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Within-subjects changes in lipreading and visual enhancement among older adults

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WITHIN-SUBJECTS CHANGES IN LIPREADING AND VISUAL ENHANCEMENT AMONG OLDER ADULTS

by

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Abstract: After 10-14 years, 14 older adults were retested to assess changes in V-only ability and VE. Results showed no significant declines, however, strong correlations were found between previous V-only performance and current V-only performance, as well as between previous VE and current VE, although not as strong. Age and PTA were not predictors of changes in lipreading or VE. In addition, older adults perform less well on auditory-only tasks over time.

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ABBREVIATIONS

A	Auditory-only
AV	Auditory-visual
AVI	Auditory-visual integration
CAVET	Children's Auditory Visual Enhancement Test
HI	Hearing impaired
IAS	Iowa Sentences Test
NH	Normal hearing
PTA	Pure-tone average
SBR	Signal-to-babble ratio
SNHL	Sensorineural hearing loss
V	Visual-only
VE	Visual enhancement

INTRODUCTION

It's not recent news to suggest that speech intelligibility improves when a listener receives both auditory and visual input together, compared with either alone. Sumby and Pollack in 1954 were early to measure the auditory-visual benefit in recognizing speech, especially in conditions of a highly degraded auditory signal (such as in heavy background noise). Visual cues from a talker help to fill in the blanks of the auditory signal that is masked by the background noise. The benefit in speech perception when visual information is available in addition to auditory information, known as the audiovisual advantage, can be measured by calculating visual enhancement (VE). VE is the relative amount of benefit seen in the auditory-visual (AV) condition, beyond what can already be achieved with just the auditory signal. Theoretically, the audiovisual advantage can only be determined by three mechanisms (as described by Tye-Murray, Sommers, & Spehar, 2007a). These mechanisms include the ability to lipread (visual only), the ability to process and encode auditory information alone, and the ability to integrate the information that is obtained from both auditory and visual inputs together.

The current study is the first to look at potential longitudinal changes in the audiovisual advantage among older adults (age range at initial test, 65.5 – 79.8 yr) after a period of 10-14 years. It is well documented that, among many older adults, auditory-only (A) speech perception and hearing thresholds typically show a decline after 60-65 yr (CHABA, 1988; Gates & Mills, 2005). In addition, cross-sectional studies show that, on average, visual-only (V) speech perception declines as a function of age (Dancer, Krain, Thompson, Davis, & Glenn, 1994; Honneil, Dancer, & Gentry, 1991; Lyxell & Ronnberg, 1991; Middelweerd & Plomp, 1987; Shoop & Binnie, 1979; Tye-Murray, Sommers, & Spehar, 2007b). In a more recent study, for example, Sommers et al. (2005) found that younger adults perform about 17% better than older

adults on V-only consonant tasks, which is comparable to the 1979 study by Shoop and Binnie that found better performance in younger adults by about 13% in similar consonant tasks. In the same two studies, younger adults outperformed older adults on V-only sentence level tasks by anywhere from 6-10% on average. In addition, Tye-Murray et al. (2010) found that older adults (65-85 yr) recognize fewer words under visual-only conditions than young participants (18-27 yr) on several sentence tasks. A recent study by Tye-Murray et al. (2016) showed similar declines in V-only sentence performance that occurs with age, but also showed that older adults performed poorer than younger adults in V-only tasks when the visual signal was degraded. The degradation of the visual signal has also been shown to disproportionately affect how well older adults perform on auditory-visual tasks (Tye-Murray et al., 2010; Tye-Murray, Spehar, Myerson, Sommers, & Hale, 2011), which will be discussed next.

When it comes to assessing the benefit obtained from combining auditory and visual speech information, it has been shown that older adults can benefit as well as younger adults (i.e. VE is similar in younger adults compared to older adults). In recent studies comparing younger and older adults with normal hearing, the results have generally shown that younger and older adults obtain similar VE scores, after controlling for age-related declines in V-only speech recognition. For example, Sommers et al. (2005) determined that older adults were able to achieve similar enhancement as younger adults relative to either A or V alone, despite significant reductions in V performance. The study in 2007a by Tye-Murray et al. also suggests that the ability to benefit from the visual input, but not lipreading per se, is relatively preserved in older adults who have normal hearing. The lack of age-related changes in the amount of audiovisual benefit is also strong evidence for the age-resiliency of integration ability. For example, when

unimodal performance (A and V scores) was controlled, the actual audiovisual scores were the same across both young and older adults (Tye-Murray et al., 2016).

When it comes to comparing VE between older adults with normal hearing (NH) and those with mild-moderate hearing loss, research is rather sparse, and the research that does exist has shown mixed findings. The study in 2007a by Tye-Murray et al. suggested comparable audiovisual benefit for the participants with hearing impairment (HI) and those with normal hearing. In other words, hearing loss does not seem to impact the ability to benefit from the visual stimuli. In a 2009 study by Musacchia et al., however, results were indicative of degraded AV integration in older adults with HL compared to the NH group. This was an electrophysiologic study, however, and the authors concluded that hearing loss in older people impacts the neural mechanisms of auditory-visual integration as shown in their results.

The goal of the current study was to examine the potential age-related changes in hearing and lipreading ability as predictors of changes in visual enhancement among older adults. We recalled older NH and HI adults from the Tye-Murray et al. (2007a) study and re-evaluated their audiovisual benefit. For the current, follow-up, study the testing conditions were to be as similar as possible to the testing conditions for each participant in the initial study by Tye-Murray et al. (2007a). We did everything possible to replicate the original study's testing conditions (see Methods for more detail).

METHODS

Participants

As described earlier, all participants that were recruited for the current study previously participated in a study by Tye-Murray et al. (2007a) that assessed the audiovisual integration and lipreading abilities of two populations: normal hearing and hearing impaired older adults. In the

initial study, seventy-nine adults over the age of 65 yr served as participants. Fifty-three persons (36 female) were in the NH group and 26 persons (18 female) had mild-to-moderate hearing-impairment.

All seventy-nine participants from the initial study were contacted. For those that did not participate in the current study, reasons included: bad contact number (51.3%), transportation issues (6.6%), not interested (11.8%), deceased (7.9%), and unreturned message (3.9%). Ultimately, fourteen adults (range, 77-93 yr; mean, 85.8 yr; SD, 4.1 yr) from the original population served as participants (18.4%). Eight persons (7 female) were recruited from the normal hearing population and six persons (3 female) were recruited from the hearing impaired population. Table 1 and Table 2 show demographic and audiologic data for the NH and HI groups that were recruited, as compared to the data from 2007. Data includes means and standard deviations for age, thresholds for octave frequencies from 250 to 4000 Hz, and pure-tone average (PTA) for frequencies of 500, 1000, and 2000 Hz.

All participants spoke English as their primary language and were residents of the surrounding community. They received $10 per hour for their participation in the study. Sessions were estimated to last approximately one hour, including time for paperwork and testing. Participants read and signed the informed consent document and then filled out a one-page demographic information form along with a payment form. Pure-tone air-conduction thresholds for octave frequencies from 250-8000 Hz were obtained using a calibrated Auricle audiometer with TDH-39P headphones in a sound treated booth. Since the participants were 10-14 years older than they were at the initial study by Tye-Murray et al. (2007a), thresholds were expected to have gotten worse in both the normal hearing and hearing impaired groups (see Cruickshanks et al., 1998). As a result, it was expected that at least some of the participants from the normal

hearing population in the 2007 study would now have some notable hearing loss and that the hearing impaired population from 2007 would have additional hearing loss. Tables 1 & 2 show average NH and HI hearing thresholds at all audiometric test frequencies as well as average PTAs for both test periods.

Procedures

Participants were instructed to sit in a sound treated booth approximately .5m from a 17-inch Touchsystems monitor (ELO ETC-170C) and respond to test stimuli by verbally repeating the presented stimuli (single words following a carrier phrase and words-in-sentences). Participants were tested using each of the stimulus types in three conditions: A, V, and AV. In all conditions, six-talker babble was present, which was digitally captured from the Iowa Audiovisual Speech Perception Laserdisc (Tyler, Preece & Tye-Murray, 1986) using 16-bit digitization and a sampling rate of 48 kHz (Tye-Murray et al., 2007a). Signal-to-babble ratios (SBR) were previously determined individually for each participant in order to keep A performance in the initial study at approximately 50% for both normal hearing and hearing impaired participants (Tye-Murray et al., 2007a). Using babble levels that force performance in the A-only condition to 50% was needed to be able to make comparisons across people that did not include floor performance in A or ceiling performance in AV. Also, it was preferable to performance to keep A-only performance as similar as possible when determining visual enhancement and auditory-visual integration. To keep consistency, participants were individually tested using the same order of test modality (A, V, AV) and stimulus type (words and sentences) that was used in the 2007a study by Tye-Murray et al. Stimuli were presented via a PC (Dell Precision) configured for dual-screen presentation with one screen located in the sound booth in front of the participants for stimulus presentation and the other screen outside the booth in front

of the experimenter in order to monitor progress and record results when necessary. For stimuli that included a visual component, participants viewed the head and neck of the test talker as he or she spoke the stimuli. Audio portions of the stimuli were presented via a Sound Blaster Live audio card using circumaural headphones (Sennheiser HD 265). Babble levels were kept the same as in the 2007a study by Tye-Murray et al.: 60 dB SPL and 80 dB SPL for the NH and HI groups, respectively. The level of the speech stimuli fluctuated depending on the SBR that was used for each participant. All stimulus presentation levels were calibrated with a 6-cc supra-aural flat plate coupler using a sound level meter set to the A-weighting scale.

To account for any additional hearing loss and decreased A-only perceptual ability in noise over the last 10-14 years, the individual SBR for each participant that was used in the 2007a study by Tye-Murray et al. was improved by 2 for the follow-up study. For example, if a participant previously had an SBR of -5, the new SBR would be -3. This was done for both words and sentences, and was done to help control for the possibility that participants would perform at floor level in the A-only conditions. Notably, however, the improved SBR was occasionally not enough and scores often still showed floor performance for A-only conditions. Therefore, VE scores were calculated using all participants as well as the group of participants that did not show floor performance in the A-only conditions.

Stimuli

As previously mentioned, identical word and sentence stimuli were used in this study as were used in the 2007a study by Tye-Murray et al. Word stimuli were taken from the Children's Auditory Visual Enhancement Test (CAVET; Tye-Murray & Geers, 2001), which consists of three lists of 20 words between one and three syllables long, each following the carrier phrase "Say the word…" All the stimuli in the CAVET are produced by a single young adult female

talker. In each of the conditions (A, V, AV), participants were asked to verbally repeat the word after the carrier phrase. The experimenter determined whether or not the participant spoke the word phonetically correct, and recorded correct versus incorrect responses on the computer monitor. If clarification was needed, the experimenter asked the participant to repeat the target word.

Sentence stimuli were taken from the Iowa Sentences Test (IAS), which consists of 100 sentences, with 20 talkers (10 male and 10 female) speaking five sentences each (Tyler, et al., 1986). Five lists were created with 20 sentences in each list, each sentence spoken by a different talker. Each condition (A, V, AV) was matched with the identical list used for each individual participant in the previous study by Tye-Murray et al. (2007a). For example, if Participant #1 was tested in the AV condition with List C in the first study, the same was done in this study. This was true of both words and sentences to keep consistency across studies and to reduce potential error associated with possible list variability.

Assessing Changes in VE

A major goal of the current study was to examine individuals' changes in visual enhancement (VE) over time. Visual enhancement was calculated for each participant using the formula: $VE = (AV - A) / (1 - A)$. This allows for A and AV performance to be compared for each participant. As mentioned, the lapse between studies was around 10-14 yr. We wanted to examine whether or not declines in hearing and lipreading ability over this span of time could predict changes in visual enhancement for older adults with normal (or near normal) hearing and adults with hearing loss. That is, if hearing and lipreading abilities for an individual have not declined much over time, could the same be said about VE? On the other hand, if hearing and lipreading skills have both gotten worse, would there be deficits in VE as well?

The initial study by Tye-Murray et al. (2007a) found that older adults with normal hearing and acquired mild to moderate SNHL generally lipread equally well, and also found that these two populations have comparable auditory-visual integration skills. These results suggest that acquired hearing loss does not delay the decline in lipreading abilities that is normally associated with aging, and the presence of acquired hearing loss does not result in improved lipreading abilities. In this current study, if a relationship is found between the predictor variables and the degree of decline within the measures of V-only and VE ability, then early predictors could become a useful predictor of future audiovisual speech perception ability.

RESULTS

In our results that follow, we separate out the different areas of performance that we were wanting to measure and assess longitudinally. These include: 1) changes in A-only performance (PTA change; CAVET and IAS), 2) changes in V-only performance (CAVET and IAS), 3) changes in VE (CAVET and IAS), and 4) initial PTA and change in PTA as potential predictors of change in VE. NH and HI participants were grouped together for analysis.

Changes in A-only Performance

We measured potential changes in A-only performance over time by assessing PTA and scores on word and sentence speech recognition tasks. Figure 1 shows that declines in PTA were 12.5 dB on average ($p < 0.05$), which is similar to the age-related threshold shifts over in the older population reported by Cruickshanks et al. (1998). Figure 2 shows that on average, A-only performance for words (Mean = 15%; SD = 18%) among these participants was 32.5% worse ($p < 0.05$) than in the initial study despite our attempts to adjust for potential changes over time. In addition, Figure 3 shows that A-only performance (mean, 19.4%; SD, 18.1%) for sentences among these participants was on average 20.7% worse ($p < 0.05$) than in the initial study. Such

large differences in A-only performance for words and sentences indicates speech perception ability in noise had declined more than initially expected. Notably, however, as long as scores are above floor performance in the A-only condition, comparisons using VE are still valid given that the VE formula normalizes for A-only performance.

Changes in V-only Performance

Similar to A-only results, we measured V-only performance over time by assessing any changes in V-only performance on word and sentence speech recognition tasks. A paired *t*-test showed no significant declines in V-only performance for words ($t(13) = 1.29$, $p > 0.05$) or for sentences ($t(13) = -.947$, $p > 0.05$) over this 10 to 14-year time period (see Figs. 4 & 6, respectively). However, a very strong positive correlation ($r = .807$, $p = .0002$) was found between previous V-only performance on words and current V-only performance on words (see Fig. 5). If participants were poor lipreaders for words initially, they were still poor lipreaders for words at this time, and if participants were good lipreaders for words initially, they were still good lipreaders for words now. This suggests that lipreading ability was reliable across two test dates separated by 10-14 years. Although the results did not show significant changes in V-only performance for words over time, Figure 4 showed a declining trend. There were only a handful of participants that stayed the same, and if participants weren't the same, Figure 5 showed that they were generally slightly poorer performers now.

Similar to the words, a strong positive correlation ($r = .611$, $p = .0183$) was found between previous V-only performance on sentences and current V-only performance on sentences (see Fig. 7). As with the words, measures of V-only performance for sentences among these participants were reliable over the 10 to 14-year period. Good lipreaders stayed good lipreaders, and poor lipreaders stayed poor lipreaders.

In addition, we wanted to see if the relative age of the participants could predict any declines in lipreading ability. Figures 8 & 9 show change in lipreading over time for each of the 14 participants. Notably, the relative age of each participant was not predictive of any declines in lipreading ability. That is, among the range of ages among the older participants in the study, the younger participants in the group did not decline less than those who were among the older in the group. This suggests that expected declines in lipreading ability with age had either already happened among these participants or the declines have not yet occurred.

Changes in VE – All Participant Data

Assessing individual participants' changes in VE over time was a main goal of this current study. Analyzing all participant data, a paired *t*-test showed no significant differences in individuals' VE for words ($t(13) = 1.724$, $p > 0.05$) or for sentences ($t(13) = 1.684$, $p > 0.05$) over this 10 to 14-year time period (see Figs. 10 & 12, respectively). However, despite results for VE not showing significance, there is a clear degradation of VE for both words and sentences over time as shown in Figures 10 & 12. The lack of significance may be a result of the small sample size (14 participants) and low statistical power of this study.

Correlations between VE scores (words and sentences) among participants in the initial study and the current study were assessed. VE for words showed a very weak negative correlation ($r = -.119$, $p = .6929$) between Time 1 and Time 2 (see Fig. 11) and VE for sentences showed a weak positive correlation ($r = .382$, $p = .1818$) between the two studies (see Fig. 13).

Changes in VE – Smaller Participant Sample Size

Because VE can't be accurately calculated when A-only scores are on the floor, a second correlational analysis was performed in which participants that performed at floor levels were excluded from the analysis. When we don't know exactly where the A-only level is, we can't

reliably measure benefit. Inclusion criteria was A-only word and sentence scores of 10% or better. Excluding these participants from these analyses yielded stronger positive correlations between VE for words (moderate; r = .531, *p* = .147) and sentences (moderate; r = .423, *p* = .2318) when comparing Time 1 and Time 2 (see Figs. 14 & 15, respectively).

Initial PTA and Change in PTA as Predictors of Change in VE

Finally, potential differences in hearing loss at the initial study along with changes in hearing over time were analyzed as possible predictor variables of changes in VE. As with the VE analysis, comparisons were made with the whole group and for those that were not floor performers in A-only conditions. Our analysis showed that, in both groups, neither initial PTA nor change in PTA over the 10 to 14-year time window were predictors of change in VE over this time. Our results show that even as hearing declines over time, this cannot predict any potential changes in VE.

DISCUSSION

This was the first known longitudinal research study measuring potential changes in hearing and lipreading abilities as predictors for changes in visual enhancement among older adults. We found that participants showed significant declines in PTA and A-only performance for both word and sentence speech recognition tasks over a period of 10-14 years. However, we found no significant differences over time for either V-only performance or VE for both word and sentence speech recognition tasks. Although performance on these measures was not significantly poorer, V-only performance for words as well as VE for both words and sentences did show a declining trend over time (see Figs. 4, 10, & 12). V-only performance for sentences was stable over time, but it should be noted that average scores were near floor in each study. In addition, strong positive correlations were found between V-only for word and sentence

performance across the two time intervals. Moderate positive correlations were found between VE for words and sentences over time only when participants that performed at floor levels in A-only tasks were removed from analyses.

A goal of this study was to determine if age could predict any changes in lipreading ability. We found that the relative age of each participant was not predictive of any declines in lipreading ability. We determined that the expected declines in lipreading ability had either already happened, or that they had not yet occurred. In the initial study, participants were all over the age of 65, which is right around the age, if not after the age, that hearing ability typically starts to decline (CHABA, 1988; Gates & Mills, 2005). It could be expected, then, that lipreading ability had already declined as well, along with hearing ability (A-only), by the time these participants were tested in the initial study. Our results suggested that once V-only skills decline around this age, these skills are relatively stable as these older adults age even more (beyond 65).

We also found that neither initial PTA nor change in PTA over the 10 to 14-year time window were predictors of change in VE over this time. These results are comparable to the results shown in the initial study by Tye-Murray et al. (2007a), in which they found comparable benefit from the visual stimuli in older adults with normal hearing and mild-moderate hearing loss. However, our results are in contrast to the results demonstrated by Musacchia et al. (2009) where they showed degraded integration abilities in older adults with hearing loss by using an electrophysiologic testing method, suggesting that the neural mechanisms of integration were impaired by hearing loss.

After analyzing the results, one question that we asked was: why is VE not very reliable over time even though V-only performance shows strong reliability? One reason for the lack of reliability in VE over time could be attributed to the change in unimodal A-only performance

(PTA declines; words & sentences declines), which put a good number of participants at floor level. The principle of inverse effectiveness, as described by Tye-Murray et al. (2010), may explain this further. This principle states that a participant may achieve different amounts of audiovisual benefit depending on where A-only performance starts. The poorer performance is on A-only speech tasks, the more benefit can be achieved from adding a second modality (visual) to the signal. If A-only performance is rather high, on the other hand, there is less benefit to be achieved when a visual component is added to the signal. Performance is already good to begin with, and there would not be much room for improvement. As a result, VE seems to fall apart when A-only performance is at both extremes. In this study, unimodal A-only performance significantly declined over time, and the lower A-only scores in the current study could be attributed to the fact that VE was not a very reliable measure over time, for the reasons mentioned above. We demonstrated that when the poor A-only performers were removed from analyses, VE showed stronger reliability over time. The following paragraph explains the drop in A-only performance as a limitation to this study.

One limitation of the current study was the fact that A-only performance for both words and sentences declined much more than expected over this time period, which made reliably assessing VE in the current study rather difficult. A-only performance declined more so for words than sentences over time. For sentences, a listener uses context (grammatical and semantic) which allows that listener to compensate for any sensory deprivation that may be present. This sensory deprivation that may be present would manifest itself in poorer A-only speech recognition for words, where there is no context. V-only performance is opposite; sentences are harder to lipread because of co-articulation issues. For this study, average scores were below 20% for each A-only task. As described earlier in the text, Tye-Murray et al. (2007a)

pointed out that controlling A-only performance so that everybody performed similarly (at approx. 50%) was necessary in order to truly measure VE. Our prediction of declines in A-only performance (PTA and word/sentence speech perception) was correct, however, such great declines were not expected. Therefore, our method of increasing the SBR by 2 just wasn't enough to compensate 10-14 years' worth of additional hearing loss and declines in speech perception ability. If possible, future studies assessing longitudinal changes in VE should try and keep A-only performance as consistent as possible across studies (at approx. 50%).

A second limitation of the current study was the small amount of participants (resulting in low statistical power). Several of our main analyses approached significance, however, we had to conclude that lipreading and visual enhancement did not change over time. The graphs showed clear declining trends over time (V-only words, VE words, VE sentences) but again, the lack of statistical power prevented these results from reaching significance. Although we found no differences in lipreading and visual enhancement over time, the test-retest reliability of V-only performance was quite strong. If a participant was a poor lipreader 10-14 years ago, he or she could be predicted to have poor lipreading skills today and vice versa. To our knowledge, this was the first time the reliability of lipreading over time has been measured. This finding has clinical implications when working with the elderly population with near normal and mild-moderate hearing loss. If, for example, a 72-year-old male with a mild hearing loss has trouble understanding speech in the presence of background noise, a clinician may want to assess not only auditory performance in the presence of noise, but also lipreading ability. If lipreading ability is found to be poor, then the clinician can focus more on auditory rehabilitation techniques and listening skills, rather than focus on specific techniques centered around lipreading, because chances are that this man's lipreading ability won't improve with time. The

opposite is true as well; if the same man was found to have rather good lipreading abilities at 72 years old, then the clinician should include both auditory and lipreading techniques when creating a rehabilitation plan, because chances are that his lipreading skills won't decline too much over time and could be used in addition to the auditory signal to get audiovisual benefit.

In the initial study by Tye-Murray et al. (2007a) and in the current study, stimuli of words and sentences (and consonants in the initial study) were used to assess A, V, and AV performance as well as to calculate VE. In future studies that measure longitudinal changes in lipreading and visual enhancement, perhaps using connected discourse as stimuli would be a better assessment of everyday abilities of both NH and HI listeners. Cox and colleagues (1988) describes a good connected speech test (CST) that could be used. Listening to single words and sentences are good ways to measure performance, but listening to multiple sentences or a short story would be more accurate of a daily conversational situation that an elderly person may encounter. The nuances of speech, the pronunciation of words, and the suprasegmentals of speech are different in isolation that they are in connected speech. A sentence provides some of these cues, but multiple sentences in a short topic-oriented paragraph would provide more realistic cues that could allow us as researchers to translate a participant's performance over to the real world.

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Tyler, R. D., Preece, J., & Tye-Murray, N. (1986). The Iowa laser videodisk tests. Iowa City, Iowa: University of Iowa Hospitals.

Table 1. Demographic information (age; thresholds at .25, .5, 1, 2, 4 kHz; and PTA) for the NH population comparing Time 1 and Time 2. Time 1 indicates the initial study by Tye-Murray et al. (2007) and Time 2 indicates the current study.

Variable	Mean Time 1	SD Time 1	Mean Time 2	SD Time 2
Age	73.5	3.5	87.3	3.7
Thresholds (dB HL)				
250	8.4	5.1	20.3	8.5
500	9.1	6.1	18.4	9.8
1000	9.4	4	25	11.4
2000	15	7.5	31.9	15.9
4000	21.6	10	44.1	18.2
PTA (500, 1k, 2k)	11.1	4.2	25.1	10.7

Table 2. Demographic information (age; thresholds at .25, .5, 1, 2, 4 kHz; and PTA) for the HI population comparing Time 1 and Time 2. Time 1 indicates the initial study by Tye-Murray et al. (2007) and Time 2 indicates the current study.

Variable	Mean Time 1	SD Time 1	Mean Time 2	SD Time 2
Age	71.7	3.8	83.7	3.8
Thresholds (dB HL)				
250	35.8	13.6	42.9	24.3
500	36.7	9.1	44.2	18.4
1000	41.7	8.1	55	9
2000	48.8	9.6	61.7	6.2
4000	58.8	13.3	70	14
PTA (500, 1k, 2k)	42.2	5.8	53.6	9

Figure 1. PTA (.5, 1, and 2 kHz) differences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

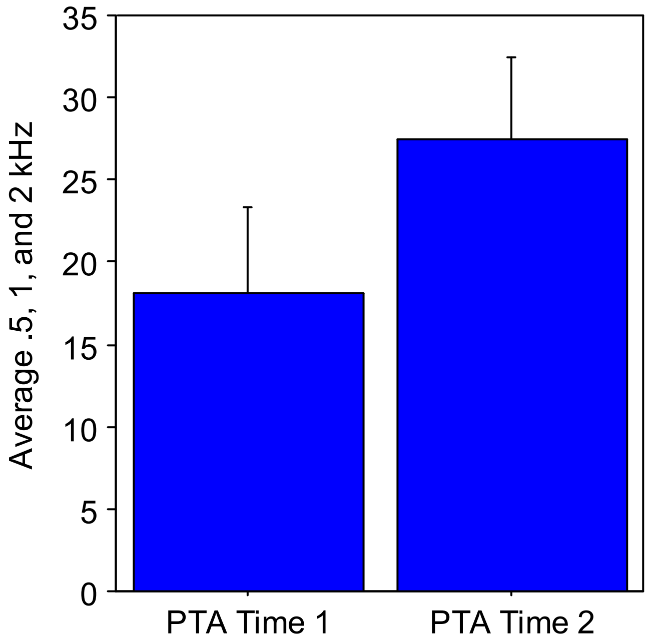


Figure 2. A-only performance for words over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

Figure 3. A-only performance for sentences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

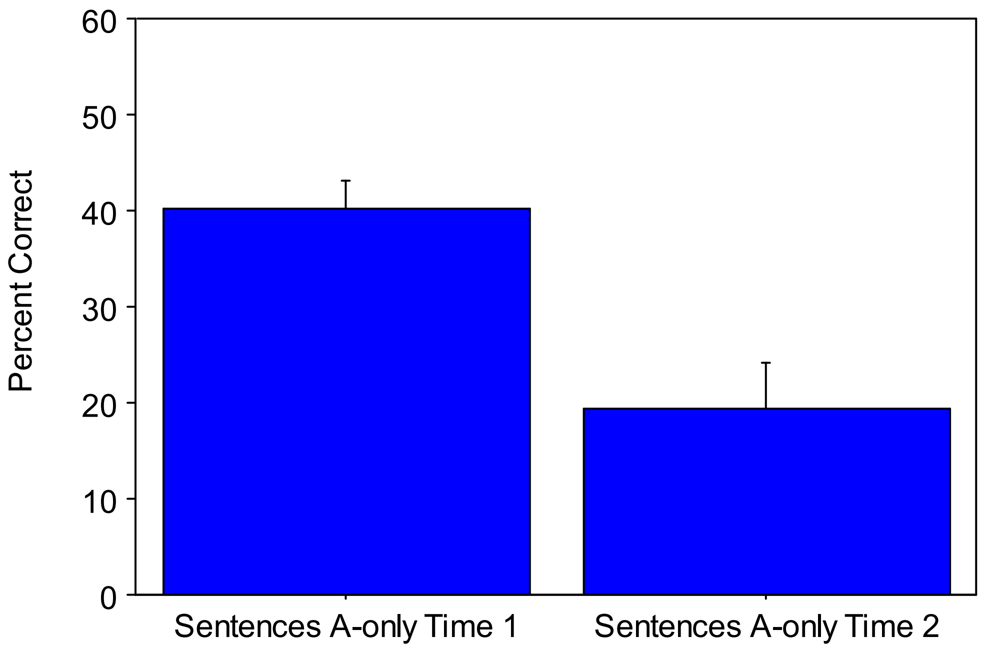


Figure 4. V-only performance for words over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

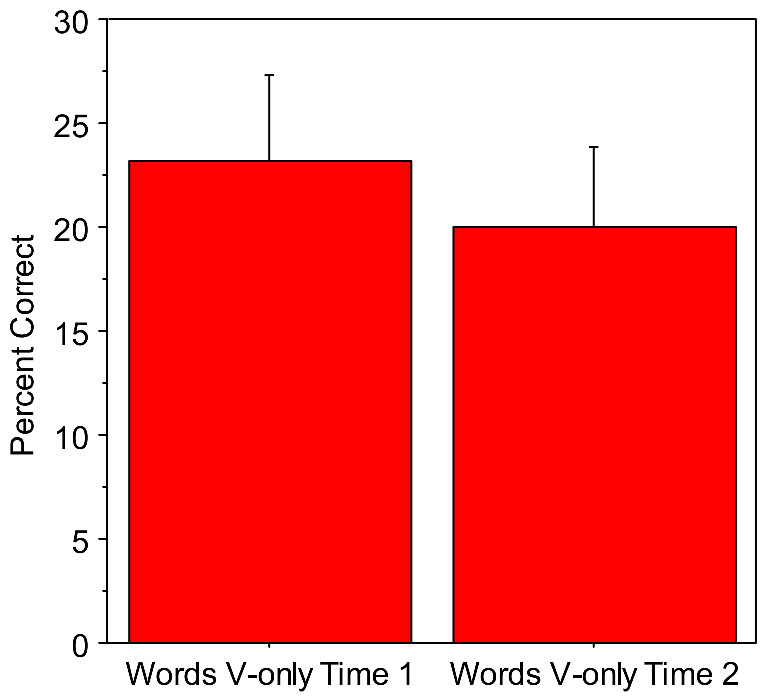


Figure 5. Assessing correlation between V-only performance for words over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.

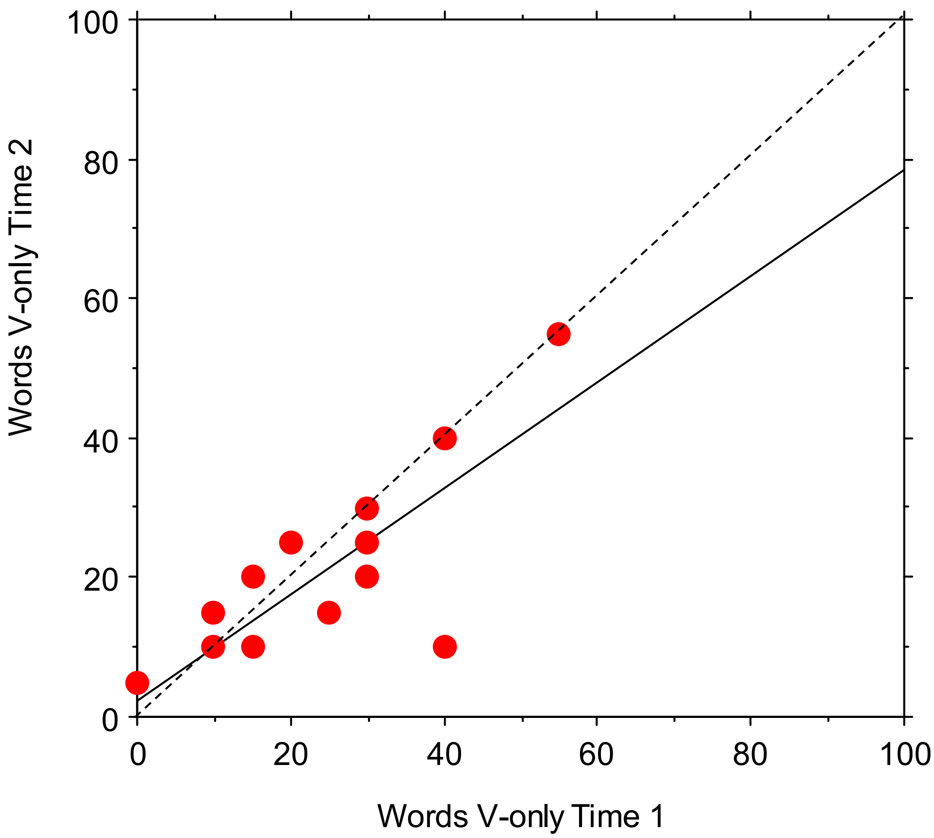


Figure 6. V-only performance for sentences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

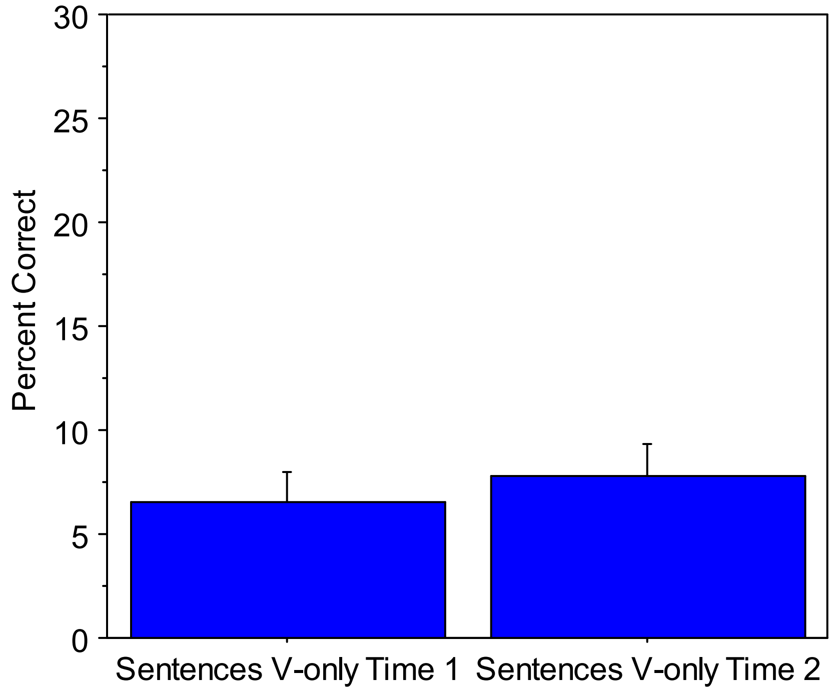
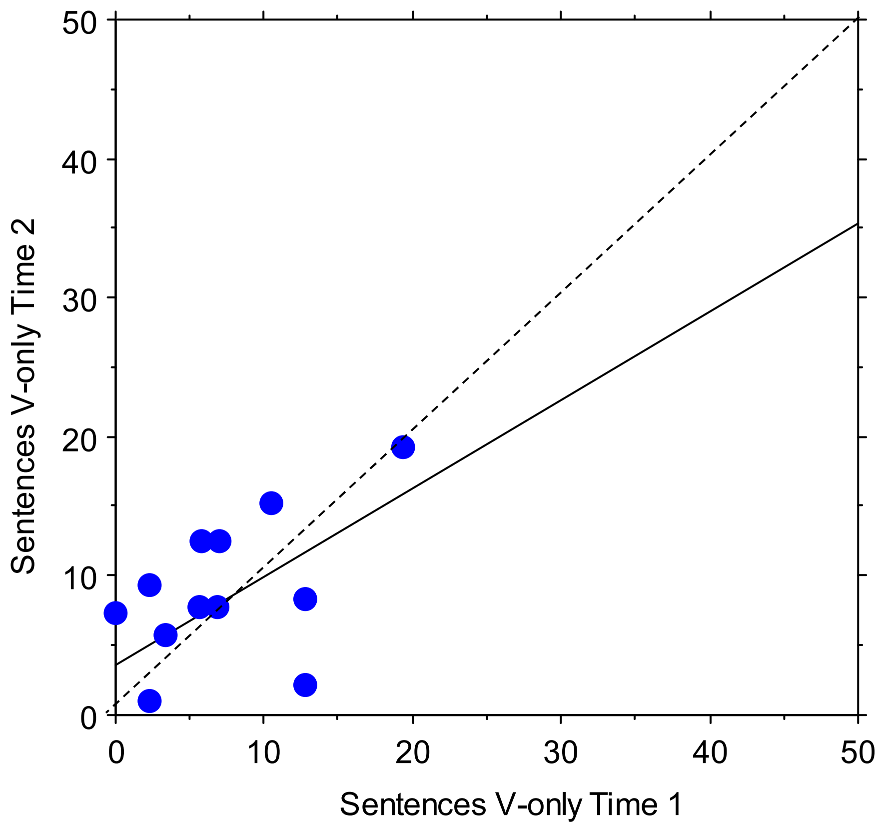


Figure 7. Assessing correlation between V-only performance for sentences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.



Figures 8 & 9. Comparing Time 1 and Time 2 for each person's lipreading scores. These show that age is not a predictor of the degree of decline in V-only scores among the older adults in this study.

Figure 8.

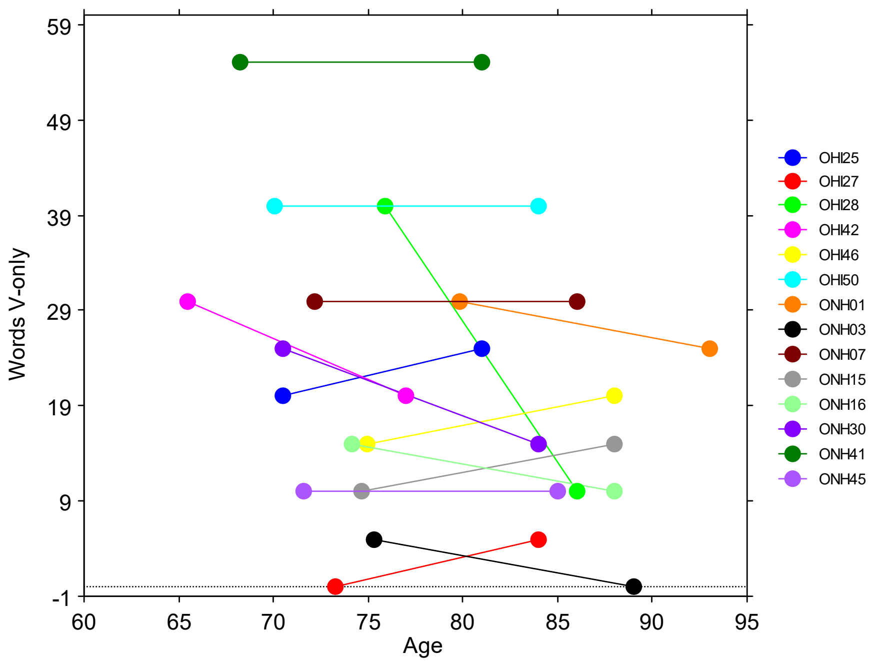


Figure 9.

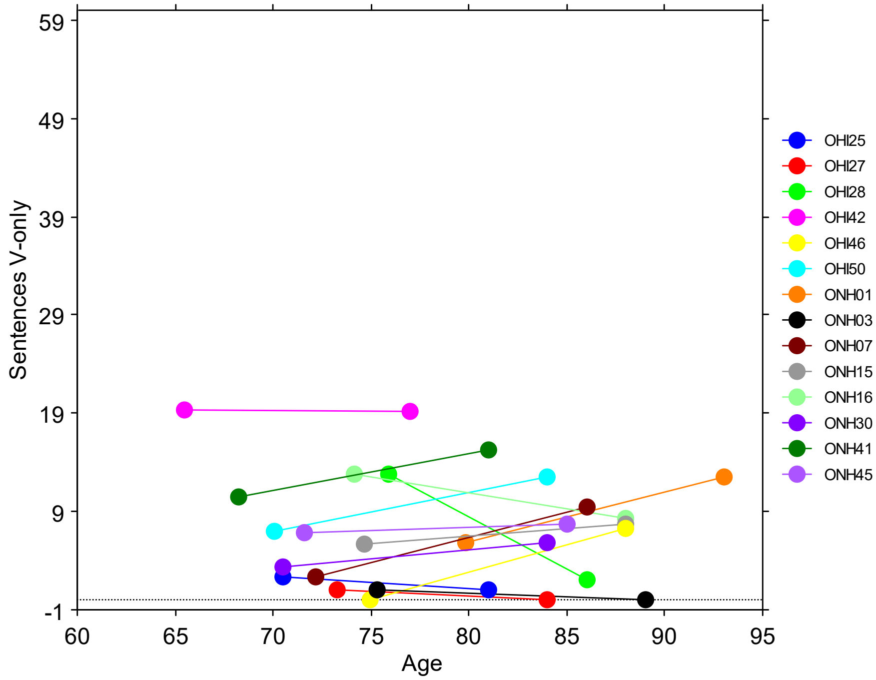

Sentences V-only
59
49
39
29
19
9
-1
60
65
70
75
80
85
90
95
Age
OHI25
OHI27
OHI28
OHI42
OHI46
OHI50
ONH01
ONH03
ONH07
ONH15
ONH16
ONH30
ONH41
ONH45

Figure 10. VE for words over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

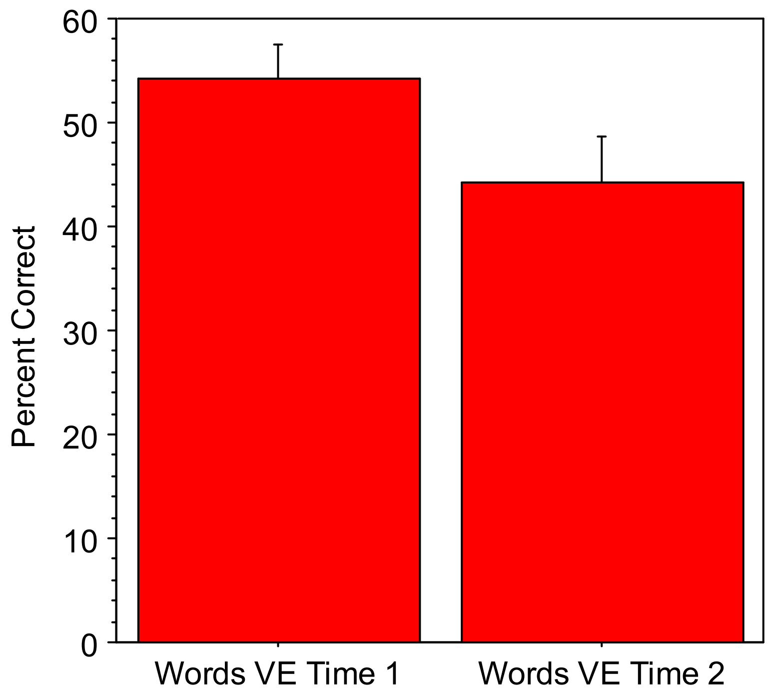


Figure 11. Assessing correlation between VE for words over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.

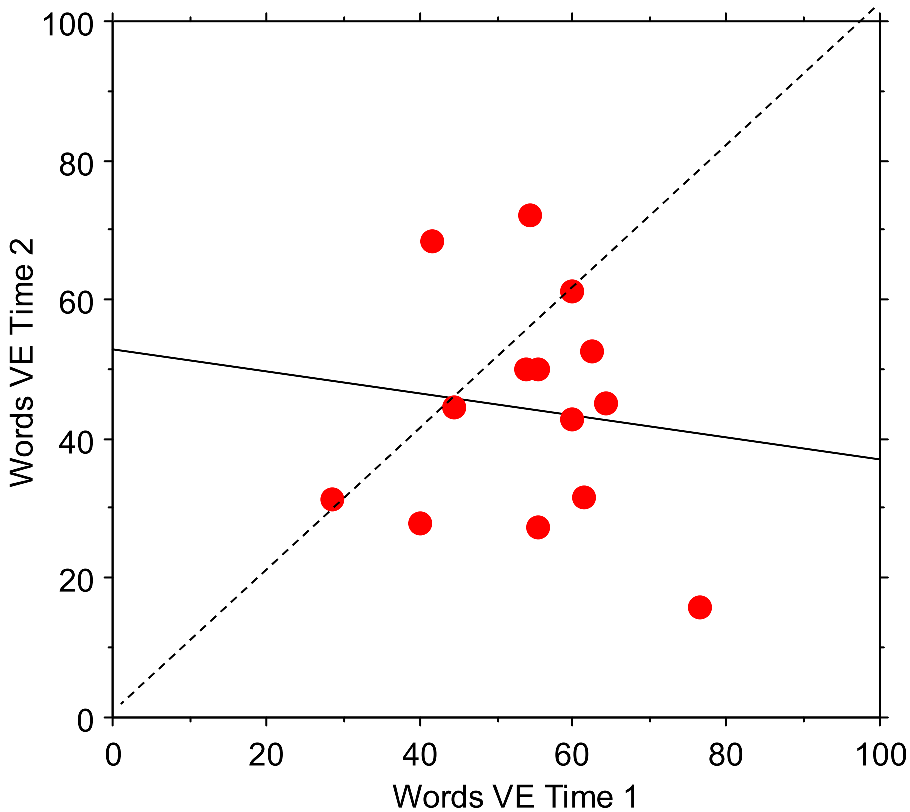


Figure 12. VE for sentences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Error bars represent standard deviations.

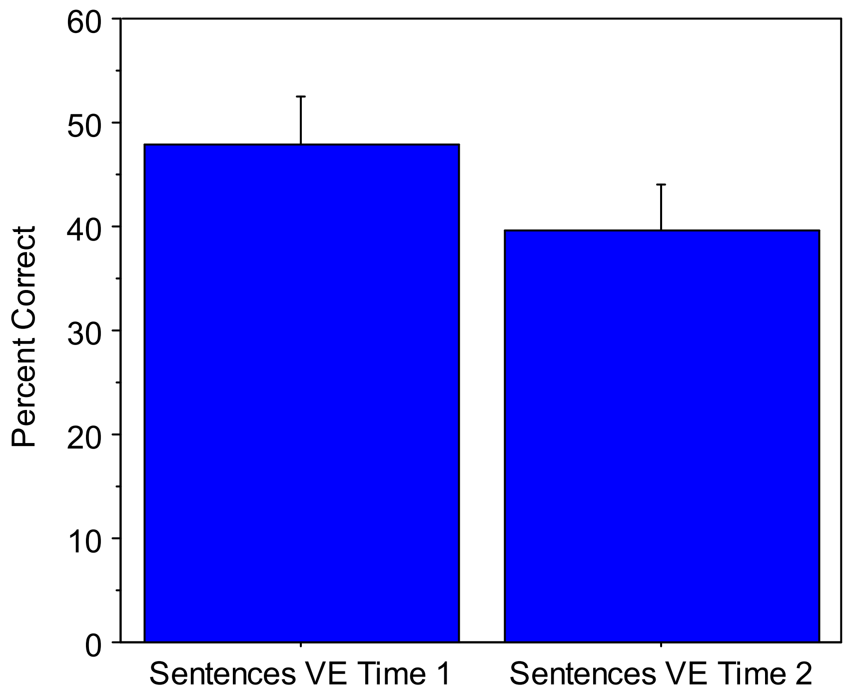


Figure 13. Assessing correlation between VE for sentences over time among participants in the current study. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.

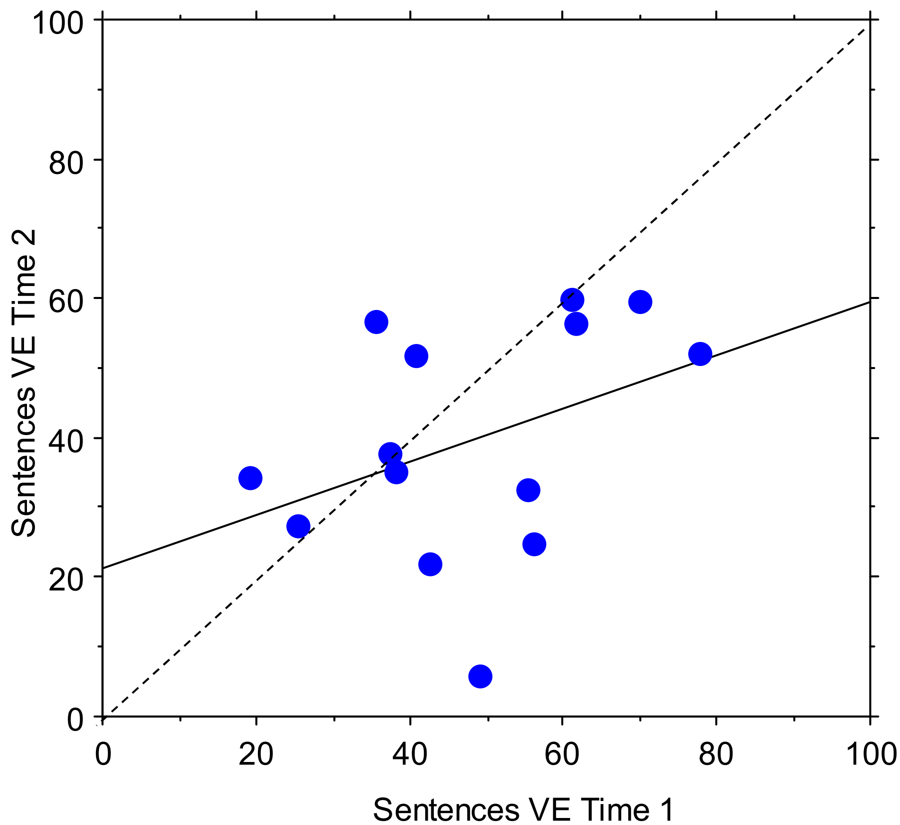


Figure 14. Similar to Fig. 9., however, participants that performed at floor were taken out of analysis (5 participants removed). Inclusion criteria was A-only word scores of 10% or better. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.

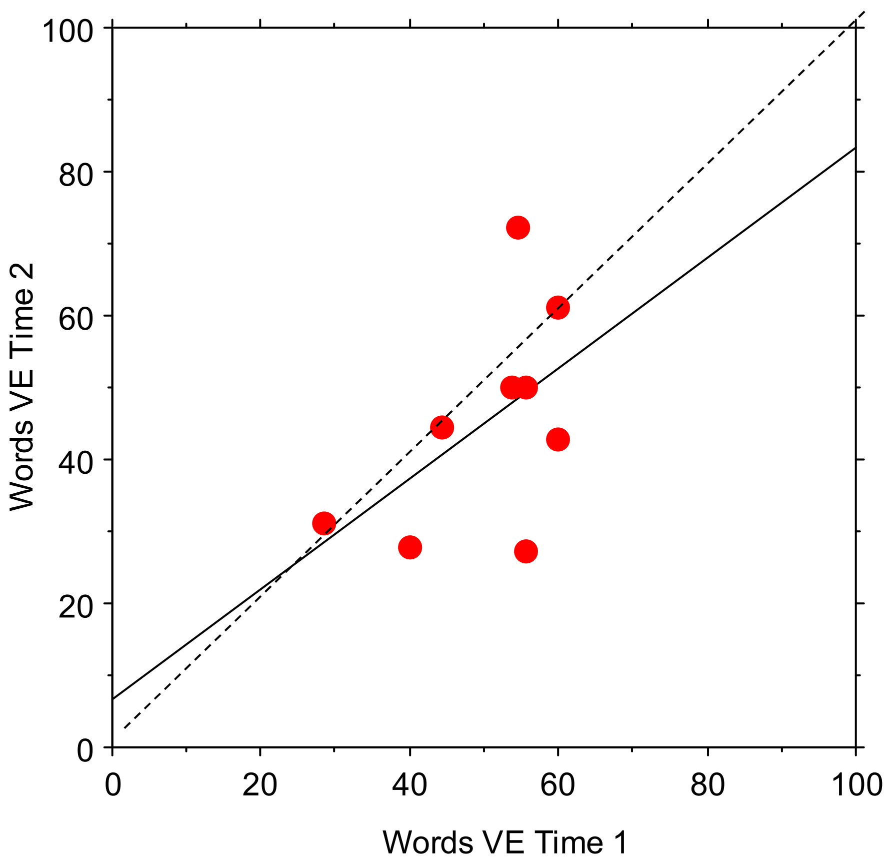


Figure 15. Similar to Fig. 11, however, participants that performed at floor on the A-only sentence task were taken out of analysis (4 participants removed). Inclusion criteria was A-only sentence scores of 10% or better. Time 1 indicates the initial study by Tye-Murray et al. (2007a), and Time 2 indicates the current study. Dotted line represents perfect 1:1 correlation.