# WHY DETECTING A MISSPELLING IN *LENGUAGE* IS EASIER THAN IN *LANGUEGE*: SEGMENTAL AND SUPRASEGMENTAL INFLUENCES ON ORTHOGRAPHIC PROCESSING


by

**Lindsay Nicole Harris**

B.A., The Ohio State University, 2001

M.S.T., Pace University, 2006

M.S., University of Pittsburgh, 2011


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This dissertation was presented

by

Lindsay Nicole Harris

It was defended on

August 11, 2014

and approved by

Julie A. Fiez, Professor, Department of Psychology

Tessa Warren, Associate Professor, Department of Psychology

Margaret G. McKeown, Clinical Professor, School of Education

Committee Chair: Charles A. Perfetti, University Professor of Psychology

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Four studies were conducted to determine the range of phonological information that can affect orthographic processes during reading under different conditions, and to investigate how the influence of phonology on orthography is affected by other relevant factors, such as linguistic context and individual differences in reading-related skills. Study 1 employed a spelling decision task in which phonemic, lexical stress, and syllabic variables were factorially manipulated in misspelled words. Both phonemes and lexical stress affected the speed and accuracy with which misspellings were detected, indicating that both segmental and suprasegmental phonological information can influence orthographic processing. Study 2 comprised two separate experiments designed to compare phonological effects on orthographic processing in a spelling decision task versus a lexical decision task. Both stress and phoneme effects were reduced in the lexical decision experiment relative to the spelling decision experiment, suggesting that the influence of phonology on orthography is stronger when more extensive phonological processing is required or allowed by a task. Study 3 included two series of analyses examining the roles of phonological feedback and individual differences in Study 2 outcomes. The analyses indicated that better spellers are less sensitive than poorer spellers to the influence of phonological feedback during reading, which supports the hypothesis that phonological feedback is a mechanism for orthographic learning. Study 4 embedded stimuli in a proofreading passage to test the hypothesis that the role of stress in reading is enhanced when

upcoming stress patterns can be more easily predicted. Misspellings were detected more often in words misspelled in stressed syllables, and in words that were less predictable from context. Spelling error detection for more predictable words was improved when the misspelling occurred in a stressed syllable. These results were consistent with our hypothesis, and suggest that stress plays a greater role in orthographic processing under more natural reading conditions compared to isolated-word reading. Taken together, these studies suggest that phonological information, including both segmental and suprasegmental phonological information, can affect orthographic processing during reading, and that the influence of phonology on orthography can be moderated by reading task, linguistic context, and individual characteristics of the reader.

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# PREFACE

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# 1.0 INTRODUCTION

Three decades ago, the notion of phonological involvement in word identification was suspect; Perfetti and McCutchen (1982) noted that "direct evidence for automatic activation" of phonemes prior to word identification was "in short supply" (p. 258). Today the issue is largely settled: dozens of studies in both alphabetic and nonalphabetic languages have demonstrated a role for phonology in silent reading. The majority of this research has investigated whether and when phonology comes online during lexical access, but few studies have investigated the influence that a phonological representation activated by an orthographic input string might have on our processing of that string. In particular, there is a shortage of research into the prediction of many models of word reading (e.g., McClelland & Rumelhart, 1986; Seidenberg & McClelland, 1989; Van Orden & Goldinger, 1994; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) that phonology should feed backwards to orthography during word identification. The range of phonological information that can affect orthographic processes is also unclear; research to date has focused primarily on the segmental (phonemic) layer of phonology in reading, despite the importance of suprasegmental stress and prosody in spoken language production and comprehension. Finally, there is a need for research into the effects of linguistic context, reading task, and individual differences in skill on phonology-orthography interactions. Our research questions, therefore, are as follows:

1. *Does suprasegmental phonology affect orthographic processes?* Harris, Perfetti, and Rickles (2014) showed that segmental phonology (i.e., phonemes) has an influence on orthographic processing by eliciting differing behavioral and electrophysiological responses to phoneme-preserving and phoneme-altering misspellings in a spelling decision task. Because phonemes map directly to graphemes in English, that phonemes could influence the processing of graphemes is a reasonable assumption. Lexical stress, conversely, does not map to graphemes in English, and is not explicitly encoded in English orthography, so a parallel influence of lexical stress on orthographic processing seems less reasonable to assume. However, lexical stress has been shown to be activated during silent reading (Ashby & Clifton, 2005), and letter-detection experiments have demonstrated increased letter-detection rates for letters occurring in stressed syllables, which does suggest that lexical stress can influence orthographic processing of the letters to which it maps (Drewnowski & Healy, 1982; Goldman & Healy, 1985). The present studies can offer converging evidence of lexical stress effects on orthographic processing, if they exist, because they require participants to perform spelling decisions, lexical decisions, and proofreading on items systematically misspelled in stressed and unstressed syllables.
2. *Do task demands modulate the influence of phonology on orthographic processes?* Because the present research uses the same or similar experimental items across multiple tasks, we are able to examine the shifting influence of phonology on orthography as phonological and orthographic processing requirements shift. Relative to a lexical decision task, for example, a spelling decision task requires extensive phonological processing to differentiate strings with a high degree of orthographic overlap, and may

involve postlexical orthographic processing to verify a spelling decision. Orthographic processing may be deemphasized in a proofreading task relative to a spelling decision task, on the other hand, because linguistic context can provide supplementary cues to word identity. These same cues may simultaneously enhance the role of lexical stress in reading, by making the stress patterns of upcoming words predictable.

3. *Do lexical and linguistic factors modulate the influence of phonology on orthographic processes?* In addition to examining task-imposed alterations in reading processes, the design of our experiments allows us to investigate the ways the language that has been encoded in writing can influence phonological activation and its relationship to orthographic processing. By manipulating the number of syllables and the location of stress in our stimuli (Study 1) and the predictability of a stimulus in its linguistic context (Study 4), we can observe the contribution of these factors to reading behaviors apart from the contribution of task demands.
4. *Do individual differences amongst readers modulate the influence of phonology on orthographic processes?* Aside from task and linguistic factors, we aim to discover how individual differences in reading, spelling, and vocabulary ability affect the phonology-orthography relationship. Specifically, we test the hypothesis that more skilled readers are, on average, less sensitive to the influence of phonology on orthography than less skilled readers, because of the relatively higher quality of more skilled readers' orthographic representations.

Taken together, the studies presented here provide a well-rounded picture of the influence a phonological representation activated by an input string has on our processing of that string as task, linguistic, and individual factors shift, and illuminates the range of phonological information capable of affecting orthographic processes under a range of conditions.

## 1.1 PHONOLOGICAL ACTIVATION DURING SILENT READING

### 1.1.1 Segmental phonological activation.

Early research that addressed the question of whether phonemes were involved in word reading relied primarily on the lexical decision task, which requires subjects to determine whether or not a letter string is a word. Many of these studies reported a pseudohomophone effect, such that a nonword (e.g., *brone*) that has limited phonemic similarity to a real word is more quickly rejected than a nonword (e.g., *brane*) that shares a pronunciation with a real word (e.g., Coltheart, Davelaar, Jonasson, & Besner, 1977). Although the pseudohomophone effect indicates that the phonetic form of a string is activated at some point during silent reading, it demands neither that the activation is prelexical, nor that it is functional in lexical access. Subsequent studies employing alternatives to and variations on the classic lexical decision task have provided strong evidence for routine and very early phonemic activation during word identification. Arguably the earliest of these studies to be highly persuasive were those that involved forward and backward masking techniques, in which a word or nonword is presented very briefly (typically for under 66 ms) and then visually "masked" when it is replaced by another string. In backward masking experiments, a trial begins and ends with the presentation of a pattern mask (e.g., XXXXX) of which the participant is consciously aware; between these, a real word target (e.g., crew) and a nonword mask that may display phonemic (e.g., KROO), orthographic (e.g., CRAE), or both phonemic and orthographic (e.g., CRUE) overlap with the target are presented in rapid, often undetectable succession. The participant is then typically asked to write down as many letters as possible of the target (e.g., Perfetti & Bell, 1991).

Complementing such backward masking studies, the forward masking, or masked priming, paradigm begins with a pattern mask but ends with a real word target; a prime (such as a phonologically similar pseudoword) and, sometimes, a second pattern mask appear imperceptibly between these events. In this task, the dependent measure is typically participants' time to decide whether or not the target is a word (e.g., Lukatela, Frost, & Turvey, 1998). In both forward and backward masking paradigms, the nonword and target are presented in different cases, so that facilitation or interference of word identification may be attributed to phonemic and not visual effects (Halderman, Ashby, & Perfetti, 2011).

The word identification process begins at the first moment of visual encounter with an orthographic string in either the fovea or, possibly, in the case of sentence reading, in the parafovea, and must be largely complete within 100-150 ms of a fixation, the point at which a motor program for a saccade is initiated (Sereno, Rayner, & Posner, 1998). Brief exposure masking studies such as those described above address the question of phonemic activation during lexical access by interrupting the word identification process partway through. If phonemic activation is part of that process, then, in a backward masking task, a nonword that overlaps phonemically with the target word should increase the chances that a participant will be able to identify the target, whether or not the target and nonword overlap orthographically. Likewise, target identification in a masked priming experiment should be speeded when the prime phonology anticipates the target phonology relative to when it does not. Such findings would also indicate that phonemic activation is functional in lexical access, as opposed being merely incidental. The vast majority of these brief exposure studies bear out these predictions and therefore do suggest an early and integral role for phonemic activation in word recognition (e.g., Perfetti & Bell, 1991; Tan & Perfetti, 1999; Verstaen, Humphreys, Olson & 'Ydewalle, 1995, Xu & Perfetti, 1999, Ferrand & Grainger, 1994), as do many eye movement and event-related potential experiments (reviewed thoroughly in Halderman et al., 2011).

Not all research supports the notion that phonological activation is obligatory in word reading, however. Effects of phonological regularity (Coltheart, Davelaar, Jonasson, & Besner, 1979), and consistency (Jared, McRae, & Seidenberg, 1990) have occasionally not been found in lexical decision tasks, although they have been consistently found in naming tasks, particularly for low-frequency words (e.g., Brown, Lupker, & Colombo, 1994; Jared, 1997; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987). Coltheart et al. (1979) have suggested that participants may adopt a more visual strategy in a lexical decision task than in a naming task, which minimizes phonological effects; Jared et al. (1990) suggested that responses in lexical decision tasks are made too quickly for phonology to affect them. Moreover, characteristics of stimuli and foils used in experiments seem to influence the strength of phonological effects. Seidenberg et al. (1984) found phonological effects only when orthographic anomalies (e.g., *aisle*) were included amongst their stimuli, and phonological effects are increased in lexical decision experiments that use pseudohomophone foils relative to experiments that use pseudoword foils (e.g., Berent, 1997; Gibbs & Van Orden, 1998; Pexman, Lupker, & Jared, 2001).

These findings suggest that phonology has a greater influence on reading under challenging conditions; Gibbs and Van Orden (1998) suggested that phonology is activated automatically in any reading task, but that its effects can only be observed in behavioral data when phonological processing demands are relatively extensive. This suggestion is consistent with the finding of phonological effects in a recent study that manipulated the phonological fidelity of misspellings in a spelling decision task (Harris, Perfetti, & Rickles, 2014), because spelling decisions presumably require more extensive phonological processing than do lexical decisions in order to differentiate strings with a high degree of orthographic overlap. In Study 2 of the present research, we compare phonological effects in such a spelling task (Study 2a) with phonological effects in a lexical decision task using the same stimuli (Study 2b), to investigate the relative influence of phonology in tasks that place differential importance on phonological processing.

### 1.1.2 Suprasegmental phonological activation.

Investigations of nonsegmental phonological activation in reading have been rarer than investigations of segmental phonology, likely because featural and suprasegmental information is not conventionally encoded in most orthographies. Phonology is accessible from writing at the level of either the phoneme, in alphabetic writing systems (such as the Roman alphabet or Korean Hangul) or the syllable, in syllabaries (such as Japanese *hiragana*) and so-called logographies (such as Chinese). It is therefore natural that studies of phonological activation in reading have been preoccupied, by and large, with the phonological representations that map onto these units. Nevertheless, research has begun to emerge regarding the role of nonsegmental phonological information, including featural, syllabic, lexical stress, and prosodic information, in visual word identification and sentence processing. Because the present study is focused on phonological influences on orthography during the reading of words, I focus here on research into lexical stress activation during reading, since this is the layer of phonology that maps onto the unit of the spoken word.

English is a “free” stress language, meaning that the stressed syllable of a word is not restricted to a single location (van Donselaar, Koster, & Cutler, 2005). However, the stressed syllable of a two-syllable English word is highly predictable by its part of speech: approximately 93-94% of disyllabic nouns are stressed on the first syllable and 69-76% of disyllabic verbs are stressed on the second syllable (Kelly & Bock, 1988; Sereno, 1986). Thus, a finding that typically stressed words are recognized more easily than atypically stressed words when presented visually would offer some indication that readers activate lexical stress during word reading. This is exactly the finding reported by Arciuli and Cupples (2006): nouns stressed on the first syllable and verbs stressed on the second syllable elicited fewer errors in naming and lexical decision tasks than their atypically stressed counterparts.

Lexical decision and naming, however, leave open the possibility that stress phonology is contacted postlexically, because these tasks do not provide an online measure of reading behavior. Eye movement studies eliminate this possibility, as fixation measures are assessed in real time. Ashby and Clifton (2005) tracked the eye movements of participants as they read sentences that contained target words with one (e.g., *sig*__*nifi*__*cant*) or two (e.g., ***fun****da****men****tal*) stressed syllables, matched on length and total number of syllables. The words containing only one stressed syllable were read more quickly (and were less likely to be refixated) than the two-stressed-syllable words.

The findings of a more recent eye-tracking study also offer tenuous support for the possibility of prelexical activation of stress information (Breen & Clifton, 2011). The experiment took advantage of the phenomenon in English of noun-verb homographs with alternating stress assignment (e.g., **per**mit, per**mit**). Limericks were strategically written so that half of the time the pronunciation required of the homograph in order for the phrase to make sense conflicted with the metrical stress required of the limerick form, e.g., *"There once was a penniless peasant/Who couldn't afford a nice present,"* versus *"There once was a penniless peasant/Who went to his master to present."* The authors found a significantly lower probability of skipping the homograph and significantly longer fixation times for weak-strong homographs in strong-weak metrical contexts. They claimed this finding suggested lexical stress patterns of words are activated in silent reading, but admitted that the results might not be generalizable due to the unnatural metrical constraints of limericks.

Evidence that phonemes and lexical stress are active during word reading, however, does not amount to evidence that phonology can or does affect orthographic processing—i.e., that the phonology activated by a string of letters can influence how we visually perceive those letters on a page or a screen. Because this bidirectional relationship between phonology and orthography is the subject of the present research, we devote the next section to reviewing current evidence that such a relationship might exist.

## 1.2 PHONOLOGICAL INFLUENCES ON ORTHOGRAPHIC PROCESSES

### 1.2.1 Segmental influences on orthographic processes.

Dual-route (e.g., Coltheart et al., 2001), PDP (e.g., Seidenberg & McClelland, 1989), and dynamic (e.g., Van Orden & Goldinger, 1994) models of word reading all assume bidirectionality between phonological and orthographic information. The flow of information from orthography to phonology is empirically noncontroversial, but empirical support for feedback from phonology to orthography has been inconsistent. The most common method of investigating phonological feedback involves the manipulation of the *feedback consistency* of stimuli in a lexical decision or naming task. A word is considered feedback consistent if its rime body maps to only one spelling (e.g., the *elf* in *shelf* can be spelled only one way), and feedback inconsistent if its rime can be spelled more than one way in the language in question (e.g., the *eer* in *sneer* can also be spelled *ear, ier,* or *ere*; Stone, Vanhoy, & Van Orden, 1997). In the first study to demonstrate feedback consistency effects, Stone et al. (1997) found that responses to feedback inconsistent words in a lexical decision task were slower than responses to feedback consistent words, and accuracy to feedback consistent words was higher. To explain these findings, Stone et al. proposed that the alternative spellings activated by feedback inconsistent rimes create conflict during decision making.

Since that original study, researchers have both successfully replicated (Ziegler, Montant, & Jacobs, 1997; Lacruz & Folk, 2004; Perry, 2003) and failed to replicate (Peereman, Content, & Bonin, 1998; Massaro & Jesse, 2005) the results of Stone et al. Two recent studies that controlled extensively for factors that might confound results came to opposite conclusions. Ziegler, Petrova, and Ferrand (2008) found no evidence of a feedback consistency effect in a lexical decision task, despite controlling for both onset and rime consistency, and were able to produce feedback consistency effects with a neural network model not sensitive to feedback consistency, suggesting that presumed feedback effects are in fact attributable to other factors. Yap and Balota (2009), conversely, showed significant effects of feedback consistency in hierarchical regression analyses of a large-scale database, after controlling for over a dozen other variables known to impact word-reading behavior. (Yap and Balota grant that it is possible that there are covariates they did not control for, but it is not clear what these might be; theirs is also the first study to examine feedback consistency effects in multisyllabic words.)

There are several issues in this body of research that may have prevented the field from reaching a clear consensus on the matter of feedback effects. First, all but one study (Perry, 2003) examined feedback effects at the level of the rime rather than at the individual phoneme. Categorically declaring a word "consistent" or "inconsistent" with regard to phonological feedback seems a rather blunt technique given that the individual phonemes in all words vary in their levels of feedback consistency. Vowels, in particular, can all be spelled more than one way in English (Kessler, Treiman, & Mullennix, 2008). Because Studies 1 and 2 in the present research utilize stimuli comprised of misspelled vowels in a spelling decision task, we have a felicitous opportunity to investigate the data from those experiments for evidence of feedback effects on behavior.

Additionally, the tasks used to investigate feedback effects have been exclusively lexical decision and naming. However, given that the cause of feedback effects is assumed to be activation by phonology of alternative spellings, a spelling decision task is a more direct test of the existence of these effects, because participants are faced with one of the activated alternatives (assuming that the word's pronunciation is not affected by the misspelling). Researchers have also generally failed to control for individuals' differences in reading and related skills in feedback consistency investigations, despite evidence that individual differences can significantly moderate cognitive processes in reading (e.g., Andrews & Hersch, 2010; Andrews & Lo, 2011). (An exception is Davies and Weekes [2005], who found feedback consistency effects in children with dyslexia, but not in control children.) Studies 2a and 2b in the present research include assessments of individual differences in participants' spelling, reading, and vocabulary knowledge, so that these may be taken into account when examining the possibility of phonological influences on orthography.

Finally, McKague, Davis, Pratt, and Johnston (2008) have proposed that phonological feedback is useful exclusively during orthographic learning, and offered initial evidence for this hypothesis in a training study that manipulated the feedback consistency of pseudowords. By analyzing the size of feedback consistency effects in Study 2 in relation to variation in participants' orthographic knowledge, we have the opportunity to seek support for their hypothesis in an experiment employing real-word stimuli. We undertake this series of analyses on Study 2 data in Study 3.

### 1.2.2 Suprasegmental influences on orthographic processes.

Unlike the influence of segmental phonology on orthographic processing, the possibility of an influence of suprasegmental phonology on orthographic processing has not been investigated. As in the case of research into phonological activation, this is likely because lexical stress does not map predictably to orthography, as do phonemes. That a phoneme might have a reciprocal relationship with the grapheme that activated it is a more natural assumption than that an increase in the pitch and duration of that phoneme might influence the visual perception of the letters it maps to. However, given the importance of lexical stress in the acquisition and comprehension of spoken language, the possibility is worth investigating. For example, research suggests that learning to attend to the predominant stress patterns of one's language in infancy is a crucial step in developing a lexicon (Jusczyk, Cutler, & Redanz, 1993), and an influential model of speech segmentation shows stress is secondary only to lexical signals as a cue to identifying word boundaries in the English speech stream (Mattys, White, & Melhorn, 2005).

There is also some empirical evidence that lexical stress enhances orthographic processing during reading. Letter detection during paragraph reading is facilitated when the letter being searched for appears in the stressed syllable of a 3-syllable word (Drewnowski & Healy, 1982; Goldman & Healy, 1985), and words in a lexical decision task are correctly identified as such at higher rates when the stress pattern of the stimulus is the typical one for its grammatical class (Arciuli & Cupples, 2006). Studies 1, 2, and 4 in the present research explore whether and under what conditions lexical stress might influence orthographic processes in reading.

## 1.3 CONTEXTUAL INFLUENCES ON ORTHOGRAPHIC PROCESSES

In Studies 1 and 2 reported here we investigate the influences of segmental and suprasegmental phonology on the orthographic processing of isolated words. In Study 4, we place target words in the context of a longer passage. In isolated-word reading, lexical stress is unlikely to be fully activated until the moment of word recognition, because stress, unlike phonemes, does not align to any sublexical component. In sentential context, by contrast, cues to the lexical stress of upcoming words are available from syntax and meaning, and these cues presumably become more reliable as words become more predictable from context. We therefore manipulate two factors in our final experiment: stress status of the misspelled syllable of target words, to test the hypothesis that stress effects will be stronger in a proofreading task than in a spelling or lexical decision task; and predictability of the target word in the sentence, to test the hypothesis that stress effects will vary with the predictability of words.

Controlling for predictability also gives us the opportunity to examine the role of predictability in error detection, which has seldom been done directly. A number of eye tracking studies have shown that less predictable words tend to receive longer fixations than more predictable words (Schotter, Bicknell, Howard, Levy, & Rayner, 2014; Ehrlich & Rayner, 1981; Zola, 1984), but although longer fixations imply an increased likelihood of noticing a misspelling, eye movements do not provide direct evidence of error detection. (Ehrlich & Rayner, 1981, did find that the probability of reporting misspellings following their experiment was higher for misspelled words that had appeared in low-constraint contexts). A related body of research has asked participants to proofread texts that they were more or less familiar with, under the assumption that every word in a familiar text is more predictable than every word in an unfamiliar text. These studies have led to mixed results, with some reporting increased error detection in more familiar passages (Levy, 1983; Levy & Begin, 1984), others reporting the opposite pattern of results (Pilotti & Chodorow, 2012), and still others reporting an interaction of success at error detection with the method through which familiarity was achieved (Pilotti, Maxwell, & Chodorow , 2006; Pilotti, Chodorow, & Thornton, 2005). In Study 4 we are able to definitively answer the question of whether predictability increases or decreases the likelihood of noticing spelling errors.

## 1.4 OVERVIEW OF THE PRESENT RESEARCH

The present project endeavors to elucidate the relationship of phonological activation to orthographic processes in a series of four studies that use systematically misspelled words as stimuli in a number of tasks and under a variety of conditions. In Study 1, we present an initial test of the hypothesis that lexical stress activated during silent reading can affect orthographic processing by manipulating the stress status of the syllable of misspelling and the phonemic preservation of the misspelled word in a spelling decision task. In Study 2, we compare the effects of stress and phonemes on orthographic processes in spelling decision and lexical decision tasks. Study 2a is essentially a replication of Study 1 with tighter stimulus control, and Study 2b features the set of Study 2a stimuli in a lexical decision task. Offline spelling skill is assessed in Study 2a; offline spelling, reading, and vocabulary skill is assessed in Study 2b. In Study 3, we analyze the data collected in Study 2 to test a number of hypotheses regarding phonological feedback effects on orthography: that activation of competing orthographic representations is the source of the effects; that feedback consistency can influence orthographic processing in spelling and lexical decision tasks; and that feedback from phonology to orthography is a tool for increasing the specificity of orthographic representations. Finally, Study 4 places in high-constraint and low-constraint contexts words misspelled in stressed and in unstressed syllables in a passage participants are asked to proofread; this task allows us to probe how stress effects on orthographic processes shift from isolated- to connected-word reading, and how these effects are impacted by the predictability of the word in context. Individual differences are also assessed in this experiment, to investigate potential interactions of reading-related skills with effects of stress and linguistic constraint.

## 2.0 STUDY 1: LEXICAL STRESS EFFECTS IN A SPELLING DECISION TASK

Study 1 comprised a spelling judgment task in which misspellings were strategically inserted into stressed or unstressed syllables. Whether or not the misspelling altered phonemes in the word (e.g., *delaxe* is pronounced differently from *deluxe*, but *sleapy* and *sleepy* share a pronunciation) was manipulated, as was the number of syllables (2 or 3) in the word, and whether stress fell on the first or second syllable. A finding that misspellings that alter phonemes in the target word facilitate spelling decisions would provide evidence that segmental phonology can affect orthographic processes; a finding that misspellings in stressed syllables are easier to detect than misspellings in unstressed syllables would provide evidence that suprasegmental phonology can affect orthographic processes. Number of syllables and syllable of stress were included in the experimental design to reveal whether and how these variables moderate the influence of segmental and suprasegmental phonological information on spelling decisions.

## 2.1 METHODS

### 2.1.1 Participants.

Fifty-one Introduction to Psychology students at the University of Pittsburgh participated in the experiment for class credit. All were native speakers of English.

### 2.1.2 Design.

A 2x2x2x2 within-subjects design was used to examine the influence of four independent variables on spelling decision outcomes: number of syllables in a word (two or three); syllable of primary stress (first or second); stress status of the syllable of misspelling (unstressed or stressed; hereafter, “stress status”); and whether the misspelling preserved or altered the phonemes of its correctly spelled counterpart (preserved or altered; hereafter, “phoneme status”). This design produces 16 stimulus types, or conditions (Table 1). Task accuracy and response latencies were recorded as dependent measures.

**Table 1.** The 16 conditions of the Study 1 design with sample stimuli.

| Condition | No. Syllables | Syllable of Primary Stress | Stress Status of Syllable of Misspelling | Phoneme Preservation Status | Example (target)* |
|---|---|---|---|---|---|
| 1 | 2 | 1 | U | P | CAC**tas** (cactus) |
| 2 | | | | A | EL**baw** (elbow) |
| 3 | | | S | P | **SLEAP**y (sleepy) |
| 4 | | | | A | **NAS**tril (nostril) |
| 5 | | 2 | U | P | **phi**SIQUE (physique) |
| 6 | | | | A | **bo**LIEVE (believe) |
| 7 | | | S | P | con**FERM** (confirm) |
| 8 | | | | A | de**LAXE** (deluxe) |
| 9 | 3 | 1 | U | P | FUR**na**ture (furniture) |
| 10 | | | | A | NEGa**tuve** (negative) |
| 11 | | | S | P | **LUV**ingly (lovingly) |
| 12 | | | | A | **CRUC**odile (crocodile) |
| 13 | | 2 | U | P | deFI**ence** (defiance) |
| 14 | | | | A | **son**SAtion (sensation) |
| 15 | | | S | P | con**SIN**sus (consensus) |
| 16 | | | | A | um**BRUL**la (umbrella) |

U = unstressed; S = stressed; P = preserved; A = altered.

*Caps = stressed syllable; bold = misspelled syllable.

### 2.1.3 Materials.

Experimental stimuli were between 5 and 9 letters in length, and were created by substituting one vowel in a word with another vowel (including *y*). Amazon Mechanical Turk (AMT) workers verified that each experimental item was recognizable as a misspelling of the intended target word (e.g., that *conferm* was perceived as a misspelling of *confirm* and not *conform*), and determined whether each stimulus was categorized as phoneme-altering or phoneme-preserving (see Harris, Perfetti, & Rickles, 2014, for further details about AMT and rating parameters for the present study).

Ten items for each of the 16 conditions were created, resulting in 160 experimental trials (misspellings). These were supplemented with 160 filler (correctly spelled) trials, for a total of 320 trials per participant. Each (unseen) target was misspelled in only one way, meaning that one stimulus list could be used for all experimental sessions. The complete list of Study 1 experimental stimuli is in Appendix A.

### 2.1.4 Procedure.

Experimental and filler stimuli were presented at the center of a computer screen in random order, using E-Prime presentation software (Schneider, Eschman, & Zuccolotto, 2002). Subjects were encouraged to respond as accurately and as quickly as possible, and were informed that half the words they would see would be misspelled, to reduce variance among participants in criterion setting. They then completed a 10-trial practice block to become familiarized with the procedure. Each trial began with a white fixation cross appearing in the center of a black screen, which was replaced after 500ms by the stimulus, also in white. Subjects were instructed to hit the *Yes* key on a serial response box if the stimulus was spelled correctly and the *No* key if it was spelled incorrectly. The stimulus remained onscreen until a response was selected, for up to 2000ms. The next trial, beginning with a fixation cross, began 750 ms after a response was selected. After the practice round, participants were given the opportunity to ask the experimenter any questions they might have about the procedure. The experimental session then proceeded in 8 blocks of 40 trials each, with participants given a chance to rest between blocks.

## 2.2 RESULTS

Task performance measures, including accuracy, latency, and d' (an index of target sensitivity), are given in Table 2. All participants had d's > 1, indicating the sample was generally able to distinguish targets from foils. Filler trials were not analyzed. Responses with latencies < 250 ms (1.46% of trials) were removed from analyses. Incorrect responses (10.1% of trials) were removed from latency analyses. Finally, five of the 160 items (3.11%) were removed from analyses due to accuracy rates at or below chance. Three of these were Type 13 stimuli, one was Type 9, and one was Type 7 (Table 1).

**Table 2.** Performance outcomes for Study 1

| Measure | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|
| Accuracy | 70.32 | 99.35 | 89.89 | .06 |
| d' | 1.50 | 3.74 | 2.46 | .50 |
| RT | 558 | 1143 | 830 | 134 |

N=51.

### 2.2.1 Stress and phoneme effects.

To understand the effects of the independent variables (number of syllables, stressed syllable, stress status, and phoneme status) on the accuracy and speed of spelling decisions, 2x2x2x2 ANOVAs were performed, with mean accuracy and mean latency to experimental stimuli as the dependent variables. All data were analyzed using both subject (*Fs*) and item (*Fi*) analyses.

#### 2.2.1.1 Accuracy.

A main effect on accuracy was found for phoneme status (*Fs*(1,50)=50.22, p<.001, $\eta^2_p$=.50; *Fi*(1,154)=19.46, p<.001, $\eta^2_p$=.12), such that accuracy was higher for items whose misspellings altered their phonemes. A main effect of stress status (*Fs*(1,50)=75.40, p<.001, $\eta^2_p$=.60; *Fi*(1,154)=20.20, p<.001, $\eta^2_p$=.13) was moderated by phoneme status (*Fs*(1,50)=62.02, p<.001, $\eta^2_p$=.55; *Fi*(1,154)=17.81, p<.001, $\eta^2_p$=.11), such that accuracy was higher for items misspelled in the stressed syllable only for phoneme-preserving items (Figure 1). A main effect of number of syllables was significant by subjects (*F*s(1,50)=12.86, p=.001, $\eta^2_p$=.21), but not by items (*Fi*(1,154)=2.70, p>.10). There was no significant main effect of syllable of stress (*Fs*(1,50)=1.51, p>.20; *Fi*(1,154)<1, p>.60).

An interaction of number of syllables with stress status was significant by subjects and marginal by items (*Fs*(1,50)=18.59, p<.001, $\eta^2_p$=.27; *Fi*(1,154)=3.34, p=.07, $\eta^2_p$=.02), indicating a trend towards higher accuracy for 2-syllable than for 3-syllable words only when the misspelling occurred in an unstressed syllable. Several other interactions were significant by subjects only: stress status x syllable of stress (*Fs*(1,50)=9.48, p<.01, $\eta^2_p$=.16; *Fi*(1,154)=2.20, p>.10); phoneme status x number of syllables (*Fs*(1,50)=7.36, p<.01, $\eta^2_p$=.13; *Fi*(1,154)=1.69, p>.10); and stress status x number of syllables x syllable of stress (*Fs*(1,50)=9.48, p<.01, $\eta^2_p$=.16; *Fi*(1,154)=2.42, p>.10).

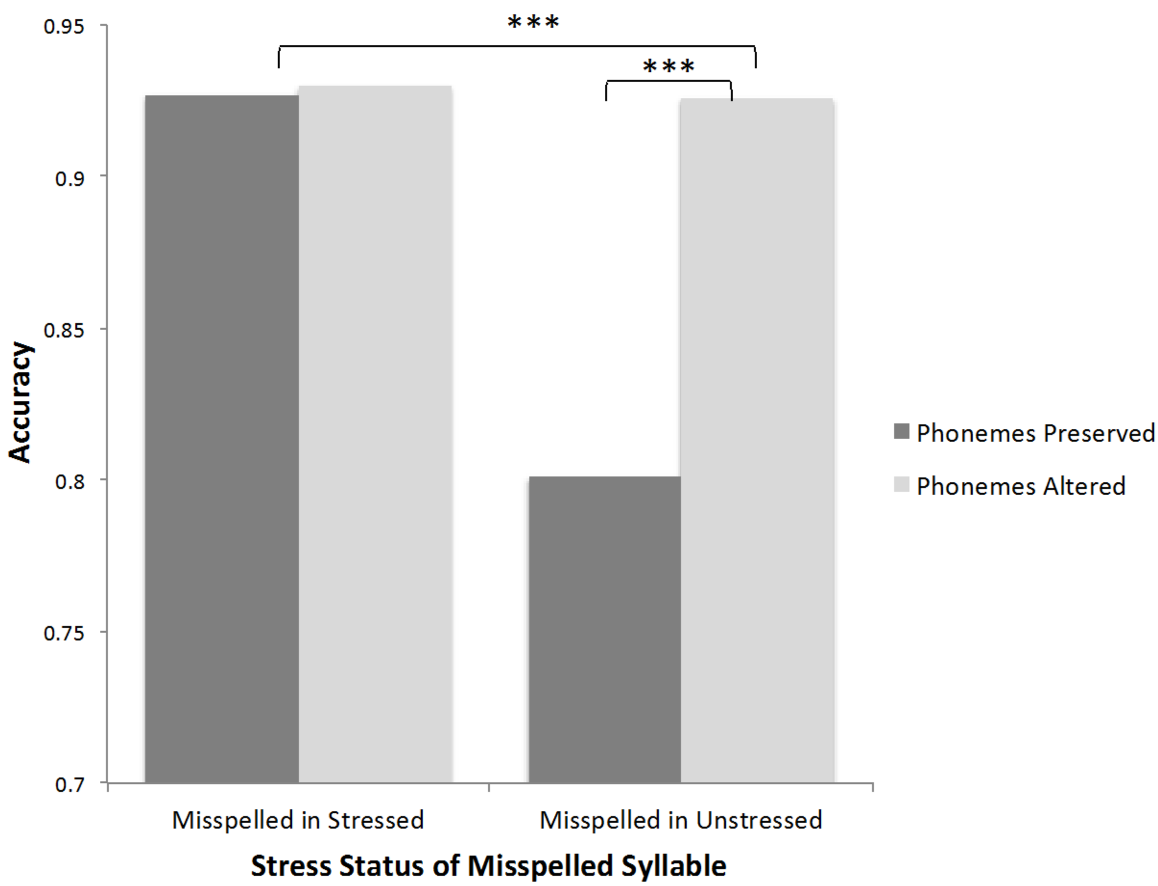


**Figure 1.** Stress status-by-phoneme status interaction on accuracy in Study 1. Data for subject means is shown; the interaction was also significant by items.

#### 2.2.1.2 Latencies.

A main effect of stress status on response latencies (*Fs*(1,50)=16.65, p<.001, $\eta^2_p$=.25; *Fi*(1,154)=4.83, p<.05, $\eta^2_p$=.03) was moderated by phoneme status (*Fs*(1,50)=31.54, p<.001, $\eta^2_p$=.39; *Fi*(1,154)=5.70, p<.05, $\eta^2_p$=.04), such that misspellings in stressed syllables were responded to faster than misspellings in unstressed syllables only when phonemes were preserved (Figure 2). (This interaction mirrors that of stress status and phoneme status in the accuracy analyses.) Stress status also interacted with number of syllables (*Fs*(1,50)=44.62, p<.001, $\eta^2_p$=.47; *Fi*(1,154)=13.14, p<.001, $\eta^2_p$=.09), such that misspellings in stressed syllables were responded to faster in 3-syllable words and misspellings in unstressed syllables were responded to faster in 2-syllable words. Main effects of number of syllables (*Fs*(1,50)=87.29, $p<.001$, $\eta^2_p=.64$; *Fi*(1,154)=30.26, $p<.001$, $\eta^2_p=.18$) and syllable of stress (*Fs*(1,50)=24.02, $p<.001$, $\eta^2_p=.32$; *Fi*(1,154)=7.34, $p<.01$, $\eta^2_p=.05$) were also significant, such that responses were faster to two-syllable items and to items stressed on the first syllable. A main effect of phoneme status was not significant (*Fs*(1,50)=1.33, $p>.20$; *Fi*(1,154)<1, $p>.30$).

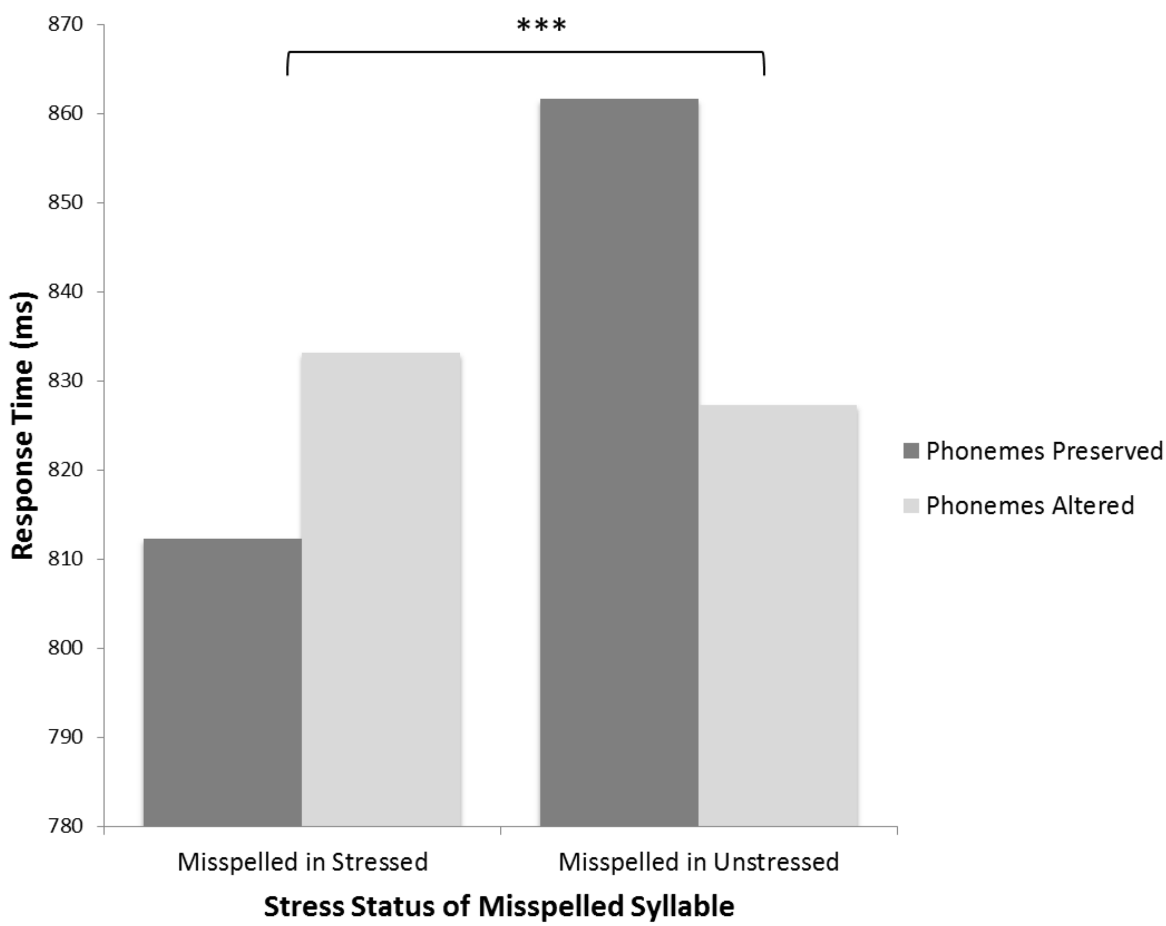


**Figure 2.** Stress status-by-phoneme status interaction on latencies in Study 1. Data for subject means is shown; the interaction was also significant by items.

## 2.3 DISCUSSION

The goal of Study 1 was to replicate the finding of Harris et al. (2014) that segmental phonology (phonemes) can influence participants' ability to detect misspellings, and to investigate whether suprasegmental phonology (lexical stress) can also impact spelling decisions. The results of Study 1 provide initial evidence that both phonemes and lexical stress can influence the orthographic processes involved in spelling decisions.

The effect of phoneme status on the accuracy of spelling decisions was significant both by subjects and by items. Participants were more likely to detect that an item was misspelled if the misspelling altered the phonemes of the word than if the misspelling preserved its correct pronunciation. This finding replicates that of Harris et al. (2014), and indicates that not only is segmental phonology routinely activated during a spelling decision, it serves as a cue alongside orthography in assessments of visual form. Phoneme status also moderated the effect of stress status on response latencies: the effect of stress on latencies was nullified when phonemes were altered by a misspelling.

Stress significantly impacted task accuracy rates in both subjects and items analyses. Misspellings in stressed syllables were detected more often, and more rapidly, than misspellings in unstressed syllables. However, as with response latencies, the effect of stress on accuracy was moderated by phonemes, such that stress only improved error detection when the error changed the word's phonemes. The interaction of stress status with phoneme status in both accuracy and latency analyses suggests that, although stress may have an effect on orthographic processing under some conditions, phonemes provide the earliest phonological information that feeds into orthographic analysis, with stress activated later.

Interactions of stress status with number of syllables in both accuracy and latency analyses are at first difficult to make sense of: why 2-syllable words should be advantaged over 3-syllable words in terms of speed and accuracy *only* when misspelled in an unstressed syllable is not immediately obvious. The explanation likely lies in an unintended consequence of changing letters in unstressed syllables: misspelling a 2-syllable word in an unstressed syllable may tend to attract stress to that syllable (e.g., *cabboge, demage, yoorself, bolieve*), with the result that it is effectively misspelled in a stressed syllable after all. Finding stress in a syllable where one does not usually encounter it may increase the salience of errors within the syllable.

Other than this interaction of stress status with number of syllables, we did not obtain reliable evidence that the number of syllables or the location of stress in a word moderates stress effects in reading. This diverges from the findings of Drewnowski and Healy (1982), who reported lexical stress effects on orthographic processing only in three-syllable words, and only when stress fell in the second or third syllable.

Study 1 provides evidence that both segmental and suprasegmental phonology can affect orthographic processes. However, this evidence should be considered as preliminary because of limitations in the experimental design. This experiment employed a between-words design (each unseen target was misspelled either in a stressed syllable or an unstressed syllable, and either to preserve the word's phonemes or alter them), and results may be confounded with word differences. In Study 2a, we attempt to replicate the findings of Study 1 under tighter stimulus control. Study 2b features the experimental items of Study 2a in a lexical decision task rather than a spelling decision task, to determine whether phonological effects on orthographic processing arise during routine word identification, or rather exert their influence during a postlexical spelling verification. Because number of syllables and syllable of stress did not play a reliable role in the phonology-orthography relationship, we do not continue to control for them in the remaining experiments reported here. Eliminating these manipulations allowed us to implement a Latin Square design in Studies 2 and 4, which affords stricter control of stimuli.

# 3.0 STUDY 2: A COMPARISON OF PHONOLOGICAL EFFECTS IN TWO READING TASKS

The results of Study 1 suggest that phonology at segmental and suprasegmental levels can influence orthographic processing, but they do not address the question of whether orthographic processes in the course of normal word identification are subject to phonological influence. Because a spelling decision task encourages postlexical orthographic processing, and because extensive prelexical phonological processing may be required to differentiate strings with a high degree of orthographic overlap, Study 1 cannot speak to whether phonology can affect orthographic processes when such careful attention to orthography is deprioritized. To understand the relationship between phonology and orthography across reading tasks, Study 2 is divided into two sub-experiments: in Study 2a, items are presented in the context of a spelling decision task, and in Study 2b the same items are presented in the context of a lexical decision task.

## 3.1 STUDY 2A: SPELLING DECISION

The primary purpose of Study 2a was to replicate the findings of stress and phoneme effects on spelling decisions in Study 1 under tighter stimulus control. In Study 1, each target word was misspelled one way, and this misspelling appeared in one of the 16 conditions; in Studies 2a and

2b, each target word was misspelled in four different ways (stressed syllable/phoneme preserving; stressed syllable/phoneme altering; unstressed syllable/phoneme preserving; unstressed syllable/phoneme altering) so that the same target was represented in each of four experimental conditions. The difficulty of creating stimuli such that each target word is misspelled in four different ways necessitated Study 2 use a simple, 2x2 design that did not account for number and location of syllables. In addition, participants' offline spelling skill was assessed following Study 2a in order to investigate the relationship between phonological influences on orthographic processing and spelling ability; this data is analyzed in Study 3.

### 3.1.1 Methods.

#### 3.1.1.1 Participants.

Participants were 145 Introduction to Psychology students at the University of Pittsburgh who had not participated in Study 1. All spoke English at a native or near-native level, and received class credit for their participation.

#### 3.1.1.2 Design.

A 2x2 within-subjects design examined the influence of stress status (misspelled in stressed syllable, misspelled in unstressed syllable) and phoneme status (misspelling preserves phonemes, misspelling alters phonemes) on spelling decision outcomes, resulting in four conditions (Table 3). Task accuracy and latencies were recorded as dependent measures.

**Table 3.** The four conditions of the Study 2 design with sample stimuli

| | | Pronunciation of Misspelling | |
|---|---|---|---|
| | | Preserves Phonemes | Alters Phonemes |
| Stress Status of Syllable of Misspelling | Stressed | *cumfort* | *camfort* |
| | Unstressed | *comfert* | *comfart* |

**3.1.1.3 Materials.**

Experimental materials were created and vetted in the same manner as in Study 1, save that in this experiment each target was misspelled four different ways, resulting in a Latin Square design. Forty items for each of the four conditions were created, and a participant saw 10 items from each condition, to ensure that s/he did not encounter two versions of the same word. This outcome required that the stimuli be divided into four lists, with a quarter of participants viewing each one. Each session consisted of 40 experimental trials (misspellings) and 40 filler (correctly spelled) trials, for a total of 80 trials per participant. The complete list of experimental stimuli used in Studies 2a and 2b is in Appendix B.

***Offline assessment.*** Study 2a included an offline spelling assessment (Perfetti & Hart, 2002) not administered to participants in Study 1, for use as a measure of spelling ability in individual differences analyses. The assessment is adapted from Olson, Wise, Conners, Rack, & Fulker (1989), and contains two subsets of items: the easier "Olson" and "Baroff" items, and the more difficult "Hart" items. For the full test, see Nelson (2010).

#### 3.1.1.4 Procedure.

The procedure was identical to that of Study 1, save that the experimental session consisted of 4 blocks of 20 trials each, and participants completed a short spelling assessment after the experimental session.

### 3.1.2 Results.

Online and offline task performance measures are given in Table 4. Filler trials were not analyzed. Two subjects (1.38%) with experimental d’ under 1.00 (indicating very poor target sensitivity) were removed from analyses, resulting in an *n* of 143. Responses with latencies < 250 ms (1.35% of trials) were removed from analyses. Incorrect trials (7.78% of trials) were removed from latency analyses. Finally, 1 of the 160 items (0.63%; stimulus Type 3) was removed from analyses due to accuracy rates below chance. Note that spelling errors were generally more transparent in this more carefully controlled stimulus set: From Study 1 to Study 2a, mean accuracy rose from 89.89% to 92.13%, mean d’ rose from 2.46 to 2.93, and the percentage of error trials dropped from 10.1% to 7.78%.

**Table 4.** Online and offline performance outcomes for Study 2a

| Measure | | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Experimental Task | Accuracy | 68.00 | 100.00 | 92.13 | .07 |
| | d’ | 1.42 | 5.61 | 2.93 | .83 |
| | RT | 527 | 1264 | 856 | 148 |
| Offline Spelling Assessment | Accuracy | 69.00 | 93.00 | 81.70 | .05 |
| | Combined d’ | 1.06 | 2.94 | 1.90 | .39 |
| | Olson d’ | 1.40 | 4.00 | 2.96 | .52 |
| | Baroff d’ | 1.37 | 4.00 | 3.01 | .68 |
| | Hart d’ | -.83 | 2.11 | .65 | .51 |

N=143 for experimental measures and N=142 for offline measures.

### 3.1.2.1 Stress and phoneme effects.

Two (phonemes preserved, phonemes altered) by two (misspelled in stressed syllable, misspelled in unstressed syllable) repeated-measures ANOVAs were performed on accuracy and latency measures. All data were analyzed using both subject (*Fs*) and item (*Fi*) analyses.

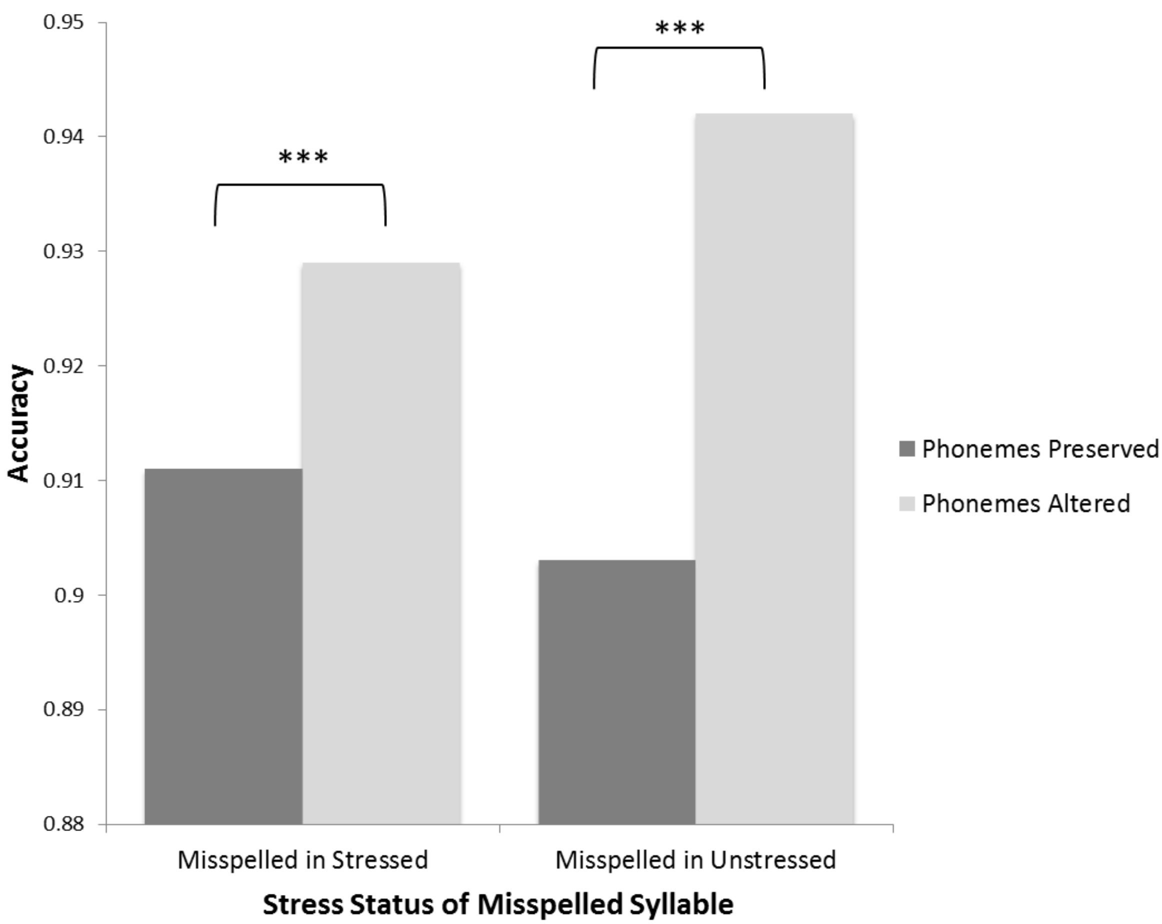


**Figure 3.** Mean accuracy by condition in Study 2a. Data for subject means is shown; a main effect of phoneme status was also significant by items.

***Accuracy.*** As in Study 1, a main effect of phoneme status was found on accuracy (Fs(1,142)=18.59, $p<.001$, $\eta^2_p=.12$; Fi(1,158)=4.16, $p<.05$, $\eta^2_p=.03$; Figure 3), although the main effect of stress status was no longer significant (Fs(1,142)<1; Fi(1,158)<1). The independent variables did not interact (Fs(1,142)=2.56, $p>.10$; Fi(1,158)<1).

***Latencies.*** Main effects of stress status (Fs(1,142)=4.69, $p<.05$, $\eta^2_p=.03$; Fi(1,158)=1.73, $p>.10$) and phoneme status (Fs(1,142)=15.03, $p<.001$, $\eta^2_p=.10$; Fi(1,158)=1.66, $p>.10$) on response latencies were significant by subjects (as in Study 1; Figure 4) but not by items (unlike Study 1). No interaction was observed (Fs(1,142)=2.11, $p>.10$; Fi(1,158)<1).

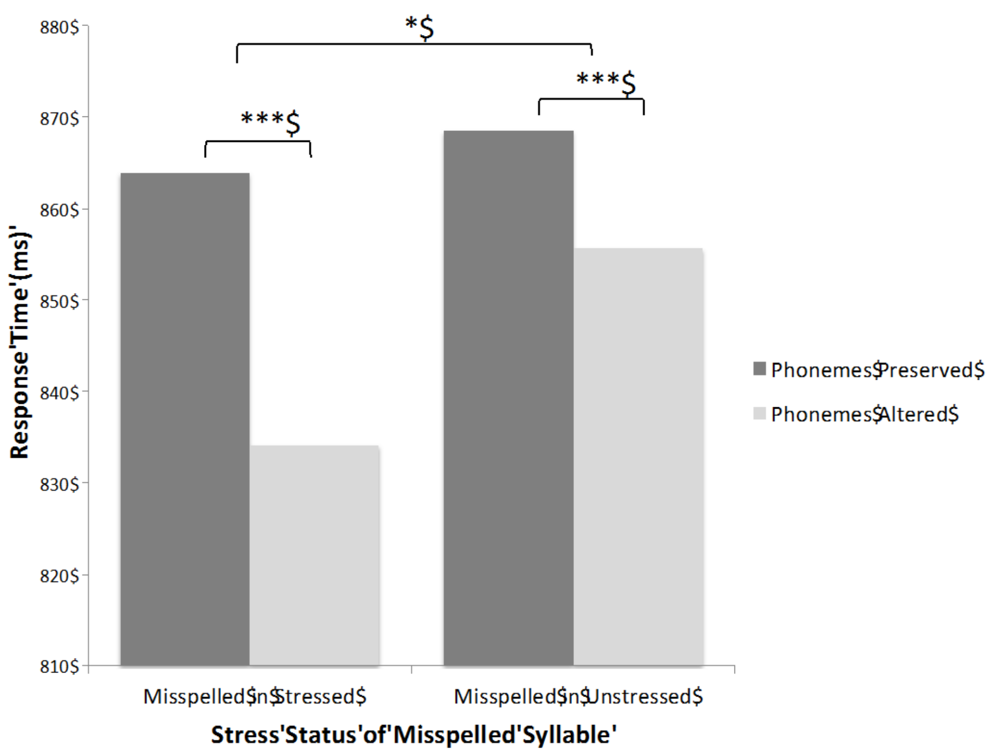


**Figure 4.** Stress status-by-phoneme status interaction on latencies in Study 2a. Data for subject means is shown; the interaction was not significant by items.

### 3.1.3 Discussion.

The primary goal of Study 2a was to replicate the findings of Study 1, i.e., a significant effect of stress status on accuracy and latencies for phoneme-preserving misspellings, and a main effect of phoneme status on accuracy and latencies. However, these effects were not entirely replicated. The main effect of phoneme status remained significant on accuracy, and emerged as significant by subjects on response latencies. This represents the third consecutive study (following Harris et al., 2014, and Study 1 above) in which misspellings were detected more consistently when they altered the phonemes of the word—i.e., the misspelling in *betroy* was, on average, easier to detect than the misspelling in *betrey*. Note that the misplaced *o* and *e* in this example are visually very similar; the differential response patterns to the two words are driven primarily by the phonemes the misplaced letters activate. Study 2b, in which these items are presented in a lexical decision task, reveals whether phonemes affect how we perceive a word on a page or screen prior to complete word identification, or postlexically, when the visual word form is being carefully scrutinized.

The role of stress status on spelling decisions, by contrast, changed considerably from Study 1 to Study 2a. In Study 2a, stress no longer influenced accuracy rates, suggesting that the effect of stress on accuracy in the first experiment was driven by stimulus factors. Stress did still have an effect on response latencies, with misspellings in stressed syllables receiving faster responses on average than misspellings in unstressed syllables; however, this effect was significant by subjects only, and did not interact with phoneme status as it did in Study 1. These data indicate that an effect of lexical stress on orthographic processes is, compared to the effect of phonemes, much weaker and much less reliable. We predict that in Study 2b, when phonological processing time is restricted and close orthographic processing is discouraged, stress effects will be diminished even further.

## 3.2 STUDY 2B: LEXICAL DECISION

Our aim in Study 2b was for participants to encounter the same items used in Study 2a, but to engage in a series of lexical decisions rather than a series of spelling decisions. The two tasks, though highly similar, differ in ways that are meaningful for the emergence of phonological effects. A lexical decision, as Henderson (1989, p. 358) noted, "oblige[s] the reader to journey exactly as far as the portals of the lexicon, to ring the bell and, if someone answer[s], to run home without further ado to report this happy domestic circumstance." A spelling decision, by contrast, requires the reader at least to stick his head inside the portal to ensure that the person who answered is the person he was looking for. Phonological information might be relied on more heavily when the burden of spelling verification is added to the basic lexical decision.

Aside from altering the instructions given to participants from Study 2a to Study 2b, we encouraged them to treat the task as a lexical decision rather than as a spelling decision in two ways: by including a number of nonwords among the stimuli, and by gradually reducing the duration that stimuli remained onscreen. A first block of stimuli were displayed for 2000 ms, as in Study 2a; a second block were displayed for 350 ms, and a third block were displayed for 150 ms, so that by the end of experiment a careful spelling decision was impossible. Further details are given in the Materials (section 3.2.1.3) and Procedure (section 3.2.1.4) sections below. Participants also completed offline assessments of spelling, reading, and vocabulary skill; this data is analyzed in Study 3.

### 3.2.1 Methods.

#### 3.2.1.1 Participants.

Participants were 110 Introduction to Psychology students at the University of Pittsburgh who had not participated in Study 1 or Study 2a. All spoke English at a native or near-native level, and received class credit for their participation.

#### 3.2.1.2 Design.

A 2x2x3 within-subjects design examined the influence of stress status (misspelled in stressed syllable, misspelled in unstressed syllable), phoneme status (misspelling preserves phonemes, misspelling alters phonemes), and exposure duration of the stimulus (2000 ms, 350 ms, or 150 ms) on spelling decision outcomes, resulting in 12 conditions. Task accuracy and latencies were recorded as dependent measures.

#### 3.2.1.3 Materials.

The spelling decision task used in Study 2a was "repackaged" as a lexical decision task by supplementing the 40 experimental stimuli of 2a, each of which has a real English word as an orthographic neighbor, with an equal number of stimuli that, while pronounceable, have no orthographic neighbors in English. These 40 "neighborless" stimuli, which we will call filler nonwords, were created by recombining the syllables of correctly spelled fillers from Studies 1 and 2a. (Thus, "adaceed" is created from syllables in *adjourn, paradigm,* and *exceed;* "carmar" is created from syllables in *carrot* and *grammar,* etc.) Another 80 stimuli, corresponding to the correctly spelled fillers of Study 2a, were used as real-word fillers. As in Study 2a, the experimental stimuli were rotated through a Latin Square, for a total of four stimulus lists. Lists consisted of 160 stimuli each, with real words and filler nonwords the same on all four lists.

***Offline assessments.*** Study 2b participants completed the spelling assessment administered in Study 2a, as well as the Nelson-Denny reading comprehension and vocabulary assessments (Brown, Bennett, & Hanna, 1981). The comprehension assessment consists of eight passages, each followed by 5-answer multiple choice comprehension questions about the passage for a total of 36 items. Participants have 15 minutes to complete as much of the test as they can (instead of the usual 20 minutes). The test is scored for both speed (% of items completed) and accuracy (% of answered items that are correct). The vocabulary assessment is given as a 7.5-minute timed test (half of the normal time allotted), and participants are instructed not to skip any of the items, which get progressively more difficult. The test is a multiple-choice test in which participants choose each word's definition from 5 choices. Questions are presented in a complete-the-sentence style (e.g. A brochure is a...). There is both a speed (% of items completed) and accuracy (% of completed items correct) measure.

**3.2.1.4 Procedure.**

The procedure mirrored that of Study 2a in all respects save the following: To further discourage participants from treating the task as a spelling decision task, they were informed that half of the stimuli they were about to see would be real English words and half would be nonwords (in the spelling decision task, participants were told that half of the stimuli were correctly spelled words and half were misspelled words). Furthermore, they were told that the nonwords would vary in their resemblance to real words, with some differing from real words by only a letter or two (as in the case of the experimental items), and others differing by several letters or not resembling a real word at all (as in the case of the filler nonwords). This way, misspellings (when detected) would be treated as nonwords rather than as misspelled real words.

We anticipated that, despite efforts to recast the task as a lexical decision task, participants might still initiate a spelling verification if a stimulus shared enough letters with a real word. In a model of spelling decisions proposed by Harris et al. (2014; Figure 5), during a decision about spelling, an input string triggers activation of the lexicon, and all entries with high orthographic overlap remain active throughout the decision. If an exact match for the input string is immediately identified amongst the active candidates, a *Yes* response is indicated. If an immediate match is not located, the most highly activated candidate is compared with the input, and if orthographic overlap is high, a final spelling verification ensues.

In a "pure" lexical decision, the decision-making process should end with the identification of, or the failure to identify, a quick exact match. Norris (2006) has noted that a spelling check is typically an inefficient strategy when making a lexical decision, unless extreme caution is called for. However, we cannot know the decision-making efficiency or the level of caution exercised by each of our participants, and a string that differs by only one letter from a word might tempt participants into verifying spelling despite task instructions. For this reason, a series of increasingly restrictive exposure durations was used for stimulus presentation, to further limit in-depth orthographic processing. The 160 stimuli were divided into three blocks of 53-54 stimuli each; half of the stimuli in each block were real words, and the other half were split between filler nonwords and experimental nonwords. Stimuli in the first block were presented for 2000 ms, stimuli in the second block were presented for 350 ms, and stimuli in the third block were presented for 150 ms; stimuli in Blocks 2 and 3 were immediately replaced with a form mask (XXXXX) until a response was selected, or for the balance of 2000 ms. Stimuli were randomly presented within blocks.

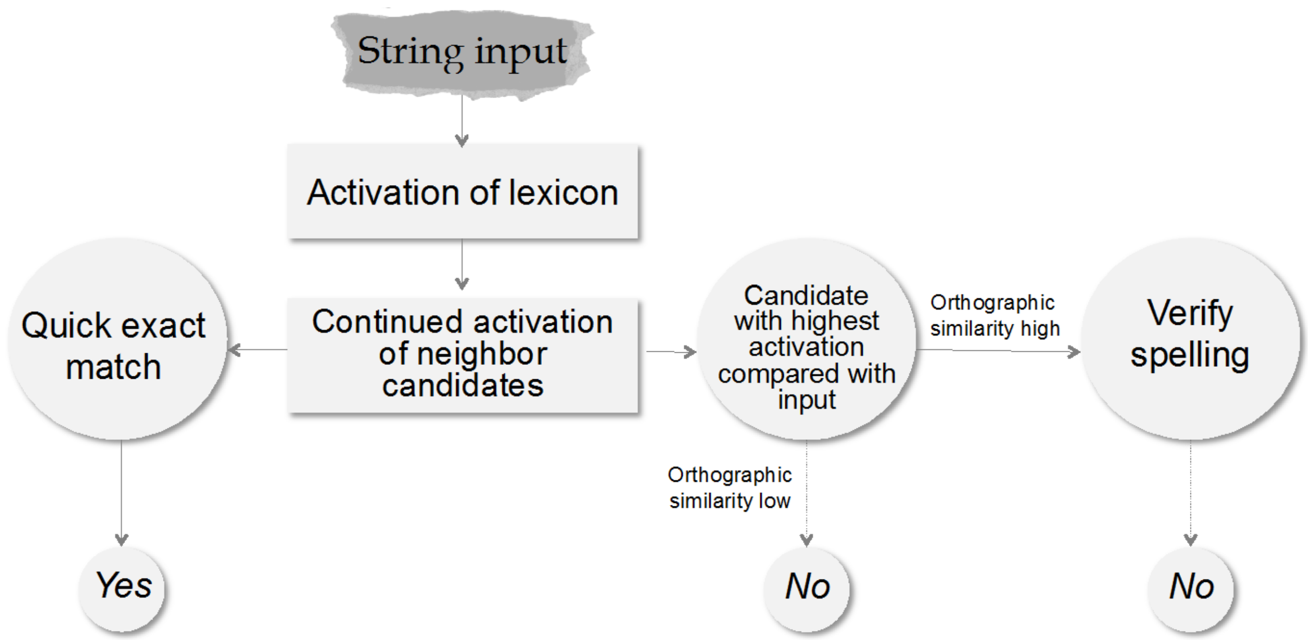


**Figure 5.** Process model of spelling decisions. When instructed to decide if a stimulus is spelled correctly, the input string will trigger activation of the lexicon and then continued activation of similar orthographic entries. If an exact match is quickly identified, a quick *Yes* response (or *No* response, if the participant's threshold for responding is low) is indicated. If no exact match is immediately identified, the lexical entry most strongly activated by the input is compared with the input string. If orthographic similarity is low, a *No* response is quickly indicated. If orthographic similarity is high, spelling verification occurs before the *No* response is indicated. (Adapted from Harris et al., 2014.)

We expected that that presenting stimuli for brief durations and interrupting orthographic processing with a mask would either short-circuit the spelling decision process, so that a decision would have to be made before the final spelling verification was initiated, or would force participants to adjust their decision-making strategy and default to the pure lexical decision regardless of the degree of overlap between the input and the neighbor candidates. In addition, the variable SOAs should shed light on how soon in word identification phonology operates on orthographic processes.

### 3.2.2 Results.

Online and offline task performance measures are given in Table 5. Filler trials, including both real-word and nonword fillers, were not analyzed. Five subjects (4.55%) with experimental d' under 1.00 (indicating very poor target sensitivity) were removed from analyses, resulting in an *n* of 105. Responses with latencies < 250 ms (0.82% of trials) were removed from analyses. Incorrect trials (13.89% of trials) were removed from latency analyses. Finally, nine of the 160 items (5.63%; one Type 1, one Type 2, five Type 3, and two Type 4) were removed from analyses due to accuracy rates at or below chance across all exposure conditions.

**Table 5.** Online and offline performance outcomes for Study 2b.

| Measure | | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Experimental Task | Accuracy | 58.00 | 100.00 | 86.03 | .09 |
| | d' | 1.01 | 3.91 | 2.37 | .63 |
| | RT | 523 | 1134 | 747 | 121 |
| Spelling Assessment | Combined d' | .88 | 3.00 | 2.01 | .40 |
| | Olson d' | 1.03 | 3.83 | 2.70 | .51 |
| | Baroff d' | .84 | 3.29 | 2.82 | .50 |
| | Hart d' | -.10 | 2.06 | 1.00 | .49 |
| Reading Assessment | Accuracy | 50.00 | 100.00 | 79.24 | 10.76 |
| | Composite score | 2.40 | 33.60 | 19.95 | 6.25 |
| Vocabulary Assessment | Accuracy | 47.00 | 98.00 | 77.75 | 11.85 |
| | Composite score | 7.60 | 94.00 | 50.64 | 18.92 |

N=105 for experimental measures and N=102 for offline measures. Composite score = (number correct) – [(number incorrect and unanswered)/(number response choices)].

#### 3.2.2.1 Stress and phoneme effects.

Two (phonemes preserved, phonemes altered) by two (misspelled in stressed syllable, misspelled in unstressed syllable) by three (2000 ms, 350 ms, 150 ms) repeated-measures ANOVAs were performed on accuracy measures. Because high error rates were obtained in the 350-ms and 150-ms conditions, there were often few or no correct trials of a given stimulus type to analyze in those conditions for a given subject, and so latency analyses were collapsed across exposure conditions. Two (phonemes preserved, phonemes altered) by two (misspelled in stressed syllable, misspelled in unstressed syllable) ANOVAs were performed on latency data. All data were analyzed using both subject (*Fs*) and item (*Fi*) analyses.

***Accuracy.*** ANOVAs on accuracy revealed a main effect of exposure condition, ($Fs(1,2)=37.14$, $p<.001$, $\eta^2_p=.19$; $Fi(1,2)=55.53$, $p<.001$, $\eta^2_p=.20$), such that accuracy improved as stimulus exposure duration increased (Figure 6). A main effect of phoneme status was marginally significant by subjects only ($Fs(1,312)=3.43$, $p=.065$, $\eta^2_p=.01$; $Fi(1,452)=1.75$, $p>.10$). A main effect of stress status was not significant ($Fs(1,312)=1.06$, $p>.10$; $Fi(1,452)=1.89$, $p>.10$). No interactions were observed.

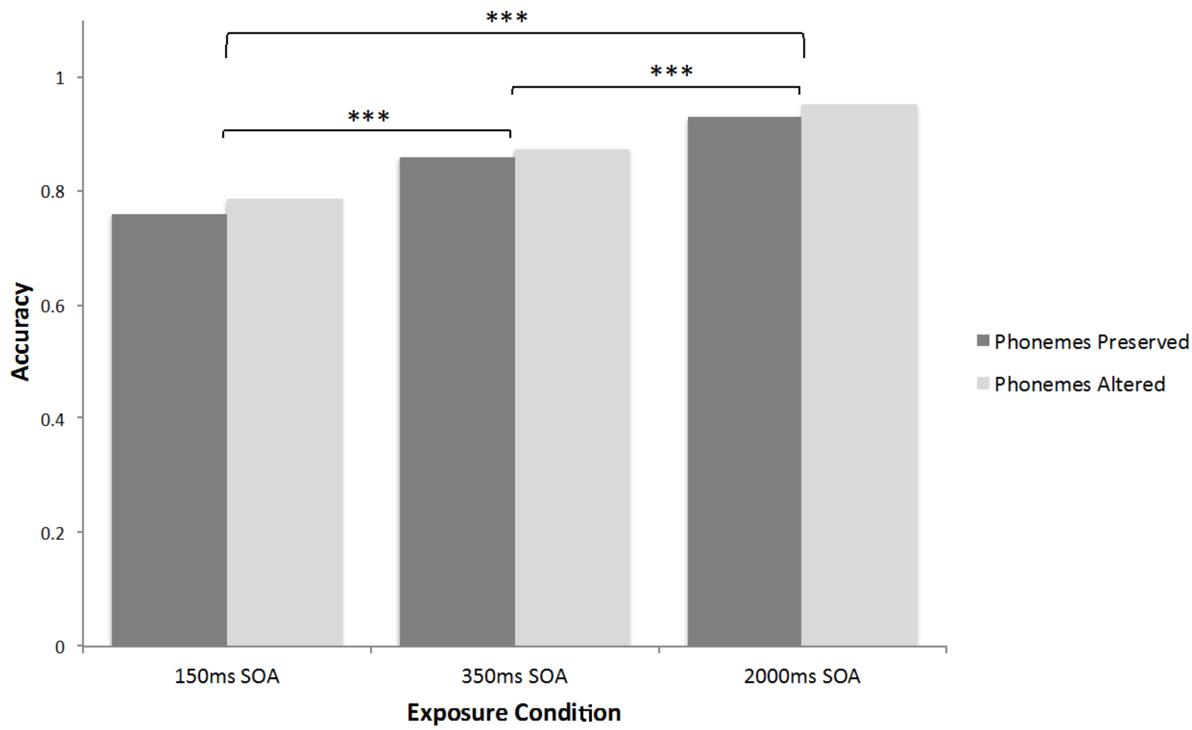


**Figure 6.** Subjects accuracy by exposure condition and phoneme status for Study 2b. An effect of phoneme status was marginal ($p$ = .065) and did not interact with the effect of exposure condition ($p$ < .001).

***Latencies.*** ANOVAs on latency, collapsed across exposure conditions, revealed no significant effect of stress status (Fs(1,104)<1; Fi(1,150)<1), no significant effect of phoneme status (Fs(1,104)<1; Fi(1,150)<1), and no significant interaction of the two (Figure 7).

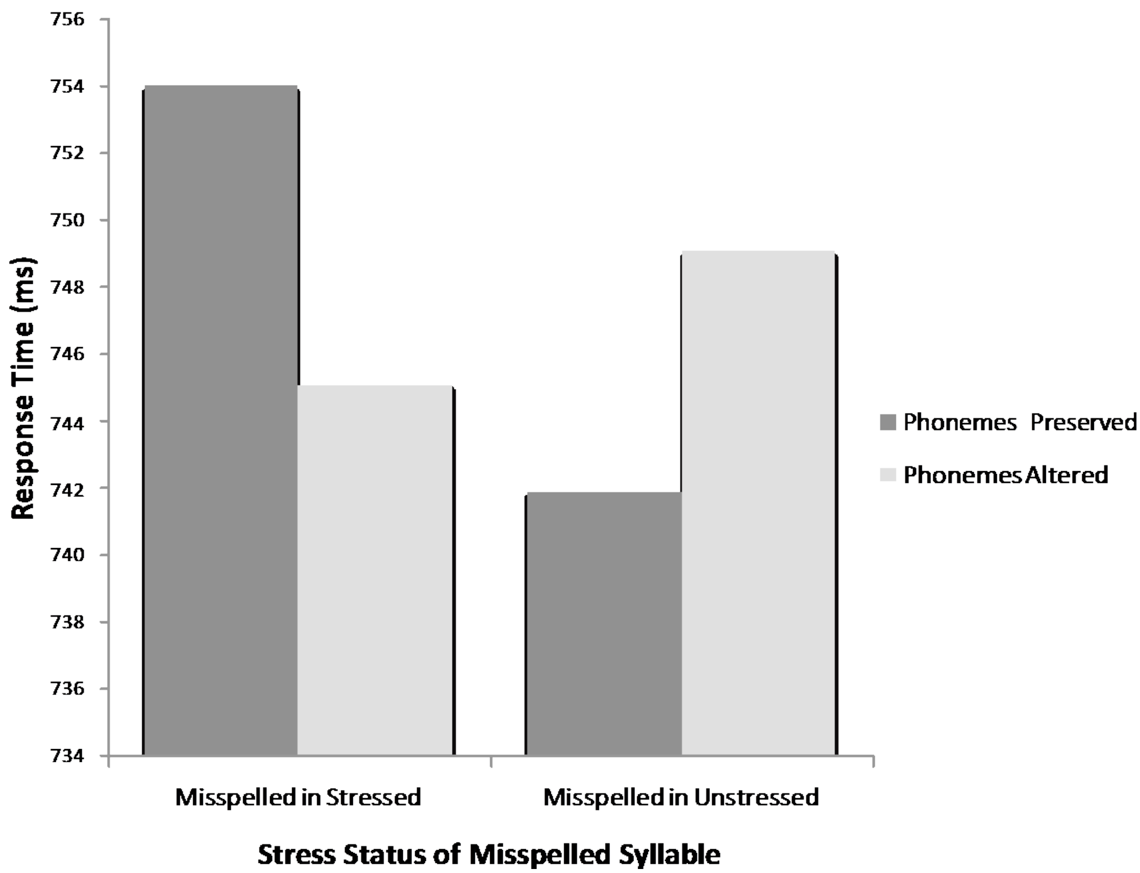


**Figure 7.** Mean latencies by condition in Study 2b. Data for subject means is shown.

### 3.2.3 Discussion.

As predicted, the effects of stress on orthographic processing, which decreased considerably from Study 1 to Study 2a, disappeared entirely in Study 2b. Likewise, phonemic effects were reduced, with phoneme status no longer affecting response latencies, and affecting accuracy in the subjects analyses only. The diminished role of stress and phonemes from the spelling decision task to the lexical decision task is consistent with the suggestion that the ability to behaviorally detect phonological effects in reading tasks decreases as phonological processing demands decrease (Gibbs & Van Orden, 1998). The phonological processing burden was eased in the lexical decision task by at least two means. First, the foils used in the spelling decision task were exclusively misspelled words, and half of the misspellings were pseudohomophones (phoneme-preserving). In the lexical decision task, only one third of foils were homophones, and an additional third were nonwords that shared limited orthographic overlap with real words. Previous research has shown that phonological effects increase when pseudohomophones are used as foils compared to when nonwords are used (Pexman, Lupker, & Jared, 2001; Berent, 1997; Gibbs & Van Orden, 1998).

Second, the nature of the tasks themselves places differing demands on phonological processing. In a separate model explaining the misidentification of misspelled words as correctly spelled (Figure 8), Harris et al. (2014) proposed that both orthographic and phonological cues in a word string are taken into account during the spelling verification stage. If phonological information conflicts with orthographic information, as in the case of a phoneme-preserving misspelling, decisions are more challenging and the chance of making an error increases. Because of its use in the spelling verification, phonology is a heavily relied-on cue in spelling decisions, and a premium is placed on thorough phonological processing. Because the spelling verification step is circumvented in a lexical decision, phonological information activated by a string plays a diminished role in the decision-making process.

Thinking on the effects of phonology across tasks and sets of materials has generally centered on segmental phonology, but our findings suggest that the forces that drive segmental effects drive suprasegmental effects as well. We return to the issue of how task and materials affect suprasegmental effects in Study 4. First, however, we turn to the question of how phonology contacts orthography. In Study 3, we test the hypothesis that feedback from phonology to orthography is the mechanism by which phonological information might exert an influence on orthographic processes.

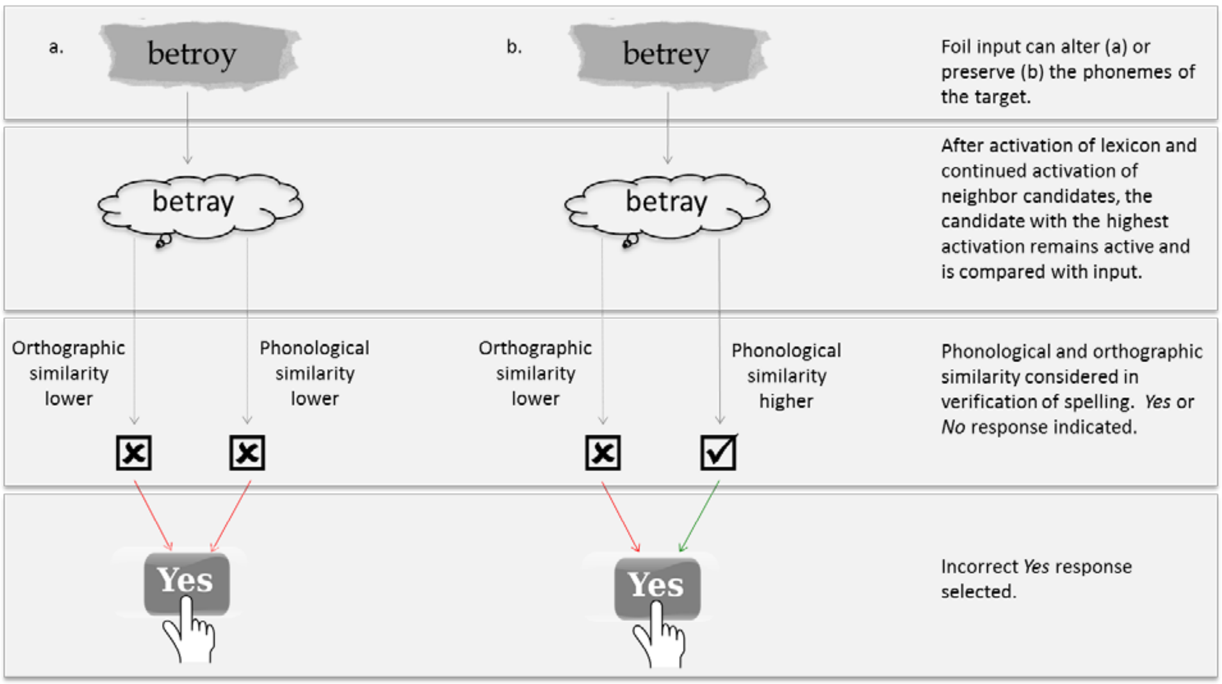


**Figure 8.** Process model of errors made to misspellings in a spelling decision task. (Adapted from Harris et al., 2014.)

# 4.0 STUDY 3: THE INFLUENCE OF PHONOLOGICAL FEEDBACK ON ORTHOGRAPHIC PROCESSING AND ORTHOGRAPHIC LEARNING

In Study 3, we investigate phonological feedback consistency information as a possible source of the phonological effects on spelling and lexical decisions, and test alternative possible mechanisms for this influence. Further, we provide a test of the hypothesis that feedback from phonology to orthography during word reading is a scaffold for orthographic learning (McKague, Davis, Pratt, & Johnston, 2008).

## 4.1 STUDY 3A: CONSISTENCY EFFECTS

Empirical evidence for feedback consistency effects in word reading—i.e., effects of the number of mappings from phonemes in a word to graphemes that can legally represent them—has been inconsistent, with some studies reporting significant feedback consistency effects (Stone et al., 1997; Ziegler, Montant, & Jacobs, 1997; Lacruz & Folk, 2004; Perry, 2003; Yap & Balota, 2009) and others unable to detect them (Peereman et al., 1998; Massaro & Jesse, 2005; Ziegler et al., 2008). Study 3a had two goals: to identify the mechanism of phonological effects on spelling and lexical decisions, and to identify whether feedback consistency influences such decisions when other factors (including feedforward consistency) are controlled for.

To accomplish the first goal, we performed correlations of two measures of feedforward and feedback consistency with spelling and lexical decision outcomes. The first was a *count* measure of phonological consistency. Feedforward count (FF count) was defined as the number of phonemes to which the misspelled grapheme maps in English (e.g., because the letter *i* maps to seven different phonemes in English, *bisiness* was assigned a FF count of 7), and feedback count (FB count) was defined as the number of graphemes to which the misspelled phoneme maps in English (e.g., because the phoneme /ɪ/ maps to 22 different spellings in English, *bisiness* was assigned a FB count of 22). We reasoned that if FB count was a significant predictor of lexical and spelling decision performance, then errors in misspelling detection must result from an underspecified representation of the vowel slot that is caused by the existence of many mappings from the activated phoneme to spellings.

Our second measure of phonological consistency was a *ratio* measure. Feedforward ratio (FF ratio) was defined as the percentage of instances in which the misspelled grapheme is pronounced the way it is pronounced in the stimulus (e.g., in 72.24% of occurrences of the letter *i* it is pronounced /ɪ/, so *bisiness* was assigned a FF ratio of .7224), and feedback ratio (FB ratio) was defined as the percentage of instances in which the misspelled phoneme is spelled the way it is spelled in the stimulus (e.g., /ɪ/ is spelled with an *i* 68.4% of the time, so *bisiness* was assigned a FB ratio of .6840). We reasoned that if FB ratio was a significant predictor performance, then errors in misspelling detection must result from a phoneme activating the spelling a participant is presented with, and the participant therefore interpreting the misspelling as correct. We were also prepared for significant correlations of both FB count and FB ratio with performance, because both an underspecified orthographic representation and misdirection from phonemic information might simultaneously influence behavior. Table 6 gives feedforward and feedback consistency measures for the 160 misspellings in our experiment.

To accomplish the second goal of Study 3a—to identify whether feedback consistency plays a role in reading beyond other factors—we constructed stepwise regression models using a variety of candidate factors to predict Study 2a and 2b outcomes, with feedback consistency entered as the sixth step.

**Table 6.** Feedforward and feedback count and ratio* measures of phonological consistency for the four misspellings of each of the 40 items in Study 2.

| Target | Misspelled phoneme (IPA/Hanna) | Correctly spelled as | Misspelled as | FB count | FB ratio | FF count | FF ratio |
|---|---|---|---|---|---|---|---|
| announcer | aʊ / OU | ou | au | 5 | .0000 | 4 | .0000 |
| | | | eu | 5 | -- | 5 | -- |
| | ər / U2 + E5 | er | ir | 15 | .0679 | 2 | .9739 |
| | | | ar | 15 | -- | 2 | -- |
| another | ʌ / U3 | o | u | 6 | .8595 | 9 | .4245 |
| | | | a | 6 | -- | 10 | -- |
| | r̩ / U2 + E5 | er | ur | 15 | .1361 | 1 | 1 |
| | | | yr | 15 | -- | 1 | -- |
| betray | eɪ / A | ay | ey | 16 | .6200 | 5 | .2258 |
| | | | oy | 16 | -- | 2 | -- |
| | ə / ə | e | u | 22 | .4930 | 9 | .1040 |
| | | | o | 22 | -- | 11 | -- |
| bleachers | iː / E | ea | ee | 16 | 9.81 | 3 | .8557 |
| | | | eo | 16 | -- | 2 | -- |
| | ər / U2 + E5 | er | ur | 15 | 13.61 | 1 | 1 |
| | | | ar | 15 | -- | 2 | -- |
| business | ɪ / I3 | u | i | 22 | 68.4 | 7 | 0.7224 |
| | | | a | 22 | -- | 10 | -- |
| | ə / ə | e | i | 22 | 22.4 | 7 | 0.1821 |
| | | | a | 22 | -- | 10 | -- |
| certainly | ɝː / U2 + E5 | er | yr | 15 | 0.22 | 1 | 1 |
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | ai | ae | 22 | 0 | 2 | 0 |
| | | | ao | 22 | -- | 1 | -- |
| colorful | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | i | 6 | -- | 7 | -- |
| | ə / ə | u | o | 22 | 26.79 | 11 | 0.2575 |

| Target | Misspelled phoneme (IPA/Hanna) | Correctly spelled as | Misspelled as | FB count | FB ratio | FF count | FF ratio |
|---|---|---|---|---|---|---|---|
| | | | i | 22 | -- | 7 | -- |
| comfort | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | a | 6 | -- | 10 | -- |
| | ər / U2 + E5 | or | er | 15 | 58.27 | 3 | 0.9668 |
| | | | ar | 15 | -- | 2 | -- |
| consensus | e / E3 | e | y | 13 | 0 | 5 | 0 |
| | | | o | 13 | -- | 11 | -- |
| | ə / ə | o | u | 22 | 4.93 | 9 | 0.1040 |
| | | | a | 22 | -- | 10 | -- |
| container | eɪ / A | ai | ay | 16 | 5.82 | 4 | 0.9632 |
| | | | ao | 16 | -- | 1 | -- |
| | ə / ə | o | u | 22 | 4.93 | 9 | 0.1040 |
| | | | e | 22 | -- | 10 | -- |
| covering | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | a | 6 | -- | 10 | -- |
| | ɪ / I3 | i | y | 22 | 23.04 | 5 | 0.8824 |
| | | | u | 22 | -- | 9 | -- |
| determine | ɝː / U2 + E5 | er | ur | 15 | 13.61 | 1 | 1 |
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | e | i | 22 | 22.4 | 7 | 0.1821 |
| | | | o | 22 | -- | 11 | -- |
| dirtier | ɝː / U2 + E5 | ir | er | 15 | 58.27 | 3 | 0.9668 |
| | | | ar | 15 | -- | 2 | -- |
| | ər / U2 + E5 | er | yr | 15 | 0.22 | 1 | 1 |
| | | | ar | 15 | -- | 2 | -- |
| discover | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | e | 6 | -- | 10 | -- |
| | ɪ / I3 | i | y | 22 | 23.04 | 5 | 0.8824 |
| | | | o | 22 | -- | 11 | -- |
| divergent | ɝː / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |
| | | | ar | 15 | -- | 2 | -- |
| | aɪ / I | i | y | 14 | 14.23 | 5 | 0.1034 |
| | | | u | 14 | -- | 9 | -- |
| divergent | ɝː / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |
| | | | ar | 15 | -- | 2 | -- |
| | aɪ / I | i | y | 14 | 14.23 | 5 | 0.1034 |
| | | | u | 14 | -- | 9 | -- |
| diversion | ɝː / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |
| | | | ar | 15 | -- | 2 | -- |
| | aɪ / I | i | y | 14 | 14.23 | 5 | 0.1034 |
| | | | o | 14 | -- | 11 | -- |
| divulge | ʌ / U3 | u_e | o_e | 6 | 1.84 | 8 | 0 |

| Target | Misspelled phoneme (IPA/Hanna) | Correctly spelled as | Misspelled as | FB count | FB ratio | FF count | FF ratio |
|---|---|---|---|---|---|---|---|
| | | | y_e | 6 | -- | 2 | -- |
| | ɪ / I3 | i | e | 22 | 0.06 | 10 | 0.0006 |
| | | | o | 22 | -- | 11 | -- |
| dynamite | aɪ / I | y | i | 14 | 37.38 | 7 | 0.0749 |
| | | | u | 14 | -- | 9 | -- |
| | aɪ / I | i_e | y_e | 14 | 1.55 | 5 | 0.1034 |
| | | | a_e | 14 | -- | 8 | -- |
| easily | i: / E | ea | ee | 16 | 9.81 | 3 | 0.8557 |
| | | | eo | 16 | -- | 2 | -- |
| | ə / ə | i | e | 22 | 12.68 | 10 | 0.0952 |
| | | | o | 22 | -- | 11 | -- |
| governor | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | i | 6 | -- | 7 | -- |
| | ər / U2 + E5 | er | ur | 15 | 13.61 | 1 | 1 |
| | | | or | 15 | -- | 2 | -- |
| interpret | ɝ: / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | e | y | 22 | 0.38 | 5 | 0.0113 |
| | | | a | 22 | -- | 10 | -- |
| language | æ / A3 | a | e | 3 | 96.58 | 10 | 0.0020 |
| | | | o | 3 | -- | 11 | -- |
| | ɪ / I3 | a | e | 22 | 0.06 | 10 | 0.0006 |
| | | | o | 22 | -- | 11 | -- |
| lovingly | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | e | 6 | -- | 10 | -- |
| | ɪ / I3 | i | y | 22 | 23.04 | 5 | 0.8824 |
| | | | a | 22 | -- | 10 | -- |
| machine | i: / E | i_e | e_e | 16 | 2.44 | 9 | 0.1761 |
| | | | o_e | 16 | -- | 8 | -- |
| | ɪ / I3 | a | e | 22 | 0.06 | 10 | 0.0006 |
| | | | y | 22 | -- | 5 | -- |
| motherly | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |
| | | | e | 6 | -- | 10 | -- |
| | r̩ / U2 + E5 | er | ur | 15 | 13.61 | 1 | 1 |
| | | | ar | 15 | -- | 2 | -- |
| movement | u: / O6 | o_e | u_e | 16 | 7.5 | 8 | 0.0934 |
| | | | e_e | 16 | -- | 9 | -- |
| | ə / ə | e | i | 22 | 22.4 | 7 | 0.1821 |
| | | | o | 22 | -- | 11 | -- |
| mystical | ɪ / I3 | y | i | 22 | 68.4 | 7 | 0.7224 |
| | | | o | 22 | -- | 11 | -- |
| | ə / ə | a | u | 22 | 4.93 | 9 | 0.1040 |
| | | | i | 22 | -- | 7 | -- |
| percolate | ɝ: / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |

| Target | Misspelled phoneme (IPA/Hanna) | Correctly spelled as | Misspelled as | FB count | FB ratio | FF count | FF ratio |
|---|---|---|---|---|---|---|---|
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | o | u | 22 | 4.93 | 9 | 0.1040 |
| | | | i | 22 | -- | 7 | -- |
| physical | ɪ / I3 | y | i | 22 | 68.4 | 7 | 0.7224 |
| | | | o | 22 | -- | 11 | -- |
| | ɪ / I3 | i | y | 22 | 23.04 | 5 | 0.8824 |
| | | | o | 22 | -- | 11 | -- |
| prettiest | ɪ / I3 | e | i | 22 | 68.4 | 7 | 0.7224 |
| | | | o | 22 | -- | 11 | -- |
| | I / E | i | y | 16 | 0 | 5 | 0 |
| | | | u | 16 | -- | 9 | -- |
| prevail | eɪ / A | ai | ei | 16 | 0.62 | 8 | 0.2456 |
| | | | oi | 16 | -- | 1 | -- |
| | ɪ / I3 | e | i | 22 | 68.4 | 7 | 0.7224 |
| | | | u | 22 | -- | 9 | -- |
| purpose | ɝː / U2 + E5 | ur | er | 15 | 58.27 | 3 | 0.9668 |
| | | | ar | 15 | -- | 2 | -- |
| | ə / ə | o_e | u_e | 22 | 0.06 | 8 | 0.0110 |
| | | | a_e | 22 | -- | 8 | -- |
| refurbish | ɝː / U2 + E5 | ur | er | 15 | 58.27 | 3 | 0.9668 |
| | | | or | 15 | -- | 2 | -- |
| | I / E | e | i | 16 | 1.49 | 7 | 0.0051 |
| | | | o | 16 | -- | 11 | -- |
| retreat | iː / E | ea | ee | 16 | 9.81 | 3 | 0.8557 |
| | | | eu | 16 | -- | 5 | -- |
| | I / E | e | i | 16 | 1.49 | 7 | 0.0051 |
| | | | o | 16 | -- | 11 | -- |
| service | ɝː / U2 + E5 | er | ir | 15 | 6.79 | 2 | 0.9739 |
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | i | y | 22 | 0.38 | 5 | 0.0113 |
| | | | a | 22 | -- | 10 | -- |
| surgery | ɝː / U2 + E5 | ur | er | 15 | 58.27 | 3 | 0.9668 |
| | | | or | 15 | -- | 2 | -- |
| | ə / ə | e | u | 22 | 4.93 | 9 | 0.1040 |
| | | | o | 22 | -- | 11 | -- |
| various | e / A2 | a | e | 9 | 1.81 | 10 | 0.0005 |
| | | | o | 9 | -- | 11 | -- |
| | I / E | i | y | 16 | 0 | 5 | 0 |
| | | | u | 16 | -- | 9 | -- |
| weirdest | ɪ / E2 | ei | yi | 8 | 0 | 0 | 0 |
| | | | oi | 8 | -- | 1 | -- |
| | ə / ə | e | y | 22 | 0.38 | 5 | 0.0113 |
| | | | a | 22 | -- | 10 | -- |
| wonderful | ʌ / U3 | o | u | 6 | 85.95 | 9 | 0.4245 |

| Target | Misspelled phoneme (IPA/Hanna) | Correctly spelled as | Misspelled as | FB count | FB ratio | FF count | FF ratio |
|---|---|---|---|---|---|---|---|
| worthless | | | e | 6 | -- | 10 | -- |
| | ə / ə | u | o | 22 | 26.79 | 11 | 0.2575 |
| | | | y | 22 | -- | 5 | -- |
| | ɝː / U2 + E5 | or | er | 15 | 58.27 | 3 | 0.9668 |
| | | | ar | 15 | -- | 2 | -- |
| | ə / ə | e | i | 22 | 22.4 | 7 | 0.1821 |
| | | | o | 22 | -- | 11 | -- |

* Note that consistency ratios were not calculated for phoneme-altering misspellings: because pronunciation of these items is likely varies within and between participants, there is no way of knowing the percentage of instances in which the misspelled grapheme is pronounced the way it is pronounced in the stimulus (i.e., feedforward ratio).

### 4.1.1 Methods.

#### 4.1.1.1 Partcipants.

Participants were the 143 and 105 subjects whose data was analyzed in Studies 2a and 2b, respectively.

#### 4.1.1.2 Materials.

All 160 Study 2 stimuli were coded for two types of feedforward and feedback consistency information: *type* (based on FF and FB ratio measures) and *token* (based on FF and FB count measures; Table 6). This information was drawn from the report *Phoneme-Grapheme Correspondences as Cues to Spelling Improvement* (Hanna, Hanna, Hodges, & Rudorf, 1966), which was commissioned by what was then the Office of Education of the U.S. Department of Health, Education, and Welfare. The purpose of the report, according to the abstract, was "to analyze phoneme/grapheme correspondences in a 17,310-entry word list drawn form the

Thorndike-Lorge word list and Merriam-Webster's New Collegiate Dictionary". This report was suitable to our purposes both because of the large size of the corpus on which it is based, and because other sources of feedback consistency information (e.g., Ziegler, Stone, & Jacobs, 1997) provide data for rime bodies only.

**4.1.1.3 Procedure.**

In phase one of our analyses, feedforward type (FF type), feedforward token (FF token), feedback type (FB type), and feedback token (FB token) consistency information for phoneme-preserving Study 2 items was correlated with accuracy and latency data from Studies 2a and 2b. (Phoneme-altering items were excluded from correlations because there was no way to calculate a FF type consistency for a phoneme-altering misspelling.) These correlations were then used to determine which measure(s) of phonological consistency should be included in phase two of our analyses.

In phase two, lexical information was used to predict Study 2a and 2b outcomes in multiple regressions on accuracy and latency data. Following Yap and Balota (2009), we first entered into the model a series of standard lexical variables which are known to contribute to word reading behavior, including number of letters in the stimulus, frequency of the correctly spelled version of the stimulus, orthographic neighborhood size of the correctly spelled version of the stimulus, and mean frequency of orthographic neighbors of the correctly spelled stimulus. After lexical variables were controlled for, the appropriate phonological consistency variables indicated by our correlational analyses were entered into the model. The feedback consistency variable was entered after the feedforward consistency variable, because feedback and feedforward measures are intercorrelated (Tables 7 and 8) and feedback effects have been much less reliable in the literature than feedforward effects. Finally, interactions of feedforward and feedback consistency with frequency were entered into the model, because our consistency measures do not account for the fact that the tokens of our phoneme-grapheme types vary widely in frequency.

### 4.1.2 Results.

#### 4.1.2.1 Correlations.

Correlations of the alternative measures of feedforward and feedback consistency with Study 2a outcomes are given in Table 7; Study 2b correlations are in Table 8.

**Table 7.** Correlations of spelling decision (Study 2a) task accuracy and latency with alternative measures of feedforward and feedback consistency.

| | Accuracy | Latency | FF type | FF token | FB type | FB token |
|---|---|---|---|---|---|---|
| Accuracy | 1 | | | | | |
| Latency | -.54 *** | 1 | | | | |
| FF type | -.03 | -.05 | 1 | | | |
| FF token | -.17 ☾ | .19 † | -.63 *** | 1 | | |
| FB type | .10 | -.14 | .24 * | .30** | 1 | |
| FB token | -.20 † | .25 * | -.03 | .02 | -.44*** | 1 |

* p ≤ .05. † p ≤ .10. ☾ p ≤ .15.

**Table 8.** Correlations of lexical decision (Study 2b) task accuracy and latency with alternative measures of feedforward and feedback consistency.

| | Accuracy | Latency | FF type | FF token | FB type | FB token |
|---|---|---|---|---|---|---|
| Accuracy | 1 | | | | | |
| Latency | .05 | 1 | | | | |
| FF type | -.00 | -.11 | 1 | | | |
| FF token | -.09 | .19 † | -.61 *** | 1 | | |
| FB type | -.01 | -.13 | .22 *** | .35 *** | 1 | |
| FB token | -.17 ** | .24 * | .02 | -.06 | -.44*** | 1 |

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$. † $p \leq .10$.

***Accuracy***. In the spelling decision task (Study 2a), marginal correlations of FF token ($r = -.17$, $p < .15$) and FB token ($r = -.20$, $p < .10$) consistency were found with accuracy. In the lexical decision task (Study 2b), FB token consistency correlated significantly ($r = -.17$, $p < .01$) with accuracy. In neither experiment did type measures of feedforward and feedback consistency correlate with accuracy.

***Latencies.*** In the spelling decision task (Study 2a), FF token consistency correlated marginally ($r = .19$, $p < .10$) and FB token consistency correlated significantly ($r = .25$, $p < .05$) with latency data. In the lexical decision task (Study 2b), FF token consistency correlated marginally ($r = .19$, $p < .10$) and FB token consistency correlated significantly ($r = .25$, $p < .05$) with latency data. In neither experiment did type measures of feedforward and feedback consistency correlate with accuracy.

**4.1.2.2 Regressions.**

Because type measures of feedforward and feedback consistency did not correlate with spelling or lexical decision outcomes, only FB and FF token consistency measures were entered into our regression models as consistency variables predicting accuracy and latency data. Table 9 presents the results of regression analyses on Study 2a and 2b outcomes. Note that the regression coefficients reported in the table reflect the coefficients for variables entered in that particular step, rather than coefficients obtained from entering all variables simultaneously in the model. Implications of the regression outcomes are discussed in the next section.

**Table 9.** Standardized accuracy and latency regression coefficients from steps 1 through 8 of the item-level regression analyses for spelling decision (Study 2a) and lexical decision (Study 2b) performance. The *p*-value for each $R^2$ change is represented with asterisks.

| Predictor variable | Spelling Decision (*n* = 159) | | Lexical Decision (*n* = 151) | |
|---|---|---|---|---|
| | Accuracy | Latency | Accuracy | Latency |
| *Standard Lexical Variables* | | | | |
| Number of letters | .019 | .049 | .007 | .047 |
| Frequency | .147† | -.091 | -.007 | -.087 |
| Orth. N | .130† | .079 | .011 | -.074 |
| Freq. orth. N | .102 | -.076 | .033 | .036 |
| **Δ $R^2$** | **.046** | **.021** | **.001** | **.016** |
| *Consistency Variables* | | | | |
| FF token | -.082 | .147† | -.061 | .039 |
| FB token | -.095 | .171* | -.145** | .173* |
| **Δ $R^2$** | **.016** | **.049** | **.021** | **.030** |
| *Theoretically Motivated Interactions* | | | | |
| FF token x freq. | .035 | .037 | -.064 | .179 |
| FB token x freq. | .062 | -.325 | -.176 | -.158 |
| **Δ $R^2$** | **.000** | **.013** | **.005** | **.014** |

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$. † $p \leq .10$.

Orth. N = orthographic neighborhood of target; Freq. orth. N = mean frequency of target's orthographic neighbors.

### 4.1.3 Discussion.

Our aim in Study 3a was to identify the likely mechanism of phonological influences on orthographic processes by testing alternate measures of feedback consistency, and to determine whether feedback consistency is a significant determinant of spelling and lexical decision performance after controlling for other factors we would expect to influence those tasks. Our results are somewhat unexpected on both fronts.

To identify the mechanism of phonological influences on orthographic processes, we correlated both token and type measures of feedback consistency with accuracy and latency data from previously conducted spelling (Study 2a) and lexical (Study 2b) decision tasks. We hypothesized that the token consistency measure would correlate with performance if the cause of failures to detect misspellings were an underspecified orthographic representation, and that the type consistency measure would correlate with performance if the cause were activation of alternative spellings. In both tasks, token measures of consistency predicted outcomes at a significant or marginal level and type measures did not. This finding supports the hypothesis that phonemes that map to many graphemes lead to underspecified orthographic representations of the phoneme in question in a given word, which increases the chances that a reader will be unsure of the correct spelling, or unable to detect a misspelling of the phoneme. Although this situation makes intuitive sense, it is surprising that activation of competing spellings played no statistically detectable role in participants' decisions, given that type measures of feedback consistency have reliably predicted word reading behavior in past studies (Perry, 2003; Yap & Balota, 2009). The primary difference between our study and those studies is the stimuli of interest: in past research, data for responses to real words, which were chosen on the basis of the consistency or inconsistency of their phoneme-grapheme relationships, was analyzed, whereas in the present study, we were interested in responses to the misspellings/nonwords in our stimulus set. It is possible that, when faced with a word for which a lexical representation exists in the mind of the participant, competing orthographic representations activated by phonological feedback can interfere with decisions, but when faced with a string that has no exact match in the mental lexicon, the number of possible spellings of the sounds activated by the string becomes the better predictor of performance.

A divergence of the stimuli of interest in the present and past research also explains our finding that feedback consistency was a more reliable predictor of performance in our experiments than was feedforward consistency (i.e., feedback correlation coefficients were larger and significant at lower alpha levels), as feedforward effects are observed more consistently in the word reading literature (e.g., Glushko, 1979; Jared et al., 1990; Cortese & Simpson, 2000) than feedback effects (e.g., Peereman et al., 1998; Massaro & Jesse, 2005). Information flowing from orthography to phonology appears to be the greater driver of behavior when one is faced with a real word; information flowing from phonology to orthography has the greater influence when one is faced with a misspelling or nonword. This is consistent with our model of spelling decisions (Figure 5), in which a real-word input facilitates a quick exact match with an entry in the lexicon and phonology has little time to activate, let alone feed backwards to influence orthographic processing. By contrast, a nonword or misspelling initiates additional steps before a decision is reached, so that the feedback loop has more opportunity to cycle.

This pattern of a greater role for feedback than for feedforward information was replicated in our regression analyses, and the same explanation likely applies. The purpose of the regressions was to determine whether phonological feedback to orthography influences spelling and lexical decision behavior after controlling for more reliable predictors of behavior, including word length, frequency, and neighborhood size. FB token consistency did account for significant variance in spelling decision latencies and in lexical decision latencies and accuracy, which is in itself notable because of the unreliability of feedback measures in past experiments. More notable, though, is perhaps the almost complete absence of any influence of the standard lexical variables on performance. Aside from a marginal influence of frequency and orthographic neighborhood size on accuracy in spelling decisions, the standard lexical variables contributed no significant variance to performance on the tasks. The most likely explanation for this result is the small size of our sample. A recent analysis of the English Lexicon Project database, for example, which also relied on multiple regressions to identify predictors of reading behavior (and found significant contributions for the variables included in our analysis), included 9,639 words, as opposed to our 159 and 151, respectively (Yap & Balota, 2009). The fact that feedback effects exerted such a strong influence on behavior in our studies, despite their small number of items, is a testament to the ascendant role of phonological feedback in reading misspelled words.

Feedback from phonology to orthography has been proposed as a basis for building orthographic representations of less well-known words (McKague et al., 2008). In Study 3b, we test whether our data is consistent with this notion of "orthographic recoding".

## 4.2 STUDY 3B: INDIVIDUAL DIFFERENCES IN CONSISTENCY EFFECTS

Share (1995; 1999) has proposed phonological recoding (the translation of letters into sounds) as a self-teaching mechanism through which readers establish complete lexical representations of words. McKague et al. (2008) recently proposed a similar role for what they termed *orthographic recoding*, i.e., feedback from sounds to letters, in building and refining lexical representations. According to the lexical quality hypothesis (Perfetti & Hart, 2002; Perfetti, 2007), the quality of individual lexical representations can vary in their degree of completeness, or specificity. Partially specified representations can include free variables in the orthographic or phonological form where uncertainty exists; vowels are often the last element of a representation to become fully specified. McKague et al. reasoned that evidence that orthographic recoding at the level of the word leads to increased orthographic knowledge would support the lexical quality hypothesis and other item-based models of reading development (Share, 1995; Ehri, 1992). Moreover, they proposed that once an orthographic representation is fully specified phonological feedback has outlived its usefulness, and feedback consistency effects should not be observed for an item in an individual who has perfect orthographic knowledge of it. They tested this hypothesis in a training study that manipulated feedback consistency in pseudowords, and found moderate support for it.

Because we have spelling and lexical decision data coded for feedback consistency, and individual differences data for the individuals who performed the task, we have the opportunity to offer complementary evidence in favor of the McKague et al. hypothesis, if it is correct. A correlation of feedback effects with spelling ability in our experiments would be consistent with the hypothesis. This is phase one of our Study 3b analysis. In phase two, we conduct regressions to see whether feedback consistency predicts reading, spelling and vocabulary skill beyond feedforward consistency, and how this relationship differs in more and less skilled participants.

### 4.2.1 Methods.

#### 4.2.1.1 Participants.

Participants were the 143 and 105 subjects whose data was analyzed in Studies 2a and 2b, respectively.

#### 4.2.1.2 Procedure.

In phase one of our analyses, an index of sensitivity to feedforward and feedback consistency was calculated and then correlated with offline measures of individual differences for Study 2 participants (spelling for Study 2a participants; spelling, reading, and vocabulary for Study 2b participants). To calculate the feedforward effect, stimuli were divided into three categories: highly inconsistent (10 or more possible phoneme mappings of the misspelled grapheme), medium inconsistent (between three and nine possible phoneme mappings of the misspelled grapheme), and low inconsistent (two or fewer possible phoneme mappings of the misspelled grapheme). In the spelling decision experiment, overall mean accuracy to highly feedforward inconsistent stimuli was 90.03%, overall mean accuracy to medium feedforward inconsistent stimuli was 92.46%, and overall mean accuracy to low feedforward inconsistent stimuli was 93.97%. In the lexical decision experiment, overall mean accuracy to highly feedforward inconsistent stimuli was 84.25%, overall mean accuracy to medium feedforward inconsistent stimuli was 85.42%, and overall mean accuracy to low feedforward inconsistent stimuli was 89.00%. Mean accuracy per category was calculated for each subject, and accuracy for highly inconsistent words was subtracted from accuracy for low inconsistent words to achieve the feedforward effect size per subject.

To calculate the feedback effect, stimuli were divided into three categories: highly inconsistent (more than 20 possible grapheme mappings of the misspelled phoneme), medium inconsistent (10-20 possible grapheme mappings of the misspelled phoneme), and low inconsistent (fewer than 10 possible grapheme mappings of the misspelled phoneme). In the spelling decision experiment, overall mean accuracy to highly feedback inconsistent stimuli was 90.86%, overall mean accuracy to medium feedback inconsistent stimuli was 92.49%, and overall mean accuracy to low feedback inconsistent stimuli was 94.38%. In the lexical decision experiment, overall mean accuracy to highly feedback inconsistent stimuli was 83.01%, overall mean accuracy to medium feedback inconsistent stimuli was 87.42%, and overall mean accuracy to low feedback inconsistent stimuli was 88.89%. Mean accuracy per category was calculated for each subject, and accuracy for highly inconsistent words was subtracted from accuracy for low inconsistent words to achieve the feedback effect size per subject.

In phase two, regressions on accuracy and latency data in the spelling and lexical decision task were performed separately for more and less skilled readers, spellers, and vocabularies, with feedforward consistency entered into the model before feedback consistency. For spelling analyses, the top third of participants (d' ≥ 2.09, $n$ = 45 in Study 2a; d' ≥ 2.16, $n$ = 35 in Study 2b) in the offline spelling assessment were assigned to the more skilled group and the bottom third of participants (d' ≤ 1.71, $n$ = 45 in Study 2a; d' ≤ 1.79 $n$ = 33 in Study 2b) were assigned to the less skilled group. For reading analyses, the top third of participants (composite score ≥ 24, $n$ = 29) in the offline reading assessment were assigned to the more skilled group and the bottom third of participants (composite score ≤ 16.8, $n$ = 29) were assigned to the less skilled group. For vocabulary analyses, the top third of participants (composite score ≥ 58, $n$ = 32) in the offline vocabulary assessment were assigned to the more skilled group and the bottom third of participants (composite score ≤ 41.2, $n$ = 33) were assigned to the less skilled group. Descriptive statistics of more and less skilled participants in each individual difference category are given in Table 10.

**Table 10.** Individual differences descriptive statistics for more and less skilled participants in the spelling (Study 2a) and lexical (Study 2b) decision tasks.

| Individual Difference Measure | Skill Group | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Spelling d' (Spelling Decision) | More skilled (*n* = 45) | 2.09 | 2.94 | 2.35 | 0.19 |
| | Less skilled (*n* = 45) | 1.06 | 1.71 | 1.46 | 0.19 |
| Spelling d' (Lexical Decision) | More skilled (*n* = 35) | 2.16 | 3.00 | 2.44 | 0.23 |
| | Less skilled (*n* = 33) | 0.88 | 1.79 | 1.57 | 0.21 |
| Reading Composite Score | More skilled (*n* = 29) | 24.00 | 33.60 | 27.14 | 2.98 |
| | Less skilled (*n* = 29) | 2.40 | 16.80 | 12.29 | 3.72 |
| Vocabulary Composite Score | More skilled (*n* = 32) | 58.00 | 94.00 | 72.10 | 13.20 |
| | Less skilled (*n* = 33) | 7.60 | 41.20 | 30.73 | 8.82 |

### 4.2.2 Results.

#### 4.2.2.1 Correlations.

Correlations of feedforward and feedback effect sizes with Study 2a participant individual differences are given in Table 11; correlations with Study 2b participant individual differences are in Table 12. Both the feedforward and feedback effects were significantly correlated with all individual differences measures in both experiments. Spelling skill correlated negatively with the feedforward and feedback consistency effects. Vocabulary and reading skill correlated negatively with the feedforward effect and positively with the feedback effect (although the correlation of vocabulary with the feedforward effect was not significant).

**Table 11.** Correlations of consistency effect sizes in the spelling decision task (Study 2a) with offline spelling skill. The spelling measure with which the effect size correlates is represented with superscripts.

| | FF effect size | FB effect size | Spelling |
|---|---|---|---|
| FF effect size | 1 | | |
| FB effect size | .04 | 1 | |
| Spelling | -.16†[1] | -.17*[2] | 1 |

* $p \le .05$. † $p \le .10$.

[1] Baroff subtest. [2] Overall accuracy.

**Table 12.** Correlations of consistency effect sizes in the lexical decision task (Study 2b) with offline spelling, reading, and vocabulary skill. The specific individual difference measure with which the effect size correlates is represented with superscripts.

| | FF effect size | FB effect size | Spelling | Reading | Vocabulary |
|---|---|---|---|---|---|
| FF effect size | 1 | | | | |
| FB effect size | .05 | 1 | | | |
| Spelling | -.11 *[1] | -.13*[3] | 1 | | |
| Reading | -.17 **[2] | .18**[4] | .31*** | 1 | |
| Vocabulary | -.07 [4] | .23***[4] | .44*** | .753*** | 1 |

* $p \le .05$. ** $p \le .01$. *** $p \le .001$.

[1] D-prime. [2] Composite score. [3] Hart subtest. [4] Overall accuracy.

#### 4.2.2.2 Regressions.

Table 13 presents the results of regression analyses on Studies 2a and 2b outcomes for more skilled and less skilled participants. Note that the regression coefficients reported in the table reflect the coefficients for variables entered in that particular step, rather than coefficients obtained from entering all variables simultaneously in the model.

**Table 13.** Standardized accuracy and latency regression coefficients from steps 1 and 2 of the item-level regression analyses for spelling decision and lexical decision performance for more and less skilled spellers, readers, and vocabularies. The *p*-value for each $R^2$ change is represented with asterisks.

| Task | Criterion measure | Predictor variable | More Skilled | | | | Less Skilled | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accuracy | ($R^2$) | Latency | ($R^2$) | Accuracy | ($R^2$) | Latency | ($R^2$) |
| *Spelling decision* (Study 2a) $n = 159$ | Spelling d' | FF consistency | -.089 | (.008) | .048 | (.002) | -.072 | (.005) | .140$^{\dagger}$ | (.020) |
| | | FB consistency | -.059 | (.011) | .203* | (.043) | -.128☾ | (.021) | .166* | (.047) |
| | | Δ $\boldsymbol{R^2}$ | **.003** | | **.041** | | **.016** | | **.027** | |
| *Lexical decision* (Study 2b) $n = 151$ | Spelling d' | FF consistency | -.066 | (.004) | -.001 | (.000) | -.101* | (.010) | .011 | (.000) |
| | | FB consistency | -.157*** | (.029) | .112 | (.012) | -.208*** | (.053) | .126 | (.016) |
| | | Δ $\boldsymbol{R^2}$ | **.024** | | **.012** | | **.043** | | **.016** | |
| | Reading composite | FF consistency | -.054 | (.003) | -.016 | (.000) | -.191*** | (.037) | .015 | (.000) |
| | | FB consistency | -.194*** | (.040) | .098 | (.010) | -.072☾ | (.042) | .120 | (.015) |
| | | Δ $\boldsymbol{R^2}$ | **.037** | | **.009** | | **.005** | | **.014** | |
| | Vocabulary composite | FF consistency | -.144** | (.021) | .052 | (.003) | -.124** | (.015) | -.037 | (.001) |
| | | FB consistency | -.071☾ | (.026) | .062 | (.007) | -.134** | (.029) | .213** | (.046) |
| | | Δ $\boldsymbol{R^2}$ | **.005** | | **.004** | | **.018** | | **.045** | |

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$. $^{\dagger}$ $p \leq .10$. ☾ $p \leq .15$.

***Spelling decision task.*** In the spelling decision experiment, feedforward consistency contributed marginal variance to latency for less skilled spellers, and feedback consistency contributed additional significant variance to latency for both more skilled and less skilled spellers. Feedback consistency also contributed variance to accuracy for less skilled spellers at alpha = .15

***Lexical decision task.*** In the lexical decision experiment, feedforward consistency contributed significant variance to accuracy for less skilled spellers, readers, and vocabularies, but did not contribute significant variance to accuracy for more skilled participants except for those more skilled on the vocabulary measure. Feedback consistency contributed variance to accuracy beyond feedforward consistency to a significant or marginal degree in both more and less skilled spellers, readers, and vocabularies. In all cases, the $\Delta R^2$ produced by the addition of feedback consistency to the model was greater in less skilled than in high skilled participants. Additionally, the model containing feedback consistency always accounts for more variance in the outcome measure than the model containing feedforward consistency alone, although the $\Delta R^2$ is not always significant.

### 4.2.3 Discussion.

Our aim in Study 3b was to investigate our Study 2 results for evidence of orthographic recoding as a mechanism of orthographic learning. Because this was a correlational analysis and not a learning study, we cannot offer causal evidence that phonological feedback during reading is used for increasing the specificity of the orthographic representations of words. However, our analyses showed that the size of feedback effects on spelling and lexical decisions is negatively correlated with spelling ability, indicating that better spellers are less sensitive to the influence of phonological feedback during reading. This finding is consistent with the hypothesis (McKague et al., 2008) that feedback from phonology to orthography is instrumental in learning orthographic forms, and ceases to influence reading behavior once a lexical representation becomes fully specified. The finding in our regression analyses that feedback consistency accounts for a greater proportion of variance in accuracy in less skilled readers and spellers than in more skilled readers and spellers is also consistent with the hypothesis. Research in children (Davies & Weekes, 2005; Bolger, Minas, Burman, & Booth, 2008) has previously shown greater effects of feedback consistency in children with reading disability relative to normally reading children, but ours is the first study using real words and their misspellings to show such an association in adults. This association in mature readers supports item-based accounts of reading development, including the lexical quality hypothesis, that hold that lexical knowledge of individual items can vary in quality apart from one's general reading level, and orthographic learning continues on a word-by-word basis even for readers of considerable overall skill.

It is remarkable that, although feedback consistency effects were negatively associated with spelling ability in our correlational analyses, they were positively associated with reading and vocabulary knowledge. In other words, more skilled spellers use phonological feedback less during lexical decisions, but more experienced readers use feedback cues more. This statement appears contradictory given the significant intercorrelation of spelling skill with vocabulary and reading skill (Table 12), but spelling ability (indexed by d') accounts for less than 10% of the variance in reading ability ($.31^2$; indexed by the composite score) and less than 20% of the variance in vocabulary knowledge ($.44^2$; indexed by the composite score) in our sample, so good spelling is largely independent of good comprehension and good word knowledge. (By contrast, vocabulary accounts for more than 50% of the variance in comprehension skill, and vice versa.) It appears that orthographic knowledge allows one to dispense with feedback information, but skilled reading has a role for it.  This highly nuanced relationship of reading and spelling skill with feedback effects may explain why feedback effects in past studies that did not control for a variety of individual differences have tended to be small and unreliable.  Feedforward effects, on the other hand, were negatively correlated with all individual difference measures in our study, indicating a straightforward relationship between forward-flowing phonological information and reading-related skills.

## 5.0 STUDY 4: LEXICAL STRESS AND LINGUISTIC CONSTRAINT EFFECTS IN A PROOFREADING TASK

In Study 1, we found effects of the stress status of the syllable in which a misspelling occurs on the accuracy and latencies of spelling decisions. This effect was moderated by the phoneme status of the misspelling, such that the stress effects only appeared when a misspelling preserved the phonemes of the correctly spelled word. This finding suggests that syllables containing stress receive closer scrutiny than unstressed syllables by readers searching for spelling errors. However, the stress effects were diminished in Study 2, when stimuli were rotated through a Latin Square to ensure that subtle systematic differences in experimental items were not the source of the Study 1 findings. In Study 2a, also a spelling decision task, stress status affected latencies but not accuracy, and stress effects on latency were significant by subjects only. In Study 2b, a lexical decision task, no stress effects were observed.

The diminished stress effects in the more tightly controlled Study 2 leads us to conclude that the influence of stress on orthographic processes is minimal at best during lexical decisions and isolated spelling decisions. However, the importance of lexical stress to spoken sentence processing, as well as the demonstrated activation of lexical stress during the silent reading of sentences (Ashby & Clifton, 2005) and previous research reporting stress effects in letter-detection tasks during reading for comprehension (Drewnowski & Healy, 1982; Goldman & Healy, 1985) leave open the possibility that stress does affect orthographic processes under more natural reading conditions. During isolated word reading, a lexical stress pattern cannot be applied to a word until, at earliest, the moment of lexical access (although some orthographic patterns may provide prelexical cues to stress; Arciuli & Cupples, 2006; Kelly, Morris, & Verrekia, 1998), meaning that any effects of stress on orthographic processing are likely to occur postlexically. Thus it is unsurprising that we failed to find an influence of stress in our lexical decision experiment (Study 2b), when measures were taken to discourage postlexical processing. During the silent reading of sentences and longer texts, however, at least two cues to the stress patterns of upcoming words are available to readers, increasing the chances that stress will be activated prior to lexical access. First, the grammatical class of words is often predictable from the words that precede it, and stress patterns in English are highly correlated with grammatical class. Second, a word itself is often predictable from preceding context. Hypothetically, the more predictable a word is in a sentence, the earlier during word identification its stress pattern can be accessed, and the longer stress information has to potentially interact with orthography.

This is the hypothesis we test in Study 4. Words misspelled in stressed and unstressed syllables are embedded in the context of an expository passage that participants are asked to proofread, and the predictability of the words in sentential context is manipulated. If reading words in sentences increases the chance that their stress patterns will be activated and interact with orthographic processes, then the unreliable stress effects of Study 2 should be much more robust in Study 4. Because we believe it is the predictive cues offered by sentences that increase the likelihood of stress effects in a proofreading task, we expect to find stress effects to interact with the predictability of items.

There is little direct research on the effects of predictability on error detection during reading, although several eye-tracking studies have shown a link between number and duration of fixations on a word and how constrained it is by context. Zola (1984) created sentences containing nouns that were constrained to a greater (*buttered popcorn*) or lesser (*adequate popcorn*) degree by their preceding adjectives, and found slightly shorter fixations for the highly constrained nouns. Ehrlich and Rayner (1981) allowed constraint to build throughout their sentences rather than tying it to a single word; they found the probability of fixating on the target was higher in the low- than in the high-constraint condition, and higher still when the target contained a misspelling. Recently, Schotter et al. (2014) reported an interaction of task with predictability, with predictability effects on fixations greater during proofreading than in normal reading only for low-constraint sentences.

Research on proofreading and familiarity, as opposed to eye movements and predictability, has provided direct evidence of familiarity effects on error detection, which eye movement studies have not done. Unfortunately, this evidence has been contradictory. In general, familiarity is achieved in these studies by asking participants to read, copy, or memorize a passage before giving them a version to proofread. Using this method, Levy (1983) and Levy and Begin (1984) showed that prior reading of a passage increased the speed and accuracy of proofreading; Pilotti and Chodorow (2012) found the opposite result, with the likelihood of detecting errors decreasing as familiarity increased. Pilotti and Chodorow speculated that the divergence between their findings and Levy's was due to differences in their study and test materials: Levy presented essays in their entirety at study and at test, whereas Pilotti and Chodorow presented entire essays for the study period but only excerpted sentences at test. Other research by Pilotti and Chodorow (Pilotti, Maxwell, & Chodorow, 2006; Pilotti, Chodorow, & Thornton, 2005) suggests that familiarity increases the chances of noticing misspellings when participants previously became familiar with a passage through typing it (surface encoding), but not when they had been asked to generate their own essay by relying on information contained in the passage (deep encoding).

The nature of the interaction of stress and predictability depends on the influence of predictability on error detection. If our results indicate that misspellings are easier to spot in more predictable words, then words less constrained by their contexts should show the greater benefits of stress. If, on the other hand, our results indicate that misspellings are more easily detected in less predictable words, then more highly constrained words should benefit most from stress. These predictions are based on the assumption that, in the condition (high- or low-constraint) in which misspellings are easier to detect, error detection will be closer to ceiling and any added benefit of stress will produce diminished returns.

We also assess individual differences in spelling, reading, and vocabulary ability in Study 4, to investigate whether the effects of stress and constraint are associated with aptitude in these areas. Study 3 showed that more skilled readers are less sensitive to the influence of segmental phonological feedback to orthography, so it is possible that the same relationship will emerge between skill level and suprasegmental influences on orthographic processes. Accordingly, we predict that more skilled spellers/readers will show a decreased influence of stress status on misspelling error detection relative to less skilled spellers/readers. Because, to our knowledge, individual differences in reading ability have not been controlled for previously in studies of predictability in reading, we have no *a priori* hypotheses as to the relationship between these measures. It is possible that more skilled readers are more adept than less skilled readers at drawing on contextual information when proofreading, and will show heightened effects of predictability on error detection. Alternatively, more readers may be able to easily compensate for missing contextual cues when proofreading, and therefore show less sensitivity to constraint status than less skilled readers.

## 5.1 METHODS

### 5.1.1 Participants.

Participants were 94 Introduction to Psychology students at the University of Pittsburgh who had not participated in Study 1 or Study 2. Fourteen of these inadvertently received passages missing several pages and had to be eliminated from analyses, resulting in an initial *n* of 80. All spoke English at a native or near-native level, and received class credit for their participation.

### 5.1.2 Design.

A 2x2 within-subjects design examined the influence of stress status (misspelled in stressed syllable, misspelled in unstressed syllable) and predictability (high constraint, low constraint) on error detection rates during proofreading, resulting in 4 conditions.

### 5.1.3 Materials.

#### 5.1.3.1 Experimental items.

As in Study 2, we employed 40 experimental items, rotated through a Latin Square so that each appeared in one of the four conditions (high constraint [HC], misspelled in stressed syllable; high constraint [HC], misspelled in unstressed syllable; low constraint [LC], misspelled in stressed syllable; low constraint [LC], misspelled in unstressed syllable). Twenty-nine of the items were used in Study 2; 11 new items were created to replace items that could not be easily integrated into the proofreading passage. As in Studies 1 and 2, the items were subjected to rating by Amazon Mechanical Turk (AMT) workers to ensure that each was recognizable as a misspelling of the intended word. Because stress effects showed up only within the phoneme-preserving stimuli in Study 1, all misspellings in Study 4 preserved phonology. The complete list of Study 4 experimental stimuli is in Appendix C.

**5.1.3.2 Passages.**

One narrative nonfiction passage containing the 40 experimental items was adapted from the January 28, 2014 Wikipedia.com entry for Al Gore, and was modified to create four versions, one for each of the four conditions (Appendix D). The major facts of the vice-president's life were not altered, but liberties were sometimes taken with details in order to create an appropriate context for an experimental stimulus. (For example, the actual Wikipedia passage reads, *Although he was an avid reader who fell in love with scientific and mathematical theories, he did not do well in science classes in college*; the experimental version reads, *Although Gore was enraptured by news of the space program and the solar [HC]/cosmos [LC] sistem/systim growing up, he did not do well in science classes in college.*)

Whenever possible, only the word immediately preceding the critical stimulus (or one word amongst the three preceding the critical stimulus) was varied between the high- and low-constraint versions of the passage, to maximize similarity across passages. This was accomplished by searching the Corpus of Contemporary American English (COCA; Davies, 2008) for collocates of our stimuli. For the high-constraint passage, collocates were sought that predict the critical stimulus (CS) a high percentage of the time (e.g., one of the three words immediately following *solar* is *system* 23.83% of the time), that share a mutual information score of at least 5.0 with the CS (a mutual information score of 3.0 or greater typically indicates a "semantic bonding" between the two collocates; e.g., the mutual information score of *solar* and *system* is 7.76), and that co-occur in COCA at least twice (e.g., there are 3,583 instances of collocation of *solar* and *system* in COCA). For the low-constraint passage, preceding words were sought that *never* predict the CS in the corpus, as is true of *cosmos* for *system*.

High- and low-constraint sentences were then presented to AMT workers in cloze form (e.g., *Although Gore was enraptured by news of the space program and the solar* ___________ *growing up, he did not do well in science classes in college // Although Gore was enraptured by news of the space program and cosmos* ___________ *growing up, he did not do well in science classes in college*). A sentence was deemed appropriate for the high-constraint condition if at least 5 out of 10 workers supplied the CS; a sentence was deemed appropriate for the low-constraint condition if no more than 1 out of 10 workers supplied the CS (Appendix E). For approximately a quarter of the original sentence pairs, these criteria could not be met by manipulating collocates alone, and larger portions of the sentences had to be rewritten (e.g., *A joke circulated that in prep school and at Harvard Gore had taken "Southern" as a foreign lenguage/languege // A rumor circulated that Gore was unlearned in the special lenguage/languege of the South*). In all cases, differences between passages were restricted to changes within a single sentence, and the larger content of the paragraph and passage were not altered.

To further ensure that predictability of the CS was the only factor leading to differences in error detection between versions, the word immediately preceding the CS was the same length, to within two letters, in both the high-constraint and low-constraint versions of the passage for 38 of the 40 sentence pairs. For two of the sentence pairs, the words preceding the CS differed in length by 3 letters across versions (Appendix E). This precaution was taken because a word's length is a strong determinant of whether it will be skipped (Blanchard, Pollatsek, & Rayner, 1989), and the distance of a saccade can affect the fixation duration of a target word (Vitu, McConkie, Kerr, & O'Regan, 2001). To the extent possible, we wanted any variation in fixation durations between high- and low-constraint conditions to be a result of constraint status alone, because longer fixations may lead to increased error detection.

All versions of the passage were 14 double-spaced pages in length, and took participants approximately 20 minutes to read. Because we wanted participants to read for comprehension as well as for error detection, two types of errors in addition to misspellings were embedded in the passage—repetitions (e.g., *The results of the decision led to Gore winning the popular vote by approximately 500,000 votes nationwide, but but receiving 266 electoral votes to Bush's 271*) and omissions (e.g., *On August 13, 2000, Gore announced to reporters gathered the White House lawn that he had selected Senator Joe Lieberman of Connecticut as his vice presidential running mate*). The omissions, in particular, were meant to encourage reading for comprehension, a necessary condition for the emergence of predictability effects. Ten omissions and 10 repetitions were distributed across the passage, in addition to the 40 spelling errors, resulting in a total of 60 errors, or an average of 4.29 per page. Assuming 23 lines of text per page, this figure means that, on average, participants encountered an error in every fifth or sixth line of text they read (in actuality, errors were not so evenly distributed, and error density varied by page and by paragraph). Presumably, we could have heightened participant attentiveness by shortening the passage (increasing error density) or lowered it by lengthening the passage (decreasing error density); such a manipulation represents an interesting opportunity for future research. Our goal in the present study was to create reading conditions natural enough that some errors would go undetected and any latent stress or predictability effects would have a chance to emerge, while keeping participants on guard enough to perform the task. We also wanted to present a passage brief enough to sustain participants' attention for its entirety.

#### 5.1.3.3 Offline assessments.

Fifty-five Study 4 participants completed the offline spelling, reading and vocabulary assessments administered to participants in Study 2b. These subjects' data were included in the individual differences analyses (below).

### 5.1.4 Procedure.

Upon arriving for the experiment, participants were given a red pen and an instruction sheet that contained a practice-proofreading paragraph (Appendix F), and were asked to follow along as the experimenter read the instructions aloud. The instructions explained that participants would be proofreading the Wikipedia entry for Al Gore for three types of errors: misspellings, repetitions, and omissions, and would also be asked comprehension questions following the reading. A definition of each type of error was provided. Participants were instructed to circle any misspellings and repetitions, and to write an 'X' in the place of an omission. They were then told to read the practice paragraph to themselves at a natural pace, so as to be able to answer a comprehension question afterward, and to mark any errors that they detected.

After allowing the participants sufficient time to complete the reading and answer the comprehension question, the experimenter went over the errors the participants should have spotted and answered any questions they had about the procedure. Participants were then given one version of the experimental passage and seated in a quiet room to perform the proofreading. The passage was followed by four simple comprehension questions (meant to ensure ourselves that participants had read for meaning and not simply scanned the passage for errors) and two feedback questions (meant to ascertain whether the alterations to the Wikipedia entry had been obvious, and what the participants believed the purpose of the experiment was; Appendix G). Most participants completed the exercise in 20 to 30 minutes. All participants then went on to the computerized assessments of reading, spelling, and vocabulary knowledge, although 16 participants inadvertently closed their sessions before their individual differences data could be recorded. Before leaving, participants were informed that the Wikipedia entry they had read had been altered from the original for the purposes of the experiment, and were handed the unaltered version. The entire experiment was completed within an hour by the majority of subjects.

## 5.2 RESULTS

Online and offline task performance measures are given in Table 14. Seven of the 80 subjects who received complete versions of the passage failed to accurately answer at least three of the four comprehension questions and were removed from analyses. An additional two subjects were removed from analyses for attaining accuracy rates of 0% for spelling error detection. (The failure or refusal to spot any errors seems to have been strategic on the part of these subjects: in answering the feedback question probing what they believed the purpose of the experiment was, one wrote, “I believe the purpose was to trick the reader into looking for mistakes instead of comprehending,” and the other wrote, “See if people pick up on info, not the errors?” Both earned perfect scores on the comprehension questions.) The final *n* of subjects whose data was analyzed was 71. In addition, six of the 80 items (7.5%) were removed from analyses for receiving accuracy rates below chance across constraint conditions. Four of these were misspelled in unstressed syllables and two were misspelled in stressed syllables.

**Table 14.** Online and offline performance outcomes for Study 4.

| Measure | | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Experimental Task | Misspellings accuracy | 51.18 | 100.00 | 83.12 | 11.68 |
| | Repetitions accuracy | 0.00 | 100.00 | 47.89 | 27.36 |
| | Omissions accuracy | 0.00 | 100.00 | 51.83 | 22.57 |
| | No. false alarms | 0.00 | 13.00 | 2.68 | 2.49 |
| | Comprehension questions acc. | 75.00 | 100.00 | 95.00 | 0.10 |
| Spelling Assess. | Combined d' | -.26 | 3.32 | 1.71 | 0.88 |
| | Olson d' | -.45 | 4.21 | 2.13 | 1.10 |
| | Baroff d' | -.76 | 4.65 | 2.94 | 1.62 |
| | Hart d' | -.62 | 1.48 | 0.58 | 0.50 |
| Reading Assess. | Composite score | -.720 | 33.60 | 19.51 | 8.84 |
| | No. incorrect | 0.00 | 29.00 | 7.71 | 6.29 |
| Vocabulary Assess. | Composite score | -20.00 | 97.60 | 51.50 | 24.16 |
| | No. incorrect | 0.00 | 59.00 | 14.62 | 12.17 |

N=71 for experimental measures and N=55 for offline measures. *No. false alarms* refers to the number of times participants identified correctly spelled words as misspelled. *Composite score* = (number correct) – [(number incorrect and unanswered)/(number response choices)].

### 5.2.1 Stress and constraint effects.

Subject- (*Fs*) and item- (*Fi*) level ANOVAs were performed on spelling error detection accuracy data. A main effect of stress status was significant by subjects (*Fs*(1,70)=6.47, p=.01, $\eta^2_p$=.085) and marginal by items (*Fi*(1,159)=3.56, p=.06, $\eta^2_p$=.022), with errors more reliably detected in stressed than in unstressed syllables. A main effect of constraint was significant by both subjects and items (*Fs*(1,70)=17.21, p < .001, $\eta^2_p$= .197;

$Fi(1,159)=4.86$, $p<.05$, $\eta^2_p=.030$), with errors more reliably detected in less predictable than in more predictable words.

The main effect of constraint was moderated by stress status in subjects but not items analyses (Figure 9), although there was a trend toward a significant interaction in the items-level data ($Fs(1,70)=4.76$, $p < .05$, $\eta^2_p= .064$; $Fi(1,159)=1.99$, $p=.16$, $\eta^2_p=.013$). The interaction was such that detection of errors in high-constraint (i.e., more predictable) words was aided by stress, whereas detection of errors in low-constraint (i.e., less predictable) words was not.

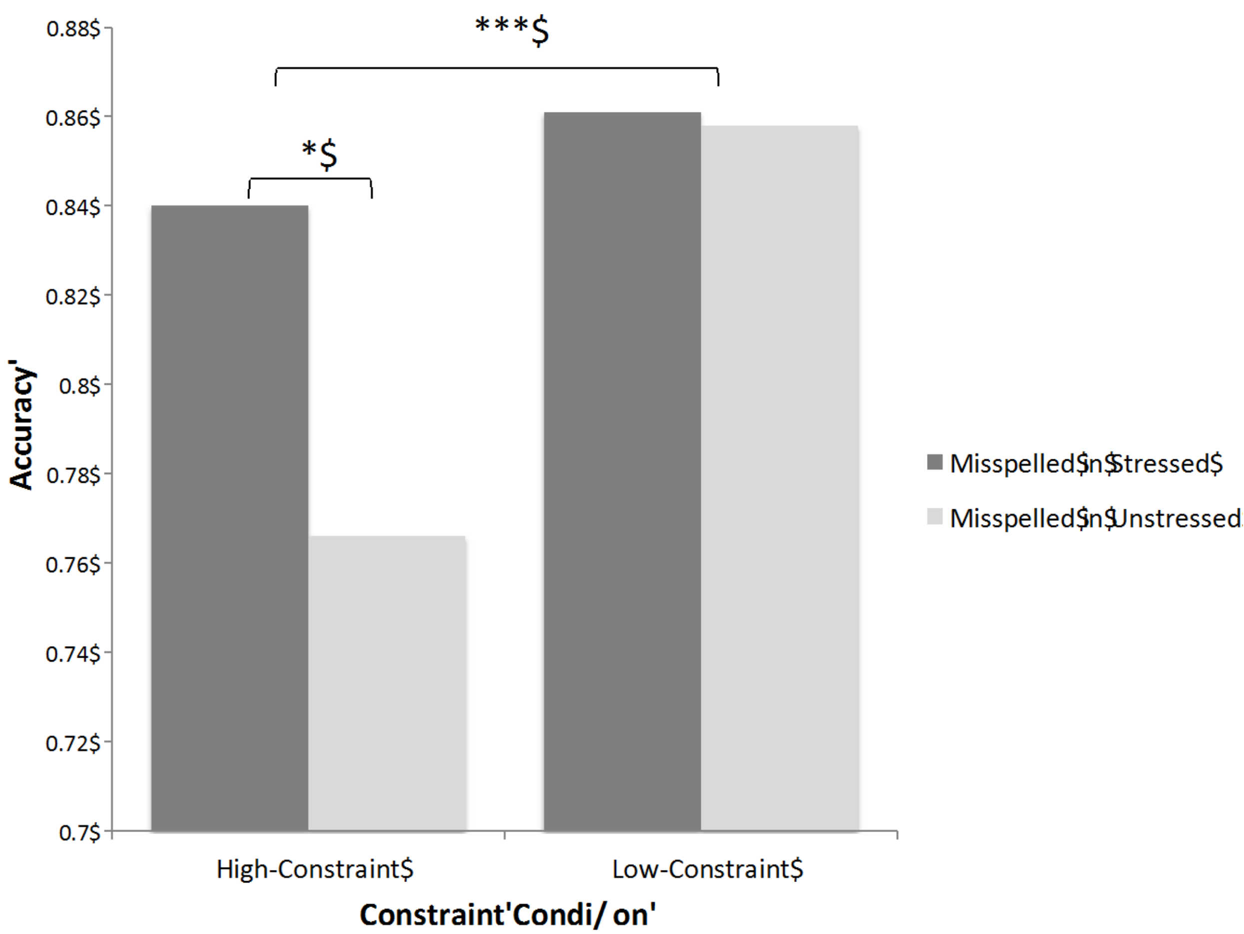


**Figure 9.** Stress status-by-constraint status interaction on accuracy in Study 4. Data for subject means is shown; the interaction was not significant by items.

### 5.2.2 Individual differences correlations.

Correlations of task performance measures with individual differences measures are given in Table 15. In addition to other measures of task performance, we calculated a *stress effect* and a *constraint effect* in order to examine sensitivity to stress and constraint amongst different skill levels. The stress effect was calculated by subtracting mean accuracy to items misspelled in unstressed syllables from mean accuracy to items misspelled in stressed syllables. The constraint effect was calculated by subtracting mean accuracy to items in high-constraint contexts from mean accuracy to items in low-constraint contexts.

The constraint effect was not correlated with any of the individual differences we assessed. The stress effect was correlated ($r$ = .271, p < .05) with one component of the vocabulary assessment (number of incorrect items). The implications of these correlations and other correlations reported in Table 15 are discussed in the next section (5.3).

**Table 15.** Correlations of proofreading (Study 4) task performance measures with individual differences.

| Task Performance Measure | Individual Difference Measure | | *r* |
|---|---|---|---|
| *Stress effect* | Vocabulary | No. incorrect | .271* |
| *Constraint effect* | -- | -- | -- |
| *Misspellings accuracy* | Spelling | Baroff d’ | -.235† |
| | Reading | No. incorrect | -.233† |
| | Vocabulary | Composite score | .423*** |
| *Repetitions accuracy* | -- | -- | -- |
| *Omissions accuracy* | Spelling | Olson d’ | -.234† |
| | | Baroff d’ | -.368** |
| | | Hart d’ | -.269* |
| | Reading | No. incorrect | -.223† |
| *No. false alarms* | Spelling | Combined d’ | -.247† |
| | Reading | Composite score | -.241† |
| | Vocabulary | Composite score | -.268* |

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$. † $p \leq .10$.

N = 55. *Composite score* = (number correct) – [(number incorrect and unanswered)/(number response choices)].

## 5.3 DISCUSSION

The primary goal of Study 4 was to determine whether stress effects on spelling error detection, which diminished from Study 1 to Study 2a and disappeared in Study 2b, would reappear in a proofreading task, in which cues to the stress patterns of upcoming words are available to readers. Our results indicate that they did. Accuracy to items misspelled in stressed syllables was 85.0%, which was significantly higher than the 81.2% accuracy to items misspelled in unstressed syllables. This outcome parallels that of Study 1, although in Study 4 the possible confound of items-level factors was eliminated. Studies 2b, 2a, and 4, respectively, represent spelling error detection tasks with progressively longer intervals available for phonological activation and processing, and the strength of stress effects across these experiments increased accordingly. Study 4 had the added advantage for stress of providing readers cues that could allow it to activate prelexically, thus potentially offering hundreds of milliseconds longer than is available in a lexical decision (in which stress is more likely to be accessed postlexically) for stress and orthography to interact. Phoneme information typically does not require such an extended interval to influence orthographic processes because of the close mapping of phonemes to graphemes in an alphabetic system: a grapheme can trigger activation of a phoneme nearly instantaneously, introducing phonemic information to the orthography-phonology loop very early in word recognition, whereas stress information is generally applied to longer strings of letters and cannot enter the loop until later.

A second goal of Study 4 was to determine whether words that are more predictable from sentential context facilitate or inhibit error detection relative to less predictable words. We found that spelling errors were more often detected in a word when it was difficult to predict from context than when it was easy to predict. As an example, the misspelled word *systim* in its low-constraint context (following *cosmos*) was spotted by 90.91% of participants, whereas *systim* in its high-constraint context (following *solar*) was spotted by only 86.67% of participants. Predictable words are seemingly identified faster and receive less careful scrutiny, even during a proofreading exercise, than words readers are not to some degree prepared to encounter. Previous studies have shown that words receive longer and more frequent fixations when they are less predictable from context (Schotter et al., 2014; Ehrlich & Rayner, 1981; Zola, 1984), but this is the first study, to our knowledge, to show a direct link between predictability and the conscious ability to detect errors during proofreading.

Finally, we conducted Study 4 to test the hypothesis that stress effects would interact with contextual constraint during proofreading, because we assumed context would be a main driver of any stress effects we observed. If, for example, context strongly indicates a particular word is upcoming (as in *the solar*), then the strong-weak stress pattern can be applied to the string *system* as it is encountered, and the benefits of stress for error detection will be immediately available to the reader. This hypothesis was also supported, although more definitively in the subjects than in the items analysis. Accuracy for low-constraint words was unaffected by the stress status of the syllable of misspelling (mean accuracy to low-constraint words misspelled in stressed syllables was 86.1%, which was not significantly different from the 85.8% accuracy to low-constraint words misspelled in unstressed syllables), whereas accuracy for high-constraint words was significantly affected by whether the misspelling occurred in a stressed (M = 84.0%) or unstressed (M = 76.6%) syllable. The additional scrutiny (and/or longer viewing times) received by less predictable words allowed their errors to be spotted at equal rates in stressed and unstressed syllables, whereas the less-closely scrutinized high-constraint words benefitted from the influence of stress. (We do not assume that, because less predictable words were perhaps fixated longer than more predictable words, they were subject to the sort of spelling verification we believe occurs in a spelling decision task. Rather, we assume lexical access proceeds in a similar fashion for more and less predictable words, but is speeded when a word is constrained by context.)

We predicted at the outset of this experiment that more skilled readers would show decreased effects of stress on task performance. This prediction was supported by the positive correlation of number of incorrect items in the vocabulary assessment with the stress effect, i.e., the difference in accuracy to items misspelled in stressed and unstressed syllables. The direction of the correlation suggests that the participants with poorer vocabularies were helped most by suprasegmental phonology in detecting misspellings, which is consistent with the Study 3 finding of greater variance in lexical and spelling decision performance accounted for by segmental phonological feedback in less skilled readers and spellers.

We had no predictions regarding the relationship of constraint with individual differences, determining it is as likely that sensitivity to context increases as reading skill improves as it is that it decreases. Our correlational analyses showed no association of constraint with individual differences, suggesting that both may be true. Some highly skilled readers may have learned to pay increased attention to unexpected words, and others may find that their skill makes it unnecessary to modify behavior based on predictability. And the opposite may be true, as well: some less skilled readers may use predictability as a cue to help compensate for other deficits, whereas insensitivity to contextual cues may be a driver of poor reading skill for others. Our failure to find a correlation of the constraint effect with individual difference measures is consistent with such a scenario.

Of all the task performance measures, spelling skill most reliably predicted success at detecting omitted words: all three subcomponents of the spelling assessment correlated with omissions accuracy, to varying degrees. Spelling ability and omissions detection both require an attention to detail, which explains their correlation. Interestingly, spelling skill was not the most reliable predictor of misspelling detection. This distinction belongs to vocabulary size, which suggests that having complete lexical representations of many words is more helpful in spotting errors while reading in context than is having highly specified orthographic representations for the words in one's mental lexicon, whatever its size.

Vocabulary and reading were correlated fairly highly in this sample (the composite scores of the respective assessments were correlated at $r = .570$, $p < .001$) and their parallel correlations with number of false alarms circled reflects this association. Given the high intercorrelation of vocabulary and reading, their divergences in other areas of task performance are particularly striking. Whereas vocabulary was the more reliable correlate of misspellings accuracy, reading and not vocabulary was associated with omissions accuracy. The correlation of reading ability with sensitivity to omissions in the passage is consistent with the greater ease with which more skilled comprehenders integrate words into text relative to less skilled comprehenders (Yang, Perfetti, & Schmalhofer, 2005). Apparently, the underlying driver of reading and vocabulary skill that causes them to be so highly associated—likely, extent of reading experience—is separate from the component of reading ability—likely, word-to-text integration—that makes more skilled readers adept at noticing missing words.

# 6.0 GENERAL DISCUSSION

## 6.1 SUMMARY OF RESULTS

We conducted four studies to determine the range of phonological information that can affect orthographic processes during reading under different conditions, and to investigate how the influence of phonology on orthography is affected by other relevant factors, such as linguistic context and individual differences in reading-related skills. Study 1 employed a spelling decision task in which the number of syllables in the stimulus, the syllable of misspelling, the stress status of the syllable of misspelling, and the phoneme preservation status of the misspelling were factorially manipulated. Accuracy of spelling error detection increased for items whose misspellings altered their phonemes, and for items misspelled in the stressed syllable when the phonemes of the correctly spelled word was preserved. Response latencies were also faster for items misspelled in the stressed syllable so as to preserve phonemes. These results suggest that activated phonological information, including segmental and suprasegmental information, can influence orthographic processing, with the influence of lexical stress secondary to the influence of phonemes.

Study 2 comprised two separate experiments designed to compare phonological effects on orthographic processing in a spelling decision task versus a lexical decision task. Study 2a, which employed a spelling decision task, attempted to replicate the findings of Study 1 with more tightly controlled stimuli. Accuracy was again higher for items whose misspellings altered their phonemes, although the stress status of the misspelled syllable no longer had an affect on accuracy. Response latencies were faster for items misspelled in the stressed syllable and for phoneme-preserving misspellings, but these effects did not interact, and were significant by subjects only. Study 2b featured the experimental items of Study 2a in a lexical decision task rather than a spelling decision task. Accuracy was higher for items whose misspellings altered their phonemes in the subjects analyses only. Stress status did not affect accuracy, and neither stress status nor phoneme preservation status affected response latencies. The reduction in phoneme effects, and the disappearance of stress effects, from Study 2a to Study 2b suggests that the influence of phonology on orthography is stronger when more extensive phonological processing is required or allowed by a task, and that stress effects require more extensive phonological processing than do phoneme effects to be observed in behavioral data.

Study 3 included two series of analyses examining phonological feedback as the mechanism for the segmental effects on orthographic processes observed in Studies 1 and 2. Study 3a comprised a corpus analysis of phonological feedforward and feedback consistency of the Study 2 stimuli, correlations of alternative measures of feedforward and feedback consistency with Study 2a and 2b outcomes, and stepwise regressions using standard lexical variables and consistency variables to predict Study 2a and 2b outcomes. In both the spelling and lexical decision tasks, token measures of consistency predicted outcomes and type measures did not. This finding supports the hypothesis that feedback effects in misspelled stimuli are the result of underspecified orthographic representations, rather than of conflict between competing representations. Furthermore, feedback consistency was a more reliable predictor of task performance than was feedforward consistency, which is the opposite pattern of what has been observed in past research. We speculate that the reason for this reversal is our use of misspelled (rather than of correctly spelled) experimental items, and that information flowing from phonology to orthography has a greater impact on reading processes when one is faced with a misspelling or nonword.

In Study 3b, the size of feedback effects observed in the Study 2 data were correlated with offline measures of participants' spelling ability, and regressions were conducted to see whether feedback consistency predicted reading, spelling and vocabulary skill beyond feedforward consistency in more- and less-skilled participants. The analyses indicated that better spellers are less sensitive than poorer spellers to the influence of phonological feedback during reading, which supports the hypothesis that phonological feedback is a mechanism for orthographic learning.

Study 4 tested the hypothesis that stress effects on orthographic processing, which were weak in the spelling decision task (Study 2a) and absent in the lexical decision task (Study 2b) would be more robust in a proofreading task, because of the early availability of cues to lexical stress patterns when words are read in sentential context. Words misspelled in stressed and unstressed syllables were embedded in the context of an expository passage that participants were asked to proofread, and the predictability of the words was manipulated. Misspellings were detected more often in words misspelled in stressed syllables, and in words that were less predictable from context. Spelling error detection for more predictable words was improved when the misspelling occurred in a stressed syllable. These results suggest that stress plays a greater role in orthographic processing under more natural reading conditions compared to isolated-word reading, and supports the hypothesis that the role of stress in reading is enhanced when upcoming stress patterns can be more easily predicted.

## 6.2 KEY FINDINGS

The goal of the present research was to investigate a number of questions relating to the potential of phonological information to affect orthographic processes during reading. These questions included:

1. *Does suprasegmental phonology affect orthographic processes?*
2. *Do task demands modulate the influence of phonology on orthographic processes?*
3. *Do lexical and linguistic factors modulate the influence of phonology on orthographic processes?*
4. *Do individual differences amongst readers modulate the influence of phonology on orthographic processes?*

On each of these fronts, our research has produced a number of interesting results.

### 6.2.1 Does suprasegmental phonology affect orthographic processes?

A key finding of the present research is that the phonological component of lexical stress can influence orthographic processes under certain conditions. Specifically, stress becomes likelier to affect orthographic processing as its activation time is maximized. The more time the stress pattern of a word is known to a reader before he or she either reaches a decision about it (Studies 1 and 2) or moves on to the next word in the sentence or paragraph (Study 4), the more likely stress is to benefit error detection. We effectively lengthened the amount of time participants in our studies had access to the stress patterns of critical words in two ways. The first way was to increase the time a participant spent processing a word, by increasing the number of steps required to complete it. Because a higher criterion is set to decide a string is a misspelled word than to decide it is a word, a spelling decision requires longer processing times than does a lexical decision. This difference is reflected in the mean response latencies for the spelling decision (Study 2a) and lexical decision (Study 2b) tasks, which were 856 ms and 747 ms, respectively. That a spelling decision took, on average, 109 ms longer to make than a lexical decision is consistent with our model of spelling decisions (Figure 5), in which extra steps are required to verify that a word is correctly spelled. During this spelling verification, a reader would have access to the complete stress pattern of the word in the lexicon to which the input string is being compared. Accordingly, stress impacted response latencies in Study 2a, but had no effect on either accuracy or latencies in Study 2b.

The second way we lengthened the amount of time participants had access to stress patterns was by making stress information available to the reader earlier in word identification. This was accomplished in Study 4 by providing syntactic and contextual cues to the identity of the upcoming critical word, so that the anticipated stress pattern could be applied to the word at the moment of encounter. Thus, even though the proofreading task did not require, on average, particularly long processing times for critical words, stress information was active and able to operate on orthography for close to the entire processing duration.

The finding of lexical stress effects in our spelling decision and proofreading tasks is consistent with past studies that found stress is active during silent reading in English (Ashby & Clifton, 2005; Arciuli & Cupples, 2006; Breen & Clifton, 2011), and with studies showing that suprasegmental information can influence our processing of orthography (Drewnowski & Healy, 1982; Goldman & Healy, 1985). The present research cannot, however, answer the question of *how* stress affects orthographic processing. Given the results of Ashby and Clifton (2005), who found that words containing more stressed syllables are fixated longer and more frequently than words containing fewer stressed syllables, a likely explanation for increased error detection in stressed syllables seems tied to the length of fixation times. We showed in the proofreading study reported here that predictable words, which are known to receive shorter/fewer fixations, receive less careful orthographic processing than do unpredictable words. Ashby and Clifton suggested that phonological units, including stress units, are assembled for phonological recoding in the completion phase of lexical access. Words with more stressed syllables require more time for the assembly of phonological units, and so are fixated longer before a saccade to the next word is triggered. This explanation accounts for the longer fixations for words with more stressed syllables in their study, but does not account for increased detection of errors in stressed syllables in ours. Indeed, Ashby and Clifton found that fixations of syllables containing stress did not differ from those of unstressed syllables. Further research is necessary to explain why written syllables with stress attached to them are more visually salient than unstressed syllables.

### 6.2.2 Do task demands modulate the influence of phonology on orthographic processes?

As discussed above (section 6.2.1), we found that the influence of suprasegmental phonology on orthographic processes is modulated by task demands, with lexical stress exerting a stronger influence on orthography the longer it is active. We found that task demands also modulate the influence of segmental phonology on orthographic processes, although, because phonemes map to graphemes and can therefore be activated much sooner than stress in the word reading process, length of processing is probably less of a factor for phoneme effects than is the extent of phonological processing required by the task.

In the spelling decision task (Study 2a), phoneme status affected both accuracy and latency of responses; in the lexical decision task (Study 2b), phoneme status affected only the accuracy of responses, and this effect was significant in the subjects analysis only. Aside from the number of steps required to complete a lexical decision relative to a spelling decision, the two tasks differ in the degree that phonological information is useful in reaching a decision. If, as we have suggested, a lexical decision is made by determining whether a quick exact match for an input string exists in the lexicon (Figure 5), then the role of phonology in such a decision is relatively restricted. If, on the other hand, a spelling decision is made by considering the phonological and orthographic information in a string during a spelling verification (Figure 5), then phonological processing in a spelling decision is considerably more extensive than it is in a lexical decision. Thus, our diminished phoneme effects in the lexical decision task is consistent with the notion that the ability to observe phonological effects in behavioral tasks corresponds to the extent of phonological processing demands required by the task (Gibbs & Van Orden, 1998). The reduced phoneme effects in the lexical decision task, which contained a smaller proportion of pseudohomophone foils than the spelling decision task, is also consistent with previous findings that phonological effects increase when pseudohomophones are used as foils (Berent, 1997; Pexman, Lupker, & Jared, 2001).

### 6.2.3 Do lexical and linguistic factors modulate the influence of phonology on orthographic processes?

We did not find compelling evidence that the lexical factors of number of syllables and location of stress in a word modulate the influence of phonology on orthographic processes. In Study 1, in which these factors were controlled for, only number of syllables interacted significantly with stress status in analyses by subjects and by items, in both the accuracy and latency analyses. We accounted for this finding by reasoning that misspellings in the unstressed syllable in 2-syllable words often cause that syllable to be stressed, whereas in 3-syllable words this is not the case. Beyond this interaction, neither number of syllables nor syllable of stress reliably predicted error detection, or moderated the influence of phonology on error detection. This finding is in contrast to that of Drewnowski and Healy (1982), who reported interactions of stress effects with both number of syllables and location of stress in a word.

The explanation for the divergence of our findings with those of Drewnowski and Healy likely likes in task differences. Drewnowski and Healy's participants were reading passages, whereas ours were making decisions about isolated words, and their participants were searching for a particular letter, whereas ours were searching for any aberration in an orthographic string. Had we controlled for number of syllables and syllable of stress in our proofreading study, we might have found the interactions that Drewnowski and Healy observed, which would indicate that stress interacts with lexical factors when stress information is available early in lexical access. Alternatively, these effects might have emerged had we asked participants to search for a particular letter in isolated words that were flashed on the screen, which would indicate that stress interacts with lexical factors when a reader is tasked with a more superficial analysis of a word's visual form.

We did, however, find evidence that linguistic constraint modulates the influence of phonology on orthographic processing. As noted above (section 6.2.1), stress effects that had disappeared in the lexical decision task (Study 2b) reappeared in the proofreading task (Study 4), which is consistent with our hypothesis that stress can be activated earlier in lexical access when syntax provides cues to upcoming stress patterns. Moreover, stress effects interacted with the predictability of the critical word in context, which adds further support to our hypothesis. If, for example, syntax indicates that the upcoming word will be a noun, the reader will be correct in activating a strong-weak stress pattern approximately 90% of the time. If context also strongly suggests the upcoming word will be *system*, the reader can activate the strong-weak stress pattern with even greater confidence. Our results show that stress was most beneficial in aiding error detection in highly predictable words, in which errors were less likely to be detected than in less predictable words. That stress did not make a difference for error detection in less predictable words is likely due to the fact that error detection already approached ceiling in those stimuli.

Because we did not manipulate phoneme preservation in the proofreading study, we cannot say whether altered phonemes are more likely to support error detection in less predictable than in more predictable words. However, we suspect this is not the case. Because phoneme information is available very early in lexical access regardless of the availability of prior cues to upcoming phonemes, it seems likely that providing such cues would result in a significant added benefit to error detection.

### 6.2.4 Do individual differences amongst readers modulate the influence of phonology on orthographic processes?

Our correlations and regressions analyses in Study 3 indicated that individual differences in reading-related skills can modulate the influence of segmental phonology on orthographic processes. Specifically, we found that reliance on phonological feedback information is linked to lower spelling ability, but to higher reading and vocabulary ability. This pattern of associations may be why feedback effects have been inconsistent in past research. According to the lexical quality hypothesis, the use of feedback information will vary for an individual across words, depending on the relative quality of the orthographic and semantic representations of each item. In an item for which an individual has high orthographic specificity, feedback effects will be small (or, according to the orthographic recoding hypothesis of McKague et al. [2008], absent), but in an item for which an individual has high semantic specificity feedback effects will be larger. When data is averaged across all the participants in an experiment, feedback effects may be vanishingly small. Our finding of an association of feedback consistency effects with spelling skill is also consistent with the hypothesis that phonological feedback is used in orthographic learning, and will disappear when the orthographic representation for an item is fully specified. However, more research is necessary to establish a causal link between feedback consistency effects and orthographic learning.

We also found evidence that individual differences in reading-related skills can predict the size of lexical stress effects on orthographic processing during reading in context. Specifically, vocabulary knowledge correlated with the stress effect in Study 4, such that participants with poorer vocabularies were helped most by suprasegmental phonology in detecting misspellings. Past research has shown that less skilled readers rely more heavily on segmental phonology during orthographic processing than do more skilled readers, but this is, to our knowledge, the first demonstration that they are also more reliant on suprasegmental information.

## 6.3 CONCLUSIONS

The present research has made several original contributions to the literature on phonological and orthographic processes in reading. Although past research reported effects of lexical stress on orthographic processing during silent reading, we have linked the emergence of these effects to the presence of specific task demands, and have shown that they can exist in the reading of isolated words. We have also provided evidence that segmental and suprasegmental phonology affect orthographic processing differentially, with segmental information impacting orthographic processes when it is particularly useful to the task, or when the reader must draw on it extensively, and suprasegmental information impacting orthographic processes when the reader is given sufficient time to make use of it. This research also shows differential effects of phonology on orthography in isolated-word reading versus reading words in the context of a paragraph or longer passage. Our finding that feedback consistency effects are linked to more skilled reading and less skilled spelling, characteristics that are not always found in the same individual, presents a possible explanation for the elusiveness of feedback consistency effects in past research, and suggests that in future research into these effects, individual differences in a variety of reading-related skills should be controlled for. Finally, this research extends the past finding that less skilled readers are more sensitive to phonological information during orthographic processing to include suprasegmental as well as segmental information.

# APPENDIX A

## STUDY 1 EXPERIMENTAL STIMULI

Type 1 Stimuli (2 syllables; 1st syllable stressed; misspelling in unstressed syllable; phonemes preserved): cactas (cactus), channal (channel), errend (errand), gerbel (gerbil), orenge (orange), poignent (poignant), racquit (racquet), rightious (righteous), spectrim (spectrum), warrent (warrant)

Type 2 Stimuli (2 syllables; 1st syllable stressed; misspelling in unstressed syllable; phonemes altered): aardvirk (aardvark), cabboge (cabbage), elbaw (elbow), froluc (frolic), incume (income), midneght (midnight), pilluw (pillow), turkay (turkey), wondar (wonder), zippar (zipper)

Type 3 Stimuli (2 syllables; 1st syllable stressed; misspelling in stressed syllable; phonemes preserved): bleechers (bleachers), dayly (daily), lenguage (language), peeple (people), speady (speedy), thurough (thorough), sleapy (sleepy), purfect (perfect), wuman (woman), reeson (reason)

Type 4 Stimuli (2 syllables; 1st syllable stressed; misspelling in stressed syllable; phonemes altered): bladgeon (bludgeon), blassom (blossom), camfort (comfort), demage (damage), furtune (fortune), handredth (hundredth), hasband (husband), jismine (jasmine), lequid (liquid), nastril (nostril)

Type 5 Stimuli (2 syllables; 2nd syllable stressed; misspelling in unstressed syllable; phonemes preserved): distroy (destroy), phisique (physique), cuncern (concern), dispite (despite), yoorself (yourself), fanesse (finesse), guzelle (gazelle), mistique (mystique), purhaps (perhaps), purplex (perplex)

Type 6 Stimuli (2 syllables; 2nd syllable stressed; misspelling in unstressed syllable; phonemes altered): mansoon (monsoon), pralong (prolong), bolieve (believe), bucome (become), raduce (reduce), porsuade (persuade), dovulge (divulge), wethdraw (withdraw), dascend (descend), shempoo (shampoo)

Type 7 Stimuli (2 syllables; 2nd syllable stressed; misspelling in stressed syllable; phonemes preserved): avoyd (avoid), conferm (confirm), unreel (unreal), reveel (reveal), conceel (conceal), unvail (unveil), repeet (repeat), retreet (retreat), preveil (prevail), betrey (betray)

Type 8 Stimuli (2 syllables; 2nd syllable stressed; misspelling in stressed syllable; phonemes altered): caboase (caboose), delaxe (deluxe), embroce (embrace), escepe (escape), exest (exist), forlern (forlorn), ignare (ignore), raccoan (raccoon), rejouced (rejoiced), typhoan (typhoon)

Type 9 Stimuli (3 syllables; 1st syllable stressed; misspelling in unstressed syllable; phonemes preserved): furnature (furniture), humerous (humorous), jeoperdy (jeopardy), luducrous (ludicrous), magizine (magazine), metiphor (metaphor), rigerous (rigorous), satallite (satellite), synthasis (synthesis), versitile (versatile)

Type 10 Stimuli (3 syllables; 1st syllable stressed; misspelling in unstressed syllable; phonemes altered): albatrass (albatross), alphabat (alphabet), barbecoe (barbecue), cannibel (cannibal), marathin (marathon), negatuve (negative), paradax (paradox), renegode (renegade), sabotege (sabotage), subjugite (subjugate)

Type 11 Stimuli (3 syllables; 1st syllable stressed; misspelling in stressed syllable; phonemes preserved): sergery (surgery) sillable (syllable), dinamite (dynamite), mistical (mystical), durtier (dirtier), birnable (burnable), cirtainly (certainly), luvingly (lovingly), mutherly (motherly), wunderful (wonderful)

Type 12 Stimuli (3 syllables; 1st syllable stressed; misspelling in stressed syllable; phonemes altered): corpenter (carpenter), crucodile (crocodile), ditriment (detriment), heckory (hickory), hoiligan (hooligan), menicure (manicure), papular (popular), surcasm (sarcasm), sercerer (sorcerer), vesitor (visitor)

Type 13 Stimuli (3 syllables; 2nd syllable stressed; misspelling in unstressed syllable; phonemes preserved): abnormel (abnormal), abundence (abundance), adjacint (adjacent), apparant (apparent), defience (defiance), dependant (dependent), implicet (implicit), insurence (insurance), opponant (opponent), peculier (peculiar)

Type 14 Stimuli (3 syllables; 2nd syllable stressed; misspelling in unstressed syllable; phonemes altered): dramatoc (dramatic), malignont (malignant), tertilla (tortilla), apartmont (apartment), porported (purported), sonsation (sensation), aerobacs (aerobics), strateguc (strategic), canveyor (conveyor) creatar (creator)

Type 15 Stimuli (3 syllables; 2nd syllable stressed; misspelling in stressed syllable; phonemes preserved): encoarage (encourage), consinsus (consensus), discuver (discover), detirmine (determine), intirpret (interpret), refirbish (refurbish), anuther (another), contaener (container), divirsion (diversion), divirgent (divergent)

Type 16 Stimuli (3 syllables; 2nd syllable stressed; misspelling in stressed syllable; phonemes altered): alfelfa (alfalfa), amnasia (amnesia), boninza (bonanza), fiesco (fiasco), horezon (horizon), mosquato (mosquito), spaghatti (spaghetti), sporedic (sporadic), umbrulla (umbrella), vacotion (vacation)

## APPENDIX B

## STUDIES 2A AND 2B EXPERIMENTAL STIMULI

**Table 16.** Studies 2a and 2b experimental stimuli

| Target | Type 1 Stimulus (Misspelling in stressed syllable, phonemes preserved) | Type 2 Stimulus (Misspelling in stressed syllable, phonemes altered) | Type 3 Stimulus (Misspelling in unstressed syllable, phonemes preserved) | Type 4 Stimulus (Misspelling in unstressed syllable, phonemes altered) |
|---|---|---|---|---|
| announcer | annauncer | anneuncer | announcir | announcar |
| certainly | cyrtainly | cortainly | certaenly | certaonly |
| consensus | consynsus | consonsus | cunsensus | cansensus |
| dirtier | dertier | dartier | dirtiyr | dirtiar |
| discover | discuver | discever | dyscover | doscover |
| dynamite | dinamite | dunamite | dynamyte | dynamate |
| machine | machene | machone | mechine | mychine |
| percolate | pircolate | porcolate | perculate | percilate |
| various | verious | vorious | varyous | varuous |
| worthless | werthless | warthless | worthliss | worthloss |
| comfort | cumfort | camfort | comfert | comfart |
| container | contayner | contaoner | cuntainer | centainer |
| divergent | divirgent | divargent | dyvergent | duvergent |
| easily | eesily | eosily | easely | easoly |
| language | lenguage | longuage | languege | languoge |
| motherly | mutherly | metherly | mothurly | motharly |
| purpose | perpose | parpose | purpuse | purpase |
| refurbish | referbish | reforbish | rifurbish | rofurbish |
| surgery | sergery | sorgery | surgury | surgory |
| weirdest | wyirdest | woirdest | weirdyst | weirdast |
| another | anuther | anather | anothur | anothyr |
| business | bisiness | basiness | businiss | businass |
| colorful | culorful | cilorful | colorfol | colorfil |

| **Target** | **Type 1 Stimulus** (Misspelling in stressed syllable, phonemes preserved) | **Type 2 Stimulus** (Misspelling in stressed syllable, phonemes altered) | **Type 3 Stimulus** (Misspelling in unstressed syllable, phonemes preserved) | **Type 4 Stimulus** (Misspelling in unstressed syllable, phonemes altered) |
|---|---|---|---|---|
| diversion | divirsion | divarsion | dyversion | doversion |
| movement | muvement | mevement | movemint | movemont |
| prettiest | prittiest | prottiest | prettyest | prettuest |
| prevail | preveil | prevoil | privail | pruvail |
| retreat | retreet | retreut | ritreat | rotreat |
| service | sirvice | sorvice | servyce | servace |
| wonderful | wunderful | wenderful | wonderfol | wonderfyl |
| betray | betrey | betroy | butray | botray |
| bleachers | bleechers | bleochers | bleachurs | bleachars |
| covering | cuvering | cavering | coveryng | coverung |
| determine | deturmine | detormine | ditermine | dotermine |
| divulge | divolge | divylge | devulge | dovulge |
| governor | guvernor | givernor | govurner | govirnor |
| interpret | intirpret | intorpret | interpryt | interprat |
| lovingly | luvingly | levingly | lovyngly | lovangly |
| mystical | mistical | mostical | mysticul | mysticil |
| physical | phisical | phosical | physycal | physocal |

**APPENDIX C**

**STUDY 4 EXPERIMENTAL STIMULI**

**Table 17.** Study 4 experimental stimuli

| **Target** | **Type 1 Stimulus** (Misspelling in stressed syllable, phonemes preserved) | **Type 2 Stimulus** (Misspelling in stressed syllable, phonemes altered) | **Type 3 Stimulus** (Misspelling in unstressed syllable, phonemes preserved) | **Type 4 Stimulus** (Misspelling in unstressed syllable, phonemes altered) |
|---|---|---|---|---|
| announcer | annauncer | anneuncer | announcir | announcar |
| certainly | cyrtainly | cortainly | certaenly | certaonly |
| consensus | consynsus | consonsus | cunsensus | cansensus |
| dirtier | dertier | dartier | dirtiyr | dirtiar |
| discover | discuver | discever | dyscover | doscover |
| dynamite | dinamite | dunamite | dynamyte | dynamate |
| machine | machene | machone | mechine | mychine |
| percolate | pircolate | porcolate | perculate | percilate |
| various | verious | vorious | varyous | varuous |
| worthless | werthless | warthless | worthliss | worthloss |
| comfort | cumfort | camfort | comfert | comfart |
| container | contayner | contaoner | cuntainer | centainer |
| divergent | divirgent | divargent | dyvergent | duvergent |
| easily | eesily | eosily | easely | easoly |
| language | lenguage | longuage | languege | languoge |
| motherly | mutherly | metherly | mothurly | motharly |
| purpose | perpose | parpose | purpuse | purpase |
| refurbish | referbish | reforbish | rifurbish | rofurbish |
| surgery | sergery | sorgery | surgury | surgory |
| weirdest | wyirdest | woirdest | weirdyst | weirdast |
| another | anuther | anather | anothur | anothyr |
| business | bisiness | basiness | businiss | businass |
| colorful | culorful | cilorful | colorfol | colorfil |

| **Target** | **Type 1 Stimulus** (Misspelling in stressed syllable, phonemes preserved) | **Type 2 Stimulus** (Misspelling in stressed syllable, phonemes altered) | **Type 3 Stimulus** (Misspelling in unstressed syllable, phonemes preserved) | **Type 4 Stimulus** (Misspelling in unstressed syllable, phonemes altered) |
|---|---|---|---|---|
| diversion | divirsion | divarsion | dyversion | doversion |
| movement | muvement | mevement | movemint | movemont |
| prettiest | prittiest | prottiest | prettyest | prettuest |
| prevail | preveil | prevoil | privail | pruvail |
| retreat | retreet | retreut | ritreat | rotreat |
| service | sirvice | sorvice | servyce | servace |
| wonderful | wunderful | wenderful | wonderfol | wonderfyl |
| betray | betrey | betroy | butray | botray |
| bleachers | bleechers | bleochers | bleachurs | bleachars |
| covering | cuvering | cavering | coveryng | coverung |
| determine | deturmine | detormine | ditermine | dotermine |
| divulge | divolge | divylge | devulge | dovulge |
| governor | guvernor | givernor | govurner | govirnor |
| interpret | intirpret | intorpret | interpryt | interprat |
| lovingly | luvingly | levingly | lovyngly | lovangly |
| mystical | mistical | mostical | mysticul | mysticil |
| physical | phisical | phosical | physycal | physocal |

## APPENDIX D

## FOUR VERSIONS OF THE PROOFREADING PASSAGE. HERE MISSPELLINGS ARE BOLDED, REPETITIONS ARE IN RED, AND OMISSIONS ARE MARKED WITH AN ASTERISK, ALTHOUGH PARTICIPANTS WERE NOT GIVEN THESE CUES TO ERROR LOCATIONS.

### D.1 VERSION 1

AL GORE

**Early Life**

Albert Gore, Jr. was born in Washington, D.C., the second of two children of Albert Gore, Sr., a U.S. Representative who later served as a U.S. Senator from Tennessee, and Pauline (LaFon) Gore, one of the first women to graduate from Vanderbilt University Law School. During the the school year he lived with his family in The Fairfax Hotel in the Embassy Row section in Washington D.C. During the summer months, he worked on the family farm in Carthage, Tennessee, where the Gores grew tobacco and hay and raised cattle.

Gore attended the all-boys St. Albans School in Washington, D.C. from 1956 to 1965, a prestigious feeder school for the Ivy League. He was an accomplished athlete in high school, engaging in all manner of strenuous **phisical** activity. He * basketball, threw discus in track and field, and was the captain of the football team. He graduated 25th in his class of 51, applied to only one college, Harvard, and was accepted.

**Marriage and Family**

Gore met Mary Elizabeth "Tipper" Aitcheson from the nearby St. Agnes School at his St. Albans senior prom in 1965. “She was the **prittiest** girl in the room,” Gore later recalled. Tipper followed Gore to Boston to attend college, and on May 19, 1970, shortly after she graduated from Boston University, they married at the Washington National Cathedral. They have four children, Karenna (b. 1973), Kristin Carlson Gore (b. 1977), Sarah LaFon Gore (b. 1979), and Albert Gore III (b. 1982). In 2009 he walked Sarah down the aisle at her wedding, also at the National Cathedral. Afterwards, he gave a moving toast during the reception at the Mandarin Oriental Hotel in Washington. “You are the most beautiful bride I have ever laid eyes on,” he declared, gazing **lovyngly** upon his daughter’s face.

In early June 2010, shortly after purchasing a new home, the Gores announced in an e-mail to friends that after "long and careful consideration," they had made a mutual decision to separate. Details of a divorce have not been released to the public, but the couple is not thought to have made a prenuptial **agreement** regarding the end of the marriage.

**Harvard, Vietnam, Journalism, and Vanderbilt (1965–1976)**

Gore enrolled in Harvard College in 1965, initially planning to major in English and write novels, but later deciding to major in government. On his second day on on campus, he began campaigning for the freshman student government council, and was elected its president.

Although Gore was enraptured by news of the space program and cosmos **sistem** growing up, he did not do well in science classes in college. His grades during his first two years put him in the lower one-fifth of the class. During his sophomore year, he reportedly spent much of his time watching television, shooting pool, and occasionally smoking marijuana. In his junior and senior years, he became more involved with his studies, earning As and Bs. In his senior year, he took a class with oceanographer and global warming theorist Roger Revelle, who sparked Gore's interest in global warming and other environmental issues.

Gore attended college during the era of anti Vietnam War protests. Though he * against that war, he disagreed with the tactics of the student protest movement, thinking it silly and juvenile to take anger at the war out on a private university. He and his friends did not participate in Harvard demonstrations. John Tyson, a former roommate, recalled that, "We distrusted these movements a lot. We were a pretty traditional bunch of guys, positive for the civil rights **movemint** and women's rights but not buying into something we considered detrimental to our country." Gore helped his father write an anti-war address to the Democratic National Convention of 1968, but stayed with his parents in their hotel room during the violent protests.

When Gore graduated in 1969, his student deferment ended and he he immediately became eligible for the military draft. His father, a vocal anti-Vietnam War critic, was facing a reelection in 1970. Gore eventually decided that the best way he could contribute to the anti-war effort was to enlist in the Army, which would improve his father's reelection prospects.

After enlisting in August 1969, Gore returned to the anti-war Harvard campus in his military uniform to say goodbye to his professors and was "jeered" at by students. He later said he was astonished by the "emotional field of negativity and disapproval and piercing glances it was like sitting on a keg of **dinamite**."

Gore was shipped to Vietnam on January 2, 1971, after his father had lost his seat in the Senate during the 1970 Senate election. Gore's months in Vietnam were a period of both external and **inturnal** conflict for the young man. He later stated that his experience in Vietnam "didn't change my conclusions about the war being a terrible mistake, but it was something I was naively unprepared for." He received an honorable discharge from the Army in May 1971.

After his return from Vietnam, Gore began to pursue a career in journalism. He worked the night shift for *The Tennessean* as an investigative reporter, uncovering corruption among members of the Nashville city **coencil** and reporting on the abysmal nutritional **servyce** ratings of local businesses. He was known for a dramatic flair in his journalism; one story about corruption opened, "It brings me no satisfaction to **riveal** the story of our council members." He took a leave of absence from *The Tennessean* to attend Vanderbilt University Law School in 1974.

**Congress and First Presidential Run (1976–1993)**

At the end of February 1976, U.S. Representative Joe L. Evins unexpectedly announced his retirement from Congress, making the Tennessee's 4th congressional district seat, which had previously been held by Albert Gore, Sr., open. Within hours of of learning the news, Gore decided to quit law school and run for the House of Representatives. Gore won a seat in Congress in 1976 and went on to win the next three elections, in 1978, 1980, and 1982. In 1984, Gore successfully ran for a seat in the U.S. Senate.

During his time in Congress, Gore was considered a "moderate" (he referred to himself as as a "raging moderate"). Despite his tendency to gravitate towards the center on many issues, Gore didn’t shy away from a political battle when an issue was important to him. He held the "first congressional hearings on the climate change, and co-sponsor[ed] hearings on toxic waste and global warming,” despite his awareness that environmentalism was considered taboo by Republicans. He sponsored several bills that would reduce carbon emissions, knowing full well that Republicans in Congress would almost **cyrtainly** vote down the legislation. Gore also became known as one of the “Atari Democrats”, so called for their interest in science and technology. He sponsored legislation involving a range of technologies, from the vending **mechine** to biomedical research.

In 1988, Gore campaigned for the Democratic Party nomination for President of the United States. After announcing that he would run, Gore ran his campaign as "a Southern centrist, [who] opposed federal funding for abortion. He favored a moment of silence for prayer in the schools and voted against banning the interstate sale of handguns." CNN noted that, "in 1988, for the first time, 12 Southern states would hold their primaries on the same day, dubbed ‘Super Tuesday’. Gore thought he would be the only serious Southern contender; he had not counted on Jesse Jackson.” Jackson defeated him * South Carolina, Alabama, Georgia, Louisiana, Mississippi and Virginia.

In addition, many Southern voters doubted whether Gore was a true Southerner, because he had spent much of his life in Washington. A joke circulated that in prep school and at Harvard Gore had taken “Southern” as a foreign **lenguage.** Gore carried seven states in the primaries, finishing third overall.

On April 3, 1989, the Gores and their six-year-old son, Albert, attended a baseball game. Albert listened to Vin Scully, the play-by-play **announcir**, on his portable radio as his parents chatted in the sweltering **bleechers**. As they left the game, tragedy struck. Albert ran across the street to see his friend and was hit by a car. He was thrown 30 feet, and then traveled along the pavement for another 20 feet. Gore later recalled: "I ran to his side and held him and called his name, but he was motionless, limp and still, without breath or pulse [...] His eyes were open with the nothingness stare of death, and we prayed, the two of us, there in the gutter, with only my voice." Albert was tended to by two nurses who happened to be present during the accident until the ambulance arrived.

At the hospital, Albert endured **surgury**, and his parents stayed by his side until his release, a month later. This event was "a trauma so shattering that [Gore] views it as a moment of personal rebirth", a "key moment in his life" which "changed everything." In August 1991, Gore announced that his son's accident was a factor in his decision not to run for president during the 1992 presidential election.

During this time, Gore wrote his first book, *Earth in the Balance*, which earned him the distinction of being the first sitting U.S. senator with a book on the New York Times bestseller list since John F. Kennedy had released *Profiles in Courage* 35 years earlier.

**Vice Presidency and Second Presidential Run (1993–2001)**

Al Gore served as Vice President during * Clinton Administration. Gore was initially hesitant to accept a position as Bill Clinton's running mate for the 1992 United States presidential election, but after clashing with the George H. W. Bush administration over global warming issues, he decided to accept the offer. Clinton stated that he chose Gore due to his foreign policy experience, work with the environment, and commitment to his family.

Clinton and Gore accepted the nomination at the Democratic National Convention on July 17, 1992, on a stage filled with festive balloons and **culorful** banners. Theirs was the first ticket since 1972 to try to capture the youth vote. Gore called the ticket "a new generation of leadership". The ticket increased in popularity after the candidates traveled with with their wives, Hillary and Tipper, on a "six-day, 1,000-mile bus ride, from New York to St. Louis." During the trip the Clintons and Gores often chatted with citizens long after scheduled appearances had officially ended, in an attempt to get "neighborly and **personel**" with voters. Although Gore took hits from the press and the pundits for being "too stiff" during televised debates, he still **easely** debated the other vice presidential candidates, Dan Quayle and James Stockdale. The Clinton-Gore ticket beat the Bush-Quayle ticket, 43%-38%. Clinton and Gore were inaugurated on January 20, 1993 and were re-elected to a second term in the 1996 election.

During the 1990s, Gore spoke out on a number of issues. In a 1992 speech on the Gulf War, Gore stated that he twice attempted to get the U.S. government to pull the plug on support to Saddam Hussein, citing Hussein's use of poison gas, support of terrorism, and his burgeoning nuclear program, but was opposed both times by by the Reagan and Bush administrations. In the wake of the Al-Anfal Campaign, during which Hussein staged deadly mustard and nerve gas attacks on Kurdish Iraqis, Gore cosponsored the Prevention of Genocide Act of 1988, which would have cut all assistance to Iraq. He also supported Clinton's controversial decision to bomb Iraq in December, 1998. The official justification for the bombings was Iraq's failure to comply with United Nations Security Council resolutions, although many suspected the President had other motives. Clinton was hoping to divert media attention away from the House impeachment hearings that were then underway by giving them other news to cover, but it isn't easy to create a **dyversion** that will keep the press from covering such a historical event.

Gore also used the platform of the Vice-Presidency to draw issues important to him personally, especially climate change. "Scientists don't often agree on the implications of data, but there is now an unlikely **cunsensus** among climate scientists that human-generated emissions of greenhouse gases are initiating climatic changes that are unprecedented in human experience during the Holocene epoch," he said in a 1996 speech. "We need to take steps to reduce our reliance on cars. Parents and schools should creatively **encoarage** kids who bike to school."

Towards the end of Clinton's second term in office, suspicions rose that Gore was planning a second presidential run. Gore formally announced his candidacy for president in a speech on June 16, 1999, with his major theme being the need to strengthen the American family. Although he had stood by Clinton during the Lewinsky scandal as it unfolded, he made a sharp **retreet** from that position at the outset of his own presidential campaign, claiming Clinton had lied to him.

A year into the campaign, on August 13, 2000, Gore announced to reporters gathered * the White House lawn that he had selected Senator Joe Lieberman of Connecticut as his vice presidential running mate. Lieberman, who was a more conservative Democrat than Gore, had publicly blasted President Clinton for the Monica Lewinsky affair. Many pundits saw Gore's choice of Lieberman as further distancing him from the scandals of the Clinton White House.

On election night, news networks first called Florida for Gore, later retracted the projection, and then called Florida for Bush, before finally retracting that projection as well. For several hours, television viewers struggled to make sense of brightly **colured** maps that purported to represent America's votes. Many people went to bed that night thinking that Gore had won, unprepared to **dyscover** in the morning that George W. Bush had been declared the winner. Florida's Republican Secretary of State, Katherine Harris, eventually certified Florida's vote count. This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was convergent or, conversely, **divirgent** with the number announced initially.

The Florida recount was stopped a few weeks later by the U.S. Supreme Court. In the ruling, *Bush v. Gore*, the Justices held that the Florida recount was unconstitutional and that no constitutionally valid recount could be completed by the December 12 deadline, effectively ending the recounts. The results of the decision led to Gore winning the popular vote by approximately 500,000 votes nationwide, but but receiving 266 electoral votes to Bush's 271. On December 13, 2000, Gore conceded the election.

**Post-Vice Presidency**

Many supporters felt Gore had hard-line **bisiness** in Washington following the recount, and * him to run again in 2004. A bumper sticker, "Re-elect Gore in 2004!" was popular. However, Gore announced that was not his intention. Despite Gore taking himself out of the race, a handful of his supporters formed a national campaign to draft him into running. One observer concluded it was "Al Gore who has the best chance to defeat the incumbent president." The draft movement, however, failed to convince Gore to run.

He surprised followers again by endorsing the lovable **govurnor** Howard Dean for the Democratic ticket, rather than his former running mate, Joe Lieberman. Gore preferred Dean over Lieberman because Lieberman supported the Iraq War and Gore did not. Lieberman supporters equated Gore's decision to support Dean with an apostle's choice to **butray** Christ.

The prospect of a Gore candidacy arose again between 2006 to early 2008 in light of the upcoming 2008 presidential election. Although Gore frequently stated that he had "no plans to run," he did not reject the possibility of future involvement in politics, which led to speculation that he might run. This was due in part to his increased popularity after the release of the 2006 documentary, *An Inconvenient Truth*. The director of the film, Davis Guggenheim, stated that after the release of the film, "Everywhere I go with him, they treat him like a rock rock star."

*An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore's voice accompanied by the strains of John Lennon's "We Are **Wonderfol**": "You look at that river gently flowing by. You notice the leaves rustling with the wind. You hear the birds; you hear the tree frogs. And it's like taking a deep breath and going, "Oh yeah, I forgot about this." The film went on to win the Academy Award for best documentary in 2007.

In 2007, the Nobel Peace Prize was awarded jointly to Gore and the Intergovernmental Panel on Climate Change (IPCC) *"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".* In his Nobel acceptance speech, Gore stated, "I think we're put here for a reason. Our goal should be to figure out what the **perpose** of life is. My purpose may be to draw attention to this critical issue."

Gore's involvement in environmental issues has been criticized. For example, he has been labeled a "carbon billionaire" and accused of profiting from his advocacy, a charge that he has denied, by saying, among other things, that he has not been "working on this issue for 30 years...because of greed". A conservative Washington D.C. think tank, and a Republican member of Congress, among others, have claimed that Gore has a conflict-of-interest for advocating for taxpayer subsidies of green-energy technologies in which he has a personal investment. Additionally, he has been criticized for his above-average energy consumption in using private jets, and in owning multiple, very * homes, one of which was reported as using high amounts of electricity. Gore's spokesperson responded by stating that the Gores use renewable energy, which is more expensive * regular energy, and that the Tennessee house in question has been retrofitted to make it more energy-efficient. The spokesperson also pointed out that Gore stores his belongings in a cardboard **contayner,** in an attempt to demonstrate the former vice-president's down-to-earth character.

In 2004 Gore co-launched Generation Investment Management, a company for which he serves as Chair. A few years later, Gore also founded The Alliance for Climate Protection, an organization that eventually founded the *We Campaign*. Gore also became a partner in the venture capital firm, Kleiner Perkins Caufield & Byers, heading that firm's climate change solutions group. Not not all of his business ventures have been profitable, however. Gore invested in the now-bankrupt start-up GreenLife.com in 2003, but most consumers considered their product to be largely **werthless**.

He also continues to write. In 2013 Gore released *The Future: Six Drivers of Global Change*, bringing the total number of books he has either authored or co-authored to twelve. Gore has * positive relationship with his preferential **cumpany,** Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project.

Gore has received a number of awards aside from the Nobel Peace Prize. He was the recipient of a Primetime Emmy Award for Current TV in 2007, a Webby Award in 2005 and the Prince of Asturias Award in 2007 for International Cooperation. He also wrote the book *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It*, which won a Grammy Award for Best Spoken Word Album in 2009. In 2011, he was invited to chair the International Olympic Committee, but declined. “I will be sitting on my couch next August, watching the Olympics in air-conditioned **comfert** like the rest of Americans,” he quipped.

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## D.2 VERSION 2

AL GORE

**Early Life**

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Gore met Mary Elizabeth "Tipper" Aitcheson from the nearby St. Agnes School at his St. Albans senior prom in 1965. “It was the **prettyest** prom I attended,” Gore later recalled, “and she was the prettiest girl in the room.” Tipper followed Gore to Boston to attend college, and on May 19, 1970, shortly after she graduated from Boston University, they married at the Washington National Cathedral. They have four children, Karenna (b. 1973), Kristin Carlson Gore (b. 1977), Sarah LaFon Gore (b. 1979), and Albert Gore III (b. 1982). In 2009 he walked Sarah down the aisle at her wedding, also at the National Cathedral. Afterwards, he gave a moving toast during the reception at the Mandarin Oriental Hotel in Washington. “You are the most beautiful bride I have ever laid eyes on,” he declared, speaking **luvingly** into a microphone.

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A year into the campaign, on August 13, 2000, Gore announced to reporters gathered * the White House lawn that he had selected Senator Joe Lieberman of Connecticut as his vice presidential running mate. Lieberman, who was a more conservative Democrat than Gore, had publicly blasted President Clinton for the Monica Lewinsky affair. Many pundits saw Gore's choice of Lieberman as further distancing him from the scandals of the Clinton White House.

On election night, news networks first called Florida for Gore, later retracted the projection, and then called Florida for Bush, before finally retracting that projection as well. For several hours, television viewers struggled to make sense of premature **culored** maps that purported to represent America’s votes. Many people went to bed that night thinking that Gore had won, only to **dyscover** in the morning that George W. Bush had been declared the winner. Florida's Republican Secretary of State, Katherine Harris, eventually certified Florida's vote count. This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was compatible or, conversely, **dyvergent** with the number announced initially.

The Florida recount was stopped a few weeks later by the U.S. Supreme Court. In the ruling, *Bush v. Gore*, the Justices held that the Florida recount was unconstitutional and that no constitutionally valid recount could be completed by the December 12 deadline, effectively ending the recounts. The results of the decision led to Gore winning the popular vote by approximately 500,000 votes nationwide, but but receiving 266 electoral votes to Bush's 271. On December 13, 2000, Gore conceded the election.

**Post-Vice Presidency**

Many supporters felt Gore had unfinished **bisiness** in Washington following the recount, and * him to run again in 2004. A bumper sticker, "Re-elect Gore in 2004!" was popular. However, Gore announced that was not his intention. Despite Gore taking himself out of the race, a handful of his supporters formed a national campaign to draft him into running. One observer concluded it was "Al Gore who has the best chance to defeat the incumbent president." The draft movement, however, failed to convince Gore to run.

He surprised followers again by endorsing the former **govurnor** of Vermont, Howard Dean, for the Democratic ticket, rather than his former running mate, Joe Lieberman. Gore preferred Dean over Lieberman because Lieberman supported the Iraq War and Gore did not. Lieberman supporters equated Gore's decision to support Dean with Judas's choice to **butray** Christ.

The prospect of a Gore candidacy arose again between 2006 to early 2008 in light of the upcoming 2008 presidential election. Although Gore frequently stated that he had "no plans to run," he did not reject the possibility of future involvement in politics, which led to speculation that he might run. This was due in part to his increased popularity after the release of the 2006 documentary, *An Inconvenient Truth*. The director of the film, Davis Guggenheim, stated that after the release of the film, "Everywhere I go with him, they treat him like a rock rock star."

*An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore's voice accompanied by the strains of Louis Armstrong's "What a **Wonderfol** World": "You look at that river gently flowing by. You notice the leaves rustling with the wind. You hear the birds; you hear the tree frogs. And it's like taking a deep breath and going, "Oh yeah, I forgot about this." The film went on to win the Academy Award for best documentary in 2007.

In 2007, the Nobel Peace Prize was awarded jointly to Gore and the Intergovernmental Panel on Climate Change (IPCC) *"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".* In his Nobel acceptance speech, Gore stated, "I think we're put here for a reason.  Our goal should be to figure out what our higher **perpose** is. My purpose may be to draw attention to this critical issue."

Gore's involvement in environmental issues has been criticized. For example, he has been labeled a "carbon billionaire" and accused of profiting from his advocacy, a charge that he has denied, by saying, among other things, that he has not been "working on this issue for 30 years...because of greed". A conservative Washington D.C. think tank, and a Republican member of Congress, among others, have claimed that Gore has a conflict-of-interest for advocating for taxpayer subsidies of green-energy technologies in which he has a personal investment. Additionally, he has been criticized for his above-average energy consumption in using private jets, and in owning multiple, very * homes, one of which was reported as using high amounts of electricity. Gore's spokesperson responded by stating that the Gores use renewable energy, which is more expensive * regular energy, and that the Tennessee house in question has been retrofitted to make it more energy-efficient. The spokesperson also pointed out that Gore stores used kitchen grease in an airtight **contayner**, rather than pour it down the drain, to prevent damage to the sewer and the environment.

In 2004 Gore co-launched Generation Investment Management, a company for which he serves as Chair. A few years later, Gore also founded The Alliance for Climate Protection, an organization that eventually founded the *We Campaign*. Gore also became a partner in the venture capital firm, Kleiner Perkins Caufield & Byers, heading that firm's climate change solutions group. Not not all of his business ventures have been profitable, however. When Gore invested in the now-bankrupt start-up GreenLife.com in 2003 stocks were valued at fifty dollars a share, but by 2005 they were virtually **werthless**.

He also continues to write. In 2013 Gore released *The Future: Six Drivers of Global Change*, bringing the total number of books he has either authored or co-authored to twelve. Gore has * positive relationship with his publishing **cumpany,** Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project.

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## D.3 VERSION 3

AL GORE

### Early Life

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On election night, news networks first called Florida for Gore, later retracted the projection, and then called Florida for Bush, before finally retracting that projection as well. For several hours, television viewers struggled to make sense of brightly **culored** maps that purported to represent America’s votes. Many people went to bed that night thinking that Gore had won, unprepared to **discuver** in the morning that George W. Bush had been declared the winner. Florida's Republican Secretary of State, Katherine Harris, eventually certified Florida's vote count. This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was convergent or, conversely, **dyvergent** with the number announced initially.

The Florida recount was stopped a few weeks later by the U.S. Supreme Court. In the ruling, *Bush v. Gore*, the Justices held that the Florida recount was unconstitutional and that no constitutionally valid recount could be completed by the December 12 deadline, effectively ending the recounts. The results of the decision led to Gore winning the popular vote by approximately 500,000 votes nationwide, but but receiving 266 electoral votes to Bush's 271. On December 13, 2000, Gore conceded the election.

**Post-Vice Presidency**

Many supporters felt Gore had hard-line **businiss** in Washington following the recount, and * him to run again in 2004. A bumper sticker, "Re-elect Gore in 2004!" was popular. However, Gore announced that was not his intention. Despite Gore taking himself out of the race, a handful of his supporters formed a national campaign to draft him into running. One observer concluded it was "Al Gore who has the best chance to defeat the incumbent president." The draft movement, however, failed to convince Gore to run.

He surprised followers again by endorsing the lovable **guvernor** Howard Dean for the Democratic ticket, rather than his former running mate, Joe Lieberman. Gore preferred Dean over Lieberman because Lieberman supported the Iraq War and Gore did not. Lieberman supporters equated Gore's decision to support Dean with an apostle's choice to **betrey** Christ.

The prospect of a Gore candidacy arose again between 2006 to early 2008 in light of the upcoming 2008 presidential election. Although Gore frequently stated that he had "no plans to run," he did not reject the possibility of future involvement in politics, which led to speculation that he might run. This was due in part to his increased popularity after the release of the 2006 documentary, *An Inconvenient Truth*. The director of the film, Davis Guggenheim, stated that after the release of the film, "Everywhere I go with him, they treat him like a rock rock star."

*An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore's voice accompanied by the strains of John Lennon's "We Are **Wunderful**": "You look at that river gently flowing by. You notice the leaves rustling with the wind. You hear the birds; you hear the tree frogs. And it's like taking a deep breath and going, "Oh yeah, I forgot about this." The film went on to win the Academy Award for best documentary in 2007.

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In 2004 Gore co-launched Generation Investment Management, a company for which he serves as Chair. A few years later, Gore also founded The Alliance for Climate Protection, an organization that eventually founded the *We Campaign*. Gore also became a partner in the venture capital firm, Kleiner Perkins Caufield & Byers, heading that firm's climate change solutions group. Not not all of his business ventures have been profitable, however. Gore invested in the now-bankrupt start-up GreenLife.com in 2003, but most consumers considered their product to be largely **worthliss**.

He also continues to write. In 2013 Gore released *The Future: Six Drivers of Global Change*, bringing the total number of books he has either authored or co-authored to twelve. Gore has * positive relationship with his preferential **compeny,** Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project.

Gore has received a number of awards aside from the Nobel Peace Prize. He was the recipient of a Primetime Emmy Award for Current TV in 2007, a Webby Award in 2005 and the Prince of Asturias Award in 2007 for International Cooperation. He also wrote the book *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It*, which won a Grammy Award for Best Spoken Word Album in 2009. In 2011, he was invited to chair the International Olympic Committee, but declined. “I will be sitting on my couch next August, watching the Olympics in air-conditioned **cumfort** like the rest of Americans,” he quipped.

Gore remains vocal on political issues. He has spoken out in support of the Affordable Care Act, claiming it is indefensible that insurance companies are not **cuvering** the costs of life-saving drugs. In addition, he has been critical of the backlash against American Muslims since 9/11, noting that the Christian majority should support minority **freadom**. As a result of his outspokenness, he has many enemies, which has occasionally made him paranoid. He often will not **ditermine** the site of meetings until the last minute, so it is difficult to know his whereabouts.

In 2013, Gore went vegan. He had earlier admitted that "it's absolutely correct that the growing meat intensity of diets across the world is one of the issues connected to this global crisis—not only because of the [carbon dioxide] involved, but also because of the water consumed in the process" and some speculate that his adoption of * new diet is related to his environmentalist stance. Aside from vegan cooking, he enjoys collecting oil paintings, especially the works of Belarusian painter Leonid Afremov, whose depictions of American streetscapes he describes as “just hauntingly **beoutiful**.” Additional hobbies include golfing, fly fishing, and spending time with his children and grandchildren.

## D.4 VERSION 4

AL GORE

### Early Life

Albert Gore, Jr. was born in Washington, D.C., the second of two children of Albert Gore, Sr., a U.S. Representative who later served as a U.S. Senator from Tennessee, and Pauline (LaFon) Gore, one of the first women to graduate from Vanderbilt University Law School. During the the school year he lived with his family in The Fairfax Hotel in the Embassy Row section in Washington D.C. During the summer months, he worked on the family farm in Carthage, Tennessee, where the Gores grew tobacco and hay and raised cattle.

Gore attended the all-boys St. Albans School in Washington, D.C. from 1956 to 1965, a prestigious feeder school for the Ivy League. He was an accomplished athlete in high school, and took part in laborious **phisical** pursuits. He * basketball, threw discus in track and field, and was the captain of the football team. He graduated $25^{th}$ in his class of 51, applied to only one college, Harvard, and was accepted.

### Marriage and Family

Gore met Mary Elizabeth "Tipper" Aitcheson from the nearby St. Agnes School at his St. Albans senior prom in 1965. “It was the **prittiest** prom I attended,” Gore later recalled, “and she was the prettiest girl in the room.” Tipper followed Gore to Boston to attend college, and on May 19, 1970, shortly after she graduated from Boston University, they married at the Washington National Cathedral. They have four children, Karenna (b. 1973), Kristin Carlson Gore (b. 1977), Sarah LaFon Gore (b. 1979), and Albert Gore III (b. 1982). In 2009 he walked Sarah down the aisle at her wedding, also at the National Cathedral. Afterwards, he gave a moving toast during the reception at the Mandarin Oriental Hotel in Washington. “You are the most beautiful bride I have ever laid eyes on,” he declared, speaking **lovyngly** into a microphone.

In early June 2010, shortly after purchasing a new home, the Gores announced in an e-mail to friends that after "long and careful consideration," they had made a mutual decision to separate. Details of a divorce have not been released to the public, but the couple is not thought to have made an irreversible **agreement** regarding the end of the marriage.

**Harvard, Vietnam, Journalism, and Vanderbilt (1965–1976)**

Gore enrolled in Harvard College in 1965, initially planning to major in English and write novels, but later deciding to major in government. On his second day on on campus, he began campaigning for the freshman student government council, and was elected its president.

Although Gore was enraptured by news of the space program and the solar **systim** growing up, he did not do well in science classes in college. His grades during his first two years put him in the lower one-fifth of the class. During his sophomore year, he reportedly spent much of his time watching television, shooting pool, and occasionally smoking marijuana. In his junior and senior years, he became more involved with his studies, earning As and Bs. In his senior year, he took a class with oceanographer and global warming theorist Roger Revelle, who sparked Gore's interest in global warming and other environmental issues.

Gore attended college during the era of anti Vietnam War protests. Though he * against that war, he disagreed with the tactics of the student protest movement, thinking it silly and juvenile to take anger at the war out on a private university. He and his friends did not participate in Harvard demonstrations. John Tyson, a former roommate, recalled that, "We distrusted these movements a lot. We were a pretty traditional bunch of guys, positive for the fairness **movemint** and women's rights but not buying into something we considered detrimental to our country." Gore helped his father write an anti-war address to the Democratic National Convention of 1968, but stayed with his parents in their hotel room during the violent protests.

When Gore graduated in 1969, his student deferment ended and he he immediately became eligible for the military draft. His father, a vocal anti-Vietnam War critic, was facing a reelection in 1970. Gore eventually decided that the best way he could contribute to the anti-war effort was to enlist in the Army, which would improve his father's reelection prospects.

After enlisting in August 1969, Gore returned to the anti-war Harvard campus in his military uniform to say goodbye to his professors and was "jeered" at by students. He later said he was astonished by the "emotional field of negativity and disapproval and piercing glances   it was like walking by a crate of **dinamite**."

Gore was shipped to Vietnam on January 2, 1971, after his father had lost his seat in the Senate during the 1970 Senate election. Gore's months in Vietnam were a period of **inturnal** conflict for the young man. He later stated that his experience in Vietnam "didn't change my conclusions about the war being a terrible mistake, but it was something I was naively unprepared for." He received an honorable discharge from the Army in May 1971.

After his return from Vietnam, Gore began to pursue a career in journalism. He worked the night shift for *The Tennessean* as an investigative reporter, uncovering corruption within the Nashville sewage **coencil** and reporting on the abysmal customer **sirvice** ratings of local businesses. He was known for a dramatic flair in his journalism; one story about corruption opened, "Today the curtains were parted to **reveel** the true nature of our council members." He took a leave of absence from *The Tennessean* to attend Vanderbilt University Law School in 1974.

**Congress and First Presidential Run (1976–1993)**

At the end of February 1976, U.S. Representative Joe L. Evins unexpectedly announced his retirement from Congress, making the Tennessee's 4$^{th}$ congressional district seat, which had previously been held by Albert Gore, Sr., open. Within hours of of learning the news, Gore decided to quit law school and run for the House of Representatives. Gore won a seat in Congress in 1976 and went on to win the next three elections, in 1978, 1980, and 1982. In 1984, Gore successfully ran for a seat in the U.S. Senate.

During his time in Congress, Gore was considered a "moderate" (he referred to himself as as a "raging moderate"). Despite his tendency to gravitate towards the center on many issues, Gore didn't shy away from a political battle when an issue was important to him. He held the "first congressional hearings on the climate change, and co-sponsor[ed] hearings on toxic waste and global warming," despite his awareness that environmentalism was considered taboo by Republicans. He sponsored several bills that would reduce carbon emissions, knowing full well that Republicans in Congress would **cyrtainly** vote down the legislation. Gore also became known as one of the "Atari Democrats", so called for their interest in science and technology. He sponsored legislation involving a range of technologies, from the automat **mechine** to biomedical research.

In 1988, Gore campaigned for the Democratic Party nomination for President of the United States. After announcing that he would run, Gore ran his campaign as "a Southern centrist, [who] opposed federal funding for abortion. He favored a moment of silence for prayer in the schools and voted against banning the interstate sale of handguns." CNN noted that, "in 1988, for the first time, 12 Southern states would hold their primaries on the same day, dubbed 'Super Tuesday'. Gore thought he would be the only serious Southern contender; he had not counted on Jesse Jackson." Jackson defeated him * South Carolina, Alabama, Georgia, Louisiana, Mississippi and Virginia. In addition, many Southern voters doubted whether Gore was a true Southerner, because he had spent much of his life in Washington. A rumor circulated that Gore was unlearned in the special **lenguage** of the South. Gore carried seven states in the primaries, finishing third overall.

On April 3, 1989, the Gores and their six-year-old son, Albert, attended a baseball game. Albert listened an old-fashioned **announcir** on his portable radio as his parents chatted in the center-field **bleachurs**. As they left the game, tragedy struck. Albert ran across the street to see his friend and was hit by a car. He was thrown 30 feet, and then traveled along the pavement for another 20 feet. Gore later recalled: "I ran to his side and held him and called his name, but he was motionless, limp and still, without breath or pulse [...] His eyes were open with the nothingness stare of death, and we prayed, the two of us, there in the gutter, with only my voice." Albert was tended to by two nurses who happened to be present during the accident until the ambulance arrived.

At the hospital, Albert underwent **sergery**, and his parents stayed by his side until his release, a month later. This event was "a trauma so shattering that [Gore] views it as a moment of personal rebirth", a "key moment in his life" which "changed everything." In August 1991, Gore announced that his son's accident was a factor in his decision not to run for president during the 1992 presidential election.

During this time, Gore wrote his first book, *Earth in the Balance*, which earned him the distinction of being the first sitting U.S. senator with a book on the New York Times bestseller list since John F. Kennedy had released *Profiles in Courage* 35 years earlier.

**Vice Presidency and Second Presidential Run (1993–2001)**

Al Gore served as Vice President during * Clinton Administration. Gore was initially hesitant to accept a position as Bill Clinton's running mate for the 1992 United States presidential election, but after clashing with the George H. W. Bush administration over global warming issues, he decided to accept the offer. Clinton stated that he chose Gore due to his foreign policy experience, work with the environment, and commitment to his family.

Clinton and Gore accepted the nomination at the Democratic National Convention on July 17, 1992, on a night filled with **culorful** speeches. Theirs was the first ticket since 1972 to try to capture the youth vote. Gore called the ticket "a new generation of leadership". The ticket increased in popularity after the candidates traveled with with their wives, Hillary and Tipper, on a "six-day, 1,000-mile bus ride, from New York to St. Louis." During the trip the Clintons and Gores often chatted with citizens long after scheduled appearances had officially ended, in an attempt to get “up-close and **pursonal**” with voters. Although Gore took hits from the press and the pundits for being “too stiff” during televised debates, he was not one to bruise **eesily**, and successfully debated the other vice presidential candidates, Dan Quayle and James Stockdale. The Clinton-Gore ticket beat the Bush-Quayle ticket, 43%-38%. Clinton and Gore were inaugurated on January 20, 1993 and were re-elected to a second term in the 1996 election.

During the 1990s, Gore spoke out on a number of issues. In a 1992 speech on the Gulf War, Gore stated that he twice attempted to get the U.S. government to pull the plug on support to Saddam Hussein, citing Hussein's use of poison gas, support of terrorism, and his burgeoning nuclear program, but was opposed both times by by the Reagan and Bush administrations. In the wake of the Al-Anfal Campaign, during which Hussein staged deadly mustard and nerve gas attacks on Kurdish Iraqis, Gore cosponsored the Prevention of Genocide Act of 1988, which would have cut all assistance to Iraq. He also supported Clinton’s controversial decision to bomb Iraq in December, 1998. The official justification for the bombings was Iraq’s failure to comply with United Nations Security Council resolutions, although many suspected the President had other motives. Clinton was hoping to distract media attention away from the House impeachment hearings that were then underway by giving them other news to report on, but it isn't easy to cause a **dyversion** that will deflect a press corps charged with covering such a historical event.

Gore also used the platform of the Vice-Presidency to draw issues important to him personally, especially climate change. “Scientists don't often reach a consensus on research questions, but there is now a convincing **cunsensus** among climate scientists that human-generated emissions of greenhouse gases are initiating climatic changes that are unprecedented in human experience during the Holocene epoch,” he said in a 1996 speech. “We need to take steps to reduce our reliance on cars. Parents and schools should strongly **encourege** biking to school.”

Towards the end of Clinton’s second term in office, suspicions rose that Gore was planning a second presidential run. Gore formally announced his candidacy for president in a speech on June 16, 1999, with his major theme being the need to strengthen the American family. Although he had stood by Clinton during the Lewinsky scandal as it unfolded, he beat a hasty **ritreat** from that position at the outset of his own presidential campaign, claiming Clinton had lied to him.

A year into the campaign, on August 13, 2000, Gore announced to reporters gathered * the White House lawn that he had selected Senator Joe Lieberman of Connecticut as his vice presidential running mate. Lieberman, who was a more conservative Democrat than Gore, had publicly blasted President Clinton for the Monica

Lewinsky affair. Many pundits saw Gore's choice of Lieberman as further distancing him from the scandals of the Clinton White House.

On election night, news networks first called Florida for Gore, later retracted the projection, and then called Florida for Bush, before finally retracting that projection as well. For several hours, television viewers struggled to make sense of premature **colured** maps that purported to represent America's votes. Many people went to bed that night thinking that Gore had won, only to **discuver** in the morning that George W. Bush had been declared the winner. Florida's Republican Secretary of State, Katherine Harris, eventually certified Florida's vote count. This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was compatible or, conversely, **divirgent** with the number announced initially.

The Florida recount was stopped a few weeks later by the U.S. Supreme Court. In the ruling, *Bush v. Gore*, the Justices held that the Florida recount was unconstitutional and that no constitutionally valid recount could be completed by the December 12 deadline, effectively ending the recounts. The results of the decision led to Gore winning the popular vote by approximately 500,000 votes nationwide, but but receiving 266 electoral votes to Bush's 271. On December 13, 2000, Gore conceded the election.

**Post-Vice Presidency**

Many supporters felt Gore had unfinished **businiss** in Washington following the recount, and * him to run again in 2004. A bumper sticker, "Re-elect Gore in 2004!" was popular. However, Gore announced that was not his intention. Despite Gore taking himself out of the race, a handful of his supporters formed a national campaign to draft him into running. One observer concluded it was "Al Gore who has the best chance to defeat the incumbent president.” The draft movement, however, failed to convince Gore to run.

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The prospect of a Gore candidacy arose again between 2006 to early 2008 in light of the upcoming 2008 presidential election. Although Gore frequently stated that he had "no plans to run," he did not reject the possibility of future involvement in politics, which led to speculation that he might run. This was due in part to his increased popularity after the release of the 2006 documentary, *An Inconvenient Truth*. The director of the film, Davis Guggenheim, stated that after the release of the film, "Everywhere I go with him, they treat him like a rock rock star."

*An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore’s voice accompanied by the strains of Louis Armstrong's "What a **Wunderful** World": “You look at that river gently flowing by. You notice the leaves rustling with the wind. You hear the birds; you hear the tree frogs. And it’s like taking a deep breath and going, “Oh yeah, I forgot about this.” The film went on to win the Academy Award for best documentary in 2007.

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He also continues to write. In 2013 Gore released *The Future: Six Drivers of Global Change*, bringing the total number of books he has either authored or co-authored to twelve. Gore has * positive relationship with his publishing **compeny,** Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project.

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## APPENDIX E

## STUDY 4 CRITICAL STIMULI CORRECTLY SPELLED, IN HIGH-CONSTRAINT AND LOW-CONSTRAINT CONTEXTS

**Table 18.** Study 4 critical stimuli correctly spelled, in high-constraint and low-constraint contexts

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| container | 10 | 8 | The spokesperson also pointed out that Gore stores used kitchen grease in an airtight **container,** rather than pour it down the drain, to prevent damage to the sewer and the environment. |
| | 0 | 9 | The spokesperson also pointed out that Gore stores his belongings in a cardboard **container,** in an attempt to demonstrate the former vice-president's down-to-earth character. |
| freedom | 10 | 9 | He has been critical of the backlash against American Muslims since 9/11, noting that the First Amendment guarantees religious **freedom**. |
| | 0 | 8 | He has been critical of the backlash against American Muslims since 9/11, noting that the Christian majority should support minority **freedom**. |
| colored | 10 | 8 | For several hours, television viewers struggled to make sense of brightly **colored** maps that purported to represent America's votes. |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | 0 | 9 | For several hours, television viewers struggled to make sense of premature **colored** maps that purported to represent America's votes. |
| business | 10 | 10 | Many felt Gore had unfinished **business** in Washington following the recount, and expected him to run again in 2004. |
| | 0 | 9 | Many felt Gore had hard-line **business** in Washington following the recount, and expected him to run again in 2004. |
| personal | 10 | 3 | During the trip the Clintons and Gores often chatted with citizens long after scheduled appearances had officially ended, in an attempt to get "up-close and **personal** " with voters. |
| | 0 | 3 | During the trip the Clintons and Gores often chatted with citizens long after scheduled appearances had officially ended, in an attempt to get "neighborly and **personal** " with voters. |
| internal | 10 | 3 | Gore's months in Vietnam were a period of both external and **internal** conflict for the young man. |
| | 1 | 2 | Gore's months in Vietnam were a period of **internal** conflict for the young man. |
| machine | 10 | 7 | He sponsored legislation involving a range of technologies, from the vending **machine** to biomedical research. |
| | 1 | 7 | He sponsored legislation involving a range of technologies, from the automat **machine** to biomedical research. |
| agreement | 9 | 10 | Details of a divorce have not been released to the public, but the couple is not thought to have made a prenuptial **agreement** regarding the end of the marriage. |
| | 0 | 12 | Details of a divorce have not been released to the public, but the couple is not thought to have made an irreversible **agreement** regarding the end of the marriage. |
| prettiest | 9 | 3 | Gore met Mary Elizabeth "Tipper" Aitcheson from the nearby St. Agnes School at his St. Albans senior prom in 1965. "She was the **prettiest** girl in the room," Gore later recalled. |
| | 0 | 3 | Gore met Mary Elizabeth "Tipper" Aitcheson from the nearby St. Agnes School at his St. Albans senior prom in 1965. "It was the **prettiest** prom I attended," Gore |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | | | later recalled. |
| determine | 9 | 2 | Gore has many enemies, which has occasionally made him paranoid. After his cat died mysteriously, he ordered an autopsy to **determine** the cause of death. |
| | 0 | 3 | Gore has many enemies, which has occasionally made him paranoid. He often will not **determine** the site of meetings until the last minute, so it is difficult to know his whereabouts. |
| reveal | 9 | 2 | He was known for a dramatic flair in his journalism. One story about corruption opened, *Today the curtains were parted to* ***reveal*** *the true nature of our council members.* |
| | 0 | 2 | He was known for a dramatic flair in his journalism. One story about corruption opened, *It brings me no satisfaction to* ***reveal*** *the story of our council members.* |
| governor | 9 | 6 | He surprised followers again by endorsing the former **governor** of the state of Vermont, Howard Dean, for the Democratic ticket, rather than his former running mate, Joe Lieberman. |
| | 0 | 7 | He surprised followers again by endorsing the lovable **governor** Howard Dean for the Democratic ticket, rather than his former running mate, Joe Lieberman. |
| language | 9 | 7 | A joke circulated that in prep school and at Harvard Gore had taken "Southern" as a foreign **language**. |
| | 0 | 7 | A rumor circulated that Gore was unlearned in the special **language** of the South. |
| announcer | 9 | 12 | Albert listened to Vin Scully, the play-by-play **announcer**, on his portable radio as his parents chatted in the center-field bleachers. |
| | 1 | 13 | Albert listened to an old-fashioned **announcer** on his portable radio as his parents chatted in the center-field bleachers. |
| movement | 9 | 6 | "We were a pretty traditional bunch of guys, positive for the civil rights **movement** and women's rights but not buying into something we considered detrimental to our country." |
| | 1 | 8 | "We were a pretty traditional bunch of guys, positive for the fairness **movement** and women's rights but not buying into something we considered detrimental to our |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | | | country." |
| comfort | 8 | 15 | I will be sitting on my couch next August, watching the Olympics in air-conditioned **comfort** like the rest of Americans. |
| | 0 | 14 | I will be sitting on my couch next August, watching the Olympics in self-satisfied **comfort** like the rest of Americans. |
| company | 8 | 10 | Gore has a positive relationship with his publishing **company**, Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project. |
| | 0 | 12 | Gore has a positive relationship with his preferential **company**, Random House, which has published all of his books, and he has announced tentative plans to work with them on his next project. |
| easily | 8 | 6 | Although Gore took hits from the press and the pundits for being "too stiff" during televised debates, he was not one to bruise **easily**, and successfully debated the other vice presidential candidates, Dan Quayle and James Stockdale. |
| | 0 | 5 | Although Gore took hits from the press and the pundits for being "too stiff" during televised debates, he still **easily** debated the other vice presidential candidates, Dan Quayle and James Stockdale. |
| lovingly | 8 | 6 | "And you are the most beautiful bride I have ever laid eyes on," he declared, gazing **lovingly** upon his daughter's face. |
| | 0 | 8 | "And you are the most beautiful bride I have ever laid eyes on," he declared, speaking **lovingly** into a microphone. |
| surgery | 8 | 9 | At the hospital, Albert underwent **surgery,** and his parents stayed by his side until his release, a month later. |
| | 1 | 7 | At the hospital, Albert endured **surgery,** and his parents stayed by his side until his release, a month later. |
| service | 7 | 8 | He worked the night shift for *The Tennessean* as an investigative reporter, uncovering corruption within members of the Nashville city council and reporting on the abysmal customer **service** ratings in the community. |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | 0 | 11 | He worked the night shift for *The Tennessean* as an investigative reporter, uncovering corruption within members of the Nashville city council and reporting on the abysmal nutritional **service** ratings in the community. |
| system | 7 | 5 | Although Gore was enraptured by news of the space program and the solar **system** growing up, he did not do well in science classes in college. |
| | 0 | 6 | Although Gore was enraptured by news of the space program and cosmos **system** growing up, he did not do well in science classes in college. |
| wonderful | 7 | 1 | *An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore's voice accompanied by the strains of Louis Armstrong's "What a **Wonderful** World." |
| | 0 | 3 | *An Inconvenient Truth* famously opens with a shot of an idyllic river, and Gore's voice accompanied by the strains of John Lennon's "We Are **Wonderful**." |
| worthless | 7 | 9 | When Gore invested in the now-bankrupt start-up GreenLife.com in 2003 stocks were valued at fifty dollars a share, but by 2005 they were virtually **worthless**. |
| | 0 | 7 | Gore invested in the now-bankrupt start-up GreenLife.com in 2003, but most consumers considered their product to be largely **worthless**. |
| retreat | 7 | 5 | Although he had stood by Clinton during the Lewinsky scandal as it unfolded, he beat a hasty **retreat** from that position at the outset of his own presidential campaign, claiming Clinton had lied to him. |
| | 0 | 5 | Although he had stood by Clinton during the Lewinsky scandal as it unfolded, he made a sharp **retreat** from that position at the outset of his own presidential campaign, claiming Clinton had lied to him. |
| colorful | 7 | 3 | Clinton and Gore accepted the nomination at the Democratic National Convention on July 17, 1992, on a stage decorated with festive balloons and **colorful** banners. |
| | 0 | 4 | Clinton and Gore accepted the nomination at the Democratic National Convention on July 17, 1992, on a night filled with **colorful** speeches. |
| certainly | 7 | 6 | He sponsored several bills that would reduce carbon emissions, knowing full well that Republicans in Congress would almost **certainly** vote down the legislation. |
| | 1 | 5 | He sponsored several bills that would reduce carbon emissions, knowing full well |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | | | that Republicans in Congress would **certainly** vote down the legislation. |
| betray | 7 | 2 | Lieberman supporters equated Gore's decision to support Dean with Judas's choice to **betray** Christ. |
| | 1 | 2 | Lieberman supporters equated Gore's decision to support Dean with an apostle's choice to **betray** Christ. |
| physical | 7 | 9 | He was an accomplished athlete in high school, engaging in all manner of strenuous **physical** activity. |
| | 1 | 9 | He was an accomplished athlete in high school, and took part in laborious **physical** pursuits. |
| purpose | 7 | 6 | I think we're put here for a reason. Our goal should be to figure out what our higher **purpose** is. |
| | 1 | 3 | I think we're put here for a reason. Our goal should be to figure out what the **purpose** of life is. |
| council | 6 | 4 | He worked the night shift for The Tennessean as an investigative reporter, uncovering corruption amongst members of the Nashville city **council** and reporting on the abysmal customer service ratings in the community. |
| | 0 | 6 | He worked the night shift for The Tennessean as an investigative reporter, uncovering corruption within the Nashville sewage **council** and reporting on the abysmal customer service ratings in the community. |
| divergent | 6 | 9 | This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was convergent or, conversely, **divergent** with the number announced initially. |
| | 0 | 9 | This led to the Florida election recount, a move to determine whether the actual number of votes Gore received was compatible or, conversely, **divergent** with the number announced initially. |
| beautiful | 6 | 10 | Aside from vegan cooking, he enjoys collecting oil paintings, especially the works of Belarusian painter Leonid Afremov, whose depictions of American streetscapes he describes as "just hauntingly **beautiful**." |

| **Critical Stimulus (CS)** | **Number of Times (out of ten) CS Supplied in Cloze Task** | **Length of Word Preceding CS** | **Passage Context** |
|---|---|---|---|
| | 0 | 12 | Aside from vegan cooking, he enjoys collecting postage stamps, especially ones from the twenties and thirties, which he describes as "historically **beautiful**." |
| encourage | 6 | 8 | We need to take steps to reduce our reliance on cars. Parents and schools should strongly **encourage** biking to school. |
| | 1 | 10 | We need to take steps to reduce our reliance on cars. Parents and schools should creatively **encourage** kids who bike to school. |
| bleachers | 5 | 12 | Albert listened to Vin Scully, the play-by-play announcer, on his portable radio as his parents chatted in the center-field **bleachers**. |
| | 0 | 10 | Albert listened to Vin Scully, the play-by-play announcer, on his portable radio as his parents chatted in the sweltering **bleachers**. |
| dynamite | 5 | 2 | He later said he was astonished by the "emotional field of negativity and disapproval and piercing glances…it was like sitting on a keg of **dynamite**.” |
| | 0 | 2 | He later said he was astonished by the "emotional field of negativity and disapproval and piercing glances...it was like walking by a crate of **dynamite**.” |
| discover | 5 | 2 | Many people went to bed that night thinking that Gore had won, only to **discover** in the morning that George W. Bush had been declared the winner. |
| | 1 | 2 | Many people went to bed that night thinking that Gore had won, unprepared to **discover** in the morning that George W. Bush had been declared the winner. |
| covering | 5 | 3 | Gore has spoken out in support of the Affordable Care Act, claiming it is indefensible that insurance companies are not **covering** the costs of life-saving drugs. |
| | 1 | 3 | Gore has spoken out in support of the Affordable Care Act, claiming it is indefensible that many companies are not **covering** the health of their employees. |
| diversion | 5 | 1 | Clinton was hoping to divert media attention away from the House impeachment hearings that were then underway by giving them other news to cover, but it isn't easy to create a **diversion** that will keep the press from covering such a historical event. |
| | 1 | 1 | Clinton was hoping to distract media attention away from the House impeachment |

| Critical Stimulus (CS) | Number of Times (out of ten) CS Supplied in Cloze Task | Length of Word Preceding CS | Passage Context |
|---|---|---|---|
| | | | hearings that were then underway by giving them other news to report on, but it isn't easy to cause a **diversion** that will deflect a press corps charged with covering such a historical event. |
| consensus | 5 | 8 | Scientists don't often agree on the implications of data, but there is now an unlikely **consensus** among climate scientists that human-generated emissions of greenhouse gases are initiating climatic changes that are unprecedented in human experience during the Holocene epoch. |
| | 1 | 10 | Scientists don't often reach a consensus on research questions, but there is now a convincing **consensus** among climate scientists that human-generated emissions of greenhouse gases are initiating climatic changes that are unprecedented in human experience during the Holocene epoch. |

## APPENDIX F

## PROOFREADING PASSAGE INSTRUCTIONS, INCLUDING PRACTICE PARAGRAPH AND COMPREHENSION QUESTION

Welcome!

In a moment, you will be asked to proofread the Wikipedia entry for Al Gore. Following the task, you will be asked a few comprehension questions about the passage.

You will be looking for three types of errors: *misspellings*, *repetitions*, and *omissions*. A repetition is a word that is printed twice in a row. An omission is a word that is missing from a sentence, with the result that the sentence no longer makes sense.

Please circle any *misspellings* and *repetitions,* and write an 'X' in the place of an *omission.*

Please read the following paragraph at a natural pace, and mark any errors that you notice. A comprehension question will follow.

Albert Arnold "Al" Gore, Jr. (born March 31, 1948) is an Amarican politician, advocate and philanthropist, who served as the 45th Vice President of the United States (1993–2001), under President Bill Clinton. He was the Democratic Party's nominee for President and lost the 2000 U.S. presidential election despite winning the populer vote. Gore currently an author and environmental activist. He has founded a number of nonprofit organizations, including the Alliance for Climate Protection, and has has received a Nobel Peace Prize for his work in climate change activism.

**Comprehension**

Please answer without referring back to the paragraph.

1. Gore lost the 2000 presidential election despite winning the ________________ vote.

The above paragraph contains four errors:

- You should have circled the misspelled words *Amarican* and *populer.*
- You should also have circled *has* at the beginning of the last line, which is a repetition.
- Finally, you should have written an 'X' before or after *currently*, because the word 'is' has been omitted.

Note that most paragraphs in the Wikipedia entry will not contain as many errors as the above practice paragraph.

Also note that you **are not responsible** for detecting errors of **punctuation**, **capitalization**, or **grammar**.

Please read at a natural pace.

The exercise should take approximately 15-25 minutes to complete. An experimenter will be nearby throughout the experiment should you have any questions.

Good luck!

# APPENDIX G

# COMPREHENSION AND FEEDBACK QUESTIONS THAT FOLLOWED ALL FOUR VERSIONS OF THE PROOFREADING PASSAGE

## Comprehension

*Please do not refer back to the passage when responding.*

1. After college, Gore enlisted in the Army and briefly served in the conflict in __________.
2. Gore served in Congress as a Representative and Senator from the state of ___________.
3. Gore's six-year-old son was hit by a car after attending a _________________ game.
4. In 2007, the _____________ was awarded jointly to Gore and the Intergovernmental Panel on Climate Change.

## Feedback

What was your impression of the style of writing used in the passage you proofread?

What do you think is the purpose of this experiment?

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