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The Detection and Retrieval of Spelling in Older Adults

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Abstract

This chapter reviews research on spelling abilities in older adults, an area of psychological research that has received little attention. Of the few studies conducted, the results have demonstrated an age-linked asymmetry between the detection and retrieval of spelling (MacKay & Abrams, 1998; MacKay, Abrams, & Pedroza, 1999): Older adults are able to detect words as either correctly spelled or misspelled, but are less accurate in retrieving both the correct spellings and the recently presented misspellings from memory. However, whether this spelling asymmetry is generalizable to all older adults uniformly and to multiple types of misspellings is unknown. We therefore investigated this age-linked spelling asymmetry in young (18-22 years), young-old (61-72 years), and old-old (73-85 years) adults using misspellings that were either phonologically compatible with a real word (e.g., *dirt* misspelled as *dert*), or were phonologically incompatible (e.g., *dort*). The results demonstrated that preservation of misspelling detection and retrieval in old age was less likely for both groups of older adults, with larger declines for old-old adults for both types of misspellings. These data are consistent with age-related declines in other cognitive tasks (e.g., Schaie, 1996) and suggest that old-old adults rely more heavily on phonological information and long-term memory when visual spelling tasks are made more difficult.

The Detection and Retrieval of Spelling in Older Adults

In general, research on spelling has received considerably less attention than research on reading, despite an increase in research investigating the cognitive processes involved in spelling over the past 15 years (Brown & Ellis, 1994). One explanation for the lack of research in this area is that spelling ability was largely viewed as a visually-based skill that did not require higher-level linguistic processes. A more recent claim is that spelling is a language-based skill that utilizes complex cognitive processes, similar to those involved in reading (e.g., Kamhi & Hinton, 2000), suggesting that processes underlying spelling are worthy of exploration. Furthermore, most of spelling research emphasizes the development of spelling in both normal and impaired populations, focusing on younger children in elementary grades (Barry, 1994). With respect to the other end of the lifespan, the literature on spelling and aging is sparse and has only begun to develop in recent years. The present chapter examines this literature and presents a new experiment that assesses the impact of aging on perception and production of spelling.

Only a few recent studies have investigated age-related declines in spelling (e.g., Abrams, White, McDermott, & Wolf, 2000; MacKay & Abrams, 1998; MacKay et al., 1999; Stuart-Hamilton & Rabbitt, 1997). Research on spelling and aging falls into two categories: spelling detection and spelling retrieval. Spelling detection refers to the ability to recognize a word as correctly or incorrectly spelled. Spelling retrieval refers to the ability to produce the spelling of a word from memory. Across these few studies, an interesting asymmetry between detection and retrieval of spelling occurs: Older adults show little or no decline in detecting words as correctly or incorrectly spelled, but they have difficulty retrieving those spellings from memory (e.g., MacKay et al., 1999). This pattern supports other age-linked asymmetries found in language comprehension and production: many comprehension processes are intact in aging, whereas many production processes exhibit large age declines (see Burke & MacKay, 1997; Burke, MacKay, & James, 2000; Fleischman & Gabrielli, 1998; MacKay & Abrams, 1996, for reviews), similar to age differences in memory for recognition versus recall (e.g., Craik & McDowd, 1987).

The research on spelling detection and aging (Abrams et al., 2000; MacKay et al., 1999) has assessed spelling detection in older adults in two ways. In MacKay et al. (1999), young adults (17-23 years) and older adults (62-85 years) saw words one at a time on a computer screen for a brief period (e.g., 290-390 ms for older adults), where the words were either spelled correctly or were misspelled by adding a single letter, e.g., *elderkly*. When asked to judge whether each word was correctly spelled, young and older adults were equivalently accurate, both for correctly-spelled and misspelled words. In Abrams et al. (2000), young adults (18-25 years) and older adults (60-86 years) took a multiple-choice recognition test, where they attempted to identify a correctly spelled word presented among four plausible misspellings of that word. In this task, older adults exhibited greater accuracy than young adults in recognizing correctly spelled words.

The research on retrieval of spelling in old age is more homogeneous in its methodology (MacKay & Abrams, 1998; Stuart-Hamilton & Rabbitt, 1997; but see MacKay et al., 1999, for an exception). In these studies, words were presented auditorily, and participants were asked to write down the correct spellings of these words. The results of these studies consistently demonstrated an age-related decline in the ability to retrieve spellings from memory. For example, Stuart-Hamilton and Rabbitt (1997) asked adults in their 50s, 60s, and 70s to spell 10 low-frequency words and 10 high-frequency words presented auditorily. They found a significant decline across these age groups in spelling low-frequency words but not in high-frequency words, and this age decline could not be explained by covarying years of education or level of vocabulary.

MacKay and Abrams (1998) conducted a similar spelling retrieval task with two groups of older adults as well as a group of college students. They auditorily presented 20 low-frequency and 20 high-frequency words and asked young adults (aged 17-23), young-old adults (aged 60-71) and old-old adults (aged 73-88) to write down the correct spellings of these words. Using vocabulary as a covariate, they found that both groups of older adults had significantly poorer retrieval of spelling than the young adults, for both high- and low-frequency words. In categorizing the types of spelling errors that were made, they also found age declines such that both groups of older adults more often misspelled irregularly-spelled letter combinations (e.g., *ea* for the sound /ĕ/) by regularizing them, e.g., spelling *pagent* instead of *pageant*. Further, old-old adults misspelled regularly-spelled letter combinations (e.g., the g in *pageant* as *padgeant*) more often than young adults. MacKay et al. (1999) assessed retrieval by having participants detect the word as correctly or incorrectly spelled and then immediately write down the word exactly as presented. Even when older adults gave the correct response on the detection task, their retrieval of these spellings (that they had just seen) was significantly poorer than young adults, both for correctly-spelled words and misspelled words.

Together, these results demonstrate an age-linked asymmetry between the perception (as measured by detection) and the production (as measured by retrieval) of spelling, where perception is spared and production is impaired in aging. Further, these data suggest some specific avenues for future research, which we address in our present study. First, data on old-old adults is noticeably absent from the detection studies. For example, the stability of spelling detection processes in MacKay et al. (1999) was based on a sample of older adults with a mean age of 70.3 years, a group of young-old adults on average. One question of interest is whether old-old adults demonstrate intact spelling detection processes similar to young-old adults. Old-old adults in their upper 70s and 80s show larger age-related declines in many cognitive tasks relative to young-old adults, both in longitudinal studies (e.g., Baltes & Mayer, 1999; Schaie, 1996) and in cross-sectional studies (e.g., Davis et al., 1990; MacKay & Abrams, 1998; White & Abrams, 2002); however, many of these studies involve a production or retrieval component.

Second, the parallels between retrieval of correct spellings and retrieval of misspellings in MacKay et al. (1999) are somewhat surprising. For words presented as correctly spelled, those spellings can be retrieved from long-term memory, where spellings have been stored for many years. For words presented as misspelled, those spellings can only be correctly retrieved from working memory. Therefore, one might expect retrieval of correct spellings to be preserved in older adults, but that retrieval of misspellings may decline if working memory has an increased load, given older adults' reduced working memory capacity (Craik, 1983) and slowed processing speed (e.g., Salthouse, 1996). To increase the constraints placed on working memory, the present study used faster presentation times than those used in MacKay et al. (1999).

Lastly, little is known about how different types of misspellings interact with aging to influence spelling detection and retrieval. MacKay et al. (1999) examined repeated- and unrepeated-letter misspellings and found that words containing an added letter that repeated an existing letter within a word (e.g., *elderdly*) were more difficult to detect and retrieve as misspelled, relative to words containing an unrepeated added letter (e.g., *elderkly*). However, these repeated-letter effects did not interact with age, as the size of this effect was equivalent for both young and older adults. The present study investigated misspellings that were either phonologically compatible or incompatible with the spellings of actual words, a type of misspelling that has been studied in prior research with young adults.

The Role of Phonological Compatibility and Cueing

Prior research (e.g., Katz & Frost, 2001; MacKay, 1968; MacKay, 1972) has shown that phonological factors play a role in dissociating young adults' detection and retrieval of spelling errors. MacKay (1968) asked participants to read sentences containing misspellings as quickly as possible and then to write down (i.e., retrieve) the sentences exactly as presented from memory. Participants were then shown the original sentences and asked if they had noticed (i.e., detected) each misspelling. His results showed that phonologically compatible misspellings (e.g., *work* misspelled as *werk*) were more difficult to detect than phonologically incompatible misspellings (e.g., *work* misspelled as *wark*), whereas phonologically compatible misspellings were easier to retrieve than phonologically incompatible misspellings.

MacKay's (1968) detection results were replicated with a different procedure by Katz and Frost (2001, Experiment 3), who used a forced-choice procedure for spelling detection. A correctly spelled word was presented along with either a phonologically compatible misspelling or a phonologically incompatible misspelling, and participants indicated which of the two choices was the correct spelling of the word. The results showed that participants made more errors and had slower response times when words were paired with a phonologically compatible misspelling relative to a phonologically incompatible misspelling. In a related experiment, Katz and Frost (2001, Experiment 4) found that more errors were made in detecting phonologically compatible misspellings when both phonologically compatible and incompatible misspellings were presented within a list, relative to a list containing only phonologically compatible misspellings. They concluded that including both phonologically compatible and incompatible misspellings biased participants toward relying on phonology when making judgments about the correctness of spelling, and this reliance on phonology was therefore more detrimental to the detection of phonologically compatible misspellings.

For spelling retrieval, reliance on phonology can be manipulated by presence of an auditory cue, which was tested by MacKay (1972). Prior to visual presentation of phonologically compatible and incompatible misspellings, half of the trials contained an auditory cue that presented the phonology of the phonologically compatible misspelling (which was also the phonology of the correctly spelled version of the word, e.g., /werk/). Participants were asked to write down the visually presented word exactly as presented. MacKay showed that relative to a simple tone, the auditory cue increased retrieval of phonologically incompatible misspellings but had no effect on retrieval of phonologically compatible misspellings, leading to greater retrieval of phonologically incompatible misspellings than phonologically compatible misspellings. The finding that retrieval of misspellings was more difficult when the auditory cue matched the phonology of the misspelling (compatible misspellings) than when it did not (incompatible misspellings) suggests that the phonology of the cue was causing confusion about which orthographic representation had actually been presented.

The above studies indicate that type of misspelling, phonologically compatible or phonologically incompatible, differentially affects spelling detection and retrieval. However, these studies were conducted only with young adults, and it is unknown whether older adults are also susceptible to the influence of phonology in making decisions about spelling. Independent of spelling, recent research by White and Abrams (in press, Experiment 1) showed that older adults activated phonology similarly to young adults upon seeing a word. Young and older adults were given homophones paired with a single letter, e.g., *beech-s*________, and were asked to complete the word stem with the first word that came to mind. Older adults completed the word stem with *sand* as often as young adults, indicating activation of the phonology /bēch/, which in turn activated *beach* and thus *sand*. Therefore, older adults are capable of activating phonology of visually presented words similarly to young adults, but the question remains as to whether older adults utilize phonology when making spelling decisions to the same degree as young adults.

The focus of the present study was to examine potential age interactions in detecting and retrieving phonologically compatible and incompatible misspellings. Misspellings were created by substituting a single letter: (1) a nonword that was phonologically compatible with a real word (e.g., *dert* instead of *dirt*) or (2) a phonologically incompatible nonword (e.g., *dort*). In addition, similar to MacKay (1972), two types of correct spellings were used that differed by a single letter in the same position as the misspellings, e.g., *dirt* and *dart*. A methodology similar to MacKay et al. (1999) was employed, where words were presented as correctly spelled or misspelled on a computer screen, but for a much briefer presentation rate, 50-90 ms. The other manipulation involved an auditory cue (e.g., /dûrt/) on half the trials. For correct spellings, the cue either matched the presented word (*dirt*) or did not match (*dart*). For misspellings, the cue either matched the phonology of the presented misspelling (*dert*) or did not match in phonology (*dort*).

The purpose of the cue, similar to MacKay (1972), was to assess the impact of auditory input on visual spelling detection as well as retrieval and to measure whether older and young adults were influenced by this auditory (i.e., phonological) information to the same degree in making judgments about spelling. For correctly spelled words, the auditory cue was expected to facilitate spelling detection and retrieval for all age groups when the visually presented word was identical to the cue because of the identical overlap in the phonological and orthographic representations. In contrast, the auditory cue was predicted to decrease spelling detection and retrieval when the visually presented word differed from the cue because the auditory input was misleading. Successful identification of the visually presented word as correctly spelled requires inhibition of the auditory cue, which is also a real word and can detract from the processing of the visual word. Detection of correct spelling in this condition may be especially difficult for older adults, who are hypothesized to have inhibition deficits (e.g., Hasher & Zacks, 1988), which make suppression of task-irrelevant information more difficult. Older adults exhibit more difficulty with similar tasks requiring inhibition, such as the Stroop task (e.g., Davidson, Zacks, & Williams, 2003; Cohn, Dustman, & Bradford, 1984; but see Verhaeghen & De Meersman, 1998, for an exception).

For misspelled words, the auditory cue was expected to decrease detection and retrieval of phonologically compatible misspellings. For these misspellings, the auditory cue’s phonology corresponds to a correctly spelled word, making it more difficult to identify the visually presented word as misspelled because of the reliance on phonology for judging correctness of spelling, as Katz and Frost (2001) proposed. For phonologically incompatible misspellings, the auditory cue was expected to increase detection and retrieval because the auditory cue activates phonology of a correctly spelled word, which is different from the visually presented misspelled word and therefore makes the discrepant information salient. If older adults rely more on phonology than young adults in spelling decisions, then age declines may increase for phonologically compatible misspellings relative to phonologically incompatible misspellings.

Although previous research on spelling detection does not address differences between older adults, we predicted that old-old adults would show increased difficulty in spelling detection relative to young-old and young adults, especially when the auditory cue's phonology was misleading in some way. The rapid presentation rate along with conflicting information will be particularly burdensome for old-old adults' working memory. In contrast, both young-old and old-old adults were expected to show age declines in spelling retrieval, consistent with prior research on retrieval of correct spelling (e.g., MacKay & Abrams, 1998; Stuart-Hamilton & Rabbitt, 1997).

Method

Participants

The 100 participants consisted of 50 young adults (18-22 years), 25 young-old adults (61-72 years), and 25 old-old adults (73-85 years), where the age cutoff between young-old and old-old adults (age 73) was taken from MacKay and Abrams (1998). All were native English speakers, reported no serious medical or neurological problems, and had normal or corrected-to-normal vision and hearing. Young adults participated in return for course credit in introductory and cognitive psychology classes at the University of Florida (UF). Older adults were part of the UF Cognition and Aging Laboratory participant pool, consisting of approximately 500 residents of Alachua County and surrounding areas. Participants in the pool were recruited from area churches, senior citizen centers, and the UF Alumni Association. They were compensated at the rate of eight dollars per hour. All participants completed the following background information forms/tests: (1) a participant questionnaire asking for age, education, ethnicity, native language, health status, and current medications, (2) a 25-item vocabulary test, and (3) forward and backward digit span tests to assess working memory. Participants were also asked to rate their current spelling ability on a scale, ranging from 1 (*poor*) to 9 (*excellent*). In addition, older adults rated their spelling ability when in their 20s on a second 9-point scale, and were also given the Mini Mental State Examination (MMSE) to screen for cognitive impairment and/or dementia.

Means and standard errors on these tests for each age group can be found in Table 1. One-way ANOVAs on these data indicated significant effects of years of education, $F(2, 97) = 107.81$, $MSE = 3.2$, $p < .001$, vocabulary, $F(2, 97) = 83.58$, $MSE = 7.12$, $p < .001$, backward digit span, $F(2, 97) = 4.85$, $MSE = 1.3$, $p < .010$, and a marginal effect of forward digit span, $F(2, 97) = 2.74$, $MSE = 1.38$, $p < .07$. Bonferroni post hoc tests indicated that for education, young-old adults had more education than old-old adults ($p < .002$), who in turn had more education than young adults ($p < .001$). For vocabulary, both groups of older adults had significantly higher vocabulary scores than the young adults ($p < .001$), but were not significantly different from each other ($p > .999$). For backward digit span, old-old adults had smaller digit spans than both young adults ($p < .019$) and young-old adults ($p < .022$), who did not differ from each other ($p > .999$). For forward digit span, young-old adults had marginally larger digit spans than old-old adults ($p < .074$), but there were no other significant age differences ($p > .256$). No age differences occurred in self-ratings of health or current spelling ability (Fs < 1) or in MMSE score, $F(1,48) = 1.38$, $MSE = 2.67$, $p > .199$. Separate t-tests were conducted to compare older adults' self-reported spelling ability in their twenties and at the current time, and the results showed that both young old adults ($p < .015$) and old-old adults ($p < .001$) rated their spelling ability now as significantly lower than when they were in their twenties.

Materials

The experiment was conducted using a Gateway Pentium II 350 MHz IBM-compatible computer with a 17-inch monitor and standard keyboard. Stimuli were presented using a program written in Microsoft Visual Basic 5.0, and were presented in black on a white background in 14-

point font. Audio files were presented over standard headphones connected to the computer's speakers.

The 40 stimuli were single words, ranging from 3 to 9 letters (*M* = 5.3 letters). Stimuli, shown in the Appendix, appeared in one of four conditions, which were created for each category by changing a single letter of the original spelling. The position of the changing letter remained constant across the four conditions, and its general shape was preserved (i.e., the letter *e* would be exchanged for an *o* or an *a*, rather than a *t*, *d*, or *p*). Stimuli were counterbalanced across participants such that two conditions were correct spellings, one of which was designated as the original spelling from which all other spellings were derived (e.g., *base*) and one which became a new word after changing the letter (e.g., *bare*). There were also two misspellings, one of which was phonologically compatible with the original spelling (e.g., *bace*), and the other which was phonologically incompatible with the original spelling (e.g., *bame*). The frequency of occurrence rating for the words in the original and new conditions, using Francis and Kucera's (1982) word frequency analysis, ranged from 0-2765 (*M* = 182.95). The phonologically compatible and incompatible nonwords were rated as easy, average, or difficult to pronounce by five young adult and five older adult independent judges. Stimuli receiving a rating of difficult were then excluded, so that all stimuli included in the experiment were rated as being of easy or average difficulty to pronounce.

Two types of auditory cues were presented immediately before the visual presentation of the word. On 50% of the trials, participants heard the Microsoft Windows beep audio file. On the other 50% of the trials, the auditory cue contained the phonology of the original correctly spelled word, e.g., /bās/. Therefore, for correct spellings, the cue matched the visual representation for the original spelling (*base*) but conflicted with the visual representation of the new spelling (*bare*). For misspellings, the cue was consistent phonologically with the visual representation for the phonologically compatible misspelling (*bace*) but also matched a real word (*base*), whereas the cue did not match the visual representation of the phonologically incompatible spelling (*bame*).

The word was shown to young participants for either 50 or 70 ms, or for either 70 or 90 ms for both groups of the older participants, with presentation rate counterbalanced across subjects. The presentation times were determined through pilot testing in an effort to avoid floor or ceiling effects in any age group.

Design

The experiment used a 2 x 2 x 2 x 3 mixed factorial design with three within-participants factors: Type of Correct Spelling (original, new), Type of Misspelling (phonologically compatible, phonologically incompatible), and Type of Cue (beep, word). The other factor was a between-participants factor, Age Group (young, young-old, and old-old).

Procedure

Participants completed six practice trials to become accustomed to the task. They were seated with the experimenter in front of the monitor and were given headphones. They were played sample audio files and were asked to adjust the volume so that they could clearly hear the words. Using both verbal and written versions of the instructions, participants were told that they would see a word appear briefly on the screen, and their task was to first decide whether it was correctly spelled and then write down the word exactly as it was presented. They were also informed that before the word appeared, they would hear either an audio file of a word or a beep over the headphones. They were further told that this word might or might not be the word that would then appear on the computer screen, but that they were not to use the word they heard to evaluate the correct spelling of the word they saw.

At the offset of the audio file, a focus point (+) appeared in the center of the screen for 250 ms, followed immediately by the visual presentation of the word. At stimulus offset, a row of eight question marks appeared in the center of the screen, indicating that the participant should make a response. Participants immediately indicated whether they perceived the word as correctly or incorrectly spelled by pressing the ? key (marked with a R during the experiment) if they thought the word was correctly spelled, or the Z key (marked with a W) if they thought the word was incorrectly spelled. Participants then wrote the word they saw in its exact presentation form on a response sheet, preserving misspellings where appropriate. When participants had finished writing, they pressed the enter key to begin the next trial.

Results

Overview of Signal Detection Theory

Previous spelling research has concentrated on the percent correct detection in each condition, analogous to the hit rate calculated in signal detection and discussed below. However, those analyses do not provide information about how well a signal is detected under more realistic conditions of uncertainty, when noise is also present. Nor do they provide a means to dissociate the detectability of the signal from the participant’s own tendencies to respond. The analyses discussed here offer that additional information.

Signal detection, developed for use in sensory experiments, is used to study performance under conditions of uncertainty. In the “classic” form of signal detection experiments, a stimulus (a brief sound presented to a participant) falls into one of two categories: *signal*, in which a signal (e.g., a faint tone) was presented, or *noise*, in which white noise, but no tone, was presented. On a given trial, participants hear a sound containing either the tone or noise, and must then answer the question “Was the tone presented or not presented?”. Signal detection theory assumes that participants’ reactions to the stimuli lie as points on two distributions: one signal distribution, one noise distribution. When the tone presented is clearly distinguishable from background noise, then the two distributions lie far apart, and detection is quite easy. However, when the tone is faint or hardly distinguishable from the white noise, the two distributions are much closer together; in fact, they may even overlap, making accuracy in the detection task much more difficult.

In order to decide whether a stimulus came from a signal or noise distribution, it is assumed that participants combine all available information about that stimulus into a single value. They then compare that value to a critical value that they have established, a minimum level of information necessary to classify a stimulus as a signal. Depending on where the stimulus value lies relative to their critical value, participants then make a yes/no judgment (i.e., “yes”, the tone was presented, or “no”, the tone was not presented). Critical values vary by participant, and participants can also be induced to change them. For example, a participant who places a high value on hearing each tone will likely respond *yes* to many more trials than a participant who places a high value on not claiming to hear a tone when no tone was presented. Thus, critical values can vary by experimental condition, participant instruction, or an individual’s approach to the task. The possibility is that young and older adults are differentially motivated to participate in experiments, and the stereotype of the cautious older adult is omnipresent in cognitive aging research (Danziger, 1980).

Sensitivity

As a measure of the distance between the means of the noise and signal distributions, *d′* is thus an estimate of the participant's sensitivity, or ability to distinguish the signal from noise trials. If *d′* is small (less sensitive), the two distributions are very close together, sharing a considerable amount of overlap, and they are difficult to distinguish from each other. If *d′* is larger (more sensitive), the two distributions are more widely spaced, and signal and noise trials are easily distinguishable. In analysis, the proportion of hits (hit rate *H*= number of correct responses /number of signal trials) and false alarms (false alarm rate *FA* = number of false positive responses/number of noise trials) is calculated for each participant. The proportion of hits and false alarms are then converted to standardized *z* scores using the inverse of the Gaussian distribution (e.g., Sorkin, 1999). The equation for calculating *d′* is: $d' = z(H) - z(FA)$. This equation can be used to describe two normal distributions: noise, for which the mean is zero, and signal, for which the mean is represented by *d′*. The parameters of *d′* range from 0 (chance performance, or an inability to discriminate between the two distributions) to 4.65 (practically perfect performance, or an ability to precisely discriminate between the two distributions) when $H = .99$ and $FA = .01$. A value of *d′* around 1.0 indicates moderate sensitivity in the discrimination task (Macmillan & Creelman, 1991). If participants' false alarm rate is larger than their hit rate, however, *d′* will be negative, although in most signal detection experiments this result occurs so rarely as to be nonexistent.

Bias

Hit and false alarm rates are also used to calculate an index of the participant's response bias, or preference for responding that a stimulus was presented (a liberal bias) or was not presented (a conservative bias). Although there are several measures of response bias, the criterion *c* ($c = -.05[z(\mathrm{H}) + z(\mathrm{FA})]$; Sorkin, 1999) is used here, as it is statistically independent of *d′*. Although Sorkin (1999) does not report a range of estimates for this particular *c*, other sources report that *c* ranges from -2.33 (extremely liberal), where *H* and *FA* equal .99, and participants almost always report seeing a signal, to +2.33 (extremely conservative), where *H* and *FA* both equal .01, and participants almost always report that no signal was presented (Macmillan & Creelman, 1991). Participants' own characteristics affect whether they tend to respond liberally or conservatively, and they can shift their criteria during the experiment for a variety of reasons (e.g., if a new experimental condition is introduced). Any shift in criterion will likewise change a participant's hit and false alarm rates. Although *d′* is independent of *c* and does not change as a result of a criterion shift, it too may change with experimental conditions that vary the strength of the signal.

Signal Detection Theory Applied to Spelling Detection

We used signal detection analysis to assess possible age differences in sensitivity (*d′*) to correct spellings or misspellings and to assess bias (*c*) in judging words as correctly spelled or misspelled. Stimulus strength in the current experiment was varied by the presence or absence of an auditory cue word, and stimuli of both strengths were presented randomly during the experimental session. The current methodology differs from a classic signal detection study in two ways: stimuli were visually presented letter strings rather than an auditory tone, and participants were instructed to classify the letter strings as correctly spelled or misspelled words, rather than to make a decision about the presence or absence of a stimulus. Thus, participants were given, in effect, two signal trials and asked to distinguish between the two. When analyzing detection of correctly spelled words, correctly spelled words were coded as signal trials, and misspelled words were coded as noise trials. Conversely, when analyzing detection of misspelled words, misspellings were coded as signal trials, while correctly spelled words were coded as noise trials. Given that the different types of correct spellings and misspellings were of interest to us, *d′* and *c* were measured for each spelling condition separately by treating that condition as signal (e.g., phonologically compatible misspelling with cue) and comparing it to a noise distribution composed of trials of the opposite spelling type (e.g., all correctly spelled trials, regardless of cue).

It is important to note some limitations of applying signal detection theory to spelling detection in the present experiment. Classic signal detection theory is predicated on the assumption that the underlying distributions are normal. In addition, large numbers of trials are required for each participant to ensure an accurate measure of *d′* and *c*. The number of trials in each condition in the present experiment was too small to permit reasonable estimation of *d′* and *c* for each participant, so these parameters were calculated by averaging data across participants. While allowing better estimation, this approach has the unfortunate effect of eliminating the variance needed for significance testing of *d′* and *c*, so discussion is limited to age-related trends without conclusive evidence of significant differences. Furthermore, because correctly spelled words and misspelled words were coded proportionally to each other (one was signal while the other was noise), the false alarm rates (the number of times a participant reported that the stimulus was correctly spelled when it was misspelled, or vice versa) could not be calculated individually and were therefore identical for each correctly spelled condition and each misspelled condition. In sum, because of their limitations, the signal detection analyses were conducted with the intent of supplementing the results provided by the ANOVAs on percent correct detection.

Detection of Correctly Spelled Words

ANOVAs

Means and standard errors of percent correct detection for correct spellings in both cue conditions are shown in Table 2. The detection data were analyzed with a 3 (Age Group) x 2 (Type of Correct Spelling) x 2 (Type of Cue) repeated-measures ANOVA. There were significant main effects of Type of Correct Spelling, $F(1, 97) = 42.36$, $MSE = .04$, $p < .001$, and Type of Cue, $F(1, 97) = 24.79$, $MSE = .05$, $p < .001$, which were moderated by a Type of Correct Spelling x Type of Cue interaction, $F(1, 97) = 63.81$, $MSE = .03$, $p < .001$. Analysis of this interaction showed that an auditory word cue consistent with the upcoming word marginally increased detection of the original spelling relative to a beep, $p < .095$, whereas an auditory word cue inconsistent with the upcoming word decreased detection of the new spelling, $p < .001$. The Age Group main effect was not significant, nor were any interactions with age (*F*s < 1).

Signal Detection Analysis

Table 3 shows the *d'* (sensitivity) and *c* (bias) for each age group in detecting correctly spelled words. For correctly spelled words that were original spellings, old-old adults were less sensitive than young and young-old adults in detecting these words as correctly spelled, but this decline in sensitivity was smaller when a word was given as an auditory cue, relative to a beep. In contrast, young and young-old adults' sensitivity were relatively unaffected by the type of cue. In terms of bias, all age groups were liberal, indicating a preference for responding that the word was correctly spelled, and this criterion was similar for both a word cue and a beep. The liberal bias was more marked for both older adult groups, who were similar in their bias, than for young adults.

For correctly spelled words that were new spellings, presence of an auditory word cue that differed from the presented spelling decreased sensitivity for all age groups, relative to a beep. Old-old adults' sensitivity was the lowest, with below-chance levels of detecting new spellings as correctly spelled following a misleading word cue, i.e., old-old adults were more likely to say new spellings were misspelled than correctly spelled. When a beep was presented, old-old adults were somewhat more sensitive than the other age groups. Given that this condition functions identically to original spellings, this change in sensitivity favoring older adults was unexpected. In terms of response bias, for a beep as a cue, old-old adults were more liberal (more willing to say that the word was correctly spelled) than young-old adults, who were more liberal than young adults; in contrast, following a word cue, old-old adults' criteria was similar to young-old adults, both of which were more liberal than young adults. The bias of all three age groups in detecting new spellings was less liberal when the cue was a different word, relative to a beep, but this shift in criteria was greater for old-old adults, relative to young-old and old-old adults. Interestingly, young adults' criteria shifted to a neutral position, indicating no overall bias toward either response, while the two older groups' criteria remained liberal overall.

Detection of Misspellings

ANOVAs

Means and standard errors of percent correct detection for misspellings in both cue conditions are shown in Table 4. Using a 3 (Age Group) x 2 (Type of Misspelling) x 2 (Type of Cue) repeated-measures ANOVA, the results yielded a significant main effect of Age Group, $F(2, 97) = 19.59$, $MSE = .15$, $p < .001$, where young adults were more accurate in detecting misspellings as misspelled than either young-old and old-old adults, $p < .001$, who did not differ from each other, $p > .217$. There was also a main effect of Type of Cue, where detection increased when given a word cue relative to a beep, $F(1, 97) = 51.17$, $MSE = .05$, $p < .001$. None of the interactions, either with or without Age Group, approached significance (ps > .188).

Signal Detection Analysis

Table 5 shows the *d'* (sensitivity) and *c* (bias) for each age group in detecting misspellings. For phonologically compatible misspellings, young-old and old-old adults had reduced sensitivities relative to young adults in detecting these misspellings, both with a word cue and with a beep. Old-old adults were particularly less sensitive when only a beep was presented. Presentation of a word cue increased sensitivity in detecting these misspellings in all three age groups, with greater increases for young-old and old-old adults. For bias, all age groups responded conservatively overall (less likely to say the word was misspelled). Following a beep, old-old adults were more conservative than young-old adults, who were more conservative than young adults. Following a word cue, young-old and old-old adults were similarly conservative and more so than young adults. When a word cue was presented relative to a beep, all three age groups shifted their criteria to become slightly less conservative, with old-old adults having a larger shift than young and young-old adults.

Similar to phonologically compatible misspellings, presentation of an auditory word cue increased sensitivity in detecting phonologically incompatible misspellings for all age groups, although old-old adults were still less sensitive than young and young-old adults, who were similar in their sensitivity. When the cue was a beep, young adults had greater sensitivity than young-old adults, who were more sensitive than old-old adults. For bias, all age groups responded conservatively overall (less likely to say the word was misspelled). For both types of cues, young-old and old-old adults were equivalently conservative, with both groups showing more conservative bias than young adults. When a word cue was presented relative to a beep, all three age groups shifted their criteria to become slightly less conservative, with similar shifts for all three age groups.

Retrieval of Correct Spellings

Table 6 displays the means and standard errors of percent correct retrieval of correct spellings in both cue conditions. A 3 (Age Group) x 2 (Type of Correct Spelling) x 2 (Type of Cue) repeated-measures ANOVA revealed main effects of Age Group, $F(2, 97) = 7.11$, $MSE = .10$, $p < .001$, and Type of Correct Spelling, $F(1, 97) = 41.15$, $MSE = .04$, $p < .001$, as well as a Type of Correct Spelling x Type of Cue interaction, $F(1, 97) = 88.85$, $MSE = .03$, $p < .001$. These effects were moderated by a three-way interaction, $F(2, 97) = 3.15$, $MSE = .03$, $p < .047$. Further analysis of this interaction showed that for retrieval of original spellings, there were no age differences when a word cue that matched the presented spelling was given, $p > .102$. In contrast, when only a beep was given prior to word presentation, old-old adults had poorer retrieval of original spellings relative to both young and young-old adults, *p*s < .001, who did not differ from each other, $p > .796$. For retrieval of new spellings, age differences were similar for both types of cues, indicating poorer retrieval for old-old adults relative to young and young-old adults, *p*s < .065, with no differences between the latter two groups, $p > .976$.

An ANOVA was also conducted on the percentage of time the cue word was written at retrieval instead of the visually presented word. Only new spellings were included in this analysis because retrieval of the cue word is identical to retrieval of the presented word for original spellings, which were analyzed in the previous paragraph. The one-way ANOVA was significant, $F(2, 97) = 5.124$, $MSE = .05$, $p < .008$, showing that old-old adults ($M = 37.8$) retrieved the cue word significantly more often than young-old adults ($M = 17.9$, $p < .007$) and marginally more than young adults (*M* = 24.6, $p < .056$). Young and young-old adults did not differ in their retrieval of the cue word, $p > .686$.

Retrieval of Misspellings

Table 7 displays the means and standard errors of percent correct retrieval for misspellings in both cue conditions. A 3 (Age Group) x 2 (Type of Misspelling) x 2 (Type of Cue) repeated-measures ANOVA found significant main effects of Age Group, $F(2, 97) = 14.55$, $MSE = .13$, $p < .001$, Type of Misspelling, $F(1, 97) = 22.71$, $MSE = .04$, $p < .001$, and Type of Cue, $F(1, 97) = 25.63$, $MSE = .03$, $p < .001$. A significant interaction between Age Group and Type of Misspelling was also revealed, $F(2, 97) = 3.87$, $MSE = .04$, $p < .024$; no other interactions were significant, *F*s < 1. Analysis of the significant interaction showed that both young adults, $p < .001$, and young-old adults, $p < .059$, were better at retrieving phonologically compatible misspellings relative to phonologically incompatible misspellings. However, old-old adults' retrieval was equivalent for both types of misspellings, $p > .203$. With respect to differences between the age groups, young adults performed better at retrieving phonologically compatible misspellings than both young-old and old-old adults, *p*s < .001, with young-old adults demonstrating marginally greater retrieval than old-old adults, $p < .067$. For phonologically incompatible misspellings, young adults had better retrieval than old-old adults, $p < .001$, with no other age comparisons having significance.

To examine the likelihood of incorrectly retrieving the auditory word cue, an ANOVA was conducted on the percentage of time the correctly spelled form of the cue word was written at retrieval following both phonologically compatible and incompatible misspellings, and the means and standard errors from this analysis are shown in Table 8. A 3 (Age Group) x 2 (Type of Spelling) repeated-measures ANOVA showed a significant main effect of Age Group, *F*(2,

97) = 5.57, *MSE* = .07, $p < .005$, such that old-old participants overall were more likely to retrieve the cue word than either young adults, $p < .001$, or young-old adults, $p < .043$, who did not differ from each other, $p > .333$. No other effects were significant, *p*s > .686.

Discussion

The present experiment demonstrated some interesting results with respect to aging, spelling detection, and spelling retrieval. First, consistent with prior research on correct spelling detection in aging (Abrams et al., 2000; MacKay et al., 1999), both groups of older adults in the present experiment showed no declines in their ability to detect words as correctly spelled, as measured by percent correct detection. Signal detection analyses of sensitivity supported these results for young-old adults but not for old-old adults, who were less sensitive in their detection relative to both young and young-old adults, for both types of cues. In terms of bias, both older adult groups had a more liberal bias than young adults for both types of correct spellings, resulting in a greater willingness to identify words as correctly spelled. This result suggests that old-old adults were generally categorizing all words as correctly spelled, which may have offset any potential age-related declines. However, although this liberal criterion facilitated older adults' detection of correct spellings, it resulted in increased false alarms for misspellings, leading to poorer misspelling detection (which is discussed in more depth later in this discussion).

Furthermore, all age groups were similarly affected by type of correct spelling and type of cue in the ANOVA analyses such that an auditory word cue (marginally) facilitated detection of identical original spellings, but decreased detection of new spellings. Signal detection analyses mimicked these results for detection of new spellings, evidenced by decreases in sensitivity and a shift toward a less liberal bias, i.e., less likely to say that a word was correctly spelled, indicating increased difficulty in the detection of new spellings for all age groups. However, signal detection analyses revealed some age differences specific to old-old adults in the detection of original spellings following a word cue: only old-old adults showed an increase in sensitivity and change in bias for detecting original spellings, suggesting a greater reliance on auditory (phonological) information relative to young and young-old adults.

The lack of age interactions in the ANOVAs illustrate that detection of correct spelling is generally intact in old age and that these abilities remain relatively stable even when misleading auditory information is presented. Despite the age equivalence in the ANOVAs, signal detection analyses revealed that an auditory word cue resulted in old-old adults having greater decreases in sensitivity and larger shifts in their bias in detection of new spellings. These results provide partial support for the Inhibition Deficit hypothesis (e.g., Hasher & Zacks, 1988) by demonstrating increased difficulty for old-old adults in ignoring the auditory word cue when it conflicted with a new spelling. However, this pattern did not occur for young-old adults, suggesting that inhibition deficits are not universally experienced across the older adult lifespan.

Also consistent with prior research (e.g., MacKay & Abrams, 1998; MacKay et al., 1999; Stuart-Hamilton & Rabbitt, 1997), there were age-related declines in the retrieval of correct spellings despite the preservation of detection abilities, but these declines were solely attributable to old-old adults. When a beep or a misleading auditory word cue was given, old-old adults had more difficulty retrieving correctly spelled words relative to young and young-old adults. Although the decline in retrieval of new spellings is consistent with more difficulty inhibiting the word cue, the declines in old-old adults' retrieval following a beep cannot be explained by inhibition deficits; there was no phonological information to inhibit from a beep. Therefore, old-old adults' declines in retrieval of correct spellings must be caused by some other mechanism.

The only condition where old-old adults did not decline in retrieval was original spellings presented with the word cue, suggesting that they were utilizing the cue, benefiting from the identical match between the cue and the visually presented word, and offsetting their declines in the retrieval of spelling by retrieving those words from long-term memory. Conversely, using the cue was detrimental in the retrieval of new spellings because old-old adults were more likely than young and young-old adults to retrieve the cue word instead of the visually presented word, again suggesting a reliance on long-term memory.

Contrary to previous research (MacKay et al., 1999), the present experiment showed age-related declines in misspelling detection, where both young-old and old-old adults were less likely to detect a misspelled word as misspelled. Signal detection analyses supported these age declines by showing reduced sensitivity in both young-old and old-old adults for both types of misspellings, but also demonstrated greater reductions in sensitivity for old-old adults. Bias also showed age differences, with both older adult groups having a more conservative bias (less willingness to identify words as misspelled) than young adults. Although presentation of a word cue facilitated misspelling detection for both types of misspellings relative to a beep for all age groups, both groups of older adults still had less percent correct detection, were less sensitive, and were more conservatively biased than young adults. Contrary to detection of correct spellings, these data suggest some age declines in misspelling detection for both young-old and old-old adults, with more pronounced declines for old-old adults.

These age-related declines occurred independent of the type of cue presented or the type of misspelling, contrary to the decreased detectability of phonologically compatible misspellings relative to phonologically incompatible misspellings that we predicted and that was found in MacKay (1968; see also Katz & Frost, 2001, although a different methodology was used). One possible explanation for the discrepancy is that MacKay used misspelling detection within the context of sentences, whereas the present experiment used single words. Sentences encourage top-down processing, which facilitates word recognition and therefore does not require that people attend to every individual word when reading. Therefore, phonologically compatible misspellings may not stand out in sentences because we know what word to expect and the phonology of the misspelling match that expectation, whereas phonologically incompatible misspellings contradict our phonological expectations. Another explanation comes from our stimuli (see Appendix), where some of the phonologically compatible misspellings were not necessarily pronounceable in the same way as the correctly spelled word. For example, although *trase* may be pronounced as /trās/, similar to *base*, it could also be pronounced as /trāz/, similar to *phase*. This potential ambiguity in some of the stimuli may have diminished the effects of phonological compatibility.

Unlike detection of misspellings, type of misspelling dissociated retrieval such that young adults and young-old adults (but not old-old adults) more accurately retrieved phonologically compatible misspellings relative to phonologically incompatible misspellings, for both types of cues. Although this result is consistent with MacKay’s (1968) data on recall of misspellings, it contradicts MacKay (1972), who found more accurate retrieval of phonologically incompatible misspellings relative to phonologically compatible misspellings when an auditory word cue was presented. Perhaps phonologically compatible misspellings were retrieved more accurately because they have an existing phonological representation stored in memory, whereas phonologically incompatible misspellings do not. For both types of misspellings, conditions of time pressure (e.g., rapid presentation rate) may allow a person to realize the word was misspelled but not have time to encode the nature of the misspelling. For phonologically compatible misspellings, a reasonable guess can be made; for example, *dert* can activate the word, *dirt*, and its corresponding phonology, /dûrt/. Since there are only two ways to misspell this phonology, as *dert* or *durt*, the misspelling can be retrieved relatively easily. In contrast, *dort* does not immediately map onto a known English word, so no particular phonology gets activated and therefore an infinite number of misspellings are possible at the time of retrieval.

The more important point for aging is that old-old adults did not experience a difference in retrieval of phonologically compatible and incompatible misspellings, suggesting greater difficulty in their ability to use existing phonological representations. Furthermore, young adults retrieved both types of misspellings better than old-old adults, confirming some fundamental declines in old-old adults' spelling retrieval abilities. Since misspellings must be stored and retrieved from working memory, old-old adults' declines in spelling retrieval are consistent with proposed declines in working memory (e.g., Craik, 1983), seen in a decreased backward digit span in the present experiment. To compensate for these declines, old-old adults relied on the auditory cue (and therefore used the word stored in long-term memory), evidenced by greater retrieval of the cue word relative to young and young-old adults, similar to the retrieval of new spellings.

The present data suggest some important implications for future research. Age constancy in spelling detection has only been demonstrated for single words not embedded in any context. An empirical question is whether these perception processes remain stable in old age in more naturalistic contexts, such as reading. Naturalistic contexts more adequately represent the conditions that older adults encounter in everyday life. For example, reading involves higher-level semantic processing without conditions of time pressure, and detection of spelling in this domain is not likely to be captured via rapid presentations of single words. Future research should simulate contexts in the laboratory that older adults encounter in real life, so that we can assess perception of spelling in a way that is more similar to processing in real-world contexts.

A second issue involves individual differences in spelling ability; within both younger and older adults, some people are inherently good spellers, whereas others are poor spellers. One proposal for this distinction is that good spellers rely on well-developed phonological skills, whereas poor spellers utilize visual memory skills to help spell (e.g., Lennox & Siegel, 1998). This distinction implies that poor spellers may be less likely to detect misspellings that “look” plausible. Furthermore, even good spellers are susceptible to effects of misspellings on retrieval of spelling, where seeing words misspelled makes words more difficult to spell correctly later (Dixon & Kaminska, 1997). A closer examination of differences between good and poor spellers within old age will allow greater specification of the relationship between perception of spelling and other cognitive processes.

A third issue involves manipulation of the form of spelling retrieval. Currently, only written spelling has been assessed in all of the studies on aging and spelling retrieval. One question of interest is whether older adults’ oral spelling retrieval declines more than their written retrieval. Given the increase in working memory load that oral spelling requires (having to hold in memory which letters have been produced and in what order), it seems likely that form of retrieval (oral vs. written) would interact with aging in affecting spelling retrieval processes, particularly for old-old adults who demonstrated retrieval declines in the present study when rapid presentation rates were used to tax working memory.

In conclusion, the present data support the idea that some aspects of spelling ability are spared in old age, while others are impaired, and these patterns of sparing and impairment are not equivalent for correctly spelled words and misspellings. When rapid presentation rates were used, detection of correct spelling remained intact even in the old-old adults, but detection of misspellings declined for all older adults. In contrast, retrieval of correct spelling remained stable for young-old adults, but not old-old adults, whereas retrieval of misspellings declined for both groups of older adults. These increased declines in old-old adults are consistent with declines in other cognitive tasks (e.g., Baltes & Mayer, 1999; Davis et al., 1990). Practically, the age-related asymmetries between detection and retrieval of spelling are interesting because older adults reported in both the current study and in previous studies that their spelling ability is declining (Abrams et al., 2000; MacKay & Abrams, 1998); they complain of a deterioration in their ability to spell words they could previously spell. However, their knowledge about spelling is intact to some degree that they can recognize both correct spellings and misspellings under certain conditions. Since negative self-stereotypes worsen memory performance and self-efficacy in older adults (Levy, 1996), a better understanding of the conditions that preserve spelling detection can help offset these stereotypes by showing older adults that they have not truly lost their ability to spell.

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Appendix

Experimental Stimuli in All Conditions

Correctly Spelled Words		Misspelled Words	
Original	New	Phonologically Compatible	Phonologically Incompatible
abide	abode	abyde	abude
acidity	acidify	acididy	acidiky
altercate	alternate	alterkate	altermate
base	bare	bace	bame
blew	blow	bluw	blaw
bout	boot	bowt	bort
certain	curtain	cirtain	cortain
cheek	check	cheak	cherk
confirm	conform	confurm	confarm
couch	coach	cowch	coich
dial	dual	dyal	doal
dirt	dart	dert	dort
excel	expel	exsel	exvel
fact	fast	fakt	fant
find	fond	fynd	fand
forge	forte	forje	forme
grisly	grimly	grizly	grivly
herd	hard	hurd	hord

hose	hope	hoze	hode
insert	invert	incert	inrert
laser	later	lazer	laner
literal	liberal	lideral	likeral
lockout	lookout	lohkout	lowkout
magic	manic	majic	mapic
meditate	medicate	medidate	medilate
miser	mixer	mizer	mirer
peach	perch	peech	peuch
peaks	perks	peiks	penks
protect	project	prodect	prokect
prose	prone	proze	proue
retain	remain	redain	refain
retract	refract	redract	rekract
say	soy	sey	suy
seat	sect	seet	semt
talk	tack	tawk	tark
trace	trade	trase	trake
types	tapes	tipes	topes
time	tame	tyme	tume
twain	train	tuain	tiain
wonder	wander	wunder	wender

Note. Auditory cue words were the words in the original condition.

Table 1

Background Variables for Each Age Group

	Young		Young-Old		Old-Old	
Variable	*M*	*SE*	*M*	*SE*	*M*	*SE*
Age	18.50	1.2	67.08	6.1	77.20	6.7
Years of Education	12.42	1.1	18.42	5.2	16.64	4.5
Health Rating	7.74	1.7	7.83	2.9	8.04	2.9
Spelling Ability (now)	6.04	2.5	6.25	4.9	6.04	4.7
Spelling Ability (20s)			6.96	3.9	7.20	4.6
Vocabulary (out of 25)	14.28	4.3	21.29	4.5	21.08	4.4
Forward Digit Span	7.25	1.6	7.75	2.6	7.00	2.2
Backward Digit Span	5.26	1.8	5.33	2.5	4.48	1.3
MMSE			28.80	2.9	28.20	3.6

Table 2

Percent Correct Detection of Correctly Spelled Words as a Function of Cue Type

	Young		Young-Old		Old-Old	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*
Original Spelling						
Original Word Cue	88.0	2.1	87.1	3.5	92.0	3.1
Beep	85.9	2.1	90.9	2.8	78.5	3.3
New Spelling						
Original Word Cue	59.2	4.0	61.1	5.5	61.1	6.5
Beep	87.9	2.2	89.3	3.3	82.9	4.2

Table 3

Sensitivity (d') and Bias (c) for Correctly Spelled Words

	Young		Young-Old		Old-Old	
Condition	*d'*	*c*	*d'*	*c*	*d'*	*c*
Original Spelling						
Original Word Cue	1.38	-0.51	1.36	-0.99	1.11	-1.02
Beep	1.42	-0.52	1.35	-0.98	0.94	-0.94
New Spelling						
Original Word Cue	0.38	0.00	0.13	-0.37	-0.12	-0.41
Beep	1.38	-0.51	1.14	-0.88	1.52	-1.23

Table 4

Percent Correct Detection of Misspelled Words as a Function of Cue Type

	Young		Young-Old		Old-Old	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*
Phonologically Compatible						
Original Word Cue	63.4	3.6	41.6	5.4	39.2	5.8
Beep	54.6	3.5	29.6	4.9	19.4	4.1
Phonologically Incompatible						
Original Word Cue	64.0	3.9	48.0	6.0	38.4	4.8
Beep	45.1	4.2	26.6	5.1	21.7	5.1

Table 5

Sensitivity (d') and Bias (c) for Misspelled Words

	Young		Young-Old		Old-Old	
Condition	*d'*	*c*	*d'*	*c*	*d'*	*c*
Phonetically Compatible						
Original Word Cue	1.19	0.28	0.91	0.69	0.85	0.70
Beep	1.01	0.36	0.63	0.82	0.37	0.94
Phonetically Incompatible						
Original Word Cue	1.22	0.26	1.16	0.57	0.92	0.61
Beep	0.81	0.47	0.60	0.85	0.43	0.91

Table 6

Percent Correct Retrieval of Correctly Spelled Words as a Function of Cue Type

	Young		Young-Old		Old-Old	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*
Original Spelling						
Original Word Cue	90.5	1.6	82.5	4.1	84.5	3.8
Beep	77.7	3.2	76.3	3.8	54.9	4.8
New Spelling						
Original Word Cue	59.5	3.6	59.3	5.9	44.4	6.4
Beep	79.8	2.4	79.7	3.4	66.6	6.0

Table 7

Percent Correct Retrieval of Misspelled Words as a Function of Cue Type

	Young		Young-Old		Old-Old	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*
Phonologically Compatible						
Original Word Cue	55.8	3.5	37.6	5.9	24.8	3.4
Beep	44.1	3.4	25.6	5.5	16.2	4.0
Phonologically Incompatible						
Original Word Cue	36.6	3.8	29.3	5.3	17.1	3.7
Beep	27.3	3.8	18.0	3.9	13.3	3.9

Table 8

Percent Retrieval of Correctly Spelled Cue Word instead of the Visually Presented Misspelling

	Young		Young-Old		Old-Old	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*
Misspelled Words						
Phonetically Compatible	25.5	3.3	32.8	4.5	43.2	5.3
Phonetically Incompatible	29.0	3.4	30.8	5.0	42.7	4.6