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How Repetition Influences Speech Understanding by Younger, Middle-Aged, and Older Adults

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Abstract

Objective: To examine benefit from immediate repetition of a masked speech message in younger, middle-aged and older adults.

Design: Participants listened to sentences in conditions where only the target message was repeated, and when both the target message and its accompanying masker (noise or speech) were repeated. In a follow-up experiment, the effect of repetition was evaluated using a square-wave modulated noise masker to compare benefit when listeners were exposed to the same glimpses of the target message during first and second presentation versus when the glimpses differed.

Study Sample: Younger, middle-aged, and older adults ($n = 16/\text{group}$) for the main experiment; 15 younger adults for the follow-up experiment.

Results: Repetition benefit was larger when the target but not the masker was repeated for all groups. This was especially true for older adults, suggesting that these individuals may be more negatively affected when a background message is repeated. Data obtained using noise maskers suggest that it is slightly more beneficial when listeners hear different (versus identical) portions of speech between initial presentation and repetition.

Conclusions: Although subtle age-related differences were found in some conditions, results confirm that repetition is an effective repair strategy for listeners spanning the adult age range.

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DISCLOSURE STATEMENT

The authors report no financial interest or benefit that has arisen from the direct applications of this research.

Keywords

Speech perception; aging; repetition; masking

INTRODUCTION

When a listener does not understand a talker's message, the talker often repeats what he or she just said. Although research has demonstrated that repetition is one of the most commonly used conversational repair strategies(e.g., Tye-Murray, 1991; Pajo,2013), there is little evidence to document the efficacy of this technique for listeners across the adult lifespan who are attempting to communicate under adverse listening conditions. The purpose of the present study was to quantify how repetition influences speech understanding in younger, middle-aged, and older adults.

Although how and why repetition influences masked speech recognition has received little research attention, there is an extensive literature on priming: how prior exposure to a stimulus influences recognition. Much of this research has been conducted in the visual domain, but priming also can be demonstrated using speech recognition tasks. In general, prior exposure to an auditory message can increase its perceived clarity (Wild et al., 2012; Sohoglu et al., 2014) and its ability to be understood(e.g., Jones and Freyman, 2012). On a neural level, repetition leads to decreased neural response (relative to the activity evoked by the initial presentation) and a concomitant increased sensitivity to new sounds (e.g., Rugg, 1985; Joyce et al., 1999). Some work has shown that, compared to younger adults, older adults receive less benefit from immediate prior exposure to an auditory message(e.g., Wu et al., 2012; Getzmann et al., 2014; Freyman et al., 2017). This might lead to the prediction of older adults demonstrating less repetition benefit than younger adults, although it should be kept in mind that the initial presentation in the priming paradigm is presented in the clear while, with simple repetition, this is not necessarily the case. Moreover, results of other studies suggest that the ability to benefit from a prime changes little with aging (La Voie and Light 1994, Sheldon et al 2008, Ezzatian et al 2011).

There are other reasons why aging might influence repetition benefit, either positively or negatively. Immediately repeating a message buys the listener additional time to process incoming information. This extra time could be especially helpful for older individuals, as slowing of processing speed is a hallmark of the aging process (e.g., Salthouse, 2000; Tun et al., 2009). However, if reduced audibility or distortion from age-related hearing loss makes it impossible to understand a message during the initial presentation, repetition would not be expected to remedy the situation, unless the talker modifies the loudness or clarity of the target message. Moreover, changes in a host of cognitive skills have been implicated as contributing to age-related problems understanding speech, especially in complex listening situations (e.g., Tun et al., 2002; Humes et al., 2006; Akeroyd, 2008; Anderson et al., 2013; Desjardins and Doherty, 2013; Woods et al., 2013; Helfer and Freyman, 2014). Cognitive changes also may play a role in the amount of benefit a listener receives from immediate repetition of a message. For example, well-established age-related declines in working memory (e.g., Hasher and Zacks, 1988; Wingfield et al., 1994; Wu et al., 2012) might limit

the benefit from repetition, as listeners must retain information from the initial presentation and integrate it with what they hear during the second presentation. Since working memory capacity in older adults may already be taxed in competing speech situations (Koelewijn et al., 2012; Neher et al., 2012; Anderson et al., 2013; Helfer et al., 2016), having to rely on a partially exhausted working memory resource to take advantage of repetition may limit older listeners' benefit from repetition.

Executive control of attentional processes, especially those involved in inhibiting information that is not of interest, also might be important in the extent to which repetition assists the listener in situations with competing speech. Like working memory, these processes have been found to explain variance in older adults' ability to understand speech in competing speech situations (e.g., Helfer and Jesse, 2015). Repetition of a target message presented in quiet might not be expected to be influenced by a reduction in inhibitory ability. However, in a background of competing voices, reduced ability to inhibit the to-be-ignored background could limit any benefit from repeating the target message. This may be exacerbated in situations where the to-be-ignored speech also is heard again (as might occur when listening repeatedly to a recorded (i.e., voicemail) message embedded in a background of other talkers). Some work suggests that repetition of unattended speech causes it to be more salient, and therefore more difficult to ignore (e.g., Rivenez et al., 2006). Conversely, research using the irrelevant sound effect paradigm (in which individuals must ignore an auditorily-presented distractor while performing a visual serial recall task) suggests that repeated presentation of a distractor makes it more predictable, leading to enhanced performance, at least in young adults (e.g., Bell et al., 2012; Roer et al., 2014). Our preliminary work on this topic (Helfer and Freyman, 2016) indicated that immediate repetition of a trial consisting of a target sentence and a single-talker competing speech masker was only modestly beneficial, and was slightly less effective for older (vs. middle-aged and younger) participants. Repetition benefit in the presence of non-speech noise maskers was equivalent across groups. In the present study, we used comparison of target-only repetition vs. target + masker repetition to infer listeners' ability to ignore a salient speech masker.

Another factor must also be considered that is unrelated to intelligibility or salience of the masker. When the first and second presentations are exact copies of the target and masking speech, the spectrotemporal peaks of the target and valleys of the masker (time-frequency units with high signal-to-noise ratios) are identical. Thus, the best "glimpses" of the target are not different across the two presentations, and one instead gets a second chance at piecing together the same information. It is not clear whether hearing the identical glimpses would be as beneficial as what would occur naturally, where the specific glimpses would be different across the first and second presentations. To address this issue, we used unintelligible speech-envelope modulated noise maskers that were either identical across repetitions or were allowed to vary. The use of this fluctuating noise masker presented in both repeated and non-repeated conditions helped identify whether this second factor (of identical versus primarily new glimpses) contributed to determining the size of the repetition benefit. We further examined the influence of repeated versus fresh glimpses in a more controlled manner in a follow-up study conducted on younger adults that used a square-wave modulated noise masker.

In summary, the current work explored repetition benefit with repeated maskers (replicating our earlier condition), as well as when only the target sentence was repeated but the masker was not, as would occur more naturally. Our hypothesis was that this more natural condition would lead to greater benefit from repetition, at least in part because repeating the masker (as was done Helfer and Freyman, 2016) might have led to it becoming more salient. We further hypothesized that older adults would be especially disadvantaged when both the target and speech masker were repeated (as compared to when only the target was repeated). We theorized that cognitive skills would be related to task performance: specifically, our thinking was that better cognitive abilities in general would be associated with larger repetition benefit, and that the difference in benefit between the two repetition conditions would be greater in individuals with reduced inhibitory ability. Finally, the present study also examined the effect of giving access to the same versus different glimpses of information during the first and second presentations in order to learn more about possible mechanisms behind repetition benefit. We did not have an *a priori* prediction here, as there was no previous data to guide any hypotheses regarding whether fresh or new glimpses would be more beneficial.

METHODS

Participants

Younger (20–28 years, mean 22 years), middle-aged (42–59 years, mean 53 years) and older (62–78 years, mean 69 years) adults participated in this study ($n = 16/\text{group}$). One middle-aged subject's data were eliminated from analyses as her speech recognition scores were more than two standard deviations below the mean for that group. Younger participants had normal hearing sensitivity (pure-tone thresholds less than 25 dB HL from 250 Hz – 8000 Hz bilaterally). Middle-aged and older adults were required to have a high-frequency pure-tone average (HFPTA; the average of thresholds for 2 kHz – 6 kHz) no greater than 60 dB HL in each ear. The mean HFPTA was 16 dB HL for the middle-aged group (range = 6 dB HL – 39 dB HL) and 25 dB HL for the older group (range = 1 dB HL – 48 dB HL). The average thresholds (± 1 standard deviation) for the middle-aged and older participants are shown in Figure 1. Older and middle-aged participants also were required to score at least 26 on the Mini-Mental State Exam (Folstein et al, 1975). All listeners learned English as a first language and had a negative history of neurologic or otologic disorder. Additionally, all participants had normal tympanograms (suggesting normal middle-ear function) on the day of testing. This project was approved by the University of Massachusetts Amherst Institution Review Board.

Cognitive Tests

Our selection of specific cognitive tasks in this study was driven by both our hypotheses and by prior work. As elaborated upon in the Introduction, we believed that working memory and executive function/inhibitory control were potentially important in explaining variability in our results. Prior work suggests, however, that other cognitive abilities may associated with speech understanding in complex listening situations (e.g., Tun et al., 2002; Woods et al., 2013; Fullgrabe et al., 2015). Hence, each participant completed five subtests from the NIH Cognitive Toolbox (Weintraub et al., 2013), a computerized, standardized set of

cognitive assessment tools: Picture Vocabulary Test (a measure of crystallized intelligence); Flanker Task (attention and inhibitory ability); Dimension Change Card Sort (cognitive flexibility); List Sorting (working memory); and Pattern Comparison (processing speed). A full description of each of these tasks can be found in Weintraub et al. (2013). We used the unadjusted scale scores, in which the participant's score is compared to data in the entire NIH toolbox normative sample, with no adjustment for age or demographic information.

Speech Understanding

Stimuli were sentences from the TVM Colors corpus (Helfer et al., 2016). Each of these sentences is 13 syllables in length and has the structure “*Cue name* found the colornoun and the adjectivenoun here”, where underlined words are used for scoring. The cue name was Theo, Victor, or Michael; the color was one of eight one-syllable color words; and the other key words were one- or two-syllable common nouns and adjectives. Maskers (described below) were presented from loudspeakers 60 degrees to the right and left of the listener. Each loudspeaker was 1.3 meters from the participant.

All subjects listened in four main conditions, with 30 trials for each condition (10 trials at each of three signal-to-noise ratios (SNRs) per condition). Two of the conditions used a speech masker and the other two used a noise masker. The speech masker consisted of two TVM Colors sentences recorded from talkers of the same sex as the target sentence talker, selected randomly without replacement on each trial. Each masking sentence began with cue names differing from that of the target sentence. One sentence was presented from the left and one from the right. Each of the maskers (one from each loudspeaker) was presented in a looped fashion, starting at a random point within the sentence, with the beginning of the sentence appended to the end of the sentence with no gap (see Helfer et al., 2016). During the other half of trials the masker was fluctuating speech-envelope-modulated (SEM) noise generated by extracting the wideband temporal envelope from one talker's TVM sentences, rectification and low-pass filtering at 20 Hz, then using this envelope to modulate speech spectrum noise. Different samples of noise were presented from the right and left loudspeakers.

Two types of repetition trials were completed in the presence of each of these masker conditions. In both-repeat conditions, the exact trial (target and masker) was played twice. In the target-repeat condition, the target sentence was repeated in the presence of different samples of the same masker type (either speech or noise). A fifth ‘non-repeat’ condition was presented as well, with 10 trials at each of three SNRs in the presence of the speech masker only.

Listeners were seated in a double-walled IAC sound booth (#1604A). They were instructed to repeat back the sentence presented from the front loudspeaker (located at 0 degrees azimuth) at the end of each target sentence presentation. Hence, during ‘repeat’ conditions participants responded after both the first and the second presentation, and for ‘non-repeat’ conditions they responded after the one and only presentation. The purpose of the ‘non-repeat’ condition was to ensure that subjects would pay attention to the first of the two presentations during the repeat trials. Data from these non-repeat trials were not analyzed.

Each of the five types of conditions (2 masker types x 2 repetition types, plus non-repeat trials) was completed at three SNRs determined individually for each group to facilitate comparisons of repetition benefit at equivalent accuracy levels. SNRs for the younger subjects were -10 dB, -6 dB, and -2 dB. SNRs for the other two groups were -6 dB, -2 dB, and +2 dB. Target sentences were presented at 70 dB SPL. There were 20 trials (10 sentences, each presented twice) in each of the repeat conditions at each SNR, as well as 12 non-repeat trials at each SNR. All variables were randomized from trial to trial (SNR, masker type, repetition type). Participants did not know, on a given trial, whether or not repetition would be involved. Their verbal responses were audio recorded and analyzed off-line.

RESULTS

Cognitive Tests

One-way ANOVAs identified significant group differences for each of the cognitive tasks (at the $p < .01$ level) with the exception of the List Sort (working memory) task ($F(2, 45) = 1.42$, $p = 2.52$). Post-hoc Bonferroni tests were used to determine where significant differences occurred. Younger adults had significantly poorer vocabulary scores but had better performance on the other three tasks as compared to both the middle-aged and older participants. Older and middle-aged participants' performance did not differ significantly for any of these tasks. Hence, as compared to younger participants, older and middle-aged individuals had poorer inhibitory ability and cognitive flexibility, and slower processing speed, but larger vocabularies.

Effect of Age Group and SNR on Speech Perception

Figure 2 shows speech recognition scores in percent correct for first attempts in each masker condition, averaged across repetition-type trials. Data were scored as percent of words perceived correctly. Notable is a pattern we have observed in previous research (Helfer and Jesse, 2015; Helfer and Freyman, 2016): speech recognition ability of our younger and middle-aged listeners was almost identical (at least at the common SNRs) in the presence of the noise masker, but diverged when the masker was competing speech; in this condition, the middle-aged subjects' performance fell between that of younger and older participants.

First-attempt percent-correct scores from the two common SNRs (-6 dB and -2 dB) were analyzed using repeated-measures ANOVA with masker type and SNR as within-subjects factors and group as a between-subjects factor. Results showed significant main effects for all three factors, as well as a significant group x masker type interaction [$F(2, 44) = 4.79$, $p = .013$]. Post-hoc one-way ANOVAs with Bonferroni corrections indicated that the performance of older adults differed significantly from that of the other two groups in both types of maskers. The difference between middle-aged and younger participants did not reach statistical significance for either type of masker.

Repetition Benefit

Of primary interest in this study was comparing repetition benefit within and across groups when only the target was repeated versus when both target and masker were repeated. We observed that repetition benefit appeared to be truncated by high levels of performance when

we scored each key word separately. Hence, we decided to use an alternative scoring method in which all four key words in each sentence needed to be correctly reported for a trial to be considered correct. These data are shown in the scatterplots in Figure 3, which display scores for the second attempt (on the y axis) by scores obtained on the first attempt (on the x axis). Each data point in Figure 3 is based on the result of 10 trials from each subject on both the first and second repetitions. For example, the triangle symbol highlighted by the arrow in the bottom-right panel indicates that during the 10 trials in which the target was repeated in the presence of different SEM maskers at a particular SNR, this middle-aged subject perceived 1 out of the 10 sentences completely correct on the first presentation and 9 of the 10 sentences correct on the second presentation.

An initial observation is that the large majority of the data points are above the diagonal line, indicating better performance on the second presentation than the first presentation. Second, repetition benefit is obvious for all three subject groups. Third, at high levels of performance on the first presentation there is (logically) less opportunity to observe repetition benefit. Because of the SNRs chosen, and their relatively good performance especially in the SEM maskers, the middle-age subjects achieved many of those higher scores (see also Figure 2), and it would be misleading to compare performance across groups without any consideration of these differences.

Because of these issues, and the additional possibility of floor effects when the first repetition yielded 0 percent correct, only subject/condition combinations in which performance for the first presentation was between 10% and 70% correct were analyzed further. Thus, repetition benefit was calculated as the difference in percent-correct performance between the second attempt and the first attempt, measured for all condition/subject combinations for which first-attempt performance ranged between 10% correct and 70% correct. These results are displayed in Table I while the average differences between target-repeat and both-repeat conditions are shown in Figure 4. Repetition benefit was observed for all conditions and groups, and ranged from approximately 9 to 29 percentage points. The most obvious finding is that the target-only repeat conditions yielded larger repetition benefit compared with target + masker repetition, especially for the older listeners in the speech masker, as highlighted in Figure 4. Repeated-measures ANOVA on these repetition benefit data with masker type (speech versus noise) and repetition type (target-only repeat versus both target + masker repeat) as within-subjects factors and group as a between-subjects factor showed a significant three-way interaction between masker type, repetition type, and group [$F(2,44) = 4.82, p = .013$]. Post-hoc ANOVA with Bonferroni corrections indicated that the only significant difference in repetition benefit occurred for older listeners, for whom this benefit was significantly larger for speech maskers with target-only repeated as compared to repetition benefit when both target and masker were repeated. This finding was confirmed with a second repeated-measures ANOVA that analyzed the difference in benefit between the two types of repetition conditions. The analysis indicated that this metric was significantly larger for older individuals (vs. the other two groups), but only when the masker was competing speech [$F(2,44) = 10.00, p < .001$].

Individual Variability

One of our hypotheses was that cognition would be associated with the ability to take advantage of repetition. We conducted a stepwise regression analysis on the data from middle-aged and older participants to identify connections among repetition benefit in each condition (averaged across SNR), age, better-ear high-frequency hearing (average of pure-tone thresholds for 2 kHz – 6 kHz), and performance on each cognitive task. Results of this analysis indicated that our cognitive measures did not appear to be important in explaining repetition benefit. When both the target and masker were repeated and the masker was competing speech, the only significant variable was age, and it accounted for only a modest amount of variance (see Table 2). For the target-repeat data with the SEM masker, the only significant variable was HFPTA, again accounting for only a small amount of variance. Individuals who were older derived less repetition benefit in the target + masker repeat condition when the masker was speech, and individuals with more high frequency hearing loss obtained less repetition benefit when the masker was noise and only the target was repeated. There were no significant predictor variables in the other two analyses. Hence, our hypothesis that cognitive ability would limit repetition benefit with aging was not supported.

As noted above, one key finding in the present study was that, in the presence of a competing speech masker, the difference in repetition benefit between when only the target sentence was repeated vs. when both the target and masker were repeated was substantially larger for older adults, as compared to our other participants. Why might this be the case? One possible explanation for this pattern is that older adults are more susceptible than younger adults to a salient speech masker. With the SNRs used in this experiment, the masker was often of similar loudness or even louder than the target. Repetition of those masking sentences might have made them even more difficult to ignore, and age-related hearing loss and/or cognitive decline could have affected the ability to focus on the target under such conditions. We conducted regression analyses to explore this further, with the same demographic and cognitive variables described above and with repetition benefit difference scores (target-only repeat minus target + masker repeat, for both speech and noise maskers) as the dependent variable. Age was the only significant predictor variable in the equation derived when the masker was speech, accounting for approximately 28% of the variance. Participants who were older had larger difference scores. With the noise masker, HFPTA accounted for a significant (albeit small) portion of variance in the repetition benefit difference. In this case, individuals with more high-frequency hearing loss had a smaller difference in repetition benefit. As with the regression analyses on general repetition effect, it appears that the cognitive tasks used in this study were not able to capture individual variability in these difference score metrics.

Follow-up experiment with Square-Wave Masker Modulation

The better performance obtained for non-repeated than repeated maskers even for the fluctuating noise maskers (Figure 4, right set of bars) suggests the possibility that it is advantageous for the listener to experience a different set of glimpses during second presentation than a repeat of the same glimpses. If so, this could also explain at least some of the difference in the repeat versus non-repeat masker results for the speech maskers.

However, while there were logically substantial differences in the glimpses in the non-repeated masker, the precise nature of those differences was unspecified. In order to investigate the same vs. different glimpses in a more controlled paradigm, we conducted an additional experiment. In this sub-experiment, a square-wave modulated noise masker was used with both identical and anti-phasic (180 degrees out of phase) modulations for the first and second presentation. In the in-phase condition, all the glimpses were repeated and in the anti-phasic condition, none of them were (and the previously masked sections instead became the glimpses). This sub-experiment was run in order to explore the upper bound of the effect of same vs. different glimpses. Because results of the statistical analyses of repetition benefit did not yield significant differences between groups for the noise masker, we did not feel that it would be particularly informative at this point to include multiple age groups in this follow-up experiment. Therefore, we ran this study using young, normal-hearing listeners.

Subjects were 15 young normal-hearing listeners who met the same criteria as the first set of young listeners. None had participated in the main experiment. Data were collected at three SNRs (−14 dB, −11 dB, and −8 dB) using a square-wave modulated noise masker with in-phase and out-of-phase modulations. Both target and masker were presented from the front (0 deg.) loudspeaker. All other aspects of target stimuli and procedures were identical to those used in the main experiment. Analysis again included all the data for which the first of two presentations yielded performance between 10% and 70% correct within the 10 sentences presented per condition per subject. The mean repetition benefit was 10.8 percentage points for the in-phase modulation masker and 15.0 percentage points for the masker with out-of-phase modulations. This difference was statistically significant [$t = -2.27$, $p = .029$]. Thus, like the fluctuating noise masker (and the speech masker) used in the main experiment, repetition benefit was observed for both types of maskers but was greater when a different set of glimpses was available.

DISCUSSION

The primary outcome of the present study is that immediate repetition is an effective repair strategy for individuals spanning the adult age range. Our results indicate that younger, middle-aged, and older individuals obtain substantial benefit from the immediate repetition of a message. When only the target was repeated (but not the masker), participants obtained an average 24 percentage point increase in speech recognition in the presence of the speech masker and an average 17 percentage point increase in the presence of the SEM noise masker. This is encouraging because our results likely underestimate repetition benefit that occurs in real communication scenarios. When a talker repeats a message, they often will do so in a manner that is likely to make the utterance more understandable (e.g., louder, slower, more clear). In the present study, the repetition was instead an identical replica of the original target sentence.

Compared to our previous study on the effects of repetition (Helfer et al., 2016), the present experiment yielded greater benefit in the target + masker repetition condition. In our prior study, relatively little repetition benefit was found when both the target and its accompanying speech masker were repeated (3–6 percentage points for older and middle-

aged adults, 5–9 percentage points for younger adults). In the present study’s comparable condition where both target and masker were repeated, repetition benefit averaged 9 percentage points for older adults, 16 percentage points for middle-aged adults, and 15 percentage points for younger adults (see Table 1). The substantial differences in methodologies (particularly in spatial positions of the maskers, the use of a one- vs. two-talker masker, and how the data were scored) likely accounted for at least a portion of the disparity in results.

We had hypothesized that cognitive abilities (especially working memory and inhibitory control) would be related to repetition benefit. Specifically, we thought that amount of repetition benefit would be associated with performance on our cognitive tasks. This was not the case. Rather, increased age (when the masker was speech and both target and masker were repeated) and greater high-frequency thresholds (when the masker was noise and only the target was repeated) were associated with smaller repetition benefit. Of course, this does not necessarily mean that cognitive mediation is not required to benefit from repetition. It is likely that either our tasks were not sensitive enough to identify abilities that relate to using repetition, and/or there are other domains of cognition not measured here that can explain individual variability. It does appear, however, that high-frequency hearing loss also cannot account for much (if any) variability in repetition benefit in older adults, especially when the repetition occurs in a background of other talkers.

Similarly, there was no apparent association between cognitive task performance and the difference in repetition benefit between the two types of repetition. Regression analysis did show that the difference was related to age (older = larger) when the masker was speech, and was smaller for individuals with more hearing loss when the masker was noise. The finding of an age-related increase in the difference in repetition benefit between the two types of repetition conditions, especially when it only occurred in the presence of a competing speech message, could be indicative of enhanced susceptibility to priming of unattended information and/or a general increased susceptibility to a salient, understandable speech masker. If so, the cognitive measures used in the present study seem to be unrelated to these capabilities.

Results of the follow-up study in young adults confirmed that listeners can use either glimpses of the same information during repetition or glimpses of different information (in this case, the opposite glimpses), with a small but significant advantage for the anti-phasic glimpses. This suggests that at least some of the benefit of repetition in any fluctuating masker under natural circumstances comes from the integration of the original and fresh glimpses. Future work could be directed at identifying the time limit of the integration—that is, if the repetition does not occur immediately after the initial presentation—and the degree to which this pattern holds in older adults, for whom age-related changes in working memory may limit the ability to use sequential glimpses of information. Indeed, results of the current study suggest that fresh (vs. repeated) glimpses may be even more of a factor for middle-aged and older adults than it is for younger adults. As can be observed in Table 1 and Figure 4, repetition benefit in the presence of the SEM noise masker was slightly (but not statistically significantly) larger for target-repeat trials than for target + masker repeat trials for the two older groups. Studies of speech perception using interrupted target speech or a

modulated masker have not reached consensus regarding whether aging interferes with the ability to integrate glimpses within a trial (e.g., Gordon-Salant and Fitzgibbons, 1993; Dubno et al., 2003; Grose et al., 2009; Fullgrabe et al., 2015; Shafiro et al., 2015; Grose et al., 2016). How aging affects the ability to integrate glimpses of speech across trials remains to be seen.

CONCLUSIONS

Simple repetition of a speech message is an effective strategy for increasing adults' ability to understand the utterance. This appears to be the case for individuals spanning the adult age range listening in the presence of the types of maskers used in the present study. There is, however, evidence that older adults may be more susceptible than younger adults to interference caused by a background distractor being repeated. Younger adults are able to integrate glimpses of masked speech that are either the same between the two presentations or different, although there is a slight advantage for different glimpses. Future research would need to be conducted to determine if older adults show this same pattern.

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Acronyms and Abbreviations

dB	decibels
HL	hearing level
Hz	Hertz
HFPTA	high frequency pure-tone average
SNR	signal-to-noise ratio
ANOVA	Analysis of Variance
NIH	National Institutes of Health
SEM	speech-envelope modulated
SPL	sound pressure level
vs.	versus

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Figure 1 (color online).

Average pure-tone thresholds (± 1 standard deviation, shown in the shaded region) for middle-aged (left) and older (right) adult participants at octave frequencies from 0.250 through 8 kHz as well as at interoctave frequencies 3 kHz and 6 kHz.

Figure 2 (color online).

Speech recognition scores in percent correct for first attempts in competing speech maskers (left) and speech envelope modulated noise (right). Results are shown at each SNR and are averaged across repetition-type trials. Error bars represent the standard error.

Figure 3 (color online).

Percent correct scores for the second attempt (on the y axis) by percent correct scores obtained on the first attempt (on the x axis). Each data point is based on the result of 10 trials from each subject on both the first and second presentations. Top row: scores obtained in the presence of competing speech maskers; bottom row: scores obtain in the presence of the SEM noise masker. The arrow indicates the example data point described in the text.

Figure 4 (color online).

Average repetition benefit difference for each group by masker type (left: speech masker; right: SEM noise). Repetition benefit difference was calculated as repetition benefit when only the target was repeated minus repetition benefit when both the target and masker were repeated.

Table 1.

Repetition benefit (second attempt minus first attempt, in percentage points) for data where percent-correct performance for first attempts was between 10% and 70% correct. Values in parentheses are the standard errors.

	Speech Masker		Noise Masker	
	<i>Both Repeat</i>	<i>Target Repeat</i>	<i>Both Repeat</i>	<i>Target Repeat</i>
Older	9.20 (2.19)	28.56 (2.74)	11.80 (2.44)	18.30 (2.65)
Middle-Aged	16.90 (3.12)	20.30 (2.47)	11.00 (3.01)	18.00 (2.34)
Younger	15.60 (2.78)	22.80 (2.17)	14.20 (2.73)	15.40 (1.64)

Table 2.

Results of regression analyses on the repetition benefit scores (speech masker/both repeat, noise/target repeat) and on the repetition benefit difference scores (speech masker difference, noise masker difference) from the middle-aged and older participants (n = 31). Only significant equations are shown.

Dependent Variable	Independent Variable	F	Beta	Significance	Adjusted R Squared
Speech masker/both repeat	Age	7.52	−0.454	0.010	0.179
Noise masker/target repeat	HFPTA	6.49	−0.428	0.016	0.155
Speech masker difference	Age	12.56	0.55	0.001	0.278
Noise masker difference	HFPTA	5.58	−0.402	0.025	0.132