. The analysis derived therefore can be considered valid

Table 7

Spelling Strategies Used by Average Spellers in Each Format

<i>Format</i>	<i>Strategies</i>									
	<i>Visual</i>		<i>Phonetic</i>		<i>Direct Retrieval</i>		<i>Other (guessing)</i>		<i>Combination</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Print ⁷	10.71	5.77	3.38	3.21	7.29	6.81	.13	.448	2.21	4.51
Computer ⁸	10.92	4.98	3.50	3.12	6.50	5.71	.25	.676	1.96	3.71

Note. Data represents the overall average number of strategies used in each format (max cell score = 36).

⁷ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = 12.56, p = .12$. The analysis derived therefore can be considered valid

⁸ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(4,19) = 12.56, p = .12$. The analysis derived therefore can be considered valid

No significant differences were found between the use of phonetic and direct retrieval strategies, $t(23) = -2.04$, $SEM = 1.47$, $p = .053$, $d = -.651$. These results indicate that the visual strategy was the most used spelling strategy in print and computer formats. Data also indicates that when working on a computer format of a document, the direct retrieval strategy was the second most popular spelling strategy that participants used to guide their spelling.

No main effects were found by task, $F(1,23) = 1.70$, $MSE = 4.72$, $p = .21$, or format, $F(1,23) < 1$, $MSE = .746$, $p = .51$. There was no significant interaction between task and format, $F(1,23) < 1$, $MSE = 2.12$, $p = .63$. No three-way interaction was found by task, format, and strategy, $F(2,46) < 1$, $MSE = 4.063$, $p = .74$. These results indicate that the use of spelling strategies is not affected by task or format.

Overall, results of the application of strategies seem to indicate that average spellers tend to use the same strategy across tasks and formats. Specifically, this group of average spellers predominately applied the visual strategy to detect errors, but applied both visual and direct retrieval strategies to correct misspellings. Differences between the spelling strategies used in each detection or correction task indicate that correction tasks require more than one spelling strategy to access the mental representations in long-term memory. With regard to the spelling strategies employed in each format, again, the visual strategy was the most frequently implemented strategy in both print and computer formats. Nevertheless, the direct retrieval strategy was the second most employed strategy for spelling in computer format. Since the computer tasks required frequent application of more than one strategy this indicates that working in computer represents a task that engages more cognitive resources. Nonetheless, demands imposed by computer tasks seem to activate the use of an 'inexpensive' strategy in terms of cognitive resources

(i.e., employing direct retrieval over other processing strategies such as phonology), that promotes accuracy. Lastly, although the results showed that the use of spelling strategies is not directly affected by task or format, it is indirectly affected by the combined effects of both variables, as the marginal interaction effects between task and strategy, and between format and strategy demonstrate.

These results are consistent with the idea that spellers utilize both direct retrieval (mnemonic strategies or the lexical route) and back-up strategies (in this case mainly a visual strategy, or the sub-lexical route) for spelling of words that possess unclear or partial mental representations, or when the representations are not readily accessible in the speller's lexicon. Furthermore, this group of average spellers tended to adopt a preferred spelling strategy for the spelling tasks. Therefore, this study supports the idea that speller's choice of strategy depends on the individual's accessibility to the particular strategies and their strategic efficiency (Ehri, 2000; Rittle-Johnson & Siegler, 1999).

Correlations between Spelling Performance and Standardized Test Scores

Carrying out a correlational analysis using standardized instrument provides insight into the processes occurring when a speller detects and corrects errors. Exploring whether the detection and correction scores from the experimental data are correlated with spellers' reading and writing abilities opens an opportunity to transfer the findings of this study to the field of applied psychology and education. For example, colleges and universities often use standard test scores to predict student's performance and grant legal accommodations for those students with disabilities (e.g., language disorders). Also, by relating standardized measures such as the WRAT-3 and DSPT to the different types of spelling errors it is possible to uncover crucial data to understand more deeply spelling

sub-processes. Thus, a correlational analysis was run between the standardized subtests scores, the two spelling tasks, and the three types of errors analyzed in this study. Correlational results are presented in two sections, correlations between tasks and standardized test scores, and correlations between error type and standardized tests scores.

Correlations between task and standardized scores. Analyses of the correlations by task showed significant correlations with several subtest scores. As such, the detection tasks significantly correlated to the WRAT reading, $r(22) = .423$, and spelling subtests scores, $r(22) = .648$. Detection tasks were also significantly correlated to the DSPT visual, $r(22) = .606$, and phonetic word recognition subtests, $r(22) = .671$, and spelling visual recognition subtest scores, $r(22) = .702$. The correction tasks were significantly correlated to the WRAT spelling subtest scores, $r(22) = .531$, and also to the DSPT phonetic word recognition, $r(22) = .526$, and to the spelling visual recognition subtest scores, $r(22) = .687$. No significant correlations were found between the correction tasks and the WRAT reading subtest scores, $r(22) = .324$, $p = .12$ or to the DSPT visual word recognition scores, $r(22) = .386$, $p = .063$. These results appear to demonstrate that the detection of misspellings involves careful monitoring of not only the word's spelling, but also associations of the word's other features (i.e., grapheme-phoneme association) and that automatic decoding processes such as those activated while reading are less related to spelling production than to spelling recognition. Generally speaking, tests scores seem to be more related to spelling recognition rather than to spelling production processes.

Correlations between error type and standardized scores. The three types of errors (i.e., phonological, orthographic, morphological) were significantly correlated mainly with three subtests. As such, the WRAT spelling subtest was significantly correlated to the phonological, $r(22) = .427$, orthographic, $r(22) = .549$, and

morphological errors, $r(22) = .475$. Also, the DSPT phonetic word recognition subtest was found to be significantly correlated to the phonological, $r(22) = .502$, orthographic, $r(22) = .509$, and morphological errors, $r(22) = .409$. The DSPT visual spelling recognition subtest was also significantly correlated to the phonological, $r(22) = .473$, orthographic, $r(22) = .656$, and morphological errors, $r(22) = .647$. The phonological errors were also found to be significantly correlated to the WRAT reading scores, $r(22) = .524$. These results indicate that spelling abilities, as measured by standardized tests, are related to the types of errors presented in the task. In particular, phonetic word recognition and visual spelling recognition abilities were related to the three types of spelling errors. In addition, only phonological errors were related to reading abilities as measured by the standardized tests. Results demonstrate that purposeful spelling engages spellers' attention, establishes a relationship with all three types of errors, and facilitates spelling accuracy.

No significant correlations were found between the WRAT reading subtest scores and the orthographic, $r(22) = .349$, $p = .095$, or morphological errors, $r(22) = .182$, $p = .39$. Neither were significant correlations found between the DSPT visual word recognition scores and the phonological, $r(22) = .396$, $p = .055$, or orthographic, $r(22) = .404$, $p > .05$, or morphological errors, $r(22) = .362$, $p = .082$. This lack of correlation between the types of spelling errors and reading and visual word recognition scores indicates that some proofreaders might have been processing the texts' content with high degree of error blindness without noticing the graphemic units and letter sequences in the words.

In general, the correlations indicate a strong relationship between the detection skills of this group of average spellers and the abilities measured by the standardized tests.

The numerous correlational strengths between detection tasks and all subtests scores reflects the activity of the underlying processes involved in detection, such as a multifaceted and detailed monitoring practice. Correlations between correction of misspellings and the two spelling subtests confirm that correction abilities rely heavily on phoneme-grapheme connections and on the ability to differentiate between homophones and homographs.

The types of spelling errors are found to be mainly correlated to three subtests scores: spelling, phonetic word recognition, and visual spelling recognition. Again, these correlations suggest an active engagement of general cognitive processes such as attention and memory in spelling tasks. Furthermore, this active engagement suggests that spellers use phonetic and visual recognition cues to activate different word features that facilitate spelling accuracy (i.e., increase the ability to recognize and re-produce the correct letter sequence for the different types of errors).

Lack of correlations between standardized subtest scores and the accuracy in the correction tasks might indicate that the subtests scores are tapping into different cognitive skills than those involved in the correction tasks. In addition, automatic decoding processes such as those activated while reading, are found to be less related to spelling production than to spelling recognition. Thus, subtests scores are more related to spelling recognition than to spelling production processes regardless of the type of spelling errors.

Discussion

In general, this study suggests that spelling performance depends on the type of errors encountered in the texts. The results indicate that average spellers tend to perform better in spelling of phonological errors than either orthographic or morphological errors. These results are consistent with those of Figueredo and Varnhagen (2004, 2006).

The first set of analyses found that this group of average spellers detected and corrected the same number of errors regardless of format. As previous research states, it appears that detecting an error constitutes the first step of producing the correct spelling of a word (Figueredo & Varnhagen, 2004; Flower et al., 1986). Because the presentation format of the task did not seem to affect the recognition of misspellings, it appears as if the spellers' access to mental representations of words in long-term memory is not affected by format. In the same way, the spellers' retrieval and production rates in each format were consistent, providing evidence for the isomorphic knowledge underlying these two sub-processes. Overall, these results support the findings of Masterson and Apel (2006) in that word recognition seems to access a modality-free lexical representation stored in long-term memory.

General comparisons across detection and correction rates in each error type suggest that the links between those tasks are contingent on other general cognitive processes such as attention and memory (see also Figueredo & Varnhagen, 2004, 2006). The results indicate that, in the detection task, the average spellers of this group were not processing the words in their entirety or decoding their graphemic units but that they were simply looking at the individual letters or characters, and overlooking the whole word meanings. As suggested by Voyer and Boudreau (2003), it is plausible that these average spellers found it easier to recognize the words on the basis of their physical features (lexical processing) rather than on their verbal nature (phonological and semantic processing). Consequently, it is concluded that these average spellers were unable to direct their attention to the appropriate word qualities as necessary for the spelling recognition tasks.

The lack of differences across detection and correction rates in the orthographic errors suggests that average spellers were processing the orthographic errors (e.g., *noticeble*) at a deeper level (i.e., meaning), and differently from the other types of errors (e.g., *peculiarly*, *cooly*). Similarities across detection and correction rates of orthographic errors indicate that these average spellers used their knowledge of grammatical rules for the spelling tasks, thus controlling the interference of other factors (e.g., attention, phonology) during spelling tasks.

Results from the detection tasks show a pattern consistent with Figueredo and Varnhagen's (2004) findings. Average spellers detected more phonological than orthographic and morphological errors. However, error type did not have an impact on the correction tasks. As posited by several researchers (e.g., Figueredo & Varnhagen, 2004, 2006; Flower et al., 1986; Plumb et al., 1994), the detection of misspellings is the key task for spelling. Detecting a misspelling establishes the basis for correcting the error. A difficulty seems to appear when the spellers fail to apply their acquired knowledge in the detection task, as when they miss an error. Consequently, the recognition of misspellings facilitates the spelling production process or correction tasks. Once a misspelling is detected, accessing and retrieving a word's mental representation becomes a relatively easy task despite the error type.

Detection rates indicate that the phonological errors are salient or easily detected, but that the morphological errors are more prone to be missed, easily overlooked and not detected. Correction rates suggest that average spellers are able to access and retrieve the mental representations of the three different types of errors at the same rate. These findings reveal that the quality of mental representations in average spellers have the same degree of clarity or definition in their lexicons, which cannot be modified by the

types of errors found in the texts. The results also support the idea that the cognitive processes underlying spelling processes are somewhat constant in an individual speller (e.g., memory).

Analyses by task and error type support the notion that spelling recognition and production sub-processes share word codes (e.g., phonetic), but that both sub-processes also have specialized functions (e.g., word specific function vs. grapheme-to-phoneme conversion; Coltheart, 2006). Again, it is likely that the general cognitive processes (e.g., attention, memory) create the existing difference between detection and correction tasks. Hence, an inherent processing difference between spelling recognition and production, the two sub-processes involved in spelling (Ehri, 2000, Munakata, 2001), is supported by the findings of this study. Accordingly, spelling recognition and spelling production processes rely on isomorphic knowledge but they are not isomorphic processes.

With regard to the use of spelling strategies, results show that the use of the visual strategy prevails across the average spellers of this group. Data also indicates that these average spellers tend to use the same strategies across task and format. Analysis of the use of strategies in each task showed that average spellers relied mainly on the visual strategy for detection and correction tasks. Direct retrieval was the second most used strategy for correction tasks. The study also showed that the visual strategy was the most used strategy for spelling tasks in print and computer formats. Direct retrieval was the second most used strategy for spelling tasks in computer format.

Consequently, there seems to be a variation in the spelling strategies that average spellers applied to each task and format. It is possible that these differences in the use of strategies somehow reflect the cognitive demands required for the correction tasks, and for the computer format. In both tasks, an engagement of a more efficient strategy

reduced the processing load underlying the retrieval of the words' representations (Sénéchal et al., 2006) and produced accurate spelling. The engagement of the direct retrieval strategy also supports the importance of word knowledge (knowledge hypothesis; Ehri, 2005; Treiman et al., 1993). Conversely, the prevalent application of a visual strategy for spelling tasks can be interpreted as inefficiency in spelling skill; this strategy requires assembling of the orthographic codes by using a converting system (e.g., phoneme-grapheme conversion; Ellis, 1993; Kwong & Varnhagen, 2005), and conversion requires a conscious effort (processing hypothesis; Rittle-Johnson & Siegler, 1999). On the other hand, results show that interactions between task and strategy, and format and strategy are occurring. Therefore, average spellers are using different spelling strategies for detection and correction, and when the task is presented in print or computer formats. These differences may reflect some of the working of the cognitive system, thus merit detailed examination in studies to come.

Overall, these findings are indicators that word recognition abilities relate to stronger and accessible mental representation of words. Spellers who use direct retrieval as the strategy for detecting and correcting misspellings in both formats tended to complete the tasks with high degrees of accuracy in both formats. Congruent with Rittle-Johnson and Siegler's (1999) findings, spellers who possess quality word representations make use of direct retrieval strategies to access the mental representations in their lexicons. These results are consistent with the idea that spellers utilize both direct retrieval (mnemonic strategies or the lexical route) and back-up strategies (in this case mainly a visual strategy, or the sub-lexical route) for the spelling of words that possess unclear or partial mental representations, or for when the representations are not readily accessible in the speller's lexicon (Ehri, 2000; Rittle-Johnson & Siegler, 1999; Treiman

& Barry, 2000). Furthermore, adopting a preferred spelling strategy supports the assumption that strategy choice depends on the speller's accessibility to the particular strategy and on its strategic efficiency (Ehri, 2000; Rittle-Johnson & Siegler, 1999).

Data resulting from correlations between tests' scores, spelling tasks, and spelling errors add evidence to the previous findings. Correlations corroborate the inherent relevance of general cognitive processes such as the attention required for spelling tasks. Correlations also indicate that spellers make use of phonetic and visual abilities regardless of the type of spelling error; accurate spelling activates multiple and multilevel representations of words regardless of the type of misspelling the word contains. In this group of spellers a more automatic decoding process (e.g., priming or automatic reading) was correlated with the phonological and orthographic errors, but not with the morphological errors. The lack of correlation with the morphological errors can be interpreted as an indicator of weak morphological representations of the words. And because the reading subtests measure word knowledge level, the lack of correlations could also be representing spellers' lack of knowledge about the morphological conventions of words, which are different from the grapheme-phoneme correspondences.

Spelling accuracy according to error type did not replicate the correlations between spelling ability and error detection reported by Figueredo and Varnhagen (2004, 2006). Nevertheless, the data revealed correlations between visual spelling recognition scores and the detection of morphological errors. Because Figueredo and Varnhagen (2004, 2006) did not assess the students in this area, they could have missed an important element explaining the student's lack of vigilance while detecting errors. The detection of spelling errors, regardless of the format is generally difficult for spellers mainly because of their reduced attention to the task (Figueredo & Varnhagen, 2006; Longcamp et al.,

2005). An alternate explanation is that by relying mostly on the visual features of a word to discriminate between misspellings and correct word spellings, participants seemingly process strings of letters without integrating other word qualities (phonological and orthographic codes). Consequently, average spellers might have been more prone to fail to detect misspellings. And at least in this case, the correlational data does not provide enough evidence of the mapping across different word qualities required for spelling. As in Voyer and Boudreau (2003), these data highlight the possibility that average spellers processed the words purely as a visual-spatial task rather than on their verbal nature as a unit with meaning. As the literature suggests, in some cases the detection or recognition process can be difficult, not necessarily in terms of spelling abilities but with regard to the attentional resources required on behalf of the proofreader (Figueredo & Varnhagen, 2004, 2006).

An issue that needs to be drawn to attention is the large standard deviations in relation to the use of strategies among the subjects. Typically, such variability could indicate one of several errors in the data. The most common error in research is that the sample used in the study might not be a close representation of the population of spellers at large. Another possible error is that the sample includes a few extreme outliers that cause the dispersion from the mean. Since the statistical analysis showed that the assumptions of equality were not violated, the range of variability encountered in this study appears to be an indicator of either individual differences in the application of strategies for spelling, or usage of spelling strategies as a highly sensitive factor related to task or format. Given that at this moment the data do not allow to make a clear conclusion in this respect, it seems appropriate to conduct a second study using more

stringent criteria to select a highly cohesive group of spellers. Such a study is presented in the next chapter.

In brief, correlational data indicate that spelling of orthographic and morphological errors is not associated to visual word features. In particular, phonological errors seem to elicit more word features than the orthographic or morphological errors as measured by the standardized tests. This finding is congruent with the literature, in that morphologically based words require an individualized storage and complete word retrieval. Literature on the topic states that morphologically based errors are generally distant from the rules of phonology or orthography in the English language. The correction of misspellings thus requires a better set of spelling skills such as good quality of word representations (e.g., clearer phonetic, visual, and morphemic word features) and higher levels of sustained attention for the written reproduction of words. Correlations with typical achievement tests and the detection tasks show that high reading and visual word recognition abilities promote accurate spelling processes.

A significant finding of this study is that format matters. The inherent function of spelling strategies (i.e. to promote cognitive efficiency) disguises the findings of previous studies focused on analyzing spelling efficiency. Previous studies have approached research on reading, writing, and spelling processes by looking at accuracy indexes either across formats or across tasks. Studies reviewed, at least for this study, have overlooked the individual's strategy choice associated with the use of a particular format and the spelling task, and thus missed important information to understand the processes involved in spelling (i.e., a differential strategy use may have masked the effects of format in regards to cognitive efficiency and spelling). Therefore, future studies should examine the

long-observed effects of format and the use of strategies for spelling recognition and production processes.

CHAPTER 3

Effects of Switching Work across Formats in Above Average Spellers

Results of the first study uncovered an important quality in spelling that related to cognitive load and strategic efficiency. The rates of spelling accuracy varied with the type of spelling error, and this pattern remained relatively constant across print and computer formats; conversely, the application of spelling strategies varied with the task and format used. It was suggested that the imperceptibility of the changes in spelling accuracy was due to an adaptive application of strategies. The use of strategies may have resolved any cognitive disturbance caused by task overload or format and promoted cognitive efficiency, thus assisting spellers to attain their accuracy levels. These findings revealed that format matters in spelling.

The previous study opened new sets of questions regarding the effects of working format on spelling efficiency (i.e., increase cognitive load or facilitate spelling tasks). The lines of research reviewed present diverse explanations. One theoretical perspective states that there is an increase in cognitive load when people carry on two or more tasks, such as reading and writing (Berninger et al., 2002; Kreiner, 1996), or written spelling to dictation (Delattre, Bonin, & Barry, 2006). Another theoretical perspective recommends that the use of computers reduces cognitive load and facilitates the fluency of written expression (Day & Edwards, 1996; Higgins & Zvi, 1996; Li & Hamel, 2003). In addition, there are other theoretical perspectives that urgently require research studies addressing individual differences in cognitive and language processes, and task format (e.g., computer vs. paper and pencil) and response formats (e.g., handwritten vs. computer; Lindstrom, 2007), particularly in post-secondary students (Li & Hamel, 2003). Similarly, findings from Study 1 demonstrated that the differences in the number of strategies used

by the spellers in each format, thus reflected an increase in cognitive load despite the fact that the effects of format in spelling accuracy were statistically irrelevant. Consequently, an unavoidable question is whether switching between formats would require additional cognitive resources compared to working in a single format, and whether such effects could be noticeable in skilled spellers.

The lines of research presented discuss the importance of conducting studies that test format presentation sequence in spelling recognition and production. These studies are beneficial for anyone engaged in the area of education, or for those whose work demands efficient writing and precise spelling. Considering the increased implementation of computer use to achieve efficiency and fluency of expression in writing and spelling (including the assistance granted to disabled students), it appears indispensable to experimentally explore the effects of working formats in the cognitive integration of spelling skills.

The research reviewed suggests that the efficiency effects of working format could be noticeable in levels of error blindness, and perhaps in the number of quality mental representations a speller possesses (see Ehri, 2000 regarding the fragility of the representations), particularly if the representations are accessed when such a speller switches to a dominant or most familiar working format. To this effect, theories supporting the superiority of handwriting over typing or keyboarding (Berninger et al., 2006; Cunningham & Stanovich, 1990; Longcamp et al., 2005; Treiman & Bourassa, 2000b) would predict higher rates of spelling accuracy when the detection task is done in a printed format. Conversely, theoretical postulates supporting typing or keyboarding as a way to increase availability of cognitive resources (Berninger et al., 1998; Longcamp et al., 2005) would predict a higher number of corrected errors when the task is completed

in a computer format. Moreover, postulates supporting the adaptive use of spelling strategies (Rittle-Johnson & Siegler, 1999) would hypothesize individual variation on the selected spelling strategies associated with switching work between formats.

A precise knowledge of the cognitive consequences of different types of writing (i.e., handwriting vs. keyboarding) may lead cognitive scientists to a better understanding of the trade-offs involved in various cognitive activities such as spelling, supportive processes, and the quality of the mental representation of a word. The study of spelling would benefit from more research in support of the theoretical contention that spelling sub-processes are indeed different despite their shared grounds (i.e., isomorphic knowledge and analogous cognitive processes). The two sub-processes are thought to impact, among others, the note-taking on comprehension (Bourdin & Fayol, 2000) and/or how reading is used in the revision of writing (Ehri, 2000). If spelling recognition and spelling production are connected because they depend on identical mental representations and cognitive processes, one should expect them to be quite comparable, thus the development of one should parallel the other closely. And, to acknowledge the separability of those two sub-processes, researchers need to provide solid evidence to support a developmental model of spelling recognition and spelling production relations. Such theoretical work is necessary to provide fair access to computers for those with disabilities as well as further instructional practice and research in the areas of written and spoken language.

Study 2

Study 1 demonstrated that spelling ability varied with error type. However, it is likely that the inability to detect and then correct errors in textual material may reflect transfer effects from the format presentation sequence in the spelling tasks. To re-

examine this issue, the present study was designed to incorporate the variable of switching work between formats in above average spellers. By examining the impact of the shifting sequence on the sub-processes of spelling this study could assist in resolving the debate surrounding the role of working format and cognitive load in spelling processes.

As the literature suggests (Berninger et al., 2006; Cunningham & Stanovich, 1990; Longcamp et al., 2005) switching working formats could produce spelling differences related to the direction of the shift, from print to computer, or from computer to print. Thus, the direction of the shift could increase the cognitive load or produce other efficiency effects. In this way, the present study aimed to identify any processing differences associated with switching work between formats. Study 2 examined any variation in spelling skills related to the three types of spelling errors, and the strategies used by above average spellers when switching work between formats. The study was based on the assumptions that any significant differences in above average spellers' accuracy, and an adaptive use of strategies would be associated with the format shifting sequence. Theoretically, significant differences in spelling accuracy would indicate a superiority of one of those formats in regards to spelling. In addition, large variability in the application of spelling strategies in above average spellers would support the individual preferences theory (Rittle-Johnson & Siegler, 1999). To verify the previous assumptions, the present study incorporated the analysis of the two different shifting sequences in the experimental spelling tasks (i.e., printing to keyboarding and keyboarding to printing).

The main purpose of Study 2 was to examine the effects of switching formats on the accuracy rate for detection and correction of phonological, orthographic, or

morphological errors, and the application of spelling strategies in each task. The study also intended to determine the valence (positive and/or negative) of the possible transfer effects. To achieve these goals, Study 2 incorporated the variable of format shifting sequence to the research design used in the previous study. To also increase the validity of the data from the experimental tasks, the sources of variability were reduced in the experiment by lessening the masking effects caused by individual differences.

Considering the above reasons, participants in this study were chosen with a more stringent selection criteria and assigned to one of four counterbalanced groups based on the two shifting sequences for each task (see Study 1). The tasks, assessment, and formats were identical to those in Study 1. It was hypothesized that: 1) differences in spelling accuracy (detection or correction) associated with the direction of the shift (from printing to keyboarding or from keyboarding to printing) would indicate superiority of the format in spelling skills; 2) detection and correction rates would differ in relation to error type and task; 3) use of spelling strategies would vary as a function of task and shifting sequence; and 4) scores from the standardized spelling tests would have a linear relationship to detection and correction rates.

The present research explores the effects of cognitive load associated with the common practice of shifting work between formats. The originality of the study resides in the analysis of the effects of changing working formats on the cognitive activity involved in the sub-processes of spelling in a group of above average spellers. Findings from this research would expose the roles that attention and memory play in accurate spelling across writing formats. By adding a research study that integrates the variables of error monitoring and quality of mental representations into the functional models for reading, one advances the knowledge into the broad area of language processing. Finally, the

analysis of error blindness and the quality of mental representations could be applied to the design of more efficient programs to improve literacy and academic skills. Findings of this study would also support corrective actions and regulations allowing students to compensate for spelling deficits and/or to increase their fluency in written expression. The results of this study will also provide the basis to further explore spelling processes across types of spellers.

Method

Participants

Forty undergraduate students from the University of Northern British Columbia who had not taken part in the first study participated in the present study for bonus course credit. All participants were native English speakers and reported normal or corrected-to-normal vision. The participants' age average was 22 years, 1 month ($SD = 7$ years, 6 months). Participants rated their writing skills as moderate (spelling skill $M = 5.15$, $SD = .22$; proofreading skill $M = 5.35$, $SD = .25$). In general, their reading scores ($M = 111.85$, $SD = 7.42$) were within the high average range, and their spelling scores ($M = 109.38$, $SD = 6.82$) were in the upper limits of the average range, as measured by the WRAT-3 (Wilkinson, 1993). Subjects visual spelling recognition scores ($M = 110.15$, $SD = 7.04$) were in the high average range, and their visual ($M = 98.92$, $SD = 4.86$) and phonetic word recognition scores ($M = 106.28$, $SD = 4.98$) were within the average range, as measured by the DSPT (Arena, 1982).

Apparatus and Materials

The same materials described in Study 1 were used.

Procedure

Experimental procedures were identical to those described in Study 1.

Scoring

Scoring principles used in the previous study were applied in this experiment. Rates for general detection and correction tasks, by error type, and spelling strategies applied in each task and format were obtained.

Research design

As in Study 1, the primary manipulations were the presentation format (print vs. computer) for each task (detection and correction) in a Latin Square research design. Similarly, participants were randomly assigned to one of four conditions created by alternating the format presentation sequence of the essays in each task. The order and sequence of task presentation were counterbalanced across groups. Analyses of spelling performance (accuracy rate) across groups by error type, and the spelling strategies used by each group in each task were conducted separately. Therefore, a four-way mixed factorial design was used for this experiment, in which the groups' format presentation sequence of the spelling tasks was the between factors variable. The two statistical analyses of this part of the study were a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) x 2 (Sequence: print-first, computer-first), and a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Strategy: visual, phonetic, direct retrieval) x 2 (Sequence: print-first, computer-first) mixed factorial designs.

Results

The results of this study are presented in several sections. The first section reports data on spelling performance in detection and correction tasks as a function of format,

error type, and shifting sequence, including the analysis of error blindness and quality of mental representations. The second section examines the spelling strategies used in each task, format, and shifting sequence. The third section presents an analysis of the correlations between standardized tests scores, and both the spelling accuracy rate and the types of errors in each task. Unless noted, all effects were statistically significant at the $p < .05$.

Spelling Performance as a Function of Shifting Sequence in Each Task.

To compare the spelling detection and correction rates associated with the shifting sequence, a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) x 2 (Sequence: print-first, computer-first) four-way mixed factorial design was conducted. To identify any significant differences in the findings, paired t -test comparisons with Bonferroni corrections were used (adjusted $\alpha = .0167$) to account for falsely significant results.

The mixed factorial ANOVA showed a main effect of error type, $F(2,72) = 72.89$, $MSE = 1.65$, $\eta^2 = .669$ (see Table 8). Paired t -test comparisons with Bonferroni corrections between the different types of errors showed significant differences between all three types of errors. As such, there were significant differences between phonological and orthographic, $t(39) = 4.73$, $SEM = .602$, $d = .948$, and morphological errors, $t(39) = 12.29$, $SEM = .560$, $d = 2.17$, and also between orthographic and morphological errors, $t(39) = 7.05$, $SEM = .571$, $d = 1.09$. These results indicate that quality and availability of mental representations of words differ according to error type. Skilled spellers were more accurate with phonological errors than with either orthographic or morphological errors, and they were also more accurate with orthographic than morphological errors.

Table 8

Above Average Spellers' Accuracy According to Error Type

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
20.05	2.32	17.20	3.57	13.18	3.82

Also, a significant interaction effect between task and error type was found, $F(2, 72) = 56.07$, $MSE = .981$, $\eta^2 = .609$ (see Table 9). Paired t -test comparisons with Bonferroni corrections across detection and correction tasks in each error type showed significant differences across detection and correction of phonological errors, $t(39) = 4.69$, $SEM = .288$, $d = 0.916$, with higher detection than correction rates. There was also a significant difference across detection and correction of morphological errors, $t(39) = -5.14$, $SEM = .423$, $d = -.934$, however, in this case, the correction rates were higher than the detection rates. There was no significant difference across detection and correction of orthographic errors, $t(39) = 1.29$, $SEM = .386$, $p = .20$, $d = .231$. As in Study 1, these results confirm that detection and correction skills are subject to greater variability when phonological and morphological errors are presented in the texts; conversely, detection and correction skills are more equivalent when texts contain orthographic errors.

For each detection and correction task, paired t -test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. In the detection tasks, the results showed significant differences between detection of phonological and orthographic, $t(39) = 5.94$, $SEM = .311$, $d = 1.29$,

and morphological errors, $t(39) = 12.35$, $SEM = .421$, $d = 2.93$; there were also significant differences between orthographic and morphological errors, $t(39) = 9.67$, $SEM = .346$, $d = 1.64$. In the correction tasks, the results showed significant differences between correction of phonological and orthographic, $t(39) = 2.44$, $SEM = .410$, $p = .0167$, $d = .456$, and morphological errors, $t(39) = 4.69$, $SEM = .357$, $d = .788$ (see Table 9); however, no significant differences were found between correction of orthographic and morphological errors, $t(39) = 1.61$, $SEM = .420$, $p = .116$, $d = .275$. As in Study 1, these results demonstrate a difference between detection and correction abilities related to the types of misspellings encountered in texts. That is, the type of spelling error impacted mainly detection skills, and less so, correction skills. Data shows that the ability to detect misspellings fluctuated with the type of spelling errors; the ability to correct misspellings also oscillated with phonological errors, but was less affected by orthographic and morphological errors. Consequently, above-average spellers were more susceptible to error blindness in the presence of morphological errors; however, they were able to access and retrieve morphological representations with the same ease as the orthographic representations in the correction tasks. Nonetheless, their detection and correction abilities appear to be highly sensitive to phonological errors, which were the most prominent detected and corrected errors.

The results also revealed a marginally significant four-way interaction effect between task, error type, format, and shifting sequence, $F(2, 72) = 2.69$, $MSE = .608$, $p < .075$, $\eta^2 = .069$ (see Table 10). The interaction needed to be analyzed in four ways, by sequence, format, task, and error type. As the main variables of interest were format and shifting sequence, the interaction by error type were eliminated from the analysis, thus only one analysis by task is being presented. Three-way ANOVA analyses were

conducted to investigate each interaction effect. The significant findings were followed by paired *t*-test comparisons with Bonferroni corrections (adjusted $\alpha = .0167$).

Table 9

Above Average Spellers' Accuracy by Error Type in Each Task

Task	Error Type					
	Phonological		Orthographic		Morphological	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	10.70	.992	8.85	1.76	5.50	2.30
Correction	9.35	1.83	8.35	2.50	7.68	2.37

Note: Data represents the average number of errors detected and corrected in the two formats (max. cell score = 12).

Shifting sequence. To compare the spelling accuracy levels in each shifting sequence, a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) three-way ANOVA analysis was conducted separately for each sequence. The shifting sequence print-first showed a main effect of error type, $F(2, 38) = 51.91$, $MSE = 1.32$, $\eta^2 = .732$ (see Table 11). Paired *t*-test comparisons with Bonferroni corrections across the different types of errors showed significant differences among all three types of errors. As such there were significant differences between phonological and orthographic, $t(19) = 3.73$, $SEM = .671$, $d = .903$,

Table 10

Above Average Spellers' Accuracy as a Function of Shifting Sequence, Error type, and Format in Each Task

<i>Error Type</i>	<i>Shifting Sequence</i>	<i>Task and Format</i>							
		<i>Detection</i>				<i>Correction</i>			
		<i>Print</i>		<i>Computer</i>		<i>Print</i>		<i>Computer</i>	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Phonological	Print-First	5.35	.587	5.40	.681	4.75	.910	4.45	1.24
	Computer-First	5.70	.571	5.50	.607	4.60	.940	4.60	.940
Orthographic	Print-First	4.65	.933	4.40	1.14	4.15	1.14	4.20	1.40
	Computer-First	4.45	1.09	4.45	1.19	4.20	1.51	4.05	1.32
Morphological	Print-First	2.45	1.36	2.40	1.09	3.70	1.26	4.10	1.65
	Computer-First	2.70	1.42	3.00	1.26	4.25	1.29	3.95	1.57

and morphological errors, $t(19) = 11.31$, $SEM = .645$, $d = 2.57$, and also between orthographic and morphological errors, $t(19) = 5.66$, $SEM = .848$, $d = 1.55$. These results indicate that the shifting sequence print-first affected the availability of the mental representations as it varied with the type of spelling error. This is, above average spellers were more accurate with phonological errors than either orthographic or morphological errors, and were also more accurate with orthographic than morphological errors when shifting work from print to computer.

Table 11

Above Average Spellers' Accuracy by Error Type with the Shifting Sequence from Print to Computer

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
19.75	2.48	17.25	3.02	12.45	3.15

The shifting sequence print-first also showed a significant interaction effect between task and error type, $F(2, 38) = 28.57$, $MSE = 1.00$, $\eta^2 = .601$ (see Table 12). Comparisons across tasks revealed significant differences between detection and correction of phonological errors $t(19) = 4.13$, $SEM = .399$, $d = 1.07$, with higher detection than correction rates. There were also significant differences between detection and correction of morphological errors, $t(19) = -4.81$, $SEM = .531$, $d = -1.29$, with higher correction than detection rates. There were no significant differences between detection and correction of orthographic errors $t(19) = .597$, $SEM = .586$, $p = .56$, $d = .175$. The

results indicate that the shifting sequence print-first effected the above average spellers' ability to detect and correct phonological and morphological errors; nonetheless their ability to detect and correct orthographic errors was not affected when shifting work from print to computer.

Table 12

Above Average Spellers' Accuracy by Task and Error Type with the Shifting Sequence from Print to Computer

<i>Task</i>	<i>Error Type</i>					
	<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	10.70	.979	8.80	1.64	4.95	2.01
Correction	9.05	1.93	8.45	2.31	7.50	1.93

Note: Data represents the average number of errors detected and corrected in the two formats (max. cell score = 12).

For each detection and correction task, paired *t*-test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. In the detection tasks, the results showed significant differences between detection of phonological and orthographic, $t(19) = 5.47$, $SEM = .347$, $d = 1.40$, and morphological errors, $t(19) = 11.97$, $SEM = .481$, $d = 3.63$; there were also significant differences between orthographic and morphological errors, $t(19) = 7.34$, $SEM = .525$, $d = 2.09$. In the correction tasks, the results showed significant differences between

correction of phonological and morphological errors, $t(19) = 3.54$, $SEM = .438$, $d = .802$; no significant differences were found between correction of orthographic and phonological, $t(19) = 1.28$, $SEM = .467$, $p = .21$, $d = .282$, and morphological errors, $t(19) = 1.67$, $SEM = .569$, $p = .11$, $d = .446$. These results show that the shifting sequence print-first affected the detection ability of above average spellers according to the type of spelling error; however, their correction ability was impacted to a lesser degree by the type of spelling error (i.e., phonological and orthographic). Consequently, shifting work from print to computer affected the above average spellers' susceptibility to error blindness according to the type of error encountered in the text. Furthermore, the spellers' accessibility to the mental representation of words appeared to be anchored by the correction of orthographic errors as indicated by the similar correction rates between these errors and the phonological and morphological errors.

No main effects associated with the shifting sequence print-first were found by task, $F(1,19) < 1$, $MSE = 3.45$, $p = .63$, or format, $F(1,19) < 1$, $MSE = .30$, $p = .81$. There was no interaction between task and format, $F(1,19) < 1$, $MSE = .460$, $p = .46$, or between error type and format, $F(2,38) = 1.07$, $MSE = .519$, $p = .354$. There was no three-way interaction between task, error type, and format, $F(2,38) = 1.20$, $MSE = .755$, $p = .31$.

Analysis of the shifting sequence computer-first showed a main effect of error type, $F(2, 38) = 26.57$, $MSE = 1.99$, $\eta^2 = .583$ (see Table 13). Paired t -test comparisons with Bonferroni corrections across the different types of errors showed significant differences between all three types of errors. As such, there were significant differences between phonological and orthographic, $t(19) = 3.16$, $SEM = 1.01$, $d = .972$, and morphological errors, $t(19) = 6.99$, $SEM = .922$, $d = 1.88$, and also between orthographic and morphological errors, $t(19) = 4.35$, $SEM = .746$, $d = .767$. These results indicate that

shifting work from computer to print impacted the accessibility of a word's mental representation in relation to the type of spelling error. That is, above average spellers were more accurate with phonological errors than either orthographic or morphological errors, and were also more accurate with orthographic than morphological errors.

Table 13

Above Average Spellers' Accuracy by Error Type with the Shifting Sequence from Computer to Print

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
20.35	2.16	17.15	4.12	13.90	4.35

The shifting sequence computer-first also showed a significant interaction effect between task and error type, $F(2, 38) = 27.25$, $MSE = .978$, $\eta^2 = .589$ (see Table 14). Comparisons across tasks revealed significant differences between detection and correction of morphological errors, $t(19) = -2.71$, $SEM = .663$, $d = -.683$, with higher correction than detection rates. There were no significant differences between detection and correction of phonological $t(19) = 2.54$, $SEM = .413$, $p = .02$ $d = .739$, or orthographic errors $t(19) = 1.26$, $SEM = .514$, $p = .22$, $d = .275$. The results indicate that with the shifting sequence computer-first, above average spellers showed different ability to detect and correct morphological errors; nonetheless their ability to detect and correct phonological and orthographic errors was not affected when they shifted work from computer to print.

Table 14

Above Average Speller's Accuracy by Task and Error Type with the Shifting Sequence from Computer to Print

<i>Task</i>	<i>Error Type</i>					
	<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	10.70	1.03	8.90	1.92	6.05	2.48
Correction	9.65	1.73	8.25	2.73	7.85	2.77

Note: Data represents the average number of errors detected and corrected in the two formats (max. cell score = 12).

For each detection and correction task, paired *t*-test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. In the detection tasks, the results showed significant differences between detection of phonological and orthographic, $t(19) = 3.42$, $SEM = .526$, $d = 1.17$, and morphological errors, $t(19) = 6.82$, $SEM = .682$, $d = 2.44$; there were also significant differences between orthographic and morphological errors, $t(19) = 6.52$, $SEM = .437$, $d = 1.29$. In the correction tasks, the results showed significant differences between correction of phonological and morphological errors, $t(19) = 3.14$, $SEM = .574$, $d = .778$; no significant differences were found between correction of orthographic and phonological, $t(19) = 2.076$, $SEM = .674$, $p = .05$, $d = .613$, and morphological errors, $t(19) = .639$, $SEM = .626$, $p = .53$, $d = .145$. These results show that the shifting sequence

computer-first produced a degree of variability in the detection ability of above average spellers according to the type of spelling error. Nonetheless, their correction ability was less affected in the presence of phonological and morphological errors given the proximity in the correction rates of both, and the orthographic errors. Consequently, shifting work from computer to print affected the above average speller's susceptibility to error blindness according to the type of spelling error. The ability to access and retrieve the words' mental representations of above average spellers appeared to be linked to the correction tasks, and to the orthographic rules as indicated by the similarity in the correction rates between the orthographic errors and the other two types of errors.

No main effects associated with the shifting sequence computer-first were found by task, $F(1,19) < 1$, $MSE = 1.88$, $p = .89$, or format, $F(1,19) < 1$, $MSE = .625$, $p = .57$. No interaction effects were found between task and format, $F(1,19) = 1.32$, $MSE = .381$, $p = .26$, or between error type and format, $F(2,38) < 1$, $MSE = .475$, $p = .89$, or between task, error type, and format, $F(2,38) = 1.71$, $MSE = .471$, $p = .195$.

These results indicate that the shifting sequence did not affect detection and correction rates of orthographic errors in above average spellers. Detection and correction of phonological and morphological errors were, however, affected by the shifting sequence. The direction of the effect in the morphological errors (i.e., higher correction than detection rates) suggests an increase in saliency and accessibility of mental representations in the correction tasks.

Format. To compare the spelling accuracy levels in each format, a 2 (Sequence: print-first, computer-first) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) three-way ANOVA was conducted separately for each format. The printed format showed a main effect of error type $F(2,76) = 69.92$, $MSE =$

1.06, $\eta^2 = .627$ (see Table 15). Paired t -test comparisons with Bonferroni corrections between the different types of errors showed significant differences between all three types of errors. As such, there were significant differences between phonological and orthographic, $t(39) = 4.34$, $SEM = .334$, $d = 1.24$, and morphological errors, $t(39) = 9.93$, $SEM = .345$, $d = 1.93$, and also between orthographic and morphological errors, $t(39) = 5.27$, $SEM = .375$, $d = 1.32$. These results indicate that accuracy rates differ between the phonological, orthographic, and morphological errors in the printed format. That is, when conducting spelling tasks in a printed format, above average spellers achieved higher levels of accuracy for phonological than either orthographic or morphological errors, and were also more accurate with orthographic than morphological errors.

Table 15

Above Average Spellers' Accuracy in the Printed Format According to Error Type

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
10.05	1.11	8.60	2.05	6.63	2.25

The printed format also showed a significant interaction effect between task and error type, $F(2, 76) = 36.19$, $MSE = .777$, $\eta^2 = .488$ (see Table 16). Comparisons across tasks revealed significant differences between detection and correction of phonological errors $t(39) = 4.89$, $SEM = .174$, $d = 1.10$, with higher detection than correction rates. There were also significant differences between detection and correction of morphological errors, $t(39) = -5.49$, $SEM = .255$, $d = -1.05$, with higher correction than

detection rates. There were no significant differences between detection and correction of orthographic errors $t(39) = 1.80$, $SEM = .208$, $p = .08$, $d = .315$. The results indicate that above average spellers showed different ability to detect and correct phonological and morphological errors in the printed format; nonetheless their ability to detect and correct orthographic errors was not affected in the printed format.

Table 16

Above Average Spellers' Accuracy in the Printed Format by Task and Error Type

<i>Task</i>	<i>Error Type</i>					
	<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	5.53	.60	4.55	1.01	2.58	1.37
Correction	4.68	.92	4.18	1.32	3.98	1.29

For each detection and correction task, paired t -test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. In the detection tasks, the results showed significant differences between detection of phonological and orthographic, $t(39) = 5.62$, $SEM = .174$, $p < .0167$, $d = 1.18$, and morphological errors, $t(39) = 12.57$, $SEM = .235$, $d = 2.78$; there were also significant differences between orthographic and morphological errors, $t(39) = 9.26$, $SEM = .213$, $d = 1.63$. In the correction tasks, the results showed significant differences between correction of phonological and morphological errors, $t(39) = 3.68$, $SEM = .190$, $d = .625$; no significant differences were found between correction of orthographic and

phonological, $t(39) = 2.30$, $SEM = .218$, $p = .03$, $d = .44$, and morphological errors, $t(39) = .805$, $SEM = .249$, $p = .43$, $d = .153$. These results show that the detection ability of above average spellers in the printed format (proneness to error blindness) varied according to the type of spelling error. The correction ability of above average spellers in the printed format (accessibility and retrieval of the words' mental representations), was enhanced in the case of phonological and morphological errors, as their accuracy rates of those two types of errors were similar to that of orthographic errors.

The three-way ANOVA analysis found no main effects associated with the printed format by task, $F(1,38) < 1$, $MSE = 1.24$, $p = .69$, or sequence, $F(1,38) < 1$, $MSE = 2.67$, $p = .51$. No interaction effects were found between task and sequence, $F(1,38) < 1$, $MSE = 1.24$, $p = .95$, or between error type and sequence, $F(2,76) = 1.094$, $MSE = 1.05$, $p = .34$, or by task, error type, and sequence, $F(2,76) = 1.29$, $MSE = .777$, $p = .28$.

The computer format showed a main effect of error type $F(2,76) = 48.37$, $MSE = 1.09$, $\eta^2 = .560$ (see Table 17). Paired t -test comparisons with Bonferroni corrections between the different types of errors showed significant differences between all three types of errors. As such, there were significant differences between phonological and orthographic, $t(39) = 4.22$, $SEM = .332$, $d = .858$, and morphological errors, $t(39) = 11.77$, $SEM = .293$, $d = 2.08$, and also between orthographic and morphological errors, $t(39) = 7.27$, $SEM = .282$, $d = 1.13$. The results indicate that there are spelling accuracy differences between the phonological, orthographic, and morphological errors in the computer format. That is, when conducting spelling tasks in a computer format, above average spellers achieved higher levels of accuracy for phonological than either orthographic or morphological errors, and were also more accurate with orthographic than morphological errors.

Table 17

Above Average Spellers' Accuracy in the Computer Format According to Error Type

<i>Error Type</i>					
<i>Phonological</i>		<i>Orthographic</i>		<i>Morphological</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
10.00	1.45	8.60	1.79	6.55	1.84

The computer format also showed a significant interaction effect between task and error type, $F(2, 76) = 32.71$, $MSE = .825$, $\eta^2 = .463$ (see Table 18). Comparisons across tasks revealed significant differences between detection and correction of phonological errors $t(39) = 5.23$, $SEM = .177$, $d = 1.03$, with higher detection than correction rates. There were also significant differences between detection and correction of morphological errors, $t(39) = -4.93$, $SEM = .269$, $d = -1.03$, with higher correction than detection rates. There were no significant differences between detection and correction of orthographic errors $t(39) = 1.13$, $SEM = .266$, $p = .27$, $d = .239$. The results indicate that above average spellers have different ability to detect and correct phonological and morphological errors in the computer format; nonetheless their ability to detect and correct orthographic errors is not affected by the task. The results indicate that, in the computer format, the saliency and accessibility of words' mental representations would be affected for the phonological and morphological errors, while the saliency and accessibility of the orthographic errors would remain relatively constant across tasks.

For each detection and correction task, paired t -test comparisons with Bonferroni corrections were conducted separately for the rate that the different types of errors were

detected or corrected. In the detection tasks, the results showed significant differences between detection of phonological and orthographic, $t(39) = 5.10$, $SEM = .201$, $d = 1.09$, and morphological errors, $t(39) = 12.84$, $SEM = .214$, $d = 2.85$; there were also significant differences between orthographic and morphological errors, $t(39) = 8.14$, $SEM = .212$, $d = 1.47$. In the correction tasks, the results showed no significant differences between correction of phonological and orthographic, $t(39) = 1.69$, $SEM = .237$, $p = .10$, $d = .327$, or morphological errors, $t(39) = 2.24$, $SEM = .224$, $p = .03$, $d = .404$; neither significant differences were found between correction of orthographic and morphological errors, $t(39) = .454$, $SEM = .220$, $p = .65$, $d = .073$. These results show that the detection ability of above average spellers in the computer format fluctuated with the type of spelling error; nonetheless, the type of spelling error did not impact their correction ability.

Table 18

Above Average Spellers' Accuracy in the Computer Format by Task and Error Type

Task	Error Type					
	Phonological		Orthographic		Morphological	
	M	SD	M	SD	M	SD
Detection	5.45	.64	4.43	1.15	2.70	1.20
Correction	4.53	1.09	4.13	1.34	4.03	1.37

The results indicated that there was an interaction between task and error type regardless of the format in which the task was presented. The correction task in a computer format seemed to neutralize the effects of error type by balancing or equalizing

the rate in which the three types of errors were corrected in both formats, and this result was particularly noticeable in the computer format. In general, mental representations of words appeared to be more readily accessible in the computer format regardless of the type of spelling error encountered in texts. This finding seems to be explained by an orthographic anchor provided while accessing and retrieving the word's mental representations in the correction tasks.

The three-way ANOVA analysis showed no main effects associated with the computer format by task, $F(1,38) < 1$, $MSE = 1.85$, $p = .85$, or sequence, $F(1,38) < 1$, $MSE = 2.44$, $p = .62$. No interaction effects were found between task and sequence, $F(1,38) < 1$, $MSE = 1.85$, $p = .40$, or between error type and sequence, $F(2,76) < 1$, $MSE = 1.10$, $p = .70$, or by task, error type, and sequence, $F(2,76) = 1.015$, $MSE = .825$, $p = .37$.

The mixed factorial ANOVA showed no main effects by format, $F(1,36) < 1$, $MSE = .477$, $p = .56$, or task, $F(1,36) < 1$, $MSE = 2.76$, $p = .76$, or sequence, $F(1,36) < 1$, $MSE = 4.89$, $p = .55$. No interaction effects were found between task and sequence, $F(1,36) < 1$, $MSE = .276$, $p = .64$, or between format and sequence, $F(1,36) < 1$, $MSE = .447$, $p = .74$, or between error and sequence, $F(2,72) < 1$, $MSE = 1.65$, $p = .43$, or between task and format, $F(1,36) < 1$, $MSE = .436$, $p = .84$, or between error and format, $F(2,72) < 1$, $MSE = .506$, $p = .39$. Neither three-way interaction effects were significant by task, format, and sequence, $F(1,36) = 1.72$, $MSE = .436$, $p = .20$, or by error, task, and sequence, $F(2,72) < 1$, $MSE = .981$, $p = .81$, or by error, format, and sequence, $F(2,72) < 1$, $MSE = .506$, $p = .77$, or between error, task and format, $F(2,72) < 1$, $MSE = .608$, $p = .88$. These results showed that the shifting sequence, as a single factor, did not interact with task, format, or error type in a way that could have impacted the spelling skills of this group of above average spellers. Nevertheless, as the shifting sequence showed a

marginally significant four-way interaction effect with all the above mentioned factors, its relevance for spelling skills should not be underestimated.

Overall, the analyses presented in this section show that spelling accuracy varies according to error type and task. Above average spellers were more sensitive to phonological than to orthographic and morphological errors, particularly in detection tasks. However, the spellers' sensitivity for morphological errors increased with the correction tasks. Furthermore, spelling skills were found to be more consistent across tasks in the presence of orthographic errors. Results also show that the shifting sequence impacted the above average spellers' accuracy in relation to the type of spelling error and task, particularly for the correction of phonological and morphological errors in the computer format. The computer format seemed to neutralize the effects of error type by balancing or equalizing the rates in which the three types of errors were corrected. Mental representations of words seemed to be more readily accessible in the computer format regardless of the type of spelling error encountered in texts.

Strategies Used Across Tasks, Formats and Shifting Sequence

To measure the spelling strategies used by the participants in each task and format, associated with the shifting sequence, 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Strategy: visual, phonetic, direct retrieval) x 2 (Sequence: print-first, computer-first) four-way mixed factorial design was conducted. A follow up multivariate ANOVA was also used to identify any significant differences in the findings. To determine significant differences in the use of strategies associated with the presentation sequence, paired *t*-test comparisons with Bonferroni corrections were used (adjusted $\alpha = .0167$).

The mixed factorial ANOVA showed a main effect of the use of strategies, $F(2,72) = 21.55$, $MSE = 29.61$, $\eta^2 = .375$ (see Table 19). Paired t -test comparisons with Bonferroni corrections between the strategies used for spelling showed significant differences between the use of phonetic and visual, $t(39) = 6.59$, $SEM = 2.09$, $d = 1.57$, and direct retrieval strategies, $t(39) = -6.03$, $SEM = 2.29$, $d = -1.44$. No significant differences were found between the use of visual and direct retrieval strategies, $t(39) = .009$, $SEM = 2.94$, $p = .99$, $d = .002$. These results indicated that participants relied on visual and direct retrieval strategies to guide their spelling. In addition, the phonetic strategy was the least used strategy for spelling tasks. These findings are congruent with theories of spelling skill because the use of phonetic strategies is replaced by more advanced and efficient strategies as a person becomes a more proficient speller.

Table 19

Strategies Used by Above Average Spellers

<i>Strategies</i>					
<i>Visual</i> ⁹		<i>Phonetic</i> ¹⁰		<i>Direct Retrieval</i> ¹¹	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
17.68	11.11	3.85	5.51	17.70	12.42

Note: Data represents the overall average number of strategies used in the study (max. cell score = 72).

⁹ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(11,28) = 1.71$, $p = .18$.

¹⁰ Levene's Test of homogeneity of variance was significant, $F(11,28) = 5.39$, $p = .003$. Follow-up tests to evaluate pairwise differences among the strategies used by the subjects were conducted.

¹¹ Levene's Test of homogeneity showed that the assumption of equality of variance among the strategies used by the subjects was not violated, $F(11,28) = 2.08$, $p = .10$.

The mixed factorial analysis also showed a significant two-way interaction effect of task by strategy, $F(2,72) = 23.22$, $MSE = 9.53$, $\eta^2 = .392$ (see Table 20). To compare the use of strategies across detection and correction tasks paired t -test comparisons with Bonferroni corrections were conducted. The results showed significant differences in the use of strategies across tasks in the case of visual, $t(39) = 4.17$, $SEM = 1.12$, $d = .709$, and direct retrieval strategies, $t(39) = -4.74$, $SEM = .980$, $d = .667$; however, no significant differences were found in the use of the phonetic strategy across tasks, $t(39) = -1.60$, $SEM = .437$, $p = .12$, $d = -.226$. The differences in strategies used across tasks revealed that the visual strategy was the most applied strategy for the detection tasks, meanwhile the direct retrieval strategy was the most applied strategy for the correction tasks. And both strategies were applied at inverse rates (see Table 20), indicating a cross-over interaction. Nonetheless, the differences in the means of each strategy (i.e., visual, direct retrieval) for detection and correction task were unequal, so they are essentially and significantly different. Phonological strategies were not applied often by this group of above average spellers for either spelling task.

Another way to assess the significant interaction between strategy and task is to compare the strategies applied in each task. To this effect, paired t -test comparisons with Bonferroni corrections for each task were conducted separately. For the detection tasks, results showed significant differences between the use of visual and phonetic, $t(39) = 8.32$, $SEM = 1.15$, $d = 1.91$, and direct retrieval strategies, $t(39) = 2.68$, $SEM = 1.74$, $d = .694$; there were also significant differences between the use of phonetic and direct retrieval strategies, $t(39) = -4.35$, $SEM = 1.13$, $d = -.078$. For the correction tasks, results showed significant differences between the use of visual and phonetic, $t(39) = 3.29$, $SEM = 1.28$, $d = .803$, and direct retrieval strategies, $t(39) = -2.65$, $SEM = 1.75$, $d = -.683$; there

Table 20

Spelling Strategies Used by Above Average Spellers in Each Task

<i>Task</i>	<i>Strategies</i>					
	<i>Visual</i>		<i>Phonetic</i>		<i>Direct Retrieval</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection ¹²	11.18	6.81	1.58	2.10	6.50	6.67
Correction ¹³	6.50	6.37	2.28	3.82	11.15	7.21

Note: Data represents the overall average number of strategies used in each task (max. cell score = 36).

were also significant differences between phonetic and direct retrieval strategies, $t(39) = -6.40$, $SEM = 1.39$, $d = -1.54$. The results show that above average spellers predominately used visual strategies for detection tasks, but they applied a direct retrieval strategy for correction tasks. Overall, phonological strategies were used the least in both tasks. Finally, interaction between strategy and task suggest that applying any particular strategy to guide one's spelling is associated with the task. That is, spellers adjust their use of spelling strategies to the recognition or production task.

The mixed factorial analysis showed a significant three-way interaction. There was a significant interaction effect by task, format, and presentation sequence, $F(1,36) = 5.20$, $MSE = .884$, $\eta^2 = .126$ (see Table 21). The interaction was analyzed in three ways,

¹² Levene's Test of homogeneity variance was significant, $F(11,28) = 2.57$, $p = .05$. Follow-up tests to evaluate pairwise differences among the strategies used by the subjects were conducted

¹³ Levene's Test of homogeneity variance was significant, $F(11,28) = 3.79$, $p = .01$. Follow-up tests to evaluate pairwise differences among the strategies used by the subjects were conducted

by sequence, format, and task. Three-way ANOVAs were conducted to investigate each interaction effect. The significant findings were followed by paired *t*-test comparisons with Bonferroni corrections (adjusted $\alpha = .0167$).

Shifting sequence. To compare the use of spelling strategies in each shifting sequence, a 2 (Format: print, computer) x 2 (Task: detection, correction) two-way ANOVA was conducted separately for each sequence. The shifting sequence print-first showed no main effects or interactions. No main effects were found by task, $F(1,19) = 1.74$, $MSE = 11.47$, $p = .20$, or format, $F(1,19) < 1$, $MSE = 2.47$, $p = .89$. No interaction effect was found between task and format, $F(1,19) < 1$, $MSE = 2.80$, $p = .60$.

The shifting sequence computer-first showed no main effects but an interaction effect between task and format, $F(1,19) = 5.99$, $MSE = 2.27$, $\eta^2 = .240$ (see Table 21). The interaction was analyzed in two ways, by task, and format. Each interaction effect was investigated using *t*-test comparisons with Bonferroni corrections ($\alpha = .025$). The application of strategies in each task and across format was explored separately. The paired *t*-test comparisons with Bonferroni corrections in the detection tasks showed significant differences between the number of strategies used in print ($M = 9.20$, $SD = 4.51$) and computer ($M = 10.65$, $SD = 3.84$), $t(19) = -3.36$, $SEM = .432$, $d = -.345$. Paired *t*-test comparisons with Bonferroni corrections in the correction tasks showed no significant differences between the number of strategies used in print ($M = 9.70$, $SD = 4.04$) and computer ($M = 9.50$, $SD = 4.21$), $t(19) = .373$, $SEM = .536$, $p = .71$, $d = .048$. These results indicate that above average spellers used higher numbers of strategies for detection tasks in a computer than in a printed format. Nonetheless, spellers used the same number of strategies for correction tasks in both formats of the spelling task. These

Table 21

Spelling Strategies Used by Above Average Spellers in Each Task and Format as a Function of Shifting Sequence

<i>Shifting Sequence</i>	<i>Task and Format</i>							
	<i>Detection</i>				<i>Correction</i>			
	<i>Print¹⁴</i>		<i>Computer¹⁵</i>		<i>Print¹⁶</i>		<i>Computer¹⁷</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Print-First	9.45	3.57	9.20	4.02	10.25	3.91	10.40	3.69
Computer-First	9.20	4.51	10.65	3.84	9.70	4.04	9.50	4.21

¹⁴ Results of Levene's Test of homogeneity of variance were no significant, $F(37,38) = 3.01, p = .09$. The analyses derived are considered valid.

¹⁵ Results of Levene's Test of homogeneity of variance were no significant, $F(37,38) = .011, p = .92$. The analyses derived are considered valid.

¹⁶ Results of Levene's Test of homogeneity of variance were no significant, $F(37,38) = .285, p = .59$. The analyses derived are considered valid.

¹⁷ Results of Levene's Test of homogeneity of variance were no significant, $F(37,38) = .484, p = .49$. The analyses derived are considered valid.

results revealed that there was a difference in the number of strategies applied for detection or correction tasks associated to the shifting sequence. Therefore, the shifting sequence print-first did not affect the overall number of strategies used in either task, though the shifting sequence computer-first increased the number of strategies used for the detection tasks. Consequently, the shifting sequence did impact the use of strategies in above average spellers.

The interaction was analyzed a second way; therefore the application of strategies in each format and across task associated with the shifting sequence computer-first was explored separately. The paired t -test comparisons with Bonferroni corrections in the printed format showed no significant differences between the use of strategies across detection ($M = 9.20$, $SD = 4.51$) and correction tasks ($M = 9.70$, $SD = 4.04$), $t(19) = -.872$, $SEM = .574$, $p = .39$, $d = -.116$. Paired t -test comparisons with Bonferroni corrections in the computer format showed no significant differences between the use of strategies across detection ($M = 10.65$, $SD = 3.84$) and correction tasks ($M = 9.50$, $SD = 4.21$), $t(19) = 1.61$, $SEM = .716$, $p = .124$, $d = .285$. No main effects associated with the sequence computer-first were found by task, $F(1,19) = .344$, $MSE = 6.14$, $p = .56$, $\eta^2 = .018$, or format, $F(1,19) = 3.16$, $MSE = 2.47$, $p = .09$, $\eta^2 = .143$. The results showed that in the shifting sequence computer-first, above average spellers used the same number of strategies across detection and correction tasks regardless of the format. The results demonstrate that, for above average spellers, switching work from computer to print becomes irrelevant for the application of strategies across tasks in either format.

Format. To compare the use of spelling strategies in each format, a 2 (Sequence: print-first, computer-first) x 2 (Task: detection, correction) two-way ANOVA analysis was conducted separately for each format. The printed format showed no main effects or

interactions. No main effects were found by task, $F(1,38) = 1.72$, $MSE = 4.90$, $p = .20$, or sequence, $F(1,38) < 1$, $MSE = 27.53$, $p = .73$. No interaction effect was found between task and sequence, $F(1,38) < 1$, $MSE = 4.90$, $p = .76$.

The computer format showed no main effects but an interaction effect between task and sequence, $F(1,38) = 4.28$, $MSE = 6.44$, $\eta^2 = .101$ (see Table 21). The interaction was analyzed in two ways, by task, and sequence. Each interaction effect was investigated using *t*-test comparisons with Bonferroni corrections ($\alpha = .025$). Application of strategies in each task in the computer format was explored separately. The paired *t*-test comparisons with Bonferroni corrections in the detection task showed no significant differences between the sequences print-first ($M = 9.20$, $SD = 4.02$) and computer-first, ($M = 10.65$, $SD = 3.84$), $t(38) = -1.17$, $SEM = 1.24$, $p = .25$, $d = -.369$. Paired *t*-test comparisons with Bonferroni corrections in the correction task showed no significant differences between the sequences print-first ($M = 10.40$, $SD = 3.69$) and computer-first, ($M = 9.50$, $SD = 4.21$), $t(38) = .719$, $SEM = 1.25$, $p = .48$, $d = .227$. The results showed that the strategies used by above average spellers to conduct each task in the computer format were not altered by either shifting sequence. Thus, spellers used the same number of strategies to conduct detection or correction tasks in the computer format regardless of the shifting sequence. Therefore it is unclear where this interaction is coming from; it might reflect a cross-over interaction or a diffuse effect.

The interaction was analyzed a second way; therefore application of strategies in each sequence and across task was explored separately. Paired *t*-test comparisons with Bonferroni corrections in the sequence print-first showed no significant differences between the use of strategies across detection ($M = 9.20$, $SD = 4.02$) and correction ($M = 10.40$, $SD = 3.69$), $t(19) = -1.36$, $SEM = .881$, $p = .19$, $d = -.311$. Paired *t*-test comparisons

with Bonferroni corrections in the sequence computer-first showed no significant differences between the use of strategies across detection ($M = 10.65$, $SD = 3.84$) and correction ($M = 9.50$, $SD = 4.21$), $t(19) = 1.61$, $SEM = .716$, $p = .121$, $d = .285$. No main effects associated with the computer format were found by task, $F(1,38) < 1$, $MSE = 6.44$, $p = .96$, or sequence, $F(1,38) < 1$, $MSE = 24.70$, $p = .81$. These results indicate that above average spellers used similar numbers of strategies across detection and correction tasks despite the shifting sequence in which the tasks were carried out. Although the data indicates that there is a significant interaction, it is unclear from where the difference is coming. Nonetheless as the F values indicate a difference, the shifting sequence has produced differences on the spelling strategies by the above average spellers to conduct the tasks in the computer format.

Task. To compare the use of spelling strategies in each task, a 2 (Sequence: print-first, computer-first) \times 2 (Format: print, computer) two-way ANOVA analysis was conducted separately for each task. The detection tasks showed a main effect of format $F(1,38) = 4.32$, $MSE = 1.67$, $\eta^2 = .102$ (see Table 21). Paired t -test comparisons across the formats showed marginally significant differences between the number of strategies used in print ($M = 9.32$, $SD = 4.02$) and computer ($M = 9.93$, $SD = 3.95$), $t(39) = -1.90$, $SEM = .316$, $p = .06$, $d = -.153$, with higher rates of strategies used in computer than in printed formats. The result shows that when above average spellers conducted detection tasks in a printed format they required less number of strategies than when they completed the tasks in a computer format.

The detection tasks also showed a significant interaction effect between format and sequence, $F(1, 38) = 8.67$, $MSE = 1.67$, $\eta^2 = .186$. Considering that these interaction effects have been reported in the previous sections (i.e., format and sequence), they are

not presented here to avoid redundancy. The correction tasks showed no main effects or interactions. As such no main effects were found by format, $F(1,38) < 1$, $MSE = 3.34$, $p = .95$, or sequence, $F(1,38) < 1$, $MSE = 28.18$, $p = .54$. No interaction effect was found between format and sequence, $F(1, 38) < 1$, $MSE = 3.34$, $p = .67$.

The mixed factorial ANOVA found no main effects by task, $F(1,36) < 1$, $MSE = 3.05$, $p = .45$, or format, $F(1,36) = 1.93$, $MSE = .909$, $p = .17$, or sequence, $F(1,36) < 1$, $MSE = .019$, $p = .97$. No significant two way interaction was found by task and format, $F(1,36) = 1.25$, $MSE = .884$, $p = .27$, or by format and strategy, $F(2,72) = 1.17$, $MSE = 2.88$, $p = .32$, or by task and sequence, $F(1,36) = 1.78$, $MSE = 3.04$, $p = .19$, or by format and sequence, $F(1,36) < 1$, $MSE = .909$, $p = .42$, or by strategy and sequence, $F(2,72) < 1$, $MSE = 29.61$, $p = .99$. There was no significant three-way interaction by task, format, and strategy, $F(2,72) < 1$, $MSE = 2.58$, $p = .87$, or by strategy, task, and sequence, $F(2,72) = 1.14$, $MSE = 9.53$, $p = .33$, or by strategy, format, and sequence, $F(2,72) < 1$, $MSE = 2.88$, $p = .62$. No significant four way interaction was found by strategy, task, format, and sequence, $F(2,72) < 1$, $MSE = 2.58$, $p = .44$. These results indicate that task, format, or presentation sequence do not affect the use of spelling strategies.

The overall results of this section showed a skill pattern as above average spellers seem to have replaced the use of the phonetic strategy with the visual and direct retrieval strategies, which are referred to in the literature as more advanced and efficient strategies (Treiman, 1993; Treiman & Bourassa, 2000a). In this study, above average spellers adjusted their application of spelling strategies across tasks, using predominantly the visual strategy for detection, and the direct retrieval strategy for correction tasks. Differences between the number of strategies applied in each spelling sequence validate the argument that variation in format presentation sequence affects the speller's selection

of strategies. Such differences are more prevalent when the first spelling sequence is conducted by computer. Initiating a spelling task in print produced a cost-efficiency effect by reducing the number of the strategies used for the spelling tasks. Conversely, starting a spelling task on computer increased the application of strategies in the detection task.

Additionally, the results showed no main effects in the number of spelling strategies by task, format, and shifting sequence alone. That is, number of spelling strategies applied in each task, format, and sequence were very similar. One must keep in mind that the combined effects of those three variables impacted the use of spelling strategies in this group of above average spellers, thus they are undoubtedly relevant for spelling. Together, findings of Study 1 and 2 suggest that computer tasks are cognitively more demanding, and thus require a higher number of spelling strategies to access quality of mental representations and to enhance accurate retrieval. Moreover, observed differences in the application of strategies justify the need to address individual differences in the sub-processes of spelling. The integration of these results supports the postulate that a speller's choice of strategy depends on its strategic efficiency (Ehri, 2000; Rittle-Johnson & Siegler, 1999).

Correlations between Spelling Performance and Standardized Test Scores

To analyze more closely the sub-processes of spelling, and the above average spellers processing abilities for the three types of errors used in this study, correlational analyses were carried out. It was explored whether detection and correction scores were associated with reading and writing abilities as measured by standardized test scores such as the WRAT-3 and the DSPT. Correlational results are presented in two sections,

correlations between tasks and standardized test scores, and correlations between error type and standardized tests scores.

Correlations between task and standardized scores. For the detection tasks, there were significant correlations between the detection accuracy rates and the WRAT spelling subtest scores, $r(38) = .322$, and the DSPT spelling visual recognition scores, $r(38) = .523$. There were no significant correlations between detection accuracy rates and the WRAT reading subtest, $r(38) = .301$, $p = .06$, or DSPT visual, $r(38) = .244$, $p = .13$, or phonetic word recognition subtest scores, $r(38) = .141$, $p = .384$. For the correction tasks, there were significant correlations between the correction accuracy rates and the WRAT reading, $r(38) = .419$, and spelling subtest scores, $r(38) = .630$, and the DSPT phonetic word recognition, $r(38) = .338$, and spelling visual recognition subtest scores, $r(38) = .803$. There were no significant correlations between correction accuracy rates and the DSPT visual word recognition scores, $r(38) = .309$, $p = .05$. These results suggested that detection of misspellings relied primarily on spelling skills such as visual recognition and accurate re-production of letter sequences, and their corresponding factors (i.e., low error blindness and high quality of mental representations). Correction of misspellings involved a wider range of word recognition skills, such as phonetic and visual spelling, which involve phonetic decoding, visual discrimination, and automatic processing, skills similar to those activated while reading. Contrary to Study 1, Study 2 suggested that at least in this group of above average spellers, automatic decoding processes were more related to spelling production than to spelling recognition processes. Spelling production also appeared to engage more of the supporting cognitive processes.

Correlations between error type and standardized scores. As in Study 1, correlational analysis confirmed that the accuracy rates in the three types of errors were

significantly correlated mainly to three subtests. As such, there were significant correlations between the WRAT reading subtest scores and the phonological, $r(38) = .429$, orthographic, $r(38) = .333$, and morphological errors, $r(38) = .330$. Also, the WRAT spelling subtest scores were also correlated to the phonological, $r(38) = .417$, orthographic, $r(38) = .488$, and morphological errors, $r(38) = .512$. In addition, there were significant correlations between the DSPT spelling visual recognition scores and the phonological, $r(38) = .471$, orthographic, $r(38) = .674$, and morphological errors, $r(38) = .758$. The DSPT visual word recognition subtest was only correlated to the phonological errors, $r(38) = .346$; this subtest was not correlated to the orthographic, $r(38) = .239$, $p = .14$, or morphological errors, $r(38) = .254$, $p = .11$. There were no significant correlations between the DSPT phonetic word recognition scores and the phonological, $r(38) = .287$, $p = .07$, orthographic, $r(38) = .219$, $p = .17$, or morphological errors, $r(38) = .244$, $p = .13$. These results indicated that regardless of the spelling error, spelling abilities of above average spellers were highly correlated to reading (automatic decoding) and spelling skills (visual discrimination and motor decoding) as measured by standardized tests. Contrary to Study 1, visual word recognition skills were found to be related only to the phonological errors. Results from Study 2 confirmed the findings of Study 1, in that purposeful spelling engages a speller's attention, re-establishes interconnections between all three types of errors (e.g., spelling accesses memory representations of letter sequences and grapho-phonemic rules), and facilitates spelling accuracy.

Overall, the lack of correlations between spelling tasks and the visual word recognition scores may suggest that this group of above average spellers decoded words' spellings in context rather than processing individual letter sequences. As in Study 1, lack

of correlations between detection tasks, and reading and phonetic word recognition scores confirmed diminished attention skills in this group of above average spellers; the lack of correlation may also denote the spellers' reliance on different word qualities to guide their spelling (Treiman & Barry, 2000). Similarly, correlations between correction of misspellings and most of the spelling subtests confirmed that correction abilities heavily rely on phoneme-grapheme connections and the ability to differentiate between homophones and homographs. On the other hand, lack of correlations between orthographic and morphological errors, and visual and phonetic word recognition scores can be interpreted as an indicator of proficient spelling. This absence of correlation may be taken as a sign of direct retrieval of word sequences from the spellers' lexicons, and the application of the most congruent spelling strategies that match the mental representation accessed and the specific word complexity (Treiman & Barry, 2000).

Discussion

In general terms, Study 2 shows that there is a definite difference in spelling accuracy associated with the type of spelling error. In this study, above average spellers exhibited the same pattern of spelling accuracy observed in other studies (i.e., Study 1; Figueredo & Varnhagen, 2004). As such, the accuracy rates were higher for the phonological errors, followed by the orthographic errors, then by the morphological errors. It is clear that the types of error relate to the speller's abilities required for detecting and correcting such error, thus contributing to achieving an error-free document.

Accuracy rates in each task showed that the type of spelling error had a larger influence in detection than in correction tasks. In detection tasks, above average spellers were able to easily identify a higher number of phonological than orthographic and morphological errors, and also a higher number of orthographic than morphological

errors. In correction tasks, above average spellers were able to easily correct more phonological than orthographic and morphological errors; however, spellers attained comparable levels of accuracy when correcting orthographic and morphological errors. These patterns demonstrate that the skill for identifying the correct letter sequence of morphological errors increased in correction tasks. As stated by Pinker (1991), the differentiation of morphological units is a rule-like process that gradually evolves to a more sophisticated level of proficiency in which spellers are able to resolve unpredictable spelling patterns (Treiman & Bourassa, 2000a). Consequently, the ability to correctly reproduce the morphological representations strengthens as those mental units are consciously activated, increasing their gradient of clarity as the correction tasks are carried on. It is clear that correction tasks require a conscious effort to activate the mental representations of words, thus opening a gate to retrieve word knowledge, and making the orthographic structure of words become readily available by a rule-like process. Overall, these findings are an extension of Owen and Borowsky's (2003) work (i.e., phonology biased orthographic processing) in which orthography has shown to have a facilitation-dominant influence on morphology.

This group of above average spellers exhibited different patterns of spelling accuracy according to the type of error across tasks. Above average spellers were more accurate in detection than in correction of phonological errors; conversely, they were more accurate in correction than in detection of morphological errors. Above average spellers were as accurate for detection as they were for correction of orthographic errors. Such equivalence between detection and correction rates of orthographic errors demonstrates that this type of error activates a specific quality in the processes underlying spelling (e.g., memory, attention). Consequently, the orthographic representations possess

higher quality gradients than those of the phonological and morphological. In this way, when texts include orthographic errors, above average spellers activate defined mental representations preventing fluctuations in their spelling performance (see Burt & Butterworth, 1996; Holmes & Castles, 2001).

An inverse detection-correction pattern of accuracy for the phonological and morphological errors was found in this group of above average spellers, which was linked to the degree of skill required for the task and the cognitive processes involved. As such, the saliency of phonological errors was clear in detection tasks due, perhaps, to the unconventional phonemes used in the stimuli (e.g., *repetishun*, *inevitabul*, see Figueredo & Varnhagen, 2004). The increased saliency of morphological errors in the correction tasks may be related to the task itself, as the spellers elicit each and every morphemic unit of a word at the time of correction (see Leong, 2009). The results suggest that orthography (and orthographic errors) provide an axis of reference in correction tasks that facilitates the representation of words graphemically (see Service & Turpeinen, 2001). Therefore, the increased accuracy in correcting morphological errors is part of a transfer effect of orthographic rules into the morphological mental representations of words.

Analysis of the effects of the shifting sequences in format, task, and type of spelling error demonstrated a combined influence of these variables on spelling performance. Two main effects from the shifting sequences that related to task and working format were found. An accuracy effect (i.e., rate of spelling errors accurately detected or corrected in the working format) and a cost-efficiency effect (i.e., number of strategies applied in the tasks and working format).

In terms of accuracy, the shifting sequences produced three types of patterns: 1) by error type; 2) across task and error type; and 3) by format. In terms of efficiency, the

shifting sequence also generated three patterns according to the number of strategies applied: 1) across task and format; 2) across task and sequence; and 3) across format and sequence.

The first set of accuracy patterns observed related to the type of spelling errors. This pattern reproduced the overall trend of accuracy associated to error type repeatedly observed in previous studies (e.g., Study 1; Figueredo & Varnhagen, 2004). Thus, above average spellers were more accurate with phonological than orthographic errors, and also more accurate with orthographic than morphological errors. This finding explains that above average spellers had a higher degree of error blindness for morphological than for phonological errors.

The second set of patterns related to the differences across tasks and error type. This pattern was similar to the detection-correction differences by error type discussed in Study 1 (i.e., higher detection than correction rates for phonological errors; higher correction than detection rates for morphological errors; no differences between detection and correction rates of orthographic errors). In Study 2 these patterns remained intact across formats with one exception in the phonological errors. The shifting sequence computer-first produced a change in the phonological errors, and there were no differences across detection-correction accuracy rates. This finding exposed the fragility of the phonological representations and suggests that above average spellers processed the phonological errors differently when shifting work from computer to print. Subsequently, the phonological representations became clearer for the correction tasks but also were more susceptible to error blindness in the detection tasks when initiating the spelling tasks in a computer format. Furthermore, the consistency found in the accuracy patterns for orthographic and morphological errors denotes the strength of the effect of

error type by which accessibility of a word's mental representation relates to the type of spelling error. Therefore, the degree of error blindness and the gradient of quality in the representation would be determined by whether the error has a phonological, orthographic, or morphological origin.

The degree of consistency for the spellers' accuracy in the presence of orthographic errors denotes that orthographic errors hold their clarity and saliency regardless of the shifting sequence. This consistency seems to be a true reflection of the speller's level of orthographic knowledge, which also alludes to common factors (e.g., memory, orthographic rules) between error blindness and the gradient in the quality of the representations for orthographic sequences (see Burt & Butterworth, 1996; Holmes & Castles, 2001).

In terms of orthography, the equal rate of accuracy in detection and correction of phonological errors when shifting work from computer to print presents a pattern similar to that of the orthographic errors. This pattern demonstrates a facilitatory effect of the shifting sequence computer-first on the phonological errors by which the mental representations were readily accessible and retrievable, due to an increase in saliency, because these types of errors were recognized as orthographic sequences by the above average spellers. That is, shifting work from computer to print elicited more grapheme-phoneme correspondences, creating an opposite effect to that described by Voyer and Boudreau (2003).

The detection-correction pattern of morphological errors is said to be an indicator of the spellers' failure to apply their correction knowledge to detect the errors (Figueredo & Varnhagen, 2004). However, within the framework of the present study, the direction of the effect in the morphological errors denotes the increased saliency and accessibility

of the mental representations for retrieval at the time of correction; consequently, the error blindness index decreases with an increased gradient in the quality of the representations.

Each task presented a single pattern of accuracy regardless of the shifting sequence. In the detection tasks, there were significant differences among the accuracy rates of phonological, orthographic, and morphological errors in both shifting sequences. That is, spellers were able to detect higher numbers of phonological than orthographic and morphological errors. They were also able to detect higher numbers of orthographic than morphological errors. These patterns are identical to those found by Figueredo and Varnhagen (2004) and the patterns were analogous in both sequences. The results confirmed the differences in saliency (higher for phonological errors) or susceptibility to error blindness (higher for morphological errors) of the different types of errors in the detection tasks. The correction tasks also showed a single pattern in both shifting sequences, pointing out the lack of influence of the sequence on the accessibility and retrieval of the words' mental representations. In this way, the correction accuracy rates were equivalent between orthographic and phonological errors, and between orthographic and morphological errors; correction accuracy rates between phonological and morphological errors were significantly different regardless of the sequence. Although this pattern was not expected or found in Figueredo and Varnhagen's study (2004), these results indicate that, at least for this group, above average spellers accessed and retrieved the mental representations of words via orthographic cues. The linking of phonemes-graphemes-morphemes reflects the proficiency level expected in above average spellers, who activate the multi-leveled representations of words to achieve accuracy in the correction of errors.

The third set of accuracy patterns was associated with the format used to carry out each task. In either format, the detection tasks presented the same accuracy pattern in regard to error type as that observed in the previous analysis (i.e., differences among the accuracy rates of phonological, orthographic and morphological errors). This finding suggests that format becomes irrelevant for detection tasks as the pattern seems to be mainly associated with the type of spelling error and those word features (phonology, orthography, morphology), which activate the mental representations of the words being spelled (see Berninger et al., 2006). The multiple feedback activation between the word features enhanced the quality of the representations and facilitated efficient spelling recognition processes (Seidenberg, 2005). Therefore, this finding alludes to the multiple feedback processing demonstrated by the above average spellers of this group. In addition, this finding demonstrates that spelling recognition processes rely on the multiple and multi-leveled representations of words in the speller's lexicon (Critten et al, 2007; Steffler, 2001) in which the shifting sequence or format, did not seem to have an impact (Masterson & Apel, 2006).

A different trend was observed for the correction of errors in each format. In the printed format above average spellers corrected a higher number of phonological than morphological errors, but corrected orthographic errors with the same rate of statistical accuracy as phonological and morphological errors; in the computer format, above average spellers corrected orthographic, phonological, and morphological errors with similar levels of accuracy. These findings revealed a facilitatory effect of the computer format upon the correction task for the phonological and morphological errors. Consequently, conducting the task in a computer format may trigger spellers to activate their knowledge and multiple representations of words; in this sense, the computer format

seems to directly stimulate the spellers' access to orthographic knowledge for the correction tasks. And, because all three types of errors were corrected with the same accuracy in computer, the mental representations of these three types of errors revolved around an orthographic axis (see Burt & Butterworth, 1996; Holmes & Castles, 2001). In this way, the relative fragility and quality of the mental representations (see Ehri, 2000) are revealed by the format used to carry out the task.

This single pattern of correction accuracy in the computer format regardless of the type of spelling errors reflects a positive transfer effect from the computer format by which the access and retrieval of the mental representations of words is enhanced. Therefore, the computer format neutralized the effect of error type and sequence in the correction tasks as the mental representations of words acquired equal clarity and precision, thus a higher gradient. There is a twofold explanation for this proficiency effect in spelling production tasks. From the perspective of working memory capacity and proficient spelling (Berninger et al., 1998; Longcamp et al., 2005; Neuhaus et al., 2006; Swanson, Ashbaker & Lee, 1996), the use of a computer format may have increased the availability of working memory resources in above average spellers, enhanced the accessibility to the mental representations of words, and facilitated the correct expression of their different graphemic sequences required for the tasks. From the perspective of the multiple feedback activation process required for spelling (see Seidenberg, 2005; Steffler, 2001), the orthographic units of words became readily incorporated during the correction tasks when above average spellers used the computer format.

The effects of cognitive load on spelling skills were noticed through the combined effects that the shifting sequence along with format, task, and error type had on working memory and attention; these two cognitive processes, in turn, determined the level of

spelling accuracy (degree of error blindness and fragility of the mental representations). Elements such as spelling tactics applied to complete the tasks, called spelling strategies, and the type of error encountered in texts, are factors that will influence spelling abilities. To this effect, Study 2 demonstrates that the impact that format and shifting sequence have on spelling skills is resolved through the use of spelling strategies.

In terms of efficiency, Study 2 found that this group of above average spellers applied mainly visual and direct retrieval strategies to guide their spelling, limiting the application of the phonological strategy. As such, this finding is congruent with the spelling theories that iterate that while novice spellers rely on phonetic strategies (Treiman, 1993), advanced spellers prefer to use, for the most part, direct retrieval strategies when carrying out spelling tasks (Ehri, 2005; Treiman et al., 1993).

This study also revealed an association between task and the application of spelling strategies. Thus, above average spellers used mainly the visual strategy for detection tasks and the direct retrieval strategy for correction tasks. These spellers kept the use of the phonological strategy to a minimum in both tasks. In detection tasks, the visual strategy was used at higher levels, followed by the direct retrieval, and then by the phonological strategies. In correction tasks, the direct retrieval strategy was used at higher levels, followed by the visual, and then by the phonological strategies. Differences in the use of strategies in each task revealed that the efficiency of the strategy was associated with the task and perhaps denoted a difference in spelling recognition and production processes. As proposed by Rittle-Johnson and Siegler (1999), these differences denoted that the use of strategies depends on task complexity and strategic efficiency. Moreover, the frequency with which the visual and direct retrieval strategies were applied was inverse to each other, as the use of one increased, thus the use of the

other decreased (i.e., cross-over interaction). It seems that such a pattern may demonstrate a coordinated compensatory action for approaching each spelling task with the most appropriate strategy. Therefore the analysis of this pattern of strategic engagement may uncover a different type of cognitive tactic (i.e., compensatory strategy) used to tackle the change occurring with the spelling sub-processes.

As indicated previously, the shifting sequences also produced distinct patterns of strategic efficiency. The first efficiency pattern relates to differences in the use of strategies according to task and working format in relation to the direction of the shift. The shifting sequence print-first showed no differences in the number of strategies used in either task or format. The sequence computer-first showed no differences in the use of strategies in either format, but in the tasks. In this way, shifting work from computer to print urged above average spellers to apply higher number of strategies for the detection tasks in computer than in print. Nonetheless, they applied equivalent rates of spelling strategies for the correction tasks across formats. Consequently, shifting work from computer to print is a cognitively taxing and more demanding task than shifting work from print to computer, as observed in the detection tasks. Shifting work from print to computer did not influence the above average spellers' use of strategies in either format or task, indicating that such a sequence causes an equivalent cognitive demand across spelling tasks regardless of the format. Therefore, the direction of the shifting sequence in above average spellers does not impact correction but certainly effects detection tasks.

Shifting work from computer to print increased the cognitive load for detection tasks in computer, as seen by a greater number of strategies used to carry on those tasks. This increment has a twofold explanation. It appears that the shifting sequence computer-first increases the availability of cognitive resources (e.g., attention) for spelling activity

(see Berninger et al., 1998; Longcamp et al., 2005, Swanson et al., 1996a). Nevertheless, the limitations of the cognitive processes (e.g., working memory) that support spelling determine the extent of the level of the engagement required for each process (see Coltheart et al., 2001; Neuhaus et al., 2006; Plaut et al., 1996; Tiu et al., 2003).

Consequently, the increment in the number of strategies applied reveals a compensatory action in which more cognitive resources are allocated to the task at hand. However, the processing activity remains subject to the capacity of the cognitive processes involved. And although there was a higher strategic engagement associated with the shifting sequence computer-first for the detection tasks, this effect did not necessarily transfer into higher accuracy levels. This finding most likely unveils a facilitatory effect from the shifting sequence print-first in the detection tasks.

The second efficiency pattern connects the influence of task with shifting sequence in each format. This pattern reveals an enmeshed trend in the number of strategies applied in each format. Conducting spelling tasks in a printed format presented no differences in the use of strategies across tasks despite the shifting sequence. Conversely, conducting spelling tasks in a computer format brought about an interaction effect of task and sequence that was difficult to disentangle. Analysis of the strategic engagement in the computer format showed that above average spellers applied an equal number of strategies for both tasks and sequences. The combined effects of task and sequence revealed a unique silhouette of the cognitive load imposed on the attention and memory of the above average spellers when conducting the spelling tasks in a computer format. The unexplainable discrepancy may suggest that task and sequence exercise equal influence on the use of strategies for spelling tasks in the computer format. As increase in cognitive load is difficult to observe in above average spellers, it is possible that one

factor alone would not be sufficient to produce a detectable change in the use of strategies. Nevertheless, analysis of the combined effects of two or more factors may be necessary to be able to detect a significant change in the number of strategies used to resolve any increase in the cognitive load of above average spellers.

The last pattern of strategic efficiency relates to the effects of format and shifting sequence on each spelling task. Analysis of the strategies used in each task showed an increase in the number of strategies applied in detection but not in correction tasks. As such, above average spellers used a higher number of strategies for detection tasks in a computer than in a printed format. In addition, they used a different number of strategies across formats associated to the shifting sequence. The shifting sequence computer-first forced spellers to use a higher number of strategies in computer than in print for the detection tasks. Furthermore, above average spellers used a similar number of strategies across sequences in both formats and also across formats with the sequence print-first. Consequently, the findings indicate that shifting work from computer to print influenced the use of strategies in the detection tasks across formats. That is, this shifting sequence made the detection tasks more cognitively demanding for above average spellers as they resorted to increase the number of strategies used to approach these tasks in the computer format. This finding explains how the spellers' strategic engagement operates during spelling.

Correlational analyses in this study brought up distinct features of the spelling sub-processes in this group of above average spellers. Spelling recognition processes appear to completely rely upon visual recognition and accurate decoding of letter sequences (orthography); that is, detection tasks demanded low error blindness and access to a high quality of mental representations. Spelling production seems to involve a

wider range of word qualities, such as phonetic recognition and grapheme-phoneme correspondences; that is, correction tasks involved phonetic decoding, visual discrimination, and automatic processing skills such as those activated while reading. This finding places emphasis on the predictive value of reading on spelling abilities (Kahmi & Hinton, 2000). Contrary to Study 1, Study 2 suggests that at least in this group of above average spellers, automatic decoding processes were more related to spelling production than to spelling recognition. Additionally, spelling production processes engaged more of those cognitive processes that support spelling skills.

The lack of correlations between both spelling tasks and the visual word recognition scores suggests that this group of above average spellers decoded word spellings in context rather than by processing individual word-letter sequences. As in Study 1, lack of correlation between spelling recognition and reading and phonetic word recognition scores confirmed diminished attention indicating that some spellers tend to read and recognize words by extracting only partial cues (e.g., initial syllables) without processing the graphemic units of the words entirely (Frith, 1980,1985). Reliance on partial orthographic information denotes an underdeveloped orthographic representation (Holmes & Castles, 2001) (an unlikely explanation for a group of above average spellers) or reduced attention. Additionally, this lack of correlations suggests that above average spellers may resort to the use of back-up strategies to assemble the orthography of a word (Ellis, 1993; Kwong & Varnhagen, 2005) when needed, demonstrating the spellers' ability to activate the several word qualities (Treiman & Barry, 2000) as required. In parallel, correlations between spelling production and most of the spelling subtests confirmed that correction skills rely heavily on phoneme-grapheme-morpheme connections.

More so than type of spelling error, a speller's abilities, as measured by standardized tests such as automatic decoding (reading), visual discrimination, and fine-motor decoding (written spelling) were correlated to spelling skills. These correlations confirmed the findings of Study 1, in that purposeful spelling engages the spellers' attention (Rees & Russell, 1999), and accesses the multileveled representations of words (Critten et al., 2007; Steffler, 2001), providing feedback activation of phonology and semantics (Seidenberg, 2005). These findings seem to be an extension of the embodied cognition theories (see Siakaluk, Pexman, Aguilera, Owen, & Sears, 2008) in which the decoding of words (i.e., semantic feedback in the visual word recognition system) is affected by the grounding effects from the sensorimotor interaction between the speller and the spelling of the word (e.g., handwriting of words). Contrary to Study 1, visual word recognition skills of above average spellers were correlated only to the phonological errors, demonstrating the spellers' automatic sensitivity to subtly misspelled words (McConkie & Zola, 1981), and the coordinated functioning of attention and memory in spelling. An unconventional, but reasonable interpretation of the lack of correlation between orthographic and morphological errors, and visual and phonetic word recognition scores was to view them as indicators of proficient spelling. This absence of correlation may be a sign of a skilled application of spelling strategies, such as direct retrieval or alternative strategies, that are congruent with the mental representation accessed and with the specific level of word complexity (Treiman et al., 1993; Treiman & Barry, 2000) reflected in the tasks.

In sum, the findings of Study 2 support the idea that the application of strategies denotes the functioning of cognitive processes engaged in spelling (Roussel et al., 2002; Varnhagen, 1995). In terms of strategic efficiency, there seems to be an advantage in

shifting work from print to computer represented by an economic use of spelling strategies across task and format. Conversely, shifting work from computer to print seems to have increased the cognitive load, thus required an engagement of additional cognitive resources (i.e., higher number of strategies) for the detection tasks in the computer format. In this way, the direction of the shift (i.e., from printing to keyboarding, or from keyboarding to printing) produced predictable differences in spelling accuracy and efficiency (see Berninger et al., 2006; Cunningham & Stanovich, 1990; Longcamp et al., 2000). Shifting work from printing to keyboarding reduced the degree of error blindness (particularly for the phonological errors), maintained the speller's cognitive load at equal levels for the spelling tasks in either format, and demonstrated an economical use of spelling strategies. Shifting work from keyboarding to printing elicited clearer mental representations for the correction tasks, neutralized the effects of error type and task on the speller's accuracy (processing of words via orthography), increased the cognitive load of above average spellers (required higher number of strategies) in the detection tasks in the computer format, and also exposed the fragility of the mental representations.

As the average spellers in the previous study, above average spellers showed a preference for a particular type of strategy to conduct the spelling tasks. And the selection of the type of strategy was not affected by format. This finding reveals that individual differences have an important effect on the spellers' cognitive processing that goes above and beyond the effects of format.

The importance of individual differences was also noted through the large values of the standard deviations in Study 1 and 2. In spite of the efforts to minimize the effects of individual differences in this study (i.e., used a more stringent selection criteria to select the spellers for this study), findings showed that individual differences persisted in

terms of the strategic application of cognitive resources. Nevertheless, the ways that format impacts the recognition and production processes in other types of spellers (e.g., below average or second language spellers) as well as the individual strategies they choose are aspects of spelling that still remained unexplored. Therefore, a third study was planned to look into these issues.

This study indicates that strategies, and not necessarily accuracy levels, are a more sensitive index of the ways that cognitive processes work. This idea may mean that scientists should reconsider the paradigms surrounding the sub-processes of spelling and redirect their focus of study towards strategic engagement. Psychometric tests designers also need to revise their instruments and measurements in order to determine whether they target processes or strategic efficiency. Should strategies be the way to understand cognitive processes, these would need to be incorporated into cognitive and developmental models of spelling.

Overall, this study uncovers the dual effects involved in the shifting sequence and format. A higher strategic engagement when shifting work from computer to print and in the computer format alone did not necessarily transfer to an increase in spelling accuracy. And although these effects did not favour the phonological qualities of the words, they augmented the use of orthographic rules, the central skill for spelling. Nonetheless, because detection of a spelling error is necessary for the correction of that error, the computer format did not increase the chances of producing an error-free document. Thus, it is clear that shifting work between formats affects the cognitive processing of above average spellers and confirms that in spelling processes format is paramount.

CHAPTER 4

Individual Differences and Spelling Abilities

The previous study demonstrated that the shifting sequence and format affected the levels of accuracy and efficiency in spelling processes. The subtlety and relevance of the effects alluded to the number of good quality of mental representations and low error blindness indexes seen in above average spellers. The most compelling evidence for the influence of format on spelling was seen in the application of strategies in the experimental tasks. In Study 2, above average spellers applied a larger numbers of spelling strategies for spelling recognition tasks in the computer format and for the spelling reproduction tasks when shifting work from computer to print. This strategic engagement is thought to result from an increase in cognitive load, which reflects cognitive processing differences related to working format. However, the increase in strategic engagement did not produce an increase in accuracy, posing new questions to research. And the findings led to investigate the ways in which format would impact the spelling skills of other groups of spellers. In this way, it was necessary to reconsider whether accuracy (e.g., quality of mental representations, skill level) or processing differences (e.g., error blindness, strategic engagement) would better account for the differences observed with a change in format and shifting sequence in spelling recognition and production. Factors such as the role of language processing differences and the type of activity of adjacent cognitive processes (e.g., working memory, attention) as factors associated with working format in spelling recognition and production tasks were considered worth to explore for the completeness of this study.

Ascertaining what determines spelling efficiency has preoccupied researchers for some time. Without doubt, there is a broad range of factors that can interfere with the

development of spelling skills. Inattention problems, learning difficulties, and language skills (as in second language spellers) are some of the readily observed factors (Gaulin, 2000). Broadly speaking, these factors relate to language knowledge or language processing. Both, language knowledge and language processing critically depend on memory. And while language knowledge clearly reflects an individual reservoir of information about word features (e.g., phonetic codes, orthographic sequences, semantics), language processing reflects the ability to efficiently manage the various types of information (e.g., decoding and re-coding information from one form to the other). In other words, individual differences in spelling abilities emerge from general processing differences (e.g., memory, attention), and from differential gradation in the mental representations (e.g., weak boundaries between phoneme-grapheme or semantic units, poor transferability and segmentation of these units). Thus, the range of functioning within each of those processes produces differences in spelling skills, and affects the strategies used to access a word's mental representations (e.g., visual strategies for orthographic units). It is reasonable to assume that such differences would be observable by contrasting accuracy and efficiency in the recognition and production processes of different types of spellers.

A key process supporting language knowledge and language processing is working memory. Working memory models, such as Baddeley and his colleagues (Baddeley, 2003; Bayless, Jarrol, Gunn & Baddeley, 2003), emphasize the integrative function of two subsystems: the visuo-spatial sketch pad, dedicated to handling images, and the phonological loop, dedicated to handling speech sounds. The limited capacity of the phonological loop, and working memory, impose restrictions on the processing and learning of words (e.g., slow word recognition, weak mental representations) as some

information is lost from the working memory buffer before it can be analyzed. The importance of working memory capacity and attention for efficient spelling is represented in word recognition and production studies involving reading and writing. The demonstrated relationship between reading and inattention (Willcutt & Pennington, 2000; Zumberge et al., 2007), and writing with motor control and inhibition (Thompson et al., 2005) outline the strong linkages of working memory and attention for efficient spelling. Lexical access studies confirm that skilled writers are compelled to use less cognitive resources, such as attention and working memory, than are poor writers (Abu-Rabia's, 2003).

To manage spelling information effectively, spellers use incoming visual and auditory information (e.g., segmenting syllables, associating phonemes with graphemes, comparing the words to previously stored word knowledge). Unfortunately, many factors such as environmental noise and other intrusions combine to interfere with the clarity of the word perceived by the speller. In this case spellers resort to the use of adjacent word information (e.g., context, semantics, orthographic rules) to access and retrieve the mental representation of words, thus engaging other cognitive resources (e.g., memory). These two main sources of information are processed simultaneously and additively to come up with the best option for a word's spelling. Writing language adds a layer of code, as letters are graphemic symbols representing speech sounds, which together are able to portray concepts. As words are written, visual and phonological memory share and apply their resources to the spelling process. The interplay of incoming information and cognitive processing constitutes the application of spelling strategies (Gaulin, 2000).

Studies of second language (L2) speakers and groups with learning disabilities (LD) demonstrate that the access and storage of word-related information is surprisingly

similar across different groups of spellers (Cummins, 1986; Proctor, Carlo, August, & Snow, 2005). Any observed variability in spelling abilities is found to be rooted in general cognitive processing resources (e.g., memory capacity, decoding ability; Bell & Perfetti, 1994; Swanson & Berninger, 1996). To this effect, Thompson et al. (2005) noticed that to process letter sequences, particularly in detection tasks, spellers required fast visual systems as attention-gating mechanisms. In this way orthographic units represent an important cluster within the written word that facilitates the translating of orthographic into phonological word forms.

Studies in bilingual and monolingual English readers link oral language proficiency (i.e., vocabulary knowledge, fluency, and listening comprehension) and decoding (i.e., phonological and orthographic awareness) to skilled reading (Bialystok, Luk, & Kwan, 2005; Geva & Zadeh, 2006; Leong, Han, Chen, & Tan, 2005; Proctor et al., 2005). The effects of the first language (L1) on L2 proficiency levels, are explained by two theories, namely, interference (Wang & Geva, 2003) versus transfer effects (Nathenson-Mejia, 1987). Research studies have demonstrated that high proficiency L2 learners increase their reliance on visual information as the L1 orthographic effect diminishes with increased proficiency (Chikamatsu's, 2006). Bilingual readers also draw on additional comprehension strategies, notably translation and cognate awareness to enhance their reading comprehension level (Jiménez, García, & Pearson, 1996; Proctor et al., 2005). Research has shown that beyond transfer effects of phonemic and phonological awareness, various components of vocabulary knowledge (e.g., polysemy, semantics, morphology, cross-linguistic features, spelling) are also transferable across languages (Ordoñez, Carlo, Snow, & McLaughlin, 2002). Overall, these studies demonstrate that

proficiency in L2 (English) is achieved by adequate L2 decoding ability and vocabulary knowledge (Bialystok et al., 2005; Geva & Zadhe, 2006; Proctor et al., 2005).

Analogously, studies in below and average readers report that the general cognitive processes supporting the reading abilities in both groups are very similar (e.g., phonological processing; Hoskyn & Swanson, 2000). The identified differences between these groups are demonstrated by cognitive measures like decoding ability (Tiu et al., 2003), lexical and syntactic knowledge, and spatial processing (Hoskyn & Swanson, 2000). Most importantly, memory has been found to be significantly correlated to the different levels of reading skills (Palladino, Cornoldi, De Beni, & Pazzaglia, 2001).

The processing deficits seen in learning-disabled population (e.g., dyslexia, attention deficits, auditory processing disorders) resemble basic spelling skills, and lower decoding skills (Ehri, 1997; Kami & Hinton, 2000; Sénéchal et al., 2006; Treiman, 1997). Research in this group of spellers evidenced elevated contrast thresholds (i.e., impaired ability to process and discriminate across the mental representations of words), and deficits in noise exclusion (Alain, Theunissen, Chevalier, Batty, & Taylor, 2003; Sperling, Lu, Manis, & Seidenberg, 2005). These findings are thought to account for the relationship between the deficits in understanding the grapho-phonemic units and the integration of the word's features as a complete mental representation (i.e., degraded orthographic structures). Thus, weaker phoneme boundaries and/or non-optimal perceptual templates (Joshi & Aaron, 2000) affect the development of phonemic segments, generating the degraded mental representations of words observed in poor spellers.

Treiman (1997) studied the phonological processing deficits of poor readers. She noticed that they have difficulties in breaking down words and syllables into phonemes,

thus in learning the phoneme-grapheme correspondences. She found that poor readers have little difficulty learning orthographic letter sequences, but have greater difficulty applying their morphological knowledge to other cognates (e.g., from magic to magician). Treiman concluded that the main distinction between below average and good readers is the coexistence of primitive phonologically based errors (e.g., 'sop' for 'stop', 'pas' for 'past', 'pilt' for 'pit') with relatively high levels of orthographic knowledge.

The research findings have exposed the relevance of processing skills (i.e., attention and memory) as translating mechanisms for second language spellers (SLS) and below average spellers (BAS). As such, cognitive processing presents a challenge for the malleability of the mental representations contained in an individual's lexicon as it affects knowledge acquisition. In consequence, spelling research efforts should continue to expand in scope to explore the influence of individual differences on the variability of spelling abilities. Studies of the individual differences in the qualities of attention and memory and their connectivity in language processing are waiting to be developed. Most importantly, it is required that these studies analyze each of the sub-processes of spelling separately in order to facilitate the structure of a model of spelling and the application of the research findings.

Insufficient studies in the field of spelling have left many questions open regarding the functioning of the spelling recognition and production sub-processes, in second language spellers and below average spellers. To create alternatives to improve the skills of weaker spellers, new research must aim to delineate the relationships and connective strengths by which supportive cognitive processes contribute to the sub-processes of spelling. In consequence, a third study was planned with the intention of accumulating additional evidence that would demonstrate the role of individual

differences, and the effects of format, in spelling. Three groups of spellers were selected for this study: native English spellers, second language spellers, and below average spellers. The study focused on comparing and contrasting the skills of different types of spellers while considering the impact of format, in order to clarify the factors affecting spelling recognition and production processes, as well as the efficiency in spelling skills.

Study 3

Efficient spelling is a critical component of academic success. Error-free essays reflect one aspect of academic quality that stresses the significance of being able to detect and correct misspellings in one's work. Spelling skills observed within the academic population show a degree of variability, which is not necessarily attributable to achievement or diversity in student population groups. Parallel degrees of variability in spelling skills are also observed within a single individual, suggesting that spelling skills range among different levels of sophistication. Thus spelling skills may be strongly associated to individual differences in addition to factors such as misspelling type, format, and general cognitive processes. The puzzling issue of the variability in spelling skills is a topic of interest for cognitive scientists, which demands a systematic exploration across different population groups.

Spelling research confirms the similarities between reading, writing and spelling processes in different population groups. Studies centered in explaining the assortment of spelling skills repeatedly sustain that the combined effects of cognitive processing mechanisms (e.g., decoding, processing speed), storing capacity (i.e., memory), and quality of the words' mental representations are accountable for the diversity observed in individual spellers. However, most of the research on spelling tends to study one of the spelling sub-processes (i.e., production), thus the opportunity to validly compare their

results across groups of spellers is limited. To bridge and synchronize these advances in the field of individual differences, it was necessary to design a study that examined spelling abilities in diverse groups of spellers with similar academic levels (i.e., university students) and under the same parameters.

Study 3 examined the sub-processes of spelling (i.e., recognition and production) in three different groups of spellers: native English spellers, English as a second language spellers, and below average spellers. As in the two previous studies, their abilities to detect and correct phonological, orthographic, and morphological errors, and the strategies they used to carry out these tasks were also compared. Based on previous findings, it was assumed that there would be significant differences between the groups' scores in the detection and correction of errors, as a function of error type. That is, it was expected to find a relative strength in spellers orthographic knowledge regardless of their skill level, plus a weakness to apply morphological knowledge commensurate to the group's spelling skill level. In addition, it was also expected to find differences in the use of strategies between the different groups of spellers. It was assumed that second language spellers would rely more heavily on linguistic processes (e.g., cognate awareness, vocabulary knowledge) due to language transferability effects. Meanwhile, below average spellers would basically rely on non-linguistic processes (e.g., phonetic awareness), due to their processing differences (e.g., phonologically based spelling, uneven spelling skills, lower decoding skills).

Consequently, the purposes of the study were to compare and contrast the spelling abilities across three different groups of spellers in regards to: 1) detection and correction rates of phonological, orthographic, and morphological errors; 2) the strategies used to detect and correct spelling errors; and 3) whether these abilities and strategies were

associated to knowledge and/or processing differences. It was hypothesized that: 1) detection and correction rates would differ in relation to error type and task in each group of speller, as was found in previous studies; 2) use of spelling strategies would vary between the groups of spellers as each group would have a preferred strategy, which would be adapted to the task and format; 3) differences in spelling performance should indicate either cognitive processing differences or knowledge differences between the three groups of spellers (e.g., higher accuracy levels would be found in native English spellers, followed by the second language spellers, then by the below average spellers); and that 4) scores from the standardized spelling tests would have a linear relationship with detection and correction rates, as the levels of spelling skills would reflect different quality gradients in mental representations and cognitive processing efficiency. As the native English spellers are expected to have acquired a good number of quality mental representations, and to be able to sustain their attention and monitor their spelling performance more efficiently than the below average spellers, these two groups are expected to present opposite patterns of accuracy and efficiency.

This study researched individual differences in spelling processing and spelling abilities. The uniqueness of the study resides in the comparative analysis of the individual differences in the cognitive activity underlying access and retrieval of mental representations of words. Analysis of the effects of format in different groups of spellers would also contribute to the understanding of cognitive strategic engagement in spelling sub-processes. Findings of this research add to the scientific evidence of linguistic and non-linguistic mechanisms supporting spelling efficiency. The results of this study would also establish guiding principles to further explore the spelling sub-processes and their variability associated with individual differences.

Method

Participants

Twenty-four undergraduate students from the University of Northern British Columbia participated in this study for bonus course credit. There were grouped according to their types of spelling skills, native English spellers, second language spellers, and below average spellers, with eight members in each. All students reported normal or corrected-to-normal vision. The overall age of participants ranges from between 18 and 43 years, with an average of 21 years 4 months ($SD = 6$ years 8 months).

Participants in the native English spellers (NES) group were 18 years, 3 months ($SD = 6$ months) on average. They rated their writing skills as moderate (spelling skill $M = 4.75$, $SD = 1.39$; proofreading skill $M = 5.25$, $SD = 1.49$). In general, their reading ($M = 111.50$, $SD = 5.29$) and spelling scores ($M = 110.62$, $SD = 4.75$) were in the high average range, as measured by the WRAT-3 (Wilkinson, 1993). Spellers' visual spelling recognition scores ($M = 112.0$, $SD = 4.90$) were in the high average range; their visual ($M = 99.50$, $SD = 4.41$) and phonetic word recognition scores ($M = 104.25$, $SD = 4.86$), and audio-visual spelling recognition scores ($M = 105.38$, $SD = 3.58$) were within the average range, as measured by the DSPT (Arena, 1982).

Participants in the second language spellers (SLS) group were 25 years, 6 months ($SD = 10$ years 5 months) on average. All participants in this group learned English as a Second Language and were required to have achieved a university English proficiency level for reading, writing and listening comprehension as demonstrated by their scores on the Test of English as a Foreign Language (TOEFL). All SLS had a TOEFL scores of 550 or above. They rated their writing skills as above average (spelling skill $M = 5.12$, $SD = .99$; proofreading skill $M = 6.12$, $SD = .64$). In general, their reading ($M = 102.25$, $SD =$

5.97) and spelling scores ($M = 108.25$, $SD = 7.48$) were within the average range, as measured by the WRAT-3 (Wilkinson, 1993). Spellers' visual ($M = 109.38$, $SD = 7.87$), and audio-visual spelling recognition scores ($M = 102.50$, $SD = 8.69$), and visual ($M = 97.25$, $SD = 7.92$) and phonetic word recognition scores ($M = 100.38$, $SD = 6.30$) were all within the average range, as measured by the DSPT (Arena, 1982).

Participants in the below average spellers (BAS) group were 20 years, 3 months ($SD = 2$ years 6 months) on average. They all reported having a learning disability and having received special services throughout their instruction. They rated their writing skills as below average (spelling skill $M = 3.0$, $SD = 1.60$; proofreading skill $M = 3.25$, $SD = 1.83$). In general, their reading ($M = 100.0$, $SD = 5.95$) and spelling scores ($M = 91.25$, $SD = 11.1$) were within the average range, as measured by the WRAT-3 (Wilkinson, 1993). Spellers' visual ($M = 100.62$, $SD = 5.15$) and audio-visual spelling recognition scores ($M = 93.80$, $SD = 2.28$), and visual ($M = 91.0$, $SD = 8.50$) and phonetic word recognition scores ($M = 96.75$, $SD = 5.68$) were all within the average range, as measured by the DSPT (Arena, 1982).

Procedure

The same experimental procedures described in Study 1 were used.

Apparatus and Materials

The same materials described in Study 1 were used.

Scoring

Scoring principles from the previous studies were also applied to this experiment.

Research Design

As the main interest of the study was to examine the cognitive differences in the sub-processes of spelling across groups of spellers, analyses of spelling performance across groups of spellers by error category, and by application of spelling strategies in each task and format were conducted separately. The statistical analysis of this experiment was a four-way factorial design, in which the type of speller was the between factors variable. The two main statistical analysis for this part of the experiments were: 1) a 3 (Group: NES, SLS, BAS) x 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Error type: phonological, orthographic, morphological); and 2) a 3 (Group: NES, SLS, BAS) x 2 (Task: detection vs. correction) x 2 (Format: print, computer) x 3 (Strategy: visual, phonetic, mnemonic) factorial designs.

In addition, to determine the spelling profile and cognitive characteristics of each group of spellers, separate analyses were conducted in each group. The two main statistical analysis in each group were: 1) a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological); and 2) a 2 (Format: print, computer) x 2 (Task: detection vs. correction) x 3 (Strategy: visual, phonetic, mnemonic) factorial designs.

Results

The results of this study are presented in several sections. The first section reports data on spelling performance and application of spelling strategies across the groups of spellers. The second section examines spelling performance and use of strategies by task and format in each group of speller. This section also explores the error blindness indexes and quality of mental representations based on rates of accuracy in detection and corrections tasks. The third section analyzes the correlations between standardized tests

scores, and accuracy in spelling in each task and spelling error category by group of speller. Unless noted, all effects were statistically significant at the $p < .05$.

Spelling Accuracy across the Groups of Spellers

To compare the spelling detection and correction rates across group of spellers associated to each error category and format, a 3 (Group: NES, SLS, BAS) x 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Error type: phonological, orthographic, morphological) four-way factorial ANOVA was conducted. To determine any significant differences in the findings, paired t -test comparisons with Bonferroni corrections were utilized (adjusted $\alpha = .0167$ to account for falsely significant findings).

The factorial ANOVA showed a main between subjects effect of group of speller, $F(2, 21) = 5.96$, $MSE = 8.25$, $\eta^2 = .362$ (see Table 22). Paired t -test comparisons with Bonferroni corrections between the accuracy rates of the different groups of spellers showed significant differences between the BAS and the NES, $t(14) = 3.89$, $SEM = 4.24$, $d = 1.94$; no significant differences were found between the SLS and the BAS, $t(14) = 2.58$, $SEM = 5.71$, $p < .024$, $d = 1.29$ or the NES, $t(14) = .316$, $SEM = 5.54$, $p = .76$, $d = .158$. These results show that the SLS accuracy levels are comparable to that of the NES and to the BAS. The BAS group, on the other hand, was less accurate in their spelling than the NES group.

The factorial ANOVA showed no between-subjects effects of format, $F(2,21) < 1$, $MSE = .484$, $p = .60$, or error type, $F(4,42) = 1.64$, $MSE = 1.60$, $p = .18$. No interaction effects were found by task and error type, $F(4,42) = 1.28$, $MSE = 1.67$, $p = .29$, or by task and format, $F(2,21) < 1$, $MSE = .452$, $p = .63$, or by format and error type, $F(4,42) < 1$, $MSE = .665$, $p = .64$. Neither three-way between subjects effects were significant by task,

format, and error type, $F(4,42) < 1$, $MSE = .455$, $p = .75$. These results showed that format, task and type of spelling error do not create differences across groups of spellers.

Table 22

Spelling Accuracy in Three Different Types of Speller

<i>Spelling Accuracy</i>					
<i>Native English Speller</i>		<i>Second Language Speller</i>		<i>Below Average Speller</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
50.13	8.01	48.38	13.48	33.63	8.91

The factorial ANOVA also showed a marginal between subjects effect of task across group of speller, $F(2, 21) = 3.07$, $MSE = 3.35$, $p = .07$, $\eta^2 = .226$ (see Table 23). For the detection tasks, paired t -test comparisons with Bonferroni corrections between the accuracy rates across the different groups of spellers showed no significant differences between the NES and the SLS, $t(14) = -.287$, $SEM = 2.61$, $p = .78$, $d = .143$, or the BAS, $t(14) = 2.16$, $SEM = 3.06$, $p = .05$, $d = 1.08$; no significant differences were found between the SLS and the BAS, $t(14) = 2.19$, $SEM = 3.37$, $p = .05$, $d = 1.09$. For the correction tasks, paired t -test comparisons with Bonferroni corrections between the accuracy rates across the different groups of spellers showed a significant difference between the NES and the BAS, $t(14) = 4.12$, $SEM = 2.39$, $d = 2.06$; no significant differences were found between the SLS and the NES, $t(14) = .737$, $SEM = 3.39$, $p = .47$, $d = .368$, or the BAS, $t(14) = 2.18$, $SEM = 3.38$, $p = .05$, $d = 1.08$. The results indicate that the three groups of spellers achieve similar levels of accuracy in detection tasks. In correction tasks the accuracy rate of the BAS group is lower than the NES group;

however the accuracy rate in the SLS group is comparable to that of the NES and the BAS groups.

Table 23

Spelling Accuracy According to Task by Three Different Types of Spellers

<i>Task</i>	<i>Group of Spellers</i>					
	<i>Native English Spellers</i>		<i>Second Language Spellers</i>		<i>Below Average Spellers</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection ¹⁸	25.13	4.42	25.88	5.94	18.50	7.44
Correction ¹⁹	25.00	4.81	22.50	8.30	15.13	4.76

Application of Spelling Strategies across the Groups of Spellers

To compare the application of spelling strategies across group of spellers by task and format, a 3 (Group: NES, SLS, BAS) x 2 (Task: detection, correction) x 2 (Format: print, computer) x 3 (Strategy: visual, phonetic, direct retrieval) four-way factorial ANOVA was conducted. To determine any significant differences in the findings, paired *t*-test comparisons with Bonferroni corrections were used (adjusted $\alpha = .0167$).

The factorial ANOVA showed a main between subjects effect of group of speller, $F(2,21) = 3.69$, $MSE = 8.25$, $\eta^2 = .260$ (see Table 24). Paired *t*-test comparisons with Bonferroni corrections between the strategies used to carry out spelling tasks across the

¹⁸ Levene's test of homogeneity showed that the assumption of equality of variance among the three groups was not violated, $F(2,21) = .650$, $p = .532$. The analysis of the results therefore can be considered valid.

¹⁹ Levene's test of homogeneity showed that the assumption of equality of variance among the three groups was not violated, $F(2,21) = 1.76$, $p = .196$. The analysis of the results therefore can be considered valid.

different groups of spellers showed significant differences between the BAS and the NES, $t(14) = 4.10$, $SEM = 3.84$, $d = 2.05$. There were no significant differences between the SLS and the BAS, $t(14) = 2.61$, $SEM = 5.40$, $p = .024$, $d = 1.30$, or the NES, $t(14) = .294$, $SEM = 5.52$, $p = .77$, $d = .147$. These results indicate that the NES relied on higher number of strategies than the BAS to complete the spelling tasks. The SLS applied similar number of spelling strategies than the NES and than the BAS.

Table 24

Frequency with which Spelling Strategies were Applied by Three Different Types of Spellers

<i>Spelling Strategies</i>					
<i>Native English Speller</i>		<i>Second Language Speller</i>		<i>Below Average Speller</i>	
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
50.13	8.00	48.50	13.42	34.38	7.35

Note. Data represents the overall average number of strategies used in the study (max cell score = 72).

The factorial ANOVA also showed a marginal effect of task across group of speller, $F(2, 21) = 3.17$, $MSE = 2.98$, $p = .06$, $\eta^2 = .232$ (see Table 25). For the detection tasks, paired t -test comparisons with Bonferroni corrections between the application of strategies across the different groups of spellers showed no significant differences between the NES and the SLS, $t(14) = .045$, $SEM = 2.79$, $p = .96$, $d = .023$, or the BAS, $t(14) = 1.89$, $SEM = 2.17$, $p = .07$, $d = .949$; no significant differences were found between the SLS and the BAS, $t(14) = 1.44$, $SEM = 2.77$, $p = .17$, $d = .721$. For the

correction tasks, paired *t*-test comparisons with Bonferroni corrections between the application of strategies across the different groups of spellers showed a significant difference between the BAS and the NES, $t(14) = 4.50$, $SEM = 2.58$, $d = 2.25$, and the SLS, $t(14) = 2.80$, $SEM = 3.62$, $d = 1.40$; no significant differences were found between the SLS and the NES, $t(14) = .429$, $SEM = 3.49$, $p = .67$, $d = .214$. The results indicate that the three groups of spellers applied similar number of spelling strategies for the detection tasks. For the correction tasks, the BAS group applied significantly fewer spelling strategies than did the NES and the SLS groups. The SLS and the NES applied similar rates of spelling strategies to carry on the spelling tasks.

Table 25

Spelling Strategies Used in Each Task by Three Types of Spellers

Task	Group of Spellers					
	Native English Spellers		Second Language Spellers		Below Average Spellers	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Detection	25.12	4.42	25.00	6.57	21.00	4.28
Correction	25.00	4.81	23.50	8.63	13.38	5.50

Note. Data represents the overall average number of strategies used in each task (max cell score = 36).

The factorial ANOVA showed no between-subjects effects of format, $F(2,21) < 1$, $MSE = .858$, $p = .41$, or strategy, $F(4,42) < 1$, $MSE = 28.75$, $p = .42$. No interaction effects were found by task and strategy, $F(4,42) = 1.27$, $MSE = 9.36$, $p = .29$, or by task

and format, $F(2,21) < 1$, $MSE = 1.11$, $p = .56$, or by format and strategy, $F(4,42) < 1$, $MSE = 2.68$, $p = .60$. Neither three-way between subjects effects were significant by task, format, and strategy, $F(4,42) = 2.02$, $MSE = 1.49$, $p = .108$. These results showed that format, task and strategies do not generate differences across groups of spellers.

Clear differences between groups of spellers were found in terms of accuracy and efficiency. These differences were notorious between the NES and the BAS, particularly in the correction tasks. Therefore the BAS was not only the least accurate of the groups, but also the one that used the least number of effective strategies to conduct the spelling tasks. The SLS group shares levels of spelling abilities and strategic efficiency with the other two groups (e.g., higher levels of spelling accuracy in the SLS are similar to those achieved by the NES; lower levels of SLS accuracy are equivalent to those achieved by the BAS).

Spelling Accuracy in Each Group of Spellers

To determine each group's detection and correction rates associated to each error category and format, a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Error type: phonological, orthographic, morphological) three-way factorial ANOVA was conducted separately for each group of speller. To determine any significant differences in the findings, paired t -test comparisons with Bonferroni corrections were utilized (adjusted $\alpha = .0167$).

Native English Spellers (NES). The factorial ANOVA showed a main effect of error type, $F(2, 14) = 19.98$, $MSE = 1.18$, $\eta^2 = .741$ (see Table 26). Paired t -test comparisons with Bonferroni corrections between all three types of errors were conducted. The results showed significant differences in accuracy rates across all three types of errors. There were significant differences between phonological ($M = 20.12$, SD

= 2.75) and orthographic, $t(7) = 3.81$, $SEM = .885$, $d = 1.15$, and morphological ($M = 13.25$, $SD = 3.69$) errors, $t(7) = 5.12$, $SEM = 1.34$, $d = 2.11$, and between orthographic ($M = 16.75$, $SD = 3.11$) and morphological errors, $t(7) = 3.56$, $SEM = .982$, $d = 1.025$.

These results indicated that quality and accessibility of mental representations of words differ according to error type. The NES group was more accurate with phonological errors than with either orthographic or morphological errors, and was also more accurate with orthographic than with morphological errors.

Table 26

Spelling Accuracy of Each Type of Speller According to Error Category

<i>Error Type</i>	<i>Group of Spellers</i>					
	<i>Native English Spellers</i>		<i>Second Language Spellers</i>		<i>Below Average Spellers</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Phonological	20.12	2.75	18.63	2.77	15.88	2.85
Orthographic	16.75	3.11	17.88	5.36	10.75	3.99
Morphological	13.25	3.69	12.00	6.14	7.88	2.90

The factorial ANOVA also showed a significant interaction of task by error type in this group of spellers, $F(2, 14) = 13.51$, $MSE = .996$, $\eta^2 = .660$ (see Table 27). The interaction was analyzed two ways, by task and error type. In the tasks, paired t -test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. The results showed significant

differences between the detection rates of all three types of errors; conversely no significant differences were found between the spelling correction rates. As such, there were significant differences between the detection rates of phonological ($M = 11.25$, $SD = 1.03$) and orthographic, $t(7) = 3.72$, $SEM = .706$, $d = 1.65$, and morphological ($M = 5.25$, $SD = 2.43$) errors, $t(7) = 6.23$, $SEM = .964$, $d = 3.20$; there were also significant differences between orthographic ($M = 8.62$, $SD = 1.99$) and morphological errors, $t(7) = 6.78$, $SEM = .498$, $d = 1.51$. In the correction rates, no significant differences were found between phonological ($M = 8.88$, $SD = 2.03$) and orthographic, $t(7) = .970$, $SEM = .773$, $p = .36$, $d = 0.387$, or morphological ($M = 8.00$, $SD = 2.07$) errors, $t(7) = 1.43$, $SEM = .611$, $p = .19$, $d = .429$; nor significant differences were found between orthographic ($M = 8.12$, $SD = 1.88$) and morphological errors, $t(7) = .158$, $SEM = .789$, $p = .158$, $d = .060$. These results show inherent differences in spelling accuracy rates in each spelling task related to the types of misspelling encountered in the texts. Thus, the type of spelling error impacted the NES's spelling accuracy rates in detection but not in correction tasks. Correction tasks seem to have brought up the consistency of the cognitive processing in the NES group, which is not easily altered by the category of spelling error.

To assess differences across detection and correction accuracy rates, in each error type paired t -test comparisons with Bonferroni corrections were conducted separately for each type of spelling error. The results showed significant differences between detection and correction of phonological errors, $t(7) = 3.98$, $SEM = .596$, $d = 1.47$, with higher detection ($M = 11.25$, $SD = 1.04$) than correction ($M = 8.80$, $SD = 2.03$) rates; also significant differences between detection and correction of morphological errors were found, $t(7) = -2.98$, $SEM = .921$, $p = .0167$, $d = -1.46$, with higher correction ($M = 8.00$, $SD = 2.07$) than detection rates ($M = 5.25$, $SD = 2.43$); however, no significant

differences were found between detection ($M = 8.62$, $SD = 1.99$) and correction ($M = 8.12$, $SD = 1.88$) rates of orthographic errors, $t(7) = .607$, $SEM = .824$, $p = .56$, $d = .257$. These results show that detection skills are modified by error category. Spellers' abilities are subject to greater variability when the texts contain phonological and morphological errors; however, spellers' abilities across tasks are not impacted by the orthographic errors.

The factorial ANOVA showed no main effects of task, $F(1,7) < 1$, $MSE = 1.77$, $p = .94$, or format, $F(1,7) < 1$, $MSE = .284$, $p = .58$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = .451$, $p = .47$, or by error type and format, $F(2,14) < 1$, $MSE = .525$, $p = .48$. Neither three-way interaction effects were significant by task, format, and error type, $F(2,14) = 1.69$, $MSE = .451$, $p = .22$. These results showed that format, and task, do not have an impact on the spelling performance of the NES.

The type of spelling error affected spelling abilities in the NES. Spellers were more accurate with phonological than orthographic or morphological errors. The NES group also displayed different abilities for detection and correction tasks. In the detection tasks, spellers detected more phonological than orthographic or morphological errors; thus, the NES group exhibited higher error blindness for morphological than for phonological errors. In correction tasks, the NES corrected all types of errors with equivalent levels of accuracy; thus, spellers demonstrated similar clarity and accessibility to all mental representations regardless of the type of error presented in the texts. The NES group appears to possess a single correction processing pattern not affected by error type.

Second Language Spellers (SLS). The factorial ANOVA showed a main effect of error type, $F(2, 14) = 14.93$, $MSE = 1.76$, $\eta^2 = .681$ (see Table 26). Paired t -test

comparisons with Bonferroni corrections between all three types of errors were conducted. There were significant differences between morphological ($M = 12.00$, $SD = 6.14$) and orthographic, $t(7) = 4.51$, $SEM = 1.30$, $d = 1.02$, and phonological ($M = 18.62$, $SD = 2.77$) errors, $t(7) = 4.91$, $SEM = 1.35$, $d = 1.39$; no significant differences were found between phonological and orthographic ($M = 17.88$, $SD = 5.35$) errors, $t(7) = .563$, $SEM = 1.33$, $p = .59$, $d = .173$. These results indicated that quality and availability of mental representations of words differ with error type. These results demonstrated that SLS tend to be equally accurate with phonological and orthographic errors, but that they were less accurate with morphological errors.

The factorial ANOVA also showed a significant interaction effect of task by error type in this group of spellers, $F(2, 14) = 14.47$, $MSE = .900$, $\eta^2 = .674$ (see Table 27). The interaction was analyzed by task and error type. In the tasks, paired t -test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. The results showed significant differences between detection rates of all three types of errors; conversely no significant differences were found between the errors' spelling correction rates. In the detection task, there were significant differences between the rates of phonological ($M = 11.00$, $SD = 1.19$) and orthographic, $t(7) = 3.10$, $SEM = .726$, $p = .0167$, $d = 1.05$, and morphological ($M = 5.25$, $SD = 2.96$) errors, $t(7) = 7.92$, $SEM = .726$, $d = 2.54$, and between orthographic ($M = 8.75$, $SD = 2.76$) and morphological errors, $t(7) = 7.00$, $SEM = .500$, $d = 1.22$. In the correction tasks, there were no significant differences between the rates of phonological ($M = 7.62$, $SD = 2.56$) and orthographic, $t(7) = -1.47$, $SEM = 1.02$, $p = .184$, $d = -.523$; or morphological ($M = 6.75$, $SD = 3.98$) errors, $t(7) = 1.22$, $SEM = .718$, $p = .262$, $d = .261$, or between orthographic ($M = 9.12$, $SD = 3.14$) and morphological errors, $t(7) = 2.22$,

$SEM = 1.07$, $p = .062$, $d = .663$. Spelling accuracy was different across error type in detection but not in correction tasks. In correction tasks spellers' accuracy remained relatively stable across error type. Accuracy correction rate denotes similar gradients of clarity and accessibility of mental representations in SLS; that is, their processing ability remains unaltered by the category of spelling error.

To assess differences across detection and correction accuracy rates in each error type, paired t -test comparisons with Bonferroni corrections were conducted separately for each type of spelling error. The results showed significant differences between detection and correction of phonological errors, $t(7) = 3.32$, $SEM = 1.02$, $d = 1.69$, with higher detection ($M = 11.00$, $SD = 1.19$) than correction ($M = 7.62$, $SD = 2.56$) rates. There were no significant differences between detection ($M = 8.75$, $SD = 2.76$) and correction ($M = 9.12$, $SD = 3.14$) of orthographic errors, $t(7) = -.424$, $SEM = .885$, $p = .685$, $d = -.125$, or between detection ($M = 5.25$, $SD = 2.96$) and correction ($M = 6.75$, $SD = 3.95$) of morphological errors, $t(7) = -1.27$, $SEM = 1.18$, $p = .244$, $d = -.429$ (see Table 27). These results show that correction abilities of SLS for orthographic and morphological errors improve with an open detection of these errors; therefore, spellers achieve similar levels of accuracy for orthographic and morphological errors in both tasks. Spellers' detection and correction accuracy for phonological errors are simply different due perhaps to the low levels of error blindness and a decreased clarity in mental representations of the phonological errors.

The factorial ANOVA showed no main effects of task, $F(1,7) < 1$, $MSE = 4.62$, $p = .59$, or format, $F(1,7) = 2.42$, $MSE = .619$, $p = .16$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = .452$, $p = 1.00$, or by error type and format, $F(2,14) < 1$, $MSE = .534$, $p = .84$. Neither three-way interaction effects were significant by task,

format, and error type, $F(2,14) = 1.77$, $MSE = .475$, $p = .21$. These results showed that format and task do not have relevance in the spelling performance of the SLS.

The spelling ability of the SLS was hindered with the morphological errors; thus, speller's accuracy for morphological errors was reduced, in relation to the orthographic and phonological errors. Similarly, error blindness for morphological errors was higher than for phonological and orthographic errors. Nonetheless, the results also suggest that the definition of the mental representations of the three types of errors, in addition to their access and availability in SLS remains constant across error type. In addition, the accuracy of SLS across detection and correction tasks varies only for the phonological errors, which can be explained by the low levels of error blindness and the decreased quality in the mental representation of phonological errors in this group of spellers.

Below Average Spellers (BAS). The factorial ANOVA showed a main effect of error type, $F(2, 14) = 17.69$, $MSE = 1.86$, $\eta^2 = .717$ (see Table 26). Paired t -test comparisons with Bonferroni corrections between all three types of errors were conducted. There were significant differences between phonological ($M = 15.88$, $SD = 2.85$) and orthographic, $t(7) = 3.48$, $SEM = 1.47$, $d = 1.48$, and morphological ($M = 7.88$, $SD = 2.90$) errors, $t(7) = 5.76$, $SEM = 1.39$, $d = 2.78$; no significant differences were found between orthographic ($M = 10.75$, $SD = 3.99$) and morphological errors, $t(7) = 2.36$, $SEM = 1.22$, $p = .05$, $d = .822$. The results indicated that the BAS attain higher levels of accuracy with phonological than with orthographic and morphological errors; the BAS are equally accurate with orthographic and morphological errors.

The factorial ANOVA also showed a main effect of task, $F(1,7) = 10.29$, $MSE = 3.64$, $\eta^2 = .595$ (see Table 25). Paired t -test comparisons across the tasks were conducted. The results showed no significant differences between the accuracy rates across detection

($M = 18.50$, $SD = 7.44$) and correction ($M = 15.12$, $SD = 4.76$) tasks, $t(7) = 1.89$, $SEM = 3.09$, $p = .31$, $d = .540$. The results appear to indicate that the BAS detect and correct errors at similar rates or that the effects of task are not detected in the analysis due to the small n and large SD ; thus, these findings need to be taken with caution.

The factorial ANOVA also showed a significant interaction effect of task by error type in this group of spellers, $F(2, 14) = 15.15$, $MSE = 1.60$, $\eta^2 = .684$ (see Table 27). The interaction was analyzed by task and error type. In the tasks, paired t -test comparisons with Bonferroni corrections for the rate that the different types of errors were detected or corrected were conducted separately. The results showed significant differences between detection rates of all three types of errors; conversely no significant differences were found between the error's spelling correction rates. In the detection task, there were significant differences between the rates of phonological ($M = 11.12$, $SD = .99$) and orthographic, $t(7) = 5.29$, $SEM = .945$, $d = 2.46$, and morphological ($M = 6.12$, $SD = 3.75$) errors, $t(7) = 17.56$, $SEM = .420$, $d = 5.82$; there were also significant differences between orthographic ($M = 6.12$, $SD = 2.69$) and morphological errors, $t(7) = 3.15$, $SEM = .754$, $p = .0167$, $d = 1.08$. In the correction tasks, there were no significant differences between the rates of phonological ($M = 4.75$, $SD = 2.25$) and orthographic, $t(7) = .163$, $SEM = .766$, $p = .87$, $d = .056$, or morphological ($M = 4.12$, $SD = 2.99$) errors, $t(7) = .394$, $SEM = 1.40$, $p = .67$, $d = 2.23$; nor were differences between orthographic ($M = 4.62$, $SD = 2.33$) and morphological errors, $t(7) = .500$, $SEM = 1.00$, $p = .63$, $d = .186$. These results also confirm a distinctive quality between detection and correction processes in the BAS group. Error categories affected the accuracy for detection but not for correction tasks. Correction accuracy rates in the BAS reflect a stability of cognitive processes immutable to the misspelling category.

Table 27

Spelling Accuracy of Each Type of Speller According to Error Category and Task

<i>Error Type</i>	<i>Group and Task</i>											
	<i>Native English Spellers</i>				<i>Second Language Spellers</i>				<i>Below Average Spellers</i>			
	<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Phonological	11.25	1.03	8.88	2.03	11.00	1.19	7.62	2.56	11.12	.99	4.75	2.25
Orthographic	8.62	2.00	8.12	1.88	8.75	2.77	9.12	3.14	6.12	2.70	4.62	2.33
Morphological	5.25	2.43	8.00	2.07	5.25	2.96	6.75	3.95	3.75	1.49	4.12	3.00

To assess differences across detection and correction accuracy rates in each type of error, paired *t*-test comparisons with Bonferroni corrections were conducted separately for each spelling error. The results showed significant differences between detection ($M = 11.12$, $SD = .99$) and correction ($M = 4.75$, $SD = 2.25$) of phonological errors, $t(7) = 9.04$, $SEM = .706$, $d = 3.66$, with higher detection than correction rates. There were no significant differences between the accuracy rates in detection ($M = 6.12$, $SD = 2.69$) and correction ($M = 4.62$, $SD = 2.33$) of orthographic errors, $t(7) = 1.38$, $SEM = 1.09$, $p = .21$, $d = .595$, or between detection ($M = 3.75$, $SD = 1.48$) and correction ($M = 4.12$, $SD = 2.99$) of morphological errors, $t(7) = -.284$, $SEM = 1.322$, $p = .785$, $d = -.156$. These results indicate that detection and correction abilities of BAS are subject to variability when phonological errors are present in texts or tasks; however, orthographic or morphological errors do not impact the BAS detection and correction accuracy rates, this is, their spelling skills across tasks are more equivalent.

The factorial ANOVA showed no main effects of format, $F(1,7) < 1$, $MSE = .548$, $p = .60$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = .452$, $p = .56$, or by error type and format, $F(2,14) < 1$, $MSE = .936$, $p = .63$. Neither three-way interaction effects were significant by task, format, and error type, $F(2,14) < 1$, $MSE = .439$, $p = .57$. These results showed that format does not create differences in the performance of the BAS.

Results of the BAS demonstrate a higher degree of accuracy for phonological than for orthographic and morphological errors, but equal degree of accuracy for orthographic and morphological errors. Detection abilities of the BAS for the different types of errors also varied with error type, reflecting differences in their susceptibility to error blindness related to the type of spelling error. The BAS correction abilities remained unaffected by

the type of spelling error and were at similar degrees of accuracy indicating equivalence in the accessibility and retrieval of mental representations of the three types of error. Accuracy across tasks, thus spelling ability, in this group of spellers was similar with orthographic and morphological errors but different with phonological errors. Analysis of the spelling accuracy in the three groups of spellers demonstrated that the groups possess similar patterns of spelling accuracy according to error type; this is, all groups of spellers are more accurate with phonological than with morphological errors. Accuracy with orthographic errors appears to have a positive transfer effect in the accuracy for the phonological errors in SLS, and for the morphological errors in the NES. Detection and correction patterns also follow similar trends across group of spellers, represented by the high saliency of phonological errors and the high error blindness rate for morphological errors. The gradient of clarity of mental representations is also equivalent across type of spellers and error type, which is identifiable by the absence of differences in the correction rates across the groups of spellers. Conversely, spellers' skills across tasks appear to vary with type of speller as the groups present different pattern of detection-correction accuracy seemingly affected by the type of spelling error (i.e., correction of morphological errors is higher than detection in the NES group). Nevertheless, detection-correction pattern of orthographic errors remains unchangeable regardless of the type of speller.

Spelling Strategies Applied by Each Group of Spellers

To determine each group's application of strategies associated to each task and format, a 2 (Format: print, computer) x 2 (Task: detection, correction) x 3 (Strategy: visual, phonetic, direct retrieval) three-way factorial ANOVA was conducted separately

for each group of spellers. To determine any significant differences in the findings, paired *t*-test comparisons with Bonferroni corrections were utilized (adjusted $\alpha = .0167$).

Native English Spellers (NES). The factorial ANOVA showed a main effect of strategy, $F(2, 14) = 11.00$, $MSE = 20.18$, $\eta^2 = .611$ (see Table 28). Paired *t*-test comparisons with Bonferroni corrections between the types of strategies used were conducted. The results showed significant differences between the use of phonetic and visual strategies, $t(7) = 6.81$, $SEM = 2.93$, $d = 3.32$, and direct retrieval strategies, $t(7) = -3.70$, $SEM = 4.25$, $d = -1.95$. No significant differences were found between visual and direct retrieval strategies, $t(7) = .731$, $SEM = 5.82$, $p = .489$, $d = .428$. These results indicated that NES rely mostly on visual and direct retrieval strategies to conduct spelling tasks. When approaching spelling activities, this group of spellers used the phonetic strategy the least.

The factorial ANOVA also showed a marginal interaction effect between task and strategy in this group of spellers, $F(2,14) = 2.99$, $MSE = 11.43$, $p = .07$, $\eta^2 = .30$ (see Table 29). The interaction was analyzed by task and strategy. In the tasks, paired *t*-test comparisons with Bonferroni corrections for the rate that the three strategies were used in each task were conducted separately. Comparisons for the detection tasks showed significant differences between the use of visual and phonetic strategies, $t(7) = 5.18$, $SEM = 2.26$, $d = 2.72$. No significant differences were found between the use of direct retrieval strategies and phonetic, $t(7) = -2.69$, $SEM = 2.04$, $p = .031$, $d = -1.41$, or visual strategies, $t(7) = 1.88$, $SEM = 3.32$, $p = .102$, $d = 1.08$. Comparisons for the correction tasks showed significant differences between the use of phonetic and visual, $t(7) = 4.04$, $SEM = 2.04$, $d = 2.05$, and direct retrieval strategies, $t(7) = -4.00$, $SEM = 2.56$, $d = -2.00$. No significant

differences were found between the use of visual and direct retrieval strategies in the correction tasks, $t(7) = -.495$, $SEM = 4.04$, $p = .63$, $d = -.315$.

Table 28

Spelling Strategies Used by Each Type of Speller

<i>Strategy</i>	<i>Group of Spellers</i>					
	<i>Native English Spellers</i>		<i>Second Language Spellers</i>		<i>Below Average Spellers</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Visual ²⁰	22.38	8.36	18.00	12.09	17.88	8.18
Phonetic ²¹	2.38	1.59	6.50	5.12	5.12	3.09
Direct Retrieval ²²	18.12	11.29	17.50	16.08	7.25	8.82

To assess differences in the use of the strategies across tasks, paired t -test comparisons with Bonferroni corrections were conducted separately for each strategy in detection and correction tasks. The results showed no significant differences for the application of strategies across tasks, neither in the case of visual, $t(7) = 1.37$, $SEM = 2.82$, $p = .212$, $d = .669$, or phonetic, $t(7) = .664$, $SEM = .565$, $p = .528$, $d = .336$, or direct retrieval strategies, $t(7) = -2.18$, $SEM = 1.99$, $p = .06$, $d = -.691$ (see Table 20). These results demonstrate that spellers applied each strategy with the same frequency across

²⁰ Levene's test of homogeneity of variance was nonsignificant, $F(2,21) = .370$, $p = .695$

²¹ Levene's test of homogeneity of variance was significant, $F(2,21) = 3.964$, $p = .035$. Because the overall F test of the differences across groups of spellers was nonsignificant, follow-up tests to evaluate pairwise differences among the groups means were not necessary.

²² Levene's test of homogeneity of variance was nonsignificant, $F(2,21) = .860$, $p = .438$

detection and correction tasks. The equal application frequency denotes that this group of spellers tends to have a preferred type of spelling strategy, which they use regardless of the task.

The factorial ANOVA showed no main effects of task, $F(1,7) < 1$, $MSE = 1.72$, $p = .94$, or format, $F(1,7) = 3.54$, $MSE = .356$, $p = .10$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = .487$, $p = .88$, or by strategy and format, $F(2,14) = 1.91$, $MSE = 3.03$, $p = .18$, $\eta^2 = .215$. Neither three-way interaction effects were significant by task, format, and strategy, $F(2,14) < 1$, $MSE = 1.91$, $p = .52$. These results showed that format and task do not affect the application of strategies in the NES group.

The NES group applies two strategies with the same frequency, that is, visual and direct retrieval strategies; also their application of the phonetic strategy is kept to the minimum. Their application of spelling strategies denotes low error blindness indexes and good quality in the mental representation of words. The increased correction rate for morphological errors seems to be related to their reliance on the visual strategy for the detection tasks and their increased use of the direct retrieval strategy for the correction tasks. The NES also demonstrates a conservative use of the phonetic strategy.

Second Language Spellers (SLS). The factorial ANOVA showed no main effects but a three way interaction between format, strategy, and task, $F(2, 14) = 5.41$, $MSE = 1.21$, $\eta^2 = .436$ (see Table 29). The interaction was analyzed three ways, by format, strategy and task. In the formats, paired t -test comparisons with Bonferroni corrections for the rate that the three strategies were used in each task were conducted separately. In the printed format, comparisons for the detection task showed a significant difference between the use of visual and phonetic strategies, $t(7) = 2.83$, $SEM = 1.52$, $p = .0167$, $d = 1.50$. No significant differences were found between the direct retrieval and phonetic, $t(7)$

= -1.43, $SEM = 1.57$, $p = .197$, $d = -.792$, or visual strategies, $t(7) = 1.04$, $SEM = 2.03$, $p = .33$, $d = .64$. Comparisons for the correction task showed no significant differences between the use of visual and phonetic, $t(7) = 1.35$, $SEM = 1.47$, $p = .22$, $d = .634$, or direct retrieval strategies $t(7) = -.222$, $SEM = 2.81$, $p = .83$, $d = -.140$; nor were significant differences found between the phonetic and direct retrieval strategies, $t(7) = -1.22$, $SEM = 2.13$, $p = .25$, $d = -.690$. In the computer format, comparisons for the detection task showed no significant differences between the use of visual and phonetic, $t(7) = 1.33$, $SEM = 1.59$, $p = .22$, $d = .736$, or direct retrieval strategies, $t(7) = .382$, $SEM = 1.36$, $p = .49$, $d = .199$; nor were significant differences found between the use of direct retrieval and phonetic strategies $t(7) = -.724$, $SEM = 1.89$, $p = .49$, $d = -.457$.

Comparisons for the correction task showed no significant differences between the use of visual and phonetic, $t(7) = 2.20$, $SEM = 1.36$, $p = .06$, $d = 1.06$, or direct retrieval strategies $t(7) = -.633$, $SEM = 2.76$, $p = .54$, $d = -.401$; nor were significant differences found between the phonetic and direct retrieval strategies $t(7) = -2.59$, $SEM = 1.83$, $p = .04$, $d = -1.30$.

In the tasks, paired t -test comparisons with Bonferroni corrections for the rate that the three strategies were used across formats were conducted separately. In the detection tasks, comparisons for the application of each strategy across print and computer formats showed no significant differences for the visual, $t(7) = 2.51$, $SEM = .598$, $p = .04$, $d = .427$, or phonetic, $t(7) = -.942$, $SEM = .796$, $p = .37$, $d = -.357$, or direct retrieval strategies, $t(7) = .243$, $SEM = .515$, $p = .81$, $d = .036$. In the correction tasks, comparisons for the application of each strategy across print and computer formats showed no

Table 29

Spelling Strategies Applied by Each Type of Speller in Each Task

<i>Spelling Strategy</i>	<i>Group and Task</i>											
	<i>Native English Spellers</i>				<i>Second Language Spellers</i>				<i>Below Average Spellers</i>			
	<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>		<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Visual	13.12	6.06	9.25	5.50	10.50	6.80	7.50	7.25	12.62	5.57	5.25	4.33
Phonetic	1.38	.744	1.00	1.41	4.00	3.55	2.50	3.38	1.88	1.55	3.25	3.81
Direct Retrieval	6.88	5.44	11.25	7.09	7.62	6.94	9.88	9.79	4.50	5.18	2.75	4.03

significant differences for the visual, $t(7) = .000$, $SEM = .866$, $p = 1.00$, $d = 0$, or phonetic $t(7) = 2.36$, $SEM = .423$, $p = .05$, $d = .557$, or direct retrieval strategies, $t(7) = -2.04$, $SEM = .549$, $p = .08$, $d = -.225$.

Analyses of the use of strategies in each format were also conducted. Paired t -test comparisons with Bonferroni corrections for the rate that each strategy was applied across tasks were conducted separately. Comparisons for the application of the visual strategy across detection and correction tasks showed no significant differences for any of the errors. The application of the visual strategy across tasks showed no significant differences in the printed, $t(7) = 1.65$, $SEM = 1.35$, $p = .14$, $d = .614$, or computer format, $t(7) = .552$, $SEM = 1.36$, $p = .59$, $d = .203$. The application of the phonetic strategy across tasks showed no significant differences in the printed, $t(7) = -.124$, $SEM = 1.01$, $p = .90$, $d = -.059$, or computer format, $t(7) = 1.97$, $SEM = .822$, $p = .08$, $d = .997$. And the application of the direct retrieval strategy across tasks showed no significant differences in the printed $t(7) = -.435$, $SEM = 1.15$, $p = .67$, $d = -.119$, or computer format, $t(7) = -2.14$, $SEM = .818$, $p = .07$, $d = -.418$.

The factorial ANOVA showed no main effects of task, $F(1,7) < 1$, $MSE = 5.28$, $p = .45$, or format, $F(1,7) < 1$, $MSE = 1.04$, $p = .57$, or strategy, $F(2,14) = 1.76$, $MSE = 48.05$, $p = .21$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = 1.48$, $p = .52$, or by strategy and task, $F(2,14) = 1.43$, $MSE = 10.17$, $p = .27$, or by format and strategy, $F(2,14) = 1.25$, $MSE = 2.51$, $p = .32$. These results showed that format, and task do not alter the spelling performance of the SLS.

Findings of the SLS group demonstrate a true and single interaction pattern of three factors: format, strategy and task. The SLS lacks a preferred strategy to conduct the

spelling tasks as only in the printed format the SLS used the visual strategy more often than the phonetic strategy. Also, they did approach spelling tasks as a single and unitary process (i.e., SLS seem unable to separate the two sub-processes of spelling, and in contrast, they integrate the sub-processes into a single process).

Below Average Spellers (BAS). The factorial ANOVA showed a main effect of strategy, $F(2, 14) = 5.24$, $MSE = 18.03$, $\eta^2 = .428$ (see Table 28). Paired t -test comparisons with Bonferroni corrections between the types of strategies used were conducted. The results showed significant differences between the use of visual and phonetic strategies, $t(7) = 4.49$, $SEM = 2.83$, $d = 2.06$. No significant differences were found between the use of direct retrieval and visual, $t(7) = 2.00$, $SEM = 5.28$, $p = .08$, $d = 1.24$, or phonetic strategies, $t(7) = -.537$, $SEM = 3.96$, $p = .608$, $d = -.322$. The results show that BAS applied the visual strategy more often than the phonetic strategy. They also applied the direct retrieval strategy broadly or indiscriminately. In this way, the BAS applied the visual strategy as frequently as the direct retrieval strategy, but they also applied the phonetic strategy as frequently as the direct retrieval strategy.

The factorial ANOVA also showed a main effect of task, $F(1,7) = 18.23$, $MSE = 1.92$, $\eta^2 = .723$ (see Table 25). A paired t -test comparison between the strategies used in each task was conducted. Results showed a significant difference between the use of strategies for detection and correction tasks, $t(7) = 3.28$, $SEM = 2.32$, $d = 1.54$, with higher number of strategies applied for detection ($M = 21.50$, $SD = 4.28$) than for correction ($M = 13.38$, $SD = 5.50$) tasks. Findings indicate that the BAS apply different number of strategies to each spelling task. This difference is particularly noticed in the reduced number of spelling strategies applied for the correction tasks.

The factorial ANOVA also showed a significant interaction effect between task and strategy in this group of spellers, $F(2, 14) = 6.69$, $MSE = 6.46$, $\eta^2 = .489$ (see Table 29). The interaction was analyzed two ways, by task and strategy. To determine differences in the rates that each strategy was applied in the tasks, paired t -test comparisons with Bonferroni corrections were conducted separately for each task. Comparisons for the detection tasks showed significant differences between the use of visual and phonetic strategies, $t(7) = 5.26$, $SEM = 2.04$, $d = 2.62$.

No significant differences were found between the use of direct retrieval and visual, $t(7) = 2.36$, $SEM = 3.44$, $p = .05$, $d = 1.50$, or phonetic strategies, $t(7) = -1.25$, $SEM = 2.10$, $p = .25$, $d = -.685$. Comparisons for the correction tasks showed no significant differences in either pair of strategies; as such, there were no significant differences between the use of visual and direct retrieval, $t(7) = 1.11$, $SEM = 2.23$, $p = .30$, $d = .597$, or phonetic strategies, $t(7) = .853$, $SEM = 2.35$, $p = .42$, $d = .490$; nor were there differences between phonetic and direct retrieval strategies, $t(7) = .202$, $SEM = 2.47$, $p = .845$, $d = .127$.

To assess differences in the use of each strategy across task, paired t -test comparisons with Bonferroni corrections were conducted separately for each type of strategy. The results showed a significant difference in the use of the visual strategy across detection and correction of misspellings, $t(7) = 3.64$, $SEM = 2.02$, $d = 1.47$, used at higher frequency for detection ($M = 12.62$, $SD = 5.57$) than for correction ($M = 5.25$, $SD = 4.33$) tasks. There were no significant differences in the use of phonetic, $t(7) = -.789$, $SEM = 1.74$, $p = .45$, $d = -.471$, or direct retrieval strategies, $t(7) = 4.15$, $SEM = 1.013$, $p = .13$, $d = .377$, across tasks. These results indicate that the BAS group appears to adjust

their use of the visual strategy to the task at hand; and while they used the visual strategy mostly for detection tasks, they reduced the frequency with which they used the visual strategy for the correction tasks. Findings also indicate that spelling tasks do not make an impact on the use of phonetic and direct retrieval strategies in the BAS.

The factorial ANOVA showed no main effects of format, $F(1,7) < 1$, $MSE = 1.36$, $p = .51$. No interaction effects were found by task and format, $F(1,7) < 1$, $MSE = 1.36$, $p = .51$, or by strategy and format, $F(2,14) < 1$, $MSE = 2.50$, $p = .95$. Neither three-way interaction effects were significant by task, format, and strategy, $F(2,14) < 1$, $MSE = 1.36$, $p = .91$. These results showed that format do not create differences in the spelling performance of the BAS.

The BAS group relies heavily on the application of visual strategies for spelling, particularly for the detection tasks. Nonetheless, this group of spellers applies all three types of strategies at relatively similar rates for correction tasks. Their pattern reveals a need to activate all three word's features to be able to re-construct and improve the quality of their mental representation of the words being spelled. The lack of differences between phonological and direct retrieval strategies across tasks confirms the spellers need to access the multiple representations of words for reconstructive purposes.

Analysis of the application of strategies in each group of spellers demonstrated more differences than similarities between the groups. Findings showed that each group possesses a different strategic approach to spelling. The uniqueness of these patterns is observable within and across tasks. It is noticed that the NES also uses the direct retrieval strategy consistently, in particular with the correction tasks. Conversely, the BAS depends only on the visual strategy, and the SLS group appears to apply all the strategies

at approximately equal rate. Nonetheless, there is a common trend between the groups, and that is that the visual strategy is applied broadly while the phonetic strategy is applied very conservatively.

Correlations between Spelling Performance and Standardized Test Scores

Standardized achievement tests are used to evaluate reading and writing abilities. A degree of relationship between efficient spelling skills and the abilities measured by these tests needed to be established to convey the findings of this study to practicing professionals. In consequence, to gain insight into the spelling sub-processes in each group of spellers, a correlational analysis with standardized instruments such as the WRAT-3 and DSPT was carried out. Separate correlational analyses for each group of spellers were run between standardized subtests scores, the two spelling tasks, and the three error categories incorporated in this study. The results are presented in two sections by group of speller: correlations between tasks and standardized test scores, and correlations between error category and standardized tests scores.

Correlations between task and standardized scores. In the NES group, correlational analyses between tasks and tests scores showed several significant correlations. Detection tasks showed significant correlations with the WRAT reading subtest, $r(6) = .937$, and the DSPT visual, $r(6) = .715$, and phonetic word recognition subtests, $r(6) = .749$. No significant correlations were found between detection tasks and the WRAT spelling subtest, $r(6) = .547$, $p = .16$, or the DSPT visual spelling recognition subtest, $r(6) = .666$, $p = .07$. Correction tasks showed only one significant correlation with the WRAT spelling subtest scores, $r(6) = .888$. No significant correlations were found between correction tasks and the WRAT reading subtest, $r(6) = .342$, $p = .41$, or the

DSPT visual, $r(6) = -.027, p = .95$, or phonetic word recognition subtests, $r(6) = .678, p = .06$, or with the spelling visual recognition subtest, $r(6) = .691, p = .06$.

In the SLS group, correlational analysis between tasks and standardized tests scores showed significant correlations between detection tasks and the WRAT spelling subtest, $r(6) = .924$, and also with the DSPT phonetic word recognition, $r(6) = .784$, and the visual spelling recognition subtests, $r(6) = .961$. No significant correlations were found between detection tasks and the WRAT reading subtest, $r(6) = .670, p = .07$, or the DSPT visual word recognition subtest, $r(6) = .578, p = .13$. Correction tasks showed significant correlations with the WRAT spelling subtest, $r(6) = .746$, and the DSPT spelling visual recognition scores, $r(6) = .731$. No significant correlations were found between the correction tasks and the WRAT reading subtest scores, $r(6) = .588, p = .13$, or the DSPT visual, $r(6) = .517, p = .19$, or phonetic word recognition scores, $r(6) = .665, p = .07$.

In the BAS group, correlational analysis between tasks and standardized tests scores showed only one significant correlation. Detection tasks were significantly correlated with the DSPT phonetic word recognition subtest, $r(6) = .801$. No significant correlations were found between detection tasks and the WRAT reading, $r(6) = .632, p = .09$, or spelling subtests, $r(6) = .611, p = .11$; neither with the DSPT phonetic word recognition, $r(6) = .565, p = .14$, or spelling visual recognition subtests, $r(6) = .408, p = .32$. Correction tasks were not significantly correlated with the WRAT reading, $r(6) = .469, p = .24$, or spelling subtests, $r(6) = .051, p = .91$, neither with the DSPT visual, $r(6) = .335, p = .42$, or phonetic word recognition subtests, $r(6) = .350, p = .39$, or with the DSPT spelling visual recognition subtest, $r(6) = -.469, p = .24$.

These results indicate that spelling abilities, as measured by standardized test, are mostly related to the type of speller, and to lesser extent to the tasks used in this study. In the NES group, the detection tasks were correlated to all sub-tests scores except written spelling and spelling visual recognition, which added to a higher number of correlations than the correction tasks. The correction tasks only correlated to the spelling sub-test scores, thus held the lowest number of correlations, and produced a single correlational pattern. In the SLS group the detection and correction tasks, shared similar number of correlations as they both correlated to the spelling, and the visual spelling recognition sub-tests. The difference between detection and correction tasks is that the former presented an additional correlation to the phonetic word recognition sub-test. In the BAS group only the detection task held a correlation with the phonetic word recognition sub-test. The results indicate that this group of spellers uses phonology to detect errors. The lack of correlations for correction tasks denotes the low numbers and fragility of word mental representations, as well as the difficulties in accessing and retrieving the words' spelling sequences.

Correlations between error type and standardized scores. The three types of errors (i.e., phonological, orthographic, morphological) were found to be significantly correlated to different subtests in each group of spellers. In the NES group, the phonological errors were significantly correlated to the WRAT spelling subtest, $r(6) = .891$, the orthographic errors were correlated to the WRAT reading, $r(6) = .722$, and spelling subtests, $r(6) = .855$, and to the DSPT visual spelling recognition subtest, $r(6) = .770$, and the morphological errors were correlated to the WRAT reading subtest, $r(6) = .855$, and to the DSPT phonetic word recognition subtest, $r(6) = .744$. There were no

significant correlations between the phonological errors and the WRAT reading, $r(6) = .142, p = .74$, or the DSPT word, $r(6) = .018, p = .97$, or phonetic recognition subtests, $r(6) = .671, p = .07$, or to the DSPT spelling visual recognition subtest $r(6) = .584, p = .13$. Nor were there significant correlations between the orthographic errors and the DSPT visual, $r(6) = .177, p = .67$, or phonetic word recognition subtests, $r(6) = .639, p = .09$. Neither significant correlations were found between the morphological errors and the WRAT spelling, $r(6) = .430, p = .28$, or the DSPT visual word recognition, $r(6) = .658, p = .07$, or the visual spelling recognition subtests, $r(6) = .616, p = .10$.

In the SLS group, the phonological errors were significantly correlated to the WRAT spelling subtest, $r(6) = .811$, and to the DSPT phonetic word recognition, $r(6) = .728$, and visual spelling recognition subtest, $r(6) = .792$, the orthographic errors were correlated to the WRAT spelling subtest, $r(6) = .871$, and to the DSPT visual spelling recognition subtests, $r(6) = .835$, and the morphological errors were correlated to the WRAT spelling subtest, $r(6) = .747$, and to the DSPT phonetic word recognition, $r(6) = .790$, and to the visual spelling recognition subtest, $r(6) = .810$. There were no significant correlations between the phonological errors and the WRAT reading subtest, $r(6) = .688, p = .05$, or to the DSPT word visual recognition subtest, $r(6) = .707, p = .05$. Nor were there significant correlations between the orthographic errors and the WRAT reading, $r(6) = .524, p = .18$, or to DSPT visual, $r(6) = .341, p = .40$, or phonetic word recognition subtests, $r(6) = .590, p = .12$. Neither significant correlations were found between the morphological errors and the WRAT spelling subtest, $r(6) = .662, p = .07$, or the DSPT visual word recognition subtests, $r(6) = .619, p = .10$.

In the BAS group, there were no significant correlations with any of the three types of errors and the standardized test scores. Therefore, there were no significant correlations between the phonological errors and the WRAT reading, $r(6) = .497, p = .21$, or spelling subtest, $r(6) = .326, p = .43$; nor were significant correlations with the DSPT visual, $r(6) = .436, p = .28$, or phonetic word recognition subtests, $r(6) = .501, p = .21$, or with the spelling visual recognition subtest, $r(6) = .415, p = .31$. There were no significant correlations between the orthographic errors and the WRAT reading, $r(6) = .637, p = .09$, or spelling subtest, $r(6) = .308, p = .46$; nor were significant correlations with the DSPT visual, $r(6) = .657, p = .08$, or phonetic word recognition subtests, $r(6) = .218, p = .61$, or with the spelling visual recognition subtest, $r(6) = .023, p = .96$. There were no significant correlations between the morphological errors and the WRAT reading, $r(6) = .480, p = .23$, or spelling subtest, $r(6) = .423, p = .30$; nor were significant correlations with the DSPT visual, $r(6) = .695, p = .06$, or phonetic word recognition subtests, $r(6) = .623, p = .10$, or with the spelling visual recognition subtest, $r(6) = -.587, p = .13$.

These results indicate that spelling abilities of the three types of spellers differ with the type of spelling error presented in the experimental tasks. The NES group's accuracy with phonological errors was correlated to the spelling sub-test, and accuracy with the morphological errors was correlated to the reading sub-test; accuracy with orthographic errors was correlated to reading, spelling and spelling visual recognition sub-tests. The SLS group's accuracy with phonological and morphological errors was correlated to the same set of sub-tests: written spelling and visual spelling and phonetic word recognition sub-tests; accuracy with orthographic errors was correlated to spelling

and visual spelling recognition sub-tests. The BAS group's accuracy with phonological, orthographic and morphological errors was not correlated to any of the sub-test scores. The absence of correlation appears to indicate that the spelling skills of this group of spellers are not captured by the sub-tests used in the study. In general, the results denote that NES relies on orthographic features of words to conduct their spelling; SLS focus on visual and phonetic features of words, and access mnemonic sequences to guide their spelling; in addition, BAS spelling skills and use of strategies (including guessing) might have not be measured by the tests used in this study.

The number of correlations in each group seems to indicate a skill level. Thus, NES had a precise number of correlations with each task (detection vs. correction). For detection tasks, skilled spellers seem to rely on all word qualities except the ones precisely involved in the reproduction of a word's spelling (i.e., spelling and visual spelling recognition), which conforms the exact opposite correlational pattern found in the phonological errors and in the correction tasks. The SLS also showed a definite pattern associating detection tasks and phonological and morphological errors. This group of spellers appears to rely more on dual word features such as visual and phonetic word recognition cues for detection tasks; however, they depend upon visual spelling sequences for the correction tasks, and to spell orthographic errors (i.e., spelling and visual spelling recognition). The unique patterns of this group of spellers appear to indicate a reliance on complete memory representations for the spelling of words. The BAS group presented a correlational pattern that denotes no reliance on visual or phonological word recognition qualities to detect or correct spelling errors. It appears that this group of spellers have limited and fragile representation of words, which are difficult

to access and retrieve. It would appear that the lack of visual or phonetic cues leads them to fully rely on phonology, and probably use guessing as spelling strategy, to detect and correct misspellings rather than resort to the use of orthographic rules or to memorize and access visual letter and word sequences. Overall, this set of findings demonstrates common processing elements between a particular task and error type to the processing characteristics of each group of spellers.

Discussion

Analysis of the spelling abilities across the three groups of spellers showed that NES and BAS demonstrated different levels of spelling accuracy. The SLS were as accurate as the NES, and were also as accurate as the BAS. The differences in accuracy between the NES and BAS indicate that they are dissimilar to each other in relation to their access to words' qualities and definition of mental representations. Spellers accuracy rates in each task exposed additional information about their abilities. Detection skills were no different across the groups of spellers; and each of the three groups was more accurate with detection of phonological than orthographic errors, and was also more accurate with orthographic than with morphological errors. Conversely, correction skills were different across the groups; thus the NES and the BAS attained different levels of accuracy for correction tasks. Nonetheless, the SLS attained similar levels of accuracy as the NES and as the BAS for the correction of spelling errors. This finding clearly demonstrates that general cognitive processes supporting storage, access and retrieval of mental representation of words as necessary for reading, writing and spelling are relatively similar across groups of spellers (Cummings, 1986; Hosky & Swanson, 2000; Proctor et al., 2005).

The spelling patterns in each group of spellers evidenced a unique spelling profile for each group. In regards to accuracy by spelling error, the NES group was more accurate with phonological than orthographic errors, and more accurate with orthographic than morphological errors. The SLS group was equally accurate with phonological and orthographic errors but less accurate with morphological errors. The BAS was more accurate with phonological than morphological errors, but they were equally accurate with orthographic, and morphological errors. These patterns of spelling accuracy convey important information in reference to error blindness and quality in mental representations for each group. For the NES, phonological and morphological errors have the higher and lower saliency respectively; and spellers possess more quality and defined representations for phonological than for morphological errors. For the SLS, phonological and orthographic errors have equal and higher saliency than the morphological errors; thus spellers have acquired more and better quality of mental representations for phonological and orthographic errors than for morphological errors. These trends indicated that orthography had a facilitation-dominant influence on phonology (see Owen & Borowsky, 2003), suggesting that the SLS may be approaching the phonological errors through their orthographic units, and may be overlooking the phonological representations of the words. By grounding phonological errors in orthography, SLS may be also blocking the interference effects from L1 into L2 spelling (see Want & Geva, 2003). For the BAS, orthographic and morphological errors have equal but lower saliency than the phonological errors. In this way, for this group of spellers, phonology had a dominant role on their spelling (see Frith, 1980; Snowling, 1994). Furthermore, BAS appear to anchor the spelling of morphological errors through

orthography, demonstrating an extension of Owen and Borowsky's (2003) postulates of a facilitation-dominant influence of orthography on morphology.

In each task, the error category generated similar effects on the spellers' abilities. The detection skills of the three types of spellers presented the same accuracy pattern across error type; each group was more accurate with detection of phonological than orthographic errors, and were also more accurate with orthographic than with morphological errors. Conversely, the correction skills of the three types of spellers were not affected by the error category. Each group corrected phonological, orthographic and morphological errors with the same degree of accuracy. The observed patterns indicate that spellers' detection and correction skills may be related to the tasks per se. Detection skills seem to be impacted by the saliency of each error type. Differences in detection accuracy rates illustrate the saliency of the errors in a continuum of orthographic sophistication (see Figueredo & Varnhagen, 2004; Varnhagen et al., 1997). On the other hand, correction skills seem to be ruled by the demands imposed by the correction activity, which implicates access to the spellers' lexicons where a word needs to be identified by its qualities. The correction process is grounded in orthography and in a multiple activation of word features. As spelling recognition and production processes rely on shared knowledge (i.e., phonological, orthographic and morphological features of words; Kamhi & Hinton, 2001, Seidenberg, 2005; Treiman, 1997), any differences between the patterns of accuracy in detection and correction tasks can be attributable to the task per se.

Contrasting detection and correction rates by error category in each group of speller elucidated additional similarities in the spelling of the groups. Not surprisingly, all

groups attained equivalent detection-correction rates for the orthographic errors. Such equivalence indicates that each of the three groups of spellers was able to correct the same number of orthographic errors that they detected, indicating that both, error blindness and quality of mental representations are related to some degree to the spellers' mastery of the orthographic rules but also to their processing differences. The balanced detection-correction rates also suggest that orthographic representations are functioning as the principal axis for spelling processes.

In all three groups, the spelling accuracy rate of phonological errors across tasks was higher for detection than for correction tasks. This difference emphasizes the speller's sensitivity for the phonological errors, and therefore, a low error blindness index as it was easier for all three groups of spellers to recognize this type of errors (Figueredo & Varnhagen, 2004). Nonetheless, speller's mental representations of phonological errors were not as well defined, nor as readily available as expected for the correction tasks. This finding may represent a phonemic interference for the correction of the phonological errors (see Owen & Borowsky, 2003; Wang & Geva, 2003), spellers difficulties in analyzing phonemes or phonetic clusters (Treiman, 1991), or a phonology biased orthographic processing (Owen & Borowsky, 2003).

Detection-correction accuracy rates for morphological errors presented similar patterns in the SLS and BAS; this equivalence indicates that both groups activated their application of spelling rules and morphological knowledge (Leong, 2009; Service & Turpeinen, 2001) in the correction tasks via orthography. In the NES, the spelling pattern for morphological errors (higher correction than detection rates) denotes low saliency, thus high error blindness, for this type of errors in the detection tasks, but also clearer

mental representations, thus good accessibility, to the word's morphemic sequences in the correction tasks. In this case, the application of orthographic rules and morphemic analysis in the NES provides an obvious advantage for the spellers' accuracy.

Consequently the group was able to correct more morphological errors when the errors were openly presented for correction. The increased correction rate conveys the NES's accessibility to quality mental representations of morphological units to complete the tasks with high degree of accuracy (see Leong, 2009; Service & Turpeinen, 2001). The NES pattern of spelling accuracy projects the strength and transferability of the orthographic axis.

Overall, analyses of accuracy by error type denote that each error is essentially different than the others in terms of saliency. Conversely, gradients of error blindness and clarity in the mental representations seem to be a quality associated to the spellers' processing abilities, and to a lesser degree to the task and type of spelling error (see Butterfield et al., 1996). As such, by presenting an error for correction, a path to access the multiple representation of words is automatically open through an orthographic axis. In this way, the influence of the error type on accuracy, seemingly rooted in orthography, becomes less relevant to the speller, and for the cognitive processing mechanisms characteristic of each type of speller.

Study 3 uncovered the clearest differences between the groups in terms of strategic efficiency and works of the cognitive system while accessing and retrieving mental representation of words. One obvious difference is the number of strategies applied by the NES and the BAS. Conversely, no clear differences were found in the number of strategies applied by the SLS and the other two groups. That is, the number of

strategies used by the SLS and the NES, and the number of strategies used by the SLS and the BAS remained between close ranges of frequency. The difference in the application of strategies between the NES and BAS groups denotes differences in speller's strategic efficiency. And to achieve spelling accuracy the spellers need to engage their cognitive resources through the use of strategies. In this study, the NES and the SLS were able to apply efficient strategies to access and retrieve the mental representation of words. Conversely, the BAS were less effective in their application of spelling strategies as they were less successful in achieving spelling accuracy.

Differences in strategic engagement between the groups become more evident through the application of strategies in each task. In the correction tasks, the NES and the SLS groups used similar number of spelling strategies to correct misspellings; the BAS, on the other hand, used efficient strategies less than the other two groups of spellers. The number of strategies used for the correction tasks in the NES and SLS reveals direct and effective access to the mental representation of words. The lack of effective strategies for correction tasks by the BAS group may be reflecting difficulties in accessing (i.e., intrusion, noise), and perhaps retrieving weak representations with degraded orthographic structures (Joshi & Aaron, 2000). These numbers may also be indicative of the speller's obstacles for the integration of information being analyzed in working memory (see Coltheart, 2006; Seidenberg, 2005). In the detection tasks, there were no differences in the application of strategies between the groups; this lack of differences alludes to the nature of the tasks, as well as to the spellers' reliance on mostly one strategy (i.e., visual) to guide all spelling activity (see Thompson et al., 2005). The lack of differences between the groups demonstrates that spellers are approaching detection tasks primarily as a visual

activity (i.e., spellers require fast visual systems as attention gating mechanism; Thompson et al., 2005), without the integration of the phonetic information (Ehri, 1992; Frith, 1980; Gaulin, 2000; Snowling, 1994) that is required for spelling.

The application of strategies in each group of spellers shows a different pattern of strategic efficiency for each group. In this way, while the NES used direct retrieval and visual strategies with the same frequency, the BAS relied almost completely on the visual strategy to carry on spelling tasks. Consequently, the BAS used a re-constructive process by which they assembled a word's spelling by its features (e.g., phonetic, visual). Conversely, the NES applied a strategy that provided faster and direct lexical access while using fewer cognitive resources (Abu-Rabia 2003). By going through the re-constructive path, the BAS group taxes the working memory capacity, compromising its spelling accuracy (e.g., slow word recognition, loss of information; Bell & Perfetti, 1994; Swanson & Berninger, 1996). Spellers in the SLS group seem to have applied each spelling strategy with great variability. The width of the frequency range with which the spellers applied the strategies reflects not only the individual differences but that while some spellers in the group are using spelling strategies efficiently, others may be not.

By contrasting general patterns of strategic engagement across the groups of spellers, it was noted that there is a common tendency in these groups to apply the visual strategy with higher frequency while keeping the application of the phonetic strategy to the minimum. This tendency may be reflecting processing differences in the groups. For example, the use of visual strategy by BAS is perhaps an alternative to define weak boundaries and degraded orthographic structures in their mental representations (Joshi & Aaron, 2000). And the use of visual strategies by the SLS may be an alternative to avoid

interference from L1 (Wang & Geva, 2003), and an indication of increased proficiency in L2 spelling (Chikanatsu, 2006).

The application of the direct retrieval strategy across the groups was linked to the speller's use of back-up strategies. In this sense, it was observed that while the BAS group tended to use direct retrieval and phonetic strategies at similar rates, the NES group used direct retrieval and visual strategies equivalently. These observations denote that the working memory processing capacity is compromised in these two groups of spellers; therefore, they use the visual and phonetic strategies as supportive strategies (see Coltheart, 2006) in order to reduce the noise and intrusive information that affects the clarity of the representations (Gaulin, 2000). By utilizing an additional strategy spellers avoid to lose important spelling information (Abu-Rabia, 2003) that contributes to accuracy. According to working memory models, spellers are using the integrative function of their visuo-spatial sketchpad and the phonological loop to access mental representation of words stored in long term memory (Baddeley, 2003; Bayless et al., 2003). This concept is also captured by the simultaneous processing or integrative hypothesis (Kreiner & Gough, 1990; Rittle-Johnson & Siegler, 1999), which implies that visual sequences and orthographic rules need to be integrated for spelling.

Analyses of each group's strategic engagement in the spelling tasks brought light to additional similarities and differences between the groups. As such, in the detection tasks, the NES and the BAS applied the visual strategy as frequently as the direct retrieval strategy, and they also apply the direct retrieval strategy as frequently as the phonetic strategy. Nonetheless, there is a difference in the frequency with which these groups use the visual and phonetic strategies. In the correction tasks both groups

demonstrate different patterns for the application of strategies. In this way, the NES applies the phonetic strategy at a significantly lower rate than the visual, and direct retrieval strategies; however, they apply the visual and direct retrieval strategies at equal rates. On the contrary, the BAS apply all the spelling strategies with the same frequency for correction tasks. This means, that their use of strategies is undifferentiated, all within similar ranges, without selecting a preferred type of strategy type to guide their spelling. This undiscerning use of strategies by the BAS group can be explained by their difficulties in accessing and retrieving the mental representations of words, and their obstacles in integrating the information in working memory (Coltheart, 2006; Seidenberg, 2005). These difficulties may also reflect unclear mental representations in this group of spellers and their need to re-construct the spelling of words through their phonetic, orthographic and morphemic units.

Overall, the strategic engagement in the tasks evidenced that the NES applied visual and direct retrieval strategies with equal frequency in both tasks. The SLS relied equally on all and each of the strategies to carry on spelling activities across tasks and formats, with one exception in the printed format where SLS used the visual strategy for detection tasks in print. This use of the visual strategy appears to be a way to avoid L1 interference (see Wang & Geva, 2003) to L2 spelling in the printed format. The SLS increased reliance on visual information is found to diminish the orthographic effect of L1 (Chikamatsu, 2006) on L2 spelling. The BAS mainly used the visual strategy for detection tasks, while relying equally on all three strategies for the correction tasks. The groups' interaction between task and strategy reveals that the application of a phonetic strategy for spelling is generally reduced in both tasks across groups of spellers.

The use of strategies across tasks showed differences only in the BAS group. They applied greater number of spelling strategies for detection than for correction tasks, indicating that this group of spellers uses more cognitive resources for recognition than for production tasks. Although the BAS tend to use mostly visual strategies to carry on spelling tasks, it appears as if the application of the visual strategy for spelling is supported by the application of adjacent strategies (i.e., phonological, direct retrieval).

The overall results indicate that all three types of spellers tended to use the same strategy across tasks and formats. Spellers in all three groups predominately used the visual strategy to detect errors, and they used more than one strategy to correct the errors. That is, spellers paired the use of the visual strategy with an adjacent strategy to support their spelling activity in the correction tasks (e.g., phonetic, direct retrieval). Differences between the numbers of spelling strategies used in each task indicate that correction tasks are cognitively more taxing than detection tasks; thus, accessing the representations of words requires more than one strategy. Because there was no difference in the application of spelling strategies across tasks, it can be concluded that the visual strategy represents the spellers' main cognitive resource to detect and correct spelling errors. This finding suggests that differences in the use of strategies describe the spellers' cognitive processing more than the task demands. Lastly, the predominant use of visual strategy in the printed format for the SLS illustrates and reiterates the influence of format on spelling abilities.

Differences in the use of strategies across groups of speller reflect the strategic engagement of cognitive resources of the different groups of spellers. In this way, the NES mostly applied visual and direct retrieval strategies to conduct spelling tasks. The

BAS rely mostly on the visual strategy to guide their spelling. The SLS resort to all three strategies. These two groups have difficulties accessing defined mental representations and to lack of strategic support for spelling. Conversely, the NES use of direct retrieval confirms that efficient spelling is achieved by the activation of this fast accessing route leading to clear mental representations. It results interesting to see that all groups of spellers seem to avoid the application of the phonetic strategy for spelling tasks.

The SLS use of multiple strategies can be explained by the fact that the spellers may not be very familiar with all the words in their new language, thus all the English words function as exception words. It is likely that SLS cannot rely completely on a rule-based phoneme-grapheme association as their new language has different features they are unfamiliar with, such as syllabication, rhythm and intonation. Consequently, all new words act as exception words; and to correctly spell an exception word, writers must rely on richer context information, including the orthographic representations of whole words (Coltheart, 2004; Tiu et al., 2003) and the use of morphographs (Treiman & Bourassa, 2000a).

The multiple use of strategies (e.g., direct retrieval and visual strategies) has been presented in the simultaneous processing or integrative hypothesis (Kreiner & Gough, 1994; Rittle-Johnson & Siegler, 1999). In Study 3, the speller's application of multiple strategies denotes that they possess unclear, not readily accessible or partial representations of words, thus spellers need to move through lexical and sub-lexical routes to re-construct the words' spellings. In addition, as spellers tend to adopt a preferred spelling strategy to conduct the spelling tasks (Ehri, 2000; Rittle-Johnson &

Siegler, 1999), Study 3 suggests that speller's strategy choice be based on their cognitive processing qualities.

Although the results showed that format, as an independent factor, does not affect the use of spelling strategies, they demonstrate that strategic engagement in spelling is affected by the combined effects of several variables. In this way, Study 3 shows that format and task in the SLS group affect the application of strategies. The fact that other effects of format are not observable in this study can be explained several ways. First, the use of strategies automatically covers up any effects of format (i.e., strategic engagement reduces the prominence of any effect). Second, the small group size and large standard deviations overshadow the effect by minimizing the value of format and reducing the power of the effect making them difficult to identify. Third, the cognitive system is composed of self-sustainable structures that assist each other to solve any task, promoting the multiple use of strategies which in itself masks the effect of format on spelling tasks.

Skill differentiation for detection vs. correction tasks across group of spellers showed that the groups' accuracy was associated to a different set of word qualities in each type of speller. Accuracy in detection tasks was associated to reading, and visual and phonetic word recognition in the NES, and to spelling, and visual and phonetic word recognition in the SLS, but only associated to phonetic word recognition in the BAS. Accuracy in the correction tasks was associated to spelling in the NES, and to spelling and visual word recognition in the SLS, but there were no correlation in the BAS.

Correlational analysis between spellers' accuracy rates and standardized test scores confirmed the relevance of orthographic knowledge and reading skills for detection tasks, and that of orthographic analysis for correction tasks. In particular, the

SLS group relied mainly on orthographic sequences for both tasks, and the BAS used only phonetic recognition skills for phonological errors, without any other correlation of significance, indicating that their mental representations have weak boundaries, thus BAS experience difficulties for accessing and retrieving the words' representations.

Correlations between spelling abilities and error accuracy rates showed that NES relied highly on reading and visual sequences for the spelling of all three types of errors. The SLS relied highly on visual and occasional phonetic cues for detection tasks and on visual sequences for correction tasks. Meanwhile the BAS's error accuracy rates had no correlation with any of the subtests administered, indicating that their spelling activities are not lead by any of the identifiable word features measured by standardized tests.

The previous analyses suggest that spelling accuracy for the three types of errors varies with the skills measured by the standardized tests. Consequently, the NES used sophisticated cues for spelling (e.g., reading, orthographic cues), the SLS relied on two main word features for detection tasks (e.g., orthographic and phonetic clusters), and only on visual sequences for orthographic errors and for correction tasks. The BAS accuracy seems to be mostly reflecting fragile representations as their spelling skills were not associated with any identifiable word features. It is possible that group of spellers may had been using a re-constructive process of words spelling through guessing. It is also possible that the spelling abilities of this group of spellers were not captured by standardized tests.

Examining the spelling patterns of three groups of spellers allowed gaining a deeper understanding of the processing mechanisms involved in spelling. Thus, this study found that the three groups of spellers tend to perform at equable levels of accuracy in the

detection tasks (i.e., similar gradients of error blindness or attention). The differences in spelling accuracy across the groups arise from their performance in the correction tasks (i.e., memory, and word knowledge or quality gradient of mental representations), with this difference being particularly observable between the NES and BAS. Most importantly, the inaccuracies in spelling recognition and production tasks result from dysfunctional cognitive processing mechanisms and/or deficient knowledge (i.e., error blindness, quality mental representations).

The fact that spellers detect phonological errors at higher rate than they correct, but detect and correct equal numbers of orthographic and morphological errors speak about processing differences. As it is not only the quality of the error but the cognitive operations in the processor or speller. The most compelling evidence of the processing differences in the groups of spellers resides in the use of strategies and the patterns of strategic engagement across spellers.

Consistent with the findings in the previous studies, the degree of error blindness for phonological errors was significantly lower than that for orthographic and morphological errors in all groups of spellers. On the other hand, the mental representations of the three types of errors appear to possess similar quality within each group of spellers, conveying the idea of a characteristic processing quality for the tasks in each type of speller. Consequently, differences in accuracy across spellers are considered to reflect the inherent processing differences between the groups. These findings add support to the essential role of the cognitive structures underlying the word representations in the spellers' lexicons, such as sustain clarity or definition to the representations and to provide access to those representations.

Two issues need to be addressed in this study, the group size and the large SD. It is necessary to admit that the analysis of spelling skills across three groups of spellers was quite ambitious. The limited access to a diverse group of spellers restricted the sample size, thus the number of spellers studied; therefore Study 3 may not have shown clearer effects of format on the spellers abilities as there were several relevant variables affecting the spelling processes. Nonetheless the outcomes from this study show that the groups have processing differences affecting their spelling abilities. Additionally, the large SD in SLS might have raised some questions; nonetheless, equality of variance analysis showed that subjects were not essentially different from one another, thus belong to the same group of spellers. Furthermore, as the findings of this study are congruent with and supported by the literature in the field, it can be concluded that those findings are valid at least for the groups of spellers studied.

One last word in regards to effects of format on spelling processes. Although format alone did not create observable effects in two of the groups in terms of accuracy, the printed format increased the use of visual strategies for the detection tasks in SLS, thus denoting their reliance on visual cues. Inevitably Study 3 demonstrates, once again, that format impacts spelling processing.

CHAPTER 5

Spelling Recognition and Production: Spellers Accuracy and Use of Strategies Across Formats

The use of a computer format is often said to be extremely helpful for the organization and editing of work, and also for economy of time. In terms of cognitive systems, the use of a computer has the potential to allow people work more efficiently as it saves time and effort. These premises imply that processes such as spelling may be more efficient when people work in one format (i.e., computer) than in other (i.e., print). Nevertheless, the intricate nature and enmeshment of the two sub-processes involved in spelling (as evidenced in the studies presented in this dissertation) complicates the study of the effects of format on spelling accuracy and strategic efficiency. Research findings presented in the previous chapters noted that recognition and production processes are affected by the graded quality and malleability of the mental representations of words, and by the spellers' processing abilities in working memory. In these studies, the effects of the types of spelling errors and the cognitive strategies used to approach the tasks were found to denote the quality of the mental representations and the processing differences of the different spellers. The studies revealed that the format used to conduct the spelling tasks impacted the cognitive load, and the spellers' use of strategies to approach the tasks. In this way, the degree of spelling accuracy was associated with the strategic engagement in each format and the type of spelling errors in each task.

The focus of this dissertation has been to explore the different aspects of the cognitive processing underlying spelling recognition and production. These processes were investigated while people with different levels of spelling abilities worked in

different formats. The findings derived from each study have been presented in the previous chapters, therefore this chapter encompasses the global findings related to the spellers' accuracy and use of strategies in each spelling task and working format. The chapter is divided into five sections: Speller's accuracy, Application of strategies, Spelling abilities and tests scores, Discussion, and Conclusions. One must note that the native English spellers participating in this study were average, above average and below average spellers. And that the English as a second language group were compared to native English spellers, who were categorized as either average or below average spellers.

Spellers' Accuracy

The average and below average spellers demonstrated different levels of spelling accuracy. The differences between the groups denote diversity in the quality and accessibility of mental representations thus variability in error blindness indexes. There were no differences in spelling accuracy between the second language spellers and the average or below average spellers. Similarly, there were no differences in spelling accuracy across groups of spellers in the detection tasks. Similarities in levels of detection accuracy seem to be associated with the fact that general cognitive processes support spelling such as attention and memory (Cummings, 1986; Hoskyn & Swanson, 2000; Proctor et al., 2005), and with the spellers' error blindness indexes. Nonetheless, there were differences in the spelling accuracy of the average and below average spellers in the correction tasks. These differences appear to be related to the quality in the representations of words and the processes used to access and retrieve these representations.

Accuracy by Error Type. Spelling errors had different degrees of saliency according to their category. The graded quality of the errors determined the speller's accuracy. Thus, average and above average spellers were more sensitive to phonological than orthographic or morphological errors, and also more sensitive to orthographic than morphological errors. This pattern has been observed in previous studies (see Figueredo & Varnhagen, 2004) and reveals the degree of saliency of the errors.

The trend in error saliency observed in average and above average spellers changed for the second language spellers and the below average spellers. In these groups, spellers were more accurate in dealing with phonological than morphological errors. In addition, the second language spellers were more accurate with orthographic than morphological errors, but equally accurate with phonological and orthographic errors. The below average spellers were more accurate with phonological than orthographic errors, but equally accurate with orthographic and morphological errors. These differences denote a graded quality of and accessibility to the mental representations in relation to the error type for each type of speller. Additionally, orthographic errors appear to exercise a positive transfer effect in the phonological errors in second language spellers, and in the morphological errors in the below average spellers as observed by their increase in accuracy in regard to those errors.

Each group of spellers presented a unique spelling profile in terms of quality and quantity of representations and degree of error blindness. Average and above average spellers possess more quality and defined representations, thus less error blindness, for phonological than for morphological errors. The second language spellers have acquired more and better quality mental representations for phonological and orthographic errors

than for morphological errors. The below average spellers have more defined representations for phonological errors than for orthographic and morphological errors. The second language spellers' profile suggests that they may be approaching the phonological errors through their orthographic units, and may be overlooking the phonological representations of the words, demonstrating that orthography had a facilitation-dominant influence on phonology (see Owen & Borowsky, 2003). Similarly, the below average spellers profile appears to anchor the spelling of morphological errors through orthography, demonstrating an extension of Owen and Borowsky's (2003) postulates of a facilitation-dominant influence of orthography on morphology, which reduces the chances for error blindness in the morphological errors.

Accuracy in the spelling tasks. Speller accuracy was different in each task in relation to the type of spelling error presented in the texts. The differences in the tasks also varied across the groups of spellers and with the type of error. Thus, speller recognition and production abilities were related to the task demands and the strength in saliency of each type of error encountered in the texts.

There was a single and unified pattern of detection accuracy across all types of spellers similar to that identified in the previous studies. All spellers detected a higher number of phonological than orthographic and morphological errors; and also more orthographic than morphological errors. Therefore, all spellers exhibited higher error blindness for morphological than for phonological errors. The ability to recognize misspellings fluctuated with the type of spelling errors in all spellers.

All but the above average spellers presented the same pattern of correction accuracy. Average, second language and below average spellers did not show any

significant difference in the correction of errors regardless the error type. Conversely, above average spellers corrected higher numbers of phonological than orthographic and morphological errors but they corrected orthographic and morphological errors at similar rates. Therefore, all spellers appear to possess a single correction processing pattern for orthographic and morphological errors which reflects the equivalence in the gradient of clarity of mental representations across type of spellers and those types of errors. Consequently, spellers were more susceptible to error blindness in the presence of morphological errors but they were able to access and retrieve morphological representations with the same ease as the orthographic representations for the correction tasks. Nevertheless, the ability to correct phonological misspellings was effected by the error type only in the group of above average spellers; the high correction rate of phonological errors by above average spellers may reflect an engagement of phonological representations in order to increase accuracy. In general, correction tasks seem to have brought up a consistency of cognitive processing in the spellers, which is not easily altered by the category of spelling error.

For the average, second language and below average spellers, detection rates varied according to the type of spelling error, but not so for correction rates. Considering that spelling recognition and production are separate sub-processes, the variation reflected the spellers' lack of attention in carrying on the detection tasks; however, spellers amended, improved and demonstrated their skill at spelling on the correction tasks (Figueredo & Varnhagen, 2004, 2006). Differences in the patterns of error accuracy in each task were interpreted as error processing differences. That is, there was a clear distinction in the prominence of each error type (i.e., phonological errors were more

salient and easily detectable than the morphological errors), and of the tasks demands (i.e., correction tasks demanded the application of the spellers knowledge of orthographic rules). The spellers' activation of orthographic knowledge was also demonstrated in the equivalence across detection and correction rates of orthographic errors. The increased correction rates of morphological errors revealed the activation of morphemes via orthography. Overall, detection and correction abilities appear to be highly sensitive to phonological errors, which were the most prominent detected and corrected errors.

The correction pattern of above average spellers suggests that the differentiation of morphological units is based on a rule-like process (Pinker, 1991) that gradually evolves into a more sophisticated level of proficiency in which spellers are able to resolve unpredictable spelling patterns (Treiman & Bourassa, 2000a). Consequently, the ability to reproduce accurate mental representations of morphological information strengthens as such representations are consciously activated, and their gradient of clarity increases by accessing the orthographic structure of the words at hand; in this way orthography shows its facilitation-dominant influence on morphology.

Spelling accuracy across tasks presented two types of trends in relation to the error category, one for the average and above average spellers, and other for the second language spellers and below average spellers. In this way, average and above average spellers were more accurate in detection than in correction of phonological errors; conversely, they were more accurate in correction than in detection of morphological errors. Average and above average spellers were as accurate for detection as they were for correction of orthographic errors. The second language spellers and below average spellers were more accurate in detection than in correction of phonological errors; and

they were as accurate for detection as they were for correction of orthographic and morphological errors. The difference between the spellers is most observable in their accuracy regarding morphological errors across tasks, which is equivalent in the second language spellers and below average spellers but increased for the correction tasks in average and above average spellers.

Differences in spellers' accuracy for recognition and production tasks in the presence of phonological and morphological errors reflect distinct processing. Spellers approached recognition tasks automatically and processed words and syllables as visual-spatial tasks without reference to their verbal content (Voyer & Bourdreau, 2003). In this way spellers were not processing the words entirely or as graphemic units but as individual letters or characters, overlooking the word's meanings. They tended to focus on the physical features of the words (lexical processing) rather than on their verbal nature (phonological and semantic processing), failing to direct their attention to the appropriate word qualities as necessary for spelling recognition tasks, particularly for the morphological errors.

The crossover interaction between phonological and morphological errors across tasks in average and above average spellers appears to be related to the saliency of the type of errors and perhaps, to the unconventional phonemes used in the stimuli (e.g., *repetishun*, *inevitabul*, see Figueredo & Varnhagen, 2004). The increased accessibility to quality representations when spellers correct morphological errors related to the cognitive grounding in orthography; this grounding also facilitates the spellers' access to graphemic representations when the morphemic units of words were elicited at the time of correction (Leong, 2009, Service & Turpeinen, 2001). Thus, the increased accuracy in correcting

morphological errors is part of a cognitive transfer effect of orthographic rules into morphological mental representations of words.

Equivalent detection and correction accuracy rates for morphological errors in second language spellers and below average spellers indicates that both groups activated their application of spelling rules and morphological knowledge (Leong, 2009; Service & Turpeinen, 2001) in the correction tasks via orthography. The facilitatory effect of orthography on morphology increases the accessibility to quality mental representations of morphological units allowing the speller to complete the tasks with a high degree of accuracy (see Leong, 2009; Service & Turpeinen, 2001). This pattern of spelling accuracy projects the strength and transferability of the orthographic axis into spelling production processes.

The accuracy rate of phonological errors across tasks was higher for detection than for correction tasks in all groups of spellers. The high salience of the phonological errors for all spellers denotes the dominant role of phonology on their spelling (see Frith, 1980; Snowling, 1994). This difference emphasizes the spellers' sensitivity to the phonological errors, and therefore, a low error blindness index as it was easier for all spellers to recognize these types of errors (Figueredo & Varnhagen, 2004). Nonetheless, the speller's mental representations of phonological information were not as well defined, nor as readily available as expected for the correction tasks. This finding may represent a phonemic interference that hampers the correction of the phonological errors (see Owen & Borowsky, 2003), the spellers' difficulties in analyzing phonemes or phonetic clusters (Treiman, 1991), or a phonology biased orthographic processing (Owen & Borowsky, 2003).

The equivalence between detection and correction rates of orthographic errors in all spellers demonstrates a stable quality gradient in the mental representations regarding this type of error which prevent fluctuations in the speller's performance (see Burt & Butterworth, 1996; Holmes & Castles, 2001) and provide an axis for spelling processes. Therefore, spellers appear to anchor the spelling of morphological errors through orthography, demonstrating an extension of Owen and Borowsky's (2003) postulates of a facilitation-dominant influence of orthography on morphology.

The observed detection and correction patterns indicate that spelling skills may be related to the tasks *per se*. Detection skills seem to be impacted by the saliency of each error type. Differences in detection accuracy rates illustrate the saliency of the errors in a continuum of orthographic sophistication (see Figueredo & Varnhagen, 2004; Varnhagen et al., 1997). On the other hand, correction skills seem to be ruled by the demands imposed by the correction activity, which implicates access to the spellers' lexicons where a word needs to be identified by its qualities. The correction process results in a multiple activation of word features. As spelling recognition and production processes rely on shared knowledge (i.e., phonological, orthographic and morphological features of words; Kamhi & Hinton, 2001, Seidenberg, 2005; Treiman, 1997), any differences between the patterns of accuracy in detection and correction tasks can be attributable to the task *per se*.

Overall, analyses of accuracy by error type denote that each error is essentially different than the others in terms of saliency. Conversely, gradients of error blindness and clarity in the mental representations seem to be a quality associated to the spellers' processing abilities, and to a lesser degree to the task and type of spelling error (see

Butterfield et al., 1996). As such, by presenting an error for correction, a path to access the multiple representation of words is automatically opened through an orthographic axis. In this way, the influence of the error type on accuracy, seemingly rooted in orthography, becomes less relevant than the task for the cognitive processing mechanisms characteristic of each type of speller.

Accuracy across formats. The mental representations of average and above average spellers were found to be stable across format and task. Accuracy rates across detection and correction tasks were similar in each format, indicating that the spellers were able to correct every spelling error that they had detected. Detection and correction rates were also similar across format, demonstrating that there were not observable differences in the words' mental representations associated with format. In addition, accuracy across detection-correction tasks in each error type were similar across format, suggesting that format did not impact the sub-processes of spelling regardless of the error type. These results show that average and above average spellers gave the same degree of attention to each task and were able to retrieve the mental representations of words with the same degree of clarity in both formats. Findings suggest that average and above average spellers were able to apply their orthographic knowledge in both tasks and formats equally.

The issue of cognitive load and strategic engagement associated with shifting working formats was addressed in the second study with a group of above average spellers. It was understood that spelling recognition processes can be difficult, mainly in terms of the attentional resources required to process the word's meaning (Figueredo & Varnhagen, 2006; Rees & Russell, 1999) and not necessarily in regard to spelling

abilities (i.e., orthographic knowledge). In this way, the influence of format on the spelling tasks became evident when the cognitive load increased, and when spellers switched working formats to conduct the tasks (i.e., from printing to keyboarding or from keyboarding to printing). This study also showed several effects of shifting work between formats by task and error type on spelling accuracy. The findings are presented below in two main sections: direction of the shift and spelling accuracy, and effects in each working format.

Direction of the shift and spelling accuracy. In regards to error type, above average spellers achieved different levels of accuracy with phonological, orthographic and morphological errors in either shifting sequence (i.e., print-first, computer-first). They were more sensitive to the saliency of phonological than either orthographic or morphological errors, and were also more sensitive to orthographic than morphological errors. The saliency of the different types of errors resembles the patterns of spelling accuracy identified in previous studies. These results indicated that the availability of the mental representations varied with the type of spelling error regardless of the direction of the shift.

In regards to the spellers' accuracy in each task, it was found that the detection and correction abilities varied with the direction of the shift. In detection tasks, the above average spellers' accuracy fluctuated with the type of spelling error in either sequence. Their detection accuracy followed the same pattern observed in the previous studies in each sequence; that is, they were more accurate with phonological than orthographic and morphological errors, and also more accurate with orthographic than morphological errors in either sequence. However, the shifting sequence did impact the spellers'

correction ability in each of the errors in different ways. Above average spellers were more accurate with phonological than morphological errors but they were as accurate with orthographic and phonological errors as they were with orthographic and morphological errors. This unique pattern indicates that above average spellers exhibit a different ability in detecting and correcting phonological and morphological errors when the presentation sequence is accounted for. Nonetheless their correction accuracy for orthographic errors was not affected by either sequence.

Contrasting accuracy rates across tasks in each type of spelling error also showed differences associated with the direction of the shift. That is, shifting work from print to computer produced higher detection than correction rates for the phonological errors and higher correction than detection rates for the morphological errors in the above average spellers. However, the orthographic errors were not affected by the direction of the shift. Shifting work from computer to print produced higher correction than detection rates for the morphological errors only; but the detection-correction rates of phonological and orthographic errors were not different from each other. In this case, the mental representations of the phonological errors acquired more saliency and became clearer by initiating the spelling tasks in a computer format. It appears that the computer format elicited more *grapheme-phoneme correspondences*, and created an opposite effect to that described by Voyer and Boudreau (2003); thus, phonological and orthographic errors were recognized as orthographic sequences by the above average spellers. The linking of phonemes-graphemes-morphemes reflects the proficiency level expected in above average spellers, who activate the multi-leveled representations of words to achieve accuracy in the correction of errors.

The direction of the shift evidenced the fragility of the mental representations, affected production abilities of above average spellers, and produced changes across recognition and production processes, particularly for the phonological and morphological errors if the spelling tasks were initiated in a computer format. The spellers' accuracy across recognition and production of phonological errors were equivalent when the spellers shifted work from computer to print, indicating that spelling production processes were impacted to a lesser degree by the type of spelling error (i.e., phonological and orthographic) and more by the direction of the shift. In this way, starting the spelling tasks in a computer format impacted the spellers' susceptibility to error blindness, particularly for the phonological errors. The direction of the effect across tasks in the morphological errors denotes an increased clarity and accessibility of mental representation retrieval at the time of correction. This detection-correction pattern of the morphological errors could also represent low activity in the working memory component that holds the graphemic information (see de Partz, Lochy & Pillon, 2003), and therefore the presence of an inhibitory-like mechanism of the graphemic buffer at the time of detection (Service & Turpeinen, 2001). Furthermore, the degree of consistency for the spellers' accuracy in the presence of orthographic errors suggests that orthographic errors have a processing priority in the graphemic buffer and are not affected by the direction of the shift. These findings revealed that the spellers' ability to access and retrieve the words' mental representations for the correction of misspellings is grounded in the orthographic rules and enhanced regardless of the shifting sequence in the above average spellers. Additionally, shifting sequences showed that the degree of

error blindness and the gradient of quality in the representation would be determined by whether the error has a phonological, orthographic or morphological origin.

Combined effects in each working format and spellers' accuracy. The spellers' accuracy rate varied in relation to error type in both formats. Thus, above average spellers accurately identified more phonological than either orthographic or morphological errors, and were also more accurate with orthographic than morphological errors in either format. The same patterns of accuracy have been observed in previous studies. It was concluded that the accuracy of above average spellers in each format reflected the strength of the effects of error type and was not affected by the working format per se. These results indicated that the availability of the mental representations for spelling recognition and production was similar in both working formats and that, perhaps, format alone had a less clear influence than error type in the spelling tasks.

The effects of the type of spelling error in each task were evident in both working formats. Nonetheless, these effects were different in each task. The detection tasks in either format reflected the same patterns of accuracy observed in the previous studies. That is, above average spellers were more accurate with phonological than orthographic, and morphological errors, and they were more accurate with orthographic than morphological errors. These findings indicate that spelling recognition processes rely on the saliency of the error, and that the speller's proneness to error blindness varies with the type of misspelling presented in the texts; as such above average spellers had higher degree of error blindness for morphological than for phonological errors. Nonetheless, as the multiple feedback activation between the word features (phonology, semantic) seem to have facilitated spelling recognition processes (Seidenberg, 2005), the level of

accuracy in the detection of each error was not altered by the format of the tasks (Masterson & Apel, 2006).

The spellers' correction ability varied with the format, evidencing the quality and relative fragility of the mental representations (see Ehri, 2000). In the printed format the accessibility and retrieval of the mental representations of words was enhanced for phonological and morphological errors, as the accuracy rates of these two types of errors, although different from each other, were similar to that of the orthographic errors. This increase in clarity and definition demonstrated the anchoring of the spelling reproduction processes in orthography. In the computer format, the accessibility of the mental representations of words for the phonological and morphological errors was effected differently. The spellers' accuracy rates in each of the three types of spelling errors were not significantly different from each other, evidencing a unification of the processing mechanisms to access and retrieve mental representation of words. Therefore, for the correction tasks and in the computer format, the mental representations were equally accessible to the spellers regardless of the type of spelling error. The use of a single processing mechanism for spelling production tasks reveals the speller's exertion of an orthographic anchor to complete those tasks (see Burt & Butterworth, 1996; Holmes & Castles, 2001).

The combined effects of cognitive load in each format and task demonstrated the facilitatory effect of the computer format on the correction tasks for the phonological and morphological errors. All three types of errors were corrected with the same accuracy in computer, thus such format neutralized the effect of spelling error. This effect can be explained through the postulates of working memory resources (Berninger et al., 1998;

Longcamp et al., 2005; Neuhaus et al., 2006; Swanson, Ashbaker & Lee, 1996) and by the multiple feedback activation process required for spelling (see Seidenberg, 2005; Steffler, 2001). From the working memory perspective, the use of a computer format for spelling production tasks allowed spellers to reproduce the mental representations of words more rapidly, increasing the availability of cognitive resources, activating clearer and more precise phoneme-grapheme correspondences. From the multiple feedback activation perspective, the orthographic units of words become readily incorporated for the correction tasks by connecting each one of the phonetic and morphemic units in terms of orthography.

The above average spellers' accuracy rate across tasks also presents the same pattern identified in previous analyses. That is, spellers identified more phonological errors than they corrected; conversely, spellers also corrected more morphological errors than they detected. Orthographic errors were detected and corrected at the same rate. The opposite patterns were identified as a crossover interaction effect reflecting differences in saliency and accessibility of the errors associated to the task and perhaps the result of a cognitive action involving the application of spelling strategies.

It is important to note that the direction of the shifting sequence and format of the spelling tasks impacted above average spellers' accuracy, particularly for the correction of phonological and morphological errors. The computer format seemed to neutralize the effects of error type by facilitating the activation of the mental representations of words regardless of the type of spelling error presented in the texts. This facilitation can be explained by a speller's cognitive adjustment in the processing mechanisms and supported through the use of spelling strategies.

Application of Strategies

The application of spelling strategies provides information about the works of the cognitive system while it accesses and retrieves mental representation of words (Roussel et al., 2002; Varnhagen, 1995). Therefore, the application of spelling strategies uncovers the complexity and synchronization of this system and the variability associated with individual differences. It was found that the average spellers relied on higher number of strategies than the below average spellers to complete the spelling tasks. The second language spellers applied a similar number of spelling strategies as the average and below average spellers. The frequency of the application of strategies coincided with the level of accuracy achieved by each group of spellers. Therefore the number of strategies used reflect the level of skilled spelling; consequently the below average spellers were less effective than the average and the second language spellers in their application of spelling strategies as they were less successful in achieving spelling accuracy.

In detection tasks, there was a single pattern of strategic engagement across spellers. Thus, all spellers relied on the visual strategy for the recognition of errors (see Thompson et al., 2005). By approaching the detection tasks as a visual activity (i.e., use of the visual system as attention gating mechanism; Thompson et al., 2005), spellers did not integrate the phonetic or semantic information (Ehri, 1992; Frith, 1980; Gaulin, 2000; Snowling, 1994) that spelling requires. This inhibitory mechanism of certain word features is considered to speed up the detection process; nonetheless, this rapid scan also puts limits to visual attention (see Service & Turpeinen, 2001), and generates a rapid decay of the mental representations in working memory. Consequently, the access to some of the mental representations of words is restricted in the detection tasks.

In the correction tasks, the second language spellers and the average spellers applied similar rates of spelling strategies to carry on the spelling tasks; however, the below average spellers applied significantly less number of spelling strategies than the average spellers and the second language spellers. As the number of strategies used reveals an ease and efficacy in accessing the mental representation of words, the second language spellers and average spellers were using effective strategies for correction tasks. Conversely, the few strategies used by the below average spellers may be reflecting obstacles to integrating and analyzing word features in working memory (see Coltheart, 2006; Seidenberg, 2005), such as difficulties accessing (i.e., intrusions, noise) and retrieving their already weak representations with degraded orthographic structures (Joshi & Aaron, 2000).

Differences in the use of strategies across groups of spellers reflect the strategic engagement of cognitive resources of these different groups of spellers. In this way, the average spellers applied mostly visual and direct retrieval strategies to conduct spelling tasks. The below average spellers seem to rely mostly on the visual strategy to guide their spelling. The second language spellers seem to resort to all three strategies. These last two groups seem to have difficulties accessing defined mental representations and lack strategic support for spelling. Conversely, the average spellers use of the direct retrieval strategy confirms that efficient spelling is achieved by the activation of a fast accessing route leading to clear mental representations. Interestingly, all groups of spellers avoid the application of the phonetic strategy for the spelling tasks. The low frequency with which the phonetic strategy is applied may also reflect the working of an inhibitory like mechanism that reduces the analysis of phonological information in the graphemic buffer.

The tendency to use one strategy predominantly over the other may be reflecting processing differences in the groups. For example, the use of visual strategy by below average spellers is perhaps an alternative to defining the weak boundaries and degraded orthographic structures in their mental representations (Joshi & Aaron, 2000). And the use of visual strategies by the second language spellers may be an alternative employed to avoid interference from L1 (Wang & Geva, 2003), and may also be an indication of increased proficiency in L2 spelling (Chikanatsu, 2006). The second language spellers seem to have been using each spelling strategy within a wide range of variability.

The application of the direct retrieval strategy across the groups was linked to the speller's use of back-up strategies. In this sense, it was observed that while the below average spellers group applied direct retrieval and phonetic strategies at similar rates, the average spellers used direct retrieval and visual strategies equivalently. The use of back-up strategies denote that information processing in working memory is compromised, thus spellers use the visual and phonetic strategies as supportive strategies (see Coltheart, 2006) in order to reduce the noise and intrusive information that affects the clarity of the representations (Gaulin, 2000). By utilizing an additional strategy spellers avoid losing the important spelling information (Abu-Rabia, 2003) that contributes to accuracy. According to working memory models, spellers are using the integrative function of the graphemic buffer for processing information from the visuo-spatial sketchpad and the phonological loop to access mental representation of words stored in long term memory (Baddeley, 2003; Bayless et al., 2003). This concept is also captured by the simultaneous processing or integrative hypothesis (Kreiner & Gough, 1990; Rittle-Johnson & Siegler,

1999), which implies that visual sequences and orthographic rules need to be integrated for spelling.

Strategies and Spelling. Spellers showed different patterns for the application of strategies to conduct the spelling tasks. Above average and average spellers equally relied on visual and direct retrieval strategies to guide their spelling, posing equal value to the visual recognition of individual graphemic units and complete word letter sequences in long-term memory. These spellers refrained from applying the phonetic strategy, implicating a reduced value attached to the phonemic information for their spelling performance. Average and below average spellers predominantly applied the visual strategy for spelling tasks. The direct retrieval strategy was employed with the same frequency as the visual and phonetic strategies despite the fact that visual and phonetic strategies were applied at rates different from each other by these spellers. Again, using a direct retrieval strategy reflects fast accessibility and retrieval of quality mental representations (Ehri, 2005; Kwon & Varnhagen, 2005; Sénéchal et al., 2006), while visual and phonetic strategies function as supplementary strategies that enhance the clarity of the representations. Consequently, to access the mental representations of the words being spelled, average spellers constructed a gate by applying a knowledge strategy (i.e., direct retrieval), and a main processing strategy (i.e., visual or phonetic) to support their spelling activity. The predominance in the application of the visual strategy for spelling denotes its value as a lexical rehearsal mechanism in the graphemic buffer that activates mental representations from long-term memory.

Use of strategies in each task. The spellers' application of strategies for recognition and production tasks stressed the qualitative processing similarities and

differences of the types of spellers. Detection tasks in above average and average spellers were carried out mostly with the visual strategy. Above average spellers applied the direct retrieval strategy at a moderate rate and limited their use of the phonetic strategy for detection tasks. Conversely, the average spellers used the phonetic and direct retrieval strategies with the same frequency but less often than the visual strategy. For detection tasks, below average spellers applied visual and direct retrieval strategies with similar frequency; they also used phonetic and direct retrieval strategies at similar rates. However, these spellers more often applied visual than they did phonetic strategies.

Correction tasks in above average spellers were carried out mostly with the visual strategy followed by the direct retrieval. Average spellers predominantly applied visual and direct retrieval strategies with equal frequency. However, above average and average spellers refrained from using the phonetic strategy for correction tasks. The below average spellers used all three spelling strategies equally for the correction tasks.

The frequency with which each type of speller applied each strategy across tasks varied. Above average spellers applied the direct retrieval strategy more often for correction than for detection tasks; average and below average spellers applied the direct retrieval strategy with the same frequency across tasks. Above average and below average spellers applied the visual strategy at higher frequency for detection than for correction tasks; meanwhile average spellers applied the visual strategy at equal frequency across tasks.

In general, all types of spellers predominantly used the visual strategy to conduct detection tasks, but applied the phonetic strategy equivalently and conservatively across detection and correction tasks. These tendencies suggest that spellers adopted the visual

strategy as the preferred strategy to conduct detection tasks (see Ehri, 2000; Rittle-Johnson & Siegler, 1999), and that the phonetic strategy constitutes their last choice for spelling tasks. The reduced application of the phonetic strategy suggests an advanced level in spelling as its use has been replaced by the visual and direct retrieval strategies (Ehri, 2005; Treiman, 1993; Treiman & Bourassa, 2000a). It may also suggest that mental representations can be retrieved automatically without a phonological mediation (see Colombo, Fudio & Mosna, 2009).

Average spellers applied the direct retrieval and the visual strategy for correction tasks. By using these two strategies, spellers integrated visually ordered sequences of letters (i.e., orthographic information) to increase the clarity of their mental representations for the correction tasks. The integration of the information from those sources may be a factor on their increased correction rate of morphological errors.

Above average spellers applied each one of the strategies at a different rate in each task (i.e., visual strategy for detection tasks, direct retrieval strategy for correction tasks, phonetic strategy was used the least in either task), adjusting their strategic engagement to the task requirement (i.e., recognition or production). This difference in the application of strategies became more evident in the analysis across tasks. And although visual and direct retrieval strategies were applied at inverse rates (i.e., cross-over interaction), the mean differences for detection and correction tasks are unequal, suggesting that the application of strategies across tasks is essentially different (see Rittle-Johnson & Siegler, 1999 regarding task complexity and strategic efficiency). These effects suggest that each type of cognitive tactic is more suitable for one task over another. Spelling strategies seem to be congruent with the nature of the mental

representation accessed (i.e., phonetic strategies for phonological representations of words; Sénéchal et al., 2006) and to specific word features or complexity (e.g., morphology). They may also reflect the activity in working memory (e.g., visuospatial sketchpad versus phonological loop). These spellers applied the strategy that provided faster and direct lexical access to the mental representations while using fewer cognitive resources (Abu-Rabia 2003).

Nonetheless, the speller's strategy choice is based on their cognitive processing qualities. That is, although average spellers did not have a preference to applying a particular strategy to one task or another, above average spellers adjusted the spelling strategies to the task (i.e., visual strategy for detection tasks and direct retrieval strategy for correction tasks). Meanwhile the below average spellers tended to use additional strategies (i.e., phonological, direct retrieval) to support the information obtained from their application of the visual strategy.

The below average spellers used higher number of strategies for detection than for correction tasks, indicating a necessity to activate several word features to recognize the spelling errors; thus detection task was a cognitively demanding task for these spellers. Their lower application of strategies for correction tasks reveals a simpler approach where spellers focus only on the word features necessary to re-construct the correct letter sequences. These spellers used phonological and direct retrieval strategies equally across tasks confirming a simultaneous processing (Kreiner & Gough, 1994; Rittle-Johnson & Siegler, 1999) by which they assembled a word's spelling by its features (e.g., phonetic, visual). By going through the re-constructive path, the below average spellers taxes the

working memory capacity, compromising their spelling accuracy (e.g., slow word recognition, loss of information; Bell & Perfetti, 1994; Swanson & Berninger, 1996).

The second language spellers applied multiple spelling strategies to the tasks. The reason behind this unsystematic application is their lack of familiarity with all the words in their new language, thus all the English words function as exception words. It is likely that second language spellers cannot rely complete on a rule-based phoneme-grapheme association as their new language has features they are unfamiliar with, such as syllabication, rhythm and intonation. Consequently, all new words act as exception words; and to correctly spell an exception word, writers must rely on richer context information, including the orthographic representations of whole words (Coltheart, 2004; Tiu et al., 2003) and the use of morphographs (Treiman & Bourassa, 2000a).

Use of strategies associated with working format. All types of spellers applied each spelling strategy with the same frequency in each format. Such consistency speaks about strategies as established set of mental tools centered on the accessing mental representations. And although format in isolation did not show any effects, each of the studies evidenced combined effects of format and other variables (e.g., task, sequence).

For the average spellers, the working format generated a facilitation/suppression effect on their use of strategies, which indicated a processing difference. Therefore, the use of the direct retrieval strategy was facilitated by the printed format and suppressed by the computer format. In the printed format average spellers supported their use of the direct retrieval strategy with the visual or phonetic strategies in order to access more word features. In computer format, average spellers conducted spelling tasks through the application of the visual strategy and reduced the application of other tactics (i.e., direct

retrieval) that could enrich the information needed to spell. A similar effect was observed in above average spellers. Changes in working formats impacted the use of spelling strategies for the detection tasks.

For above average spellers the number of strategies applied in detection tasks increased if the spelling activity was initiated in a computer format, suggesting higher activity level in working memory, thus a processing difference associated with the direction of the shift in working formats (i.e., priming). Initiating spelling tasks in a computer format made the recognition tasks more demanding, thus engaged more spelling strategies to carry on the tasks. If format is not accounted for, the correction tasks usually engage more spelling strategies than the detection tasks, but also increase the spellers' accuracy. And an increase in accuracy was not seen in the detection tasks despite the increase in strategies involved in the task. Therefore, format effects portrayed in a form of cognitive load are observed with above average spellers.

Combined effects of format and task on the use of strategies were also evident in the second language spellers. In general, this group of spellers used multiple strategies to conduct the tasks without showing a particular preference for or predominance of any. However, when detection tasks were conducted in the printed format, second language spellers increased the application of the visual strategy to guide their spelling. This predominant application of the visual strategy in the printed format illustrates and reiterates the influence of format on spelling abilities.

Although there are undeniable effects of format in all studies, there is a natural tendency in all types of spellers to use one certain strategy across tasks and formats. Format, as an independent factor, does not show a direct effect on the use of spelling

strategies. Nonetheless, the increase in cognitive load that occurs when spellers switch work between formats produces observable effects. That is, the spellers' strategic engagement is affected by the combined effects of several variables (e.g., sequence, task). One must note that the main obstacles for observing the direct effects of format on spelling are the spelling strategies themselves, which automatically reduce the prominence of any effect. Most importantly, the cognitive system is a self-sustaining structure encompassing the coordinated functioning of sub-systems, which assist each other in solving any task, and which, therefore, promote the multiple use of strategies. This fact, in the end, masks the effect of format on spelling tasks.

Shifting sequence and the application of spelling strategies. Initiating the spelling tasks in a printed format had no significant effects on the above average spellers' use of strategies in either task or format. Nonetheless, initiating the spelling task in a computer format created a difference in the number of strategies applied to each spelling task. In this case, above average spellers increased the number of strategies they applied for recognition but not for production tasks in the computer format. Above average spellers used the same number of strategies for correction tasks in both formats of the spelling task. Therefore, shifting work on computer to print increases the spellers' cognitive load resulting in a higher engagement of the strategies used to approach the recognition tasks in a computer format (Berninger et al., 1998; Longcamp et al., 2005, Swanson et al., 1996a). This engagement likely unveils a facilitatory effect of the printed format on correction tasks associated perhaps to the visuo-motor component (see Berninger et al, 2006) and embodied experience (see Siakaluk et al, 2008) involved in the crafting of the letter sequences.

Combined effects in each working format and the use of strategies. Above average spellers applied similar numbers of strategies across detection and correction tasks in the printed format. Nonetheless, their application of spelling strategies varied with the task and the shifting sequence in the computer format. And although it was difficult to determine the direction of the effect, the interactions observed were significant and may reveal an equal influence of task and shifting sequence on the use of spelling strategies in the computer formats. Therefore, the interplay of those factors is unclear and the conclusions are not final. Together, findings of Study 1 and 2 suggest that computer tasks are cognitively more demanding and thus require higher numbers of spelling strategies to access and to enhance accurate retrieval of mental representations, even for above average spellers.

Effects of format regarding the application of strategies in the tasks. Above average spellers used a higher number of strategies for detection than for correction tasks across formats. The number of strategies they applied to resolve spelling recognition activities in the computer format indicated that the detection tasks in computer were more cognitively demanding. The second language spellers relied equally on each and every strategy to carry on spelling activities across tasks and formats, with the exception of the visual strategy, which increased in frequency of use for the detection tasks in the printed format. The undifferentiated mental representations demanded that spellers reassemble the spelling of words through their features, particularly in the printed format. Therefore, the strategic pattern of second language spellers demonstrates that such spellers are able to access to multiple and multileveled representation of words in order to recognize spelling errors and to produce the correct spelling of words.

Spelling Abilities and Test Scores

The spelling proficiency of above average spellers across tasks and error type was associated with reading and spelling (i.e., spelling visual recognition and written spelling) sub-tests. The average spellers' abilities across tasks and error type were related to phonetic word recognition and spelling (i.e., spelling visual recognition and written spelling) sub-tests. Spelling abilities in second language spellers presented the same correlation as the average spellers for the detection tasks and for the phonological and morphological errors. The accuracy of the second language spellers in the correction tasks was related to the spelling sub-tests only (i.e., spelling visual recognition and written spelling), and accuracy with the orthographic errors was correlated to the written spelling and the phonetic word recognition sub-tests. Accuracy of the below average spellers showed a single relation for the detection tasks with the word visual recognition sub-tests.

The number of correlations in each group of speller seems to indicate a skill level. Above average spellers relied on defined and automatic word knowledge. Average and second language spellers depended upon dual word feature recognition such as visual and phonetic. These groups seem to access complete memory representations of words that also have defined boundaries. The single correlation for the below average spellers group of visual word recognition for detection tasks suggests that they possess limited and fragile representations of words, which are difficult to access and retrieve. Consequently, it appears as if the below average spellers fully rely on phonology to re-construct a word spelling, and probably use guessing to detect and correct misspellings rather than resorting to the use of orthographic rules or to the accessing of visual letter sequences. It

is also possible that the spelling abilities of this group of spellers were not captured by the tests. In above average spellers, the lack of correlations between the visual and phonetic word recognition scores and detection tasks, as well as with orthographic and morphological errors added evidence of proficiency in spelling. This absence denoted a contextual decoding of a word's spellings rather than the individual processing of words and letter sequences, as spellers may be retrieving entire words directly from their lexicons.

Interestingly, visual word recognition skills were related to detection tasks in average and below average spellers and to accuracy with phonological errors in above average spellers. These particular skills seem to denote the presence or activation of complete and defined word representations. In this way, spellers may have increased the clarity of the mental representations by using the whole range of language processing features (e.g., phonology, orthography, semantics) for skillful detection (see Treiman & Barry, 2000). Consequently, purposeful spelling engaged the spellers' attention (Rees & Russell, 1999), and activated the multileveled representations of words (Critten et al., 2007; Steffler, 2001), providing feedback from phonology and semantics (Seidenberg, 2005).

Spelling recognition and production processes also showed that there was a clear link between spelling visual recognition and written spelling and in all error types. Less proficient spelling required phonetic recognition cues for the reassembling of the word's spelling. In second language spellers these cues were not used, perhaps due to interference effects or for lack of clarity and number of phonological representations of

words. The second language spellers also seem to lack visual spelling recognition cues for accuracy with the orthographic errors.

Average spellers might have read and recognized words by extracting only partial cues (e.g., initial syllables) without processing the words entirely (Frith, 1980, 1985), as there were no correlations with reading, visual and phonetic word recognition scores. Reliance on partial orthographic information may be indicating an underdeveloped orthographic representation (Holmes & Castles, 2001) or reduced attention. It is also possible that spellers may have used back-up strategies to assemble the orthography of a word (Ellis, 1993; Kwong & Varnhagen, 2005). The relevance of orthographic knowledge for correction tasks and that of orthographic analysis for the orthographic errors were evidenced in correlational analyses particularly in the group of second language spellers.

These results indicate that spelling abilities, as measured by standardized tests, are mostly related to the type of speller and to a lesser extent to the spelling tasks. The difference between detection and correction tasks in second language spellers was seen by the connection between detection and recognition of visual sequences, and the connection between correction and phonetic recognition cues. This difference was also distinct in the single and only relation of the spelling recognition skills of the below average spellers to the phonetic word recognition cues. The results indicate that less-skilled spellers use phonology to recognize errors (Treiman, 1993). The lack of correlations in below average spellers for correction tasks denotes a low number and fragility of word mental representations, as well as difficulties in accessing and retrieving a word spelling sequences.

The predictive value of reading for spelling abilities has been restated throughout the literature on spelling (e.g., Kahmi & Hinton's, 2000). There is a definite advantage in reading ability for spelling proficiency. In particular, the spelling abilities of above average spellers were highly correlated to reading (automatic decoding) and spelling skills (visual discrimination and motor decoding). Evidently reading marks a difference between above average and other types of spellers. Thus, above average spellers demonstrated an automatic sensitivity to subtly misspelled words (McConkie & Zola, 1981), and a well coordinated functioning of attention and memory by relying on automatic processes such as reading and by limiting their reassembling of words in order to gain spelling accuracy.

General Discussion

These studies demonstrate the spellers' processing differences associated with format and expressed through the use of strategies. The use of a particular strategy and the patterns of strategic engagement, more than speller accuracy, provided the most compelling evidence for the processing differences among types of spellers and for the effects of shifting work between formats on cognitive load. Analysis of the strategic engagement provides a window into the functioning of cognitive processes engaged in spelling (Roussel et al., 2002; Varnhagen, 1995).

In terms of accuracy, the speller's sensitivity to the different types of errors suggests an automatic decoding process for phonological (except for the group of second language spellers) and orthographic errors, but not for the morphological errors. The quality and strength of orthographic sequences is rooted in word knowledge, thus speller's accuracy with this type of error was highly consistent in all conditions (i.e.,

tasks, sequences, formats). The activation-strength differences for the different types of errors allude to individual qualities in spelling abilities (Harm & Seidenberg, 1999, 2004).

The type of spelling error also impacted the spellers' recognition and production skills. Recognition of misspellings related to the saliency of the errors (e.g., higher for phonological than morphological errors). Correction of misspellings relied on the speller's orthographic knowledge. Furthermore, the saliency of the error type also affected the speller's ability to recognize misspellings in the same way in both shifting sequences. Conversely, the saliency and clarity of the mental representations of the phonological errors was balanced when shifting work from computer to print, producing similar levels of accuracy across recognition and production tasks.

The effects of the type of spelling error for the correction tasks were neutralized by the use of a computer format. This format enhanced the clarity of the correct mental representations of all misspellings for the spelling reproduction activity. Furthermore, the direction of the shift in working formats from computer to print also neutralized the spellers' cognitive processing through the engagement of orthographic knowledge. It seems that the use of a computer format freed some space in working memory and equalized the levels of spelling correction accuracy among the errors (see Berninger et al., 1998; Longcamp et al., 2005; Swanson, Ashbaker & Lee, 1996).

One should consider that all the words used in this study involved misspellings in the final letters of the word, which are a vulnerable part to error for people with language problems (e.g., speech disorders). As the spellers' correction abilities remained stable across the three types of errors, it is possible that the correction tasks were facilitated by the speller's knowledge of suffixes (e.g., *lly* or *ly*; Figueredo & Varnhagen, 2004), that is,

by their reliance on orthography (Holm, Farrier, & Dodd, 2008). It may also be that phonological coding skills exerted a direct effect on spelling by enhancing the retention of phonological information in working memory (see Burt & Butterworth, 1996). This study suggests that during the production of a word spelling, the simple activation of the word's stored representation automatically selects its orthographic pattern.

Spelling skills are graded and vary within a range; nonetheless, they are relatively stable within an individual. The spellers' accuracy across task and type of spelling error showed some of these characteristics; however, format and the direction of the shift in working formats challenged the stability of these skills, which was resolved through the use of spelling strategies.

Application of spelling strategies varied with the spellers' abilities. Generally, spellers applied the direct retrieval strategy as often as the back up strategies. In this regard, average and below average spellers required additional word information from visual and phonetic strategies. Above average spellers in particular used each spelling strategy selectively for each task and type of errors (i.e., strategy matching hypothesis; Sénéchal et al., 2006).

In both tasks, above average spellers applied each strategy at a different rate, however second language spellers used all strategies equally. In detection tasks, the average spellers applied the direct retrieval and visual strategies with the same frequency, and the below average spellers applied the direct retrieval as often as the visual and the phonetic strategies. The correction tasks emphasized the differences in the use of strategies among spellers as average spellers used visual and direct retrieval strategies at similar rates while below average spellers used all strategies equally. Across tasks, all but

second language spellers used the phonetic strategy equally, however only the average and below average spellers used the direct retrieval equally across tasks. The visual strategy was applied at a higher rate for detection than for correction by the above average and below average spellers, meanwhile that strategy was used equally across tasks by the average spellers. The patterns of strategic engagement indicate that although spellers applied different types of strategies in the tasks, each group of speller also tended to apply a preferred strategy (Ehri, 2000; Rittle-Johnson & Siegler, 1999). The differences in strategic engagement among spellers related to their spelling ability and this exposed the need to address individual differences in spelling recognition and production processes.

Although format alone did not produce observable effects in the spellers in terms of accuracy, it increased the use of certain strategies for the spelling tasks in average and second language spellers. In print, average spellers applied visual and direct retrieval strategies at high but equal rates; in computer format, they used predominantly the visual strategy. In both tasks, they used the direct retrieval as often as the phonetic strategies. Average spellers applied each strategy equally across tasks. Thus the number of visual strategies used increased for the detection tasks in the printed format, particularly for the group of second language spellers. Therefore, not only are precise mental representations of words important for detection and correction of misspellings (Holmes & Castles, 2001) but so are the efficiency of the processing mechanisms (Cassar & Treiman, 1997) and the strategies used to access the appropriate representations.

The use of strategies in the shifting sequences and the formats themselves also revealed a cost-efficiency effect in terms of the number of strategies applied by the

spellers. Therefore, the shifting of work from computer to print promoted a direct attention control for the detection tasks in print by increasing the application of spelling strategies. A similar effect was observed in the recognition tasks in below average spellers as they also applied higher number of strategies in print than in computer formats. The application of spelling strategies suggests that the engagement of the first processing channel carries-over into the remaining tasks (i.e., shifting challenge). As the computer format is the more engaging format, the strategies used in computer continue to be utilized as the shift is made to print. Additionally, an increase in strategic engagement in the computer format was noticed even though the spellers' accuracy remained stable across working formats. Therefore, it is presumed that the strategic engagement itself worked to account for and balance those cognitive effects produced by format, and provided evidence for the self-sustainability of the cognitive system.

Differences in accuracy and efficiency in spelling are predictable (Berninger et al., 2006; Cunningham & Stanovich, 1990; Longcamp et al., 2000). Nevertheless, a shift in working format impacted the clarity of the representations accessed and the cognitive load needed to perform the tasks; and this effect was difficult to predict at the beginning of our study. For example, in Study 2, starting the spelling tasks in a printed format reduced the number of strategies applied, thus reflecting a strategic efficiency effect in the printed format. However, the shifting of work from computer to print required the application of higher number of strategies for the detection of errors in the computer format, indicating an increase in the cognitive load and an engagement of more cognitive resources than the printed format.

It is perhaps the apparent incongruence in the findings of this study that motivates one to take a closer look at the data in terms of the cognitive system. The inverse patterns of detection-correction accuracy of the phonological and morphological errors and that of the application of visual and direct retrieval strategies, point towards the fragility of the mental representations and the presence of a strong orthographic axis that modulates spelling activity. Above all, these patterns uncover the importance of individual differences in a self-sustaining cognitive system that has a degree of tolerance for errors and adjusts its own resources to any changes in load and word quality. Besides the influence of error type and the differences in the spelling sub-processes, recognition and production activity is affected by format, the direction of the shift in working formats and individual differences.

It appears that there is a modulatory mechanism that acts on some of the word features stored and operating in the graphemic buffer at the time of detection and correction of errors. Such a mechanism seems to respond to changes in function and cognitive load (see Service & Turpeinen, 2001) as when proofreaders search for errors or for the correct mental representations of words or when spellers shift work between formats. As cognitive load increases, the mechanism assigns greater priority to certain word features and less to others, which it inhibits. For example, the uncertainty in the search for errors (recognition process) demands the processing of great amount of data, as each word needs to be evaluated as a possible error. In this case, the modulatory mechanism inhibits some word qualities (e.g., phonology, morphology) and reduces the meaning of syntactic structures and words while other word elements remain high or may even be enhanced (i.e., orthography).

Inverse accuracy effects provide evidence for this modulatory mechanism. The direction of the effect across tasks in morphological errors denotes an increased clarity of the mental representations for easy retrieval at the time of correction. The detection-correction pattern of the phonological (higher detection than correction rate) and morphological errors (higher correction than detection rate) could represent low activity in the graphemic buffer (see de Partz, Lochy & Pillon, 2003). As a result of this process, the graphemic buffer strengthens the connection with the visuospatial sketchpad and spellers activate the visual strategy in greater numbers. This strategy makes the recognition process operate as a rapid scan and places limits on visual attention (see Service & Turpeinen, 2001). Simultaneously, the graphemic buffer also inhibits the integration of phonology and morphology for the spelling recognition tasks. The saliency of the phonological errors, due perhaps to their unconventional spelling, reaches the orthographic gate and gets easily detected; conversely the morphological errors, and incorrectly placed morphemes, are often missed.

This modulatory mechanism operates in the graphemic buffer; besides prioritizing the information it can also enhance the multiple features of a word and expand the number of strategies allocated for the correction tasks based on word features and individual preferences. In the production of correct spellings of words, the graphemic buffer holds the information about grapheme identity and position (Baddeley, 2007). It is considered that the modulatory mechanism strengthens the link with phonology and semantics to access multiple word features, while leaving orthography as the main axis. That is, the letter sequences and orthographic rules modulate the effects of other variables such as format and shifting sequence. For example, the computer format itself and

shifting work from computer to print neutralize the effects of error type and maintain the levels of correction accuracy within the same range across error type; similarly, the computer format activates a larger number of strategies than the printed format. The main quality of the modulatory mechanism is to hold orthographic knowledge in a solidly embodied manner for all spelling activity.

In this way, a continuum exists over the two tasks with detection of errors on one side and correction of errors on the other. As the load goes up prioritization and inhibition occur and, as the load goes down, space is made available with which to incorporate more or more appropriate spelling strategies.

Implications of the study. The repercussions of this study can be unfolded into three levels. At a theoretical level it provides information that deepen the understanding of spelling and the supportive cognitive processes such as working memory and attention. At an applied level it helps to develop instructional alternatives and techniques that facilitate the learning of orthography and other spelling skills; also to establish academic standards and provide reasonable accommodations for people with disabilities. At the intervention level this research would also help to improve therapeutic strategies for people with diverse language and academic difficulties. Moreover, research findings can contribute to develop people's strategies to detect and correct their own mistakes or increase spelling accuracy in fields (e.g., health records, scientific research) where uncorrected written mistakes can have unintended consequences (e.g., medical prescription, nuclear formula).

The spellers' correction abilities seem to be effected by the direction of the shift when working across formats, indicating that these skills are susceptible to change. As

the change reflects the malleability of the mental representations and demonstrates the effects of cognitive load on correction skills, the questions that follows is if the computer format resolved, eased or neutralized the cognitive load in the correction tasks or if created a difference in the mental representations.

Further exploration of the role of working memory in spelling is needed to determine if deterioration occurs in working memory. Mental representations are brought up to working memory to be reproduced, where they are exposed to malleability, thus if the representations deteriorate in working memory, then are placed back in a degraded form in long term memory. As mental representations are constantly re-defined, bringing the representations to working memory make them susceptible to deterioration. Thus a further research in this area is needed.

Future directions. The dissertation study presented provide data for: a) envisioning spelling processes under the light of cognitive strategies; b) constructing a more comprehensive Spelling Model; c) clarifying the effects of cognitive differences (constraints in working memory and attention) in different types of spellers; d) informing practitioners, educators and instructors of the tools they can implement to assist students to improve their abilities to detect and correct mistakes. Further studies in spelling may benefit by measuring the processing time spellers take to complete detection and correction tasks (i.e., real time research), as the nature of the error must be determined before correction tasks take place (Hacker et al., 1994).

This study also raises critical questions in regards to the services (e.g., allocation of additional time for academic tasks or computer use) for students with attention deficit, language or other learning disorders. In post-secondary education, there is a common

practice to allow these students to use a computer to take notes in class or to write exams in order to be able to achieve their full potential. The premise behind the academic accommodations is efficiency. For example, students with written output problems have difficulties with visuo and grapho-motor integration, retaining symbol sequences in working memory, or transcoding symbols as in copying letter sequences that manifest into the complex processes of writing or unskilled spelling, thus they are allowed to use a word processor to make their writing more efficient, free some working memory space and assist the students with their academic endeavors. These practices have been in place for years but still there is not much research on whether these tools really assist the student and/or the rate of success with the use of the accommodations. Recently, a statistical report from USA educational database (2009) indicates that performance of students with disabilities with and without academic accommodations at a college level is not significantly different. And although researchers are currently addressing the importance of working memory and visuo and grapho-motor integration into the complex process of writing (e.g., Berninger et al, 2002; Berninger et al., 2006), there is still much research needed in this area.

In health and bio-medical field, the ability to detect and correct errors is extremely important (e.g., Kawado, Hinot, Matsuyama, Yamaguchi, Hashimoto, & Ohashi, 2003; Lynch, Rosen, Selinger & Hickner, 2008). Errors in prescriptions, medication and dosages, as well as chart notes can lead to wrong interventions and have serious consequences. Clarifying the processes activated with the ability to identify and correct errors is a highly valued skill for all the health sciences. Studies that address these

abilities would be priceless by patients and practitioners and prevent many unnecessary mistakes.

This dissertation study indicates that strategies, more than accuracy levels, are sensitive indexes of the ways that cognitive processes operate. Thus, to study the cognitive operations of the sub-processes of spelling, scientists should direct the focus of the study on spelling towards strategic engagement and incorporate their findings into cognitive and developmental models of spelling. Psychometric tests designers may also need to revise their instruments and scales to measure both aspects of spelling, processes and strategic efficiency.

Conclusions

Undoubtedly word features affect spelling. Spelling requires more than phoneme-grapheme associations, but a system that supports all the activity and elements involved in this process. The cognitive system is a self-sustaining structure that regularly re-organizes the stored knowledge to incorporate new information cohesively. In this system spelling errors may be recognized by their features but specific orthographic and word knowledge is required to correctly spell the words. Spelling requires the use of tactics to connect and accurately reproduce the related mental representations on demand; that is, the use of strategies.

Analysis of the use of strategies (see Holms & Malone, 2008; Gilles and Terrell, 1997) as a factor in spelling accuracy has been overlooked by researchers. Cognitive strategies reveal the activity of the underlying processing mechanisms to gain or retrieve knowledge. A spelling strategy would reflect whether a speller is activating the phonological or orthographic qualities of a word or if they are activating complete word

sequences or assembling the words by their qualities. What still needs to be understood are the elements that make adult spellers select one strategy over another (e.g., easiness or mastery in the use of strategies as a tool). A question this raises is whether the development of spelling skills is based on learned strategies, perceptual abilities or other cognitive differences. Further studies could determine whether error blindness is a factor of sustained and/or selective attention or a shift on attention and cognitive flexibility. Investigating strategic engagement would explain many of the controversies of current research about spelling processes.

The findings this dissertation suggest that knowledge is malleable (i.e., mental representations are fragile), and although orthography provides an axis for spelling, it constitutes a processing strategy. The function of memory is to acquire knowledge by storing and organizing raw data (e.g., phonetic codes) in order to generate conceptual knowledge that can be used later. Memory is a network with a built-in self-correcting process. This network is always looking for the right connections for storing and retrieving information but makes lots of errors. In that way, the connections that lead to better outputs get reinforced (McNaughton, 2009). The graphemic buffer links visual and auditory pieces of information in order to store, retrieve and recreate data. The connections get re-organized constantly, and would undergo changes in strength as more information is acquired. Accurate retrieval requires simultaneous activation of the appropriate codes (e.g., orthographic) and connections. Attentional regulation and executive skills are needed to re-produce the spelling of words in writing. These are closely associated due in part to this shared dependence on the functioning of the pre-frontal subcortical brain systems. Executive skills are involved in the planning, initiation,

monitoring and correction of one's behaviour. It is noticed that after all, processing mechanisms are activated during the acquisition and storage of spelling knowledge. Thus, this study focuses on the cognitive strengths that may be used to compensate for areas of weaknesses in spelling skills.

Format is significant for spelling in terms of accuracy and strategic efficiency. Shifting work from one format to other may create an increase or decrease in cognitive load in relation to the direction of the shift (from print to computer or from computer to print). Strategic engagement appears to be the cognitive alternative used to minimize the impact of those variables in the spelling processes. Patterns of strategic engagement capture the processing qualities of each group of spellers, which are not otherwise noticeable. And it is precisely the action of a modulatory mechanism that evidences a self-sustaining activity in the cognitive system. This regulates the functioning of such a system. The analyses of the patterns of strategic engagement in different types of spellers are a breakthrough contribution of this dissertation for the field of spelling.

There is a question about exactly what that change is when spellers work in different formats and when they shift working formats. This study has attributed the effect to the activity in the graphemic buffer. The levels of accuracy and the strategic engagement advance the understanding of spelling processes beyond the current theories (e.g., knowledge or processing hypotheses). Individual differences regarding the extent of knowledge and the processing efficiency place independent constraints on the spelling performance in situations where there is high cognitive load (see Bayliss et al., 2003).

The graphemic buffer is concerned with manipulation and integration of information. It is capable of binding together information from different sources into a

single multi-faceted code (Baddeley, 2003). In terms of lexical access, this study suggests that the graphemic buffer prioritizes the type of information filtered in to suit the task demands and also reorganizes the information for future reference. This study also proposes that the graphemic buffer does contain some information such as embodied elements or the codes associated with the learning of the writing system (e.g., crafting letters, words and graphemes), the word-letter sequences and the orthographic rules. It appears that the graphemic buffer has a limited capacity and contains a modulatory mechanism that filters in only the information that is able to handle. This cognitive structure is very important in the self-sustaining activity of the cognitive system.

Findings of the present study suggest a modulatory mechanism in the graphemic buffer, where some of the word features are under-active although there is still integration of word qualities at some level (i.e., orthography). This mechanism seems to be tied to cognitive load as it seems that certain word features are prioritized and others inhibited by the graphemic buffer. The mechanism is also related to the use of strategies.

The present research enhances the understanding of the cognitive processing behind the application of strategies in the spelling sub-processes. Format, shifting sequence and error type are found to elucidate the dynamics of the cognitive processing that goes on during spelling. Error blindness and quality of mental representations are the result of the speller's processing qualities and relate to attention and working memory. The notion of a self-sustaining organization of the cognitive system approaches and resolves most of the disturbances imposed by the working (computer) format through the use of spelling strategies. It is expected that this dissertation has provided researchers with some insights in the way that the complicated working memory and attention

processes work together to solve spelling problems.

This dissertation seeks to understand the cognitive processing involved with the application of strategies in the spelling sub-processes. Research concerning spelling and format, shifting sequence and error type has revealed useful information regarding the dynamics of such cognitive processing. This, combined with the knowledge that error blindness and quality of mental representations are the result of the spellers' processing qualities and that they relate to attention and working memory, allow us to propose a self-sustaining organization of the cognitive system. This system involves the activity of the graphemic buffer, one that has been little understood to date. The graphemic buffer, with its intrinsic modulatory mechanism, offers a strong, viable explanation for how the speller resolves the various irregularities and disturbances that result from the spelling sub-processes of detection and correction. Findings of the present study have been suggestive of such a mechanism and support the idea that this subtle mechanism responds to the inputs of data by balancing the cognitive load with the various spelling strategies. This research points the way to further studies in working memory processes and development.

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APPENDIX A

ACHIEVEMENT TEST

Wide Range Achievement Test 3 (WRAT-3; Wilkinson, 1993)

This test is a single-level test with two equivalent forms designed with the intention to determine individual difficulties in three categories: reading, spelling, and arithmetic. Each subtest contains 40 items to test each category skill. Each subtest can be administered in 15-30 minutes. The test provides standardized scores for individuals ranging from ages 5 to 75 years of age.

Validity

Items of the test range in difficulty from very easy to very hard. Test developers report a content validity based on the Rasch statistic of item separation (1.00) for each subtest. Construct validity is addressed on the basis of increased scores corresponding to increase in the age of testees, showing congruency between the items and skills development. Subtests scores also reveal high intercorrelations with related academic skills. In addition, the correlations among WRAT-3 subtests scores and Wechsler Intelligence Scale for Children-III (WISC-III) show that these academic skills are associated with general cognitive ability, as measured by the WISC-III, measure that is also consistent with that on other standardized achievement tests.

Reliability

The test designers used alpha coefficient, alternate forms, and Pearson separation indices, plus a test-retest study as measures of internal consistency to demonstrate the reliability of this test.

Note

For the purpose of this study only two of the three subtests will be used: spelling and arithmetic.

APPENDIX B

TEST OF SPELLING POTENTIAL

Diagnostic Spelling Potential Test (DSPT; Arena, 1982)

This test was constructed to assess people's level of spelling performance and their potential for further development. It was designed to be administered to individuals from 7 years-old and over, taking between 25-40 minutes to complete. It uses 90 items that cluster into five types of scores: spelling, word recognition, visual recognition, and auditory-visual recognition.

The author uses an information processing approach to describe the spelling sub-skills of discrimination, memory, language generalization, and auditory-visual integration. In addition to subtest scores, a spelling error analysis measure differentiates between students who depend upon memorization and those who use phonetic generalizations.

Standardization

The standardization procedures for the DSPT used the spelling section of the WRAT as basis.

Reliability

The reliability coefficients obtained by the parallel forms method range from .81 to .98, with an overall average of .95 for the subtests at primary, intermediate, and secondary grade categories, thus establishing consistency of content between the two forms.

Validity

Criterion-related validity is based on the relationship of performance on the DSPT subtest to the WRAT spelling subtest. The correlations across three grade levels and for all subtests range from .59 to .93, with the secondary values consistently lower than the primary and elementary, and the spelling subtests values consistently higher than the other subtests values.

Diagnostic validity was examined by testing secondary handicapped learners, resulting in performance below the norms, which supports the idea that the DSPT can identify deficiencies in each skill area.

Norms

An equipercentile method was used to equate each subtest with the WRAT Spelling subtests, after which scores were aligned in normative scales for ages seven through adults.

Spelling Error Analysis

This measure indicates the number of student's phonetically correct spelling errors. The Spelling Error Analysis measure translates in the subject's ability to apply phonetic rules.

APPENDIX C

Questionnaire of Academic Background and Interest*Participant no* _____.*Instructions. Please answer the following questions***Demographics**

Age _____

Sex _____

Faculty (CASHS/CSAM/BMAN) _____

Major field of study _____

Year of studies _____

Languages spoken _____

Skill (%) _____

Language written _____

Skill (%) _____

English Experience

Number of English courses taken in High School _____

Last High School grade in which an English course was taken _____

Number of English courses taken at the university level _____

The most difficult English course you have ever taken was _____

*Explain***Mathematical Experience**

Number of Math courses taken in High School _____

Last High School grade in which a Math course was taken _____

Number of Math courses taken at the university level _____

The most difficult Math course you have ever taken was _____

Explain

Instructions. Please circle the number that best describe your experiences with Math and English. 1 indicates “not at all” and 7 “always”.

I have good spelling skills	1	2	3	4	5	6	7
I have a natural interest in English	1	2	3	4	5	6	7
I actively avoid situations involving writing (e.g., courses, jobs, etc.)	1	2	3	4	5	6	7
I actively avoid situations that require reading (e.g., courses, jobs)	1	2	3	4	5	6	7
I feel nervous whenever I find situations that involve reading or writing	1	2	3	4	5	6	7
I notice spelling errors on other people's written work	1	2	3	4	5	6	7
I use the spell checker on the computer	1	2	3	4	5	6	7
I use the dictionary regularly	1	2	3	4	5	6	7
The amount of reading for pleasure that I have done over the last year is: (1 = very little; 7 = very many books)	1	2	3	4	5	6	7
Compared to my peers, the amount of essays that I have written over the last year is: (1 = less; 7 = very many)	1	2	3	4	5	6	7
The number of crossword puzzles that I have done over the last year is: (1 = very little; 7 = very many)	1	2	3	4	5	6	7
I have good math skills	1	2	3	4	5	6	7
I have a natural interest in mathematics	1	2	3	4	5	6	7
I actively avoid situations involving math (e.g., courses, jobs, etc.)	1	2	3	4	5	6	7
I feel nervous whenever I find situations that involve math	1	2	3	4	5	6	7
I notice calculation errors on other people's mathematical work	1	2	3	4	5	6	7
I use the calculator to verify my work (e.g., school, budget)	1	2	3	4	5	6	7
The amount of math activities for pleasure that I have done over the last year is: (1 = very little; 7 = very many books)	1	2	3	4	5	6	7
Compared to my peers, the amount of arithmetic calculations that I have done over the last year is (1 = less; 7 = very many)	1	2	3	4	5	6	7
The amount of cross-numeric puzzles that I have done over the last year is: (1 = very little; 7 = very many)	1	2	3	4	5	6	7

APPENDIX D

SPELLING TASKS

Essay No. 1: Violence in film. Target: Detect spelling mistakes***Instructions***

Please highlight the words that are misspelled in the following text. Once you have detected a misspelling, indicate the strategy you used to detect each of the misspelled words by writing the initial of the strategy you used between parentheses above each word.

Strategies	<i>Visual</i>	(V)	(how the word looks)
	<i>Auditory</i>	(A)	(how the word sounds)
	<i>Memory</i>	(M)	(just remembered the spelling)

Violence in Film

With an incredibul increase in violence in today's society becomes increasing criticism of films containing images and sequences of violence. It is clear that movies have a noticable presence in our society, and therefore it has been generully argued that they play a significant role in our socialization. Many critics have come to the decsian that we are definitely becoming socialized to be violent as a result of the increases in violent content in film. However, there is an omishun in this logic. Art is an extention of life, not the other way around.

Unfortunately it is inevitabul that violence is ever present in today's society. It is part of the social contract under which we live. Films cannot ignore this reality, for to become defensible is more dangerous than trying to reflect it. We do not learn anything by closing our eyes to this type of material. Ordinarily, the repetishun of violence in films must be used to articulate a larger message. Any good movie containing violence is not especialey about violence; rather it is the necessary language in which preparatian of the real issues can be made.

Violent films have important and indispensible messages to say about society. They should be learned from, instead of being made eligible for prosecution. Film is peculiarly a reflection of life. If there is violence in film, it is because there is violence in society. We will not learn anything if we do not accept this. Violence may not be pretty, and it may not leave you with a warm, positive feeling about life in general, but that doesn't mean we should cooly ignore it. It is a real part of the world we live in, and if we ignore that, it will only get worse.

Essay No. 1: Violence in film. Target: Correct spelling mistakes.**Instructions**

For the following text, please indicate the correct spelling of the highlighted words on the line provided. Once you have corrected a misspelling, indicate the strategy you used to correct each of the misspelled words in the parenthesis.

Strategies	<i>Visual</i>	(V)	(how the word looks)
	<i>Auditory</i>	(A)	(how the word sounds)
	<i>Memory</i>	(M)	(just remembered the spelling)

Violence in Film

With an **incredibul** _____ () increase in violence in today's society becomes increasing criticism of films containing images and sequences of violence. It is clear that movies have a **noticable** _____ () presence in our society, and therefore it has been **generully** _____ () argued that they play a significant role in our socialization. Many critics have come to the **decisian** _____ () that we are **definitley** _____ () becoming socialized to be violent as a result of the increases in violent content in film. However, there is an **omishun** _____ () in this logic. Art is an **extention** _____ () of life, not the other way around.

Unfortunately it is **inevitabul** _____ () that violence is ever present in today's society. It is part of the social contract under which we live. Films cannot ignore this reality, for to become **defensable** _____ () is more dangerous than trying to reflect it. We do not learn anything by closing our eyes to this type of material. **Ordinarilly** _____ (), the **repetishun** _____ () of violence in films must be used to articulate a larger message. Any good movie containing violence is not **especialley** _____ () about violence; rather it is the necessary language in which **preparatian** _____ () of the real issues can be made.

Violent films have important and **indispensible** _____ () messages to say about society. They should be learned from, instead of being made **eligeble** _____ () for **prosecution** _____ (). Film is **peculiarilly** _____ () a reflection of life. If there is violence in film, it is because there is violence in society. We will not learn anything if we do not accept this. Violence may not be pretty, and it may not leave you with a warm, positive feeling about life in general, but that doesn't mean we should **cooly** _____ () ignore it. It is a real part of the world we live in, and if we ignore that, it will only get worse.

Essay No. 2. Anorexia Nervosa. Target: Detect spelling mistakes**Instructions**

Please highlight the words that are misspelled in the following text. Once you have detected a misspelling, indicate the strategy you used to detect each of the misspelled words by writing the initial of the strategy you used between parentheses above each word.

Strategies	<i>Visual</i>	(V)	(how the word looks)
	<i>Auditory</i>	(A)	(how the word sounds)
	<i>Memory</i>	(M)	(just remembered the spelling)

The Media as a Cause of Anorexia Nervosa

There can be no doubt that the media plays an incredibul role in today's society. It is a noticable aspect of every person's life. Generully, this can either have a positive or negative effect. When the media influences a person's body image, it is inevitabul that it becomes an especialey negative factor. This can often result in an eating disorder, such as anorexia nervosa. The word "anorexia" originates from the Greek word for "loss of appetite". Peculiarly, this is actually quite misleading. Victims of this disease make the decisian to starve themselves by participating in the repetishun of eating less and less. This bodily prosecution undoubtedly leads to serious health problems and possibly death.

The media is definitely not the only cause of anorexia. Ordinarily, other causes result from environmental pressures. Anorectics feel the only thing they are eligible to control is what they eat. Thus, uncontrollable dieting and starvation is an extention of this attitude. Since the media is one of the most indispensable socializing agents, it can be a driving force behind anorexia. Although precautions can be taken to become defensible to eating disorders, anyone can become a victim. The disease is cooly indiscriminate of a person's age, gender, or background.

With the rapid growth of technology, ideas move very quickly and there is no preparatian for the sheer bombardment of images. Historically, women were not expected to all maintain the same ideal. However, a significant change occurred in the 1920s when standard sizing was introduced. With standard sizes and factory production, women were expected to fit the clothes and there was no omishun or exception to the rule. From this point on, it was the fashion industry that decided what defined a normal body size.

Essay No. 2. Anorexia Nervosa. Target: Correct spelling mistakes**Instructions**

For the following text, please indicate the correct spelling of the highlighted words on the line provided. Once you have corrected a misspelling, indicate the strategy you used to correct each of the misspelled words in the parenthesis.

Strategies	Visual	(V)	(how the word looks)
	Auditory	(A)	(how the word sounds)
	Memory	(M)	(just remembered the spelling)

The Media as a Cause of Anorexia Nervosa

There can be no doubt that the media plays an **incredibul** _____ () role in today's society. It is a **noticable** _____ () aspect of every person's life. **Generully**, _____ () this can either have a positive or negative effect. When the media influences a person's body image, it is **inevitabul** _____ () that it becomes an **especialley** _____ () negative factor. This can often result in an eating disorder, such as anorexia nervosa. The word "anorexia" originates from the Greek word for "loss of appetite". **Peculiarily**, _____ () this is actually quite misleading. Victims of this disease make the **decisian** _____ () to starve themselves by participating in the **repetishun** _____ () of eating less and less. This bodily **prosecusion** _____ () undoubtedly leads to serious health problems and possibly death.

The media is **definitley** _____ () not the only cause of anorexia. **Ordinarilly**, _____ () other causes result from environmental pressures. Anorectics feel the only thing they are **eligeble** _____ () to control is what they eat. Thus, uncontrollable dieting and starvation is an **extention** _____ () of this attitude. Since the media is one of the most **indispensible** _____ () socializing agents, it can be a driving force behind anorexia. Although precautions can be taken to become **defensable** _____ () to eating disorders, anyone can become a victim. The disease is **cooly** _____ () indiscriminate of a person's age, gender, or background.

With the rapid growth of technology, ideas move very quickly and there is no **preparatian** _____ () for the sheer bombardment of images. Historically, women were not expected to all maintain the same ideal. However, a significant change occurred in the 1920s when standard sizing was introduced. With standard sizes and factory production, women were expected to fit the clothes and there was no **omishun** _____ () or exception to the rule. From this point on, it was the fashion industry that decided what defined a normal body size.

APPENDIX E

DATA ON INSTRUMENT EQUIVALENCE AND LEARNING EFFECTS

Tables for No-Significant Results

Table 1. *Detection and Correction Rates across Essay Versions*

<i>Essays</i>	<i>Task</i>			
	<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Violence in Film	12.17	2.81	11.17	3.55
Anorexia Nervosa	12.00	2.67	11.46	3.68

Table 2. *Detection and Correction Rates by Presentation Order*

<i>Presentation Order</i>	<i>Task</i>			
	<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
First	11.75	3.19	12.13	2.61
Second	11.58	3.56	11.13	3.78

Table 3. *Overall Error Detection and Correction Rates across Format*

<i>Format</i>	<i>Task</i>			
	<i>Detection</i>		<i>Correction</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Print	12.04	2.60	11.58	3.49
Computer	12.13	2.88	11.04	3.72