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Semantic Priming, Not Repetition Priming, is to Blame for False Hearing

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Abstract

Contextual and sensory information are combined in speech perception. Conflict between the two can lead to false hearing, defined as a high-confidence misidentification of a spoken word. Rogers, Jacoby, & Sommers (2012) found that older adults are more susceptible to false hearing than young adults, using a combination of semantic priming and repetition priming to create context. In the current study, the type of context (repetition vs. sematic priming) responsible for false hearing was examined. Older and young adult participants read and listened to a list of paired associates (e.g., ROW–BOAT), and were told to remember the pairs for a later memory test. Following the memory test, participants identified words masked in noise that were preceded by a cue word in the clear. Targets were semantically associated to the cue (e.g., ROW–BOAT), unrelated to the cue (e.g., JAW–PASS), or phonologically related to a semantic associate of the cue (e.g., ROW–GOAT). How often each cue word and its paired associate were presented prior to the memory test was manipulated (0, 3, or 5 times) to test effects of repetition priming. Results showed repetitions had no effect on rates of context-based listening or false hearing. However, repetition did significantly increase sensory information as a basis for metacognitive judgments in young and older adults. This pattern suggests that semantic priming dominates as the basis for false hearing, and highlights context and sensory information operating as qualitatively different bases for listening and metacognition.

Introduction

When perceiving speech, listeners can base their perceptions on two qualitatively different sources of information: sensation and context (e.g., Nittrouer & Boothroyd, 1990). Sensation denotes the acoustic characteristics of the speech stimulus as processed by the peripheral auditory system. Context refers to the mental and environmental situation in which the speech stimulus occurs (e.g., prior knowledge about a topic). As people grow older and experience age-related hearing loss, the availability of sensory information is degraded and context plays an even more important role in facilitating speech. Several studies report that speech perception performance for older adults is better than for young adults when facilitative context is available as a basis for listening (see Pichora-Fuller, 2008, for a

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review), providing compelling evidence for context as a compensatory mechanism against age-related hearing loss.

Almost of all of the studies to date have focused on objective measures of hearing. Thus, there has been little research on listeners' subjective experience of hearing, or meta-audition (Rogers, Jacoby & Sommers, 2012). Subjective experience refers to the confidence, awareness, and other metacognitive aspects listeners possess about their hearing. These kinds of experiences are important because they are used as a basis for action (Koriat & Goldsmith, 1994; 1996). For example, if about to report a fellow employee for making an inappropriate comment during a meeting, one should be fairly confident that the comment was heard correctly. Further, this confidence should be based on actually hearing the words coming out of the mouth of the fellow employee rather than being based on some prevailing notion of what that employee might say.

The notion that sensory information and context may sometimes be in conflict is critical to prior work on false hearing. False hearing—a high confidence misidentification that is consistent with prior context—has been shown to be more frequent in older than in young adults (Rogers, Jacoby, & Sommers, 2012; Sommers et al., 2014; Rogers & Wingfield, 2015). Age-related increases in these types of errors stand in contrast with much of the work in aging and speech perception that shows older adults' successful identification improves more than young adults' from the addition of context (e.g., Pichora-Fuller, 2008). Such work advocates that context serves to enhance perceptual discriminability of a stimulus (e.g., Pichora-Fuller, Schneider, & Daneman, 1995; Sommers & Danielson, 1999). However, rather than improving discriminability, the age-related increase to false hearing indicates that older adults' context use may be better characterized as replacing lapses in perception with responses that fit the context. Reliance on context is generally adaptive in real world situations, where context is infrequently misleading. When considering false hearing, reliance on context can be conceptualized as relying upon the larger word-in-context level rather than at the level of the individual word. These two levels serve as qualitatively different bases for auditory judgments, analogous to the letter and word levels in investigations of visual perception aimed at the word superiority effect (e.g., Reicher, 1969; Wheeler, 1970). For hearing, Rogers et al. (2012) held that focus toward the word level is more effortful for understanding heard messages than focusing at the word-in-context level, but is also required for successful identification of a word presented in a misleading context.

The method employed by Rogers et al. (2012) to elicit false hearing resembled that of a proactive interference paradigm used by Hay and Jacoby (1996). Rogers et al. (2012) familiarized participants on a set of semantically related cue-target pairs (e.g., ROW—BOAT) who were later were given a perception test where a given cue word was followed by a to-be-identified word in noise. The word in noise could have been congruent with respect to the earlier familiarization (e.g., ROW—BOAT), incongruent but phonologically similar to the word from familiarization (e.g., ROW—GOAT), or otherwise unrelated to the cue (e.g., JAW—PASS). Participants were instructed to identify the word in noise without considering any prior contextual cues. Older adults were much more likely to respond with a contextually consistent response than young adults, particularly in the incongruent case, and did so with extremely high levels of confidence (i.e., false hearing). Importantly, these age effects on false hearing were found even after taking into account age-related hearing loss, suggesting a cognitive rather than sensory origin for false hearing.

A limitation of the described approach to measuring false hearing is that there are at least two different kinds of context that could have been contributing to the effects observed by Rogers et al. (2012): the semantic relationship between the cue and target words, and the repetition of the cue and target during familiarization. These two sources of information reflect two common priming manipulations in cognitive psychology: semantic priming and repetition priming. Semantic priming is an important factor contributing to enhanced word identification and memory (e.g., Lash et al., 2013). Repetition priming, defined as the facilitated processing of a word upon its second presentation, has also been shown to influence the accessibility of a particular stimulus, which can lead to increases in successful identification (e.g., Sheldon, Pichora-Fuller, & Schneider, 2008) but also greater rates of false identification in older adults (e.g., Jacoby, et al., 2012). It is worthwhile to note that repetition priming has been found to reveal differential effects at different lags between presentations, leading to the conceptualization of two kinds of repetition priming, short- and long-term (see Tenpenny, 1995, for a review). Short-term repetition priming effects have been observed at lags of less than one second between prime and target (e.g., Goldinger, Luce, & Pisoni, 1989), and have been considered unlikely to be based on mechanisms that serve priming effects that last for several minutes of more (Church & Schacter, 1994) Because the lag between priming and identification of targets observed by Rogers et al. (2012) was on the order of several minutes, we will not consider this type of short-term priming further, but rather focus on long-term repetition priming, which has been shown to prime both abstract phonological representations and voice-specific acoustic features (Church & Schacter, 1995). Importantly, repeated presentations of a prime could also build an episodic context, whereby presentation of a prime and target together trigger remembering of a prior episode where the prime and target were paired. Thereby, repetition priming could lead to two classes of effects: priming based on automatic accessibility of the prior presentation of the prime, and priming based on the remembering of the specific episode in which the prime and target were prior presented (Goldinger, 2007).

An example of how a repetition manipulation could have two classes of effects comes from the false memory literature. As with false hearing, false memory also occurs more often in older adults (e.g., Norman & Schacter, 1997). In a classic proactive interference study by Jacoby (1999), young and older adults read a list of words followed by a list of words that were aurally presented. Participants were then given a recognition memory test and told only to respond yes to words that were heard, and that if participants remembered a word as occurring in the read list, they could be sure that the word was not heard. Repetition of the words could have two effects: 1) Better encoding of the word, as well as its source information (i.e., from the read list) which would lead to rejecting them item on the recognition test, and 2) Enhanced familiarity of the word, which could lead to a higher rate of false alarms to the word on the recognition test. The results of that study revealed that the more often a word was repeated in the read list, the less likely young adults were to falsely say the word was heard. The reverse was true for older adults: the more a word was repeated in the read list, the more likely it was to be falsely remembered as being heard. Such results revealed that repeated presentations could serve both enhanced encoding, leading to retrieval of source information (e.g., read vs. heard), and the automatic accessibility of an item (e.g., repetition priming). Jacoby (1999) interpreted the results in terms of a dual-process model supporting recollection, a controlled use of memory, and familiarity, the automatic basis for memory judgments. These processes could be aligned with that of false hearing: because recollection is effortful but required for correct responding when familiarity is misleading, it may be akin to focusing at the level of the individual word in speech comprehension, and familiarity may correspond to the word-in-context level.

A recent study conducted by Rogers and Wingfield (2015) revealed that age-related increases in false hearing occurred even in the absence of a familiarization phase, suggesting that semantic priming may play a more dominant role in creating false hearing than repetition priming. However, because the earlier familiarization phase used by Rogers et al. (2012) was omitted, the contribution of repetition priming could not be assessed. Dissociating these two potential sources of context requires a study in which variables underlying these types of priming are selectively manipulated.

The current study investigates the contributions of semantic and repetition priming to the phenomenon of false hearing. In this study, the number of exposures of semantically related cue target pairs was manipulated via a familiarization phase and then compared to both a baseline (no context) condition and a semantically primed but unfamiliarized condition. Rogers et al. (2012) found strong evidence for false hearing for young and older adults when cue-target pairs were repeated five times during a familiarization phase. However, it is wholly plausible that the semantic relationship of the cue to the target is sufficient to create false hearing. In the current study, some cue-target pairs were never presented during the familiarization phase (e.g., 0x trials), while others were (e.g., 3x and 5x trials). If evidence for false hearing is obtained on 0x trials, it would suggest that the effect of context in this paradigm should be attributed to semantic priming, as the cue and target were always semantically associated. Further, a carefully controlled unprimed baseline condition was essential for ensuring that age differences in listening are not attributable to age-related hearing loss, but rather age-related changes in the effects of priming.

To measure the link between subjective experience and action (such as in the earlier example related to the workplace complaint), participants were allowed to volunteer on a trial-by-trial basis which identifications they would like to be scored by the experimenter. This form of scoring is referred to as free report, as opposed to the more typical forced report in which all trials are scored. If listeners' subjective experience is well attuned to their actual perception, then participants should have a higher proportion of correct items for free than forced report (Koriat & Goldsmith, 1994; 1996). This will be considered by measuring changes in performance from forced to free report in the current study. Thus, in addition to rates of context- and sensory-based responses and confidence in those responses, the gains in accuracy from forced to free report will also be examined.

Method

Design

The design of the study was a 2 (Age: Young, Older) × 3 (Trial-type: Baseline, Congruent, Incongruent) × 3 (Presentation Count: 0x, 3x, 5x) mixed-factorial design. Trial-type refers to whether the semantic context was neutral, facilitative, or interfering with respect to successful identification. Presentation count refers to how many times the cue and its semantic associate appeared together during the familiarization phase. Trial-type and presentation count were manipulated within-participants. No baseline cues or targets were presented during the familiarization phase (0x). Example stimuli, outlines of procedures and response classification are given in Figure 1.

Participants

Participants were 18 university undergraduates (ages 18–21; M=18.93 years) and 18 healthy older adults (ages 65–83; M=70.83 years). Prior to the main experiment we determined for each participant the minimal signal-to-noise ratio (SNR) that allowed for 50% open-set identification accuracy for monosyllabic words in six-talker babble using a speech reception threshold (SRT, ASHA, 1988). The older adults' SRTs were higher than the young adults' [older adult M = 5.88, standard deviation (SD) = 3.31; young adult = 3.89, SD =2.59; t[34] = 2.02, p=0.05]. Listeners' threshold data were used to adjust SNRs to equate the young and older listeners' performance in the baseline condition. As is common (e.g., Verhaeghen, 2003), young adults had somewhat lower performance than the older adults on the Shipley vocabulary scale (Young M= 33.28, Older M= 36.06), t(34) = 3.29, p<.01.

Stimuli and Procedures

The stimuli consisted of 126 cue–target pairs drawn from the list of stimuli given in Appendix A. These pairs were divided equally amongst the baseline (e.g., JAW–PASS), congruent (e.g., ROW–BOAT), and incongruent conditions (e.g., ROW–GOAT). Participants completed two phases of the experiment: the familiarization phase and the perceptual test phase. The word pairs that were used during familiarization for congruent and incongruent trials and during speech identification for congruent trials were semantically related paired associate words (e.g., ROW—BOAT) retrieved from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 2004). The average forward association strength from cue to target was .49. During speech identification in baseline and incongruent trials, words were not semantically associated, although for incongruent trials targets were phonologically similar to a semantically related associate of the cue (e.g., ROW—GOAT). Target words in all conditions were balanced for Hyperspace Analog to Language (HAL) word frequency, neighborhood density, and frequency distributions of phonological neighbors according to norms published by the English Lexicon Project (Balota et al., 2008). All words were consonant-vowel-consonant words, recorded by an adult speaker of American English, and normalized for root mean square intensity. Targets for the congruent and incongruent conditions differed only in substitution of one consonant phoneme by place of articulation (e.g., BOAT vs. GOAT). Of these pairs, the relative proportion of word-initial to word-final substitutions were 56% and 44%, respectively[1]. The relative proportion of stop phonemes to fricative substitutions were 70% and 30% respectively. Sets of cue-target pairs (e.g., ROW—BOAT, ROW—GOAT) served equally as often in the congruent or incongruent trials across participants and were rotated equally across each combination of the trial-type (congruent/incongruent) and repetition (0x, 3x, 5x) conditions. Baseline pairs were constructed of only two words, were not rotated across conditions or participants, and were analyzed separately from congruent and incongruent trials. Each word was recorded in isolation with consistent pitch-accent type and stress. Words were always presented via headphones in a quiet room at approximately 65 dB sound pressure level.

During the familiarization phase, only cues from the congruent 3x, congruent 5x, incongruent 3x, and incongruent 5x conditions were presented, followed by their semantically related target. For incongruent trials, the congruent target is the stimulus during familiarization. This means a semantically consistent, but phonologically different alternate word was presented during the familiarization phase (e.g., "ROW—BOAT" instead of "ROW—GOAT"). Word pairs were presented zero, three, or five times during familiarization based on repetition condition. Participants were told to listen to and remember these pairs for a later memory test. After familiarization, participants performed a cued-recall test. At test, participants heard and viewed the printed cue word and were asked to recall the semantically consistent word. All participants were at 80% recall or above.

During the perceptual test phase, cue words were always presented in the clear followed by the target word masked by six-talker babble. The level of noise was set to meet the SNR that yielded the 50% SRT for each participant. The participant's task was to say the target word aloud after each word-pair had been presented, rate confidence in their identification on a scale from zero to 100%, then indicate whether they wanted to have their response scored by the experimenter (i.e. free report). Participants were told they would earn or lose one point for each correctly or incorrectly volunteered response, with no change to score if the response was not volunteered. Participants were explicitly told to respond only on the basis of what they heard and not on the basis of semantic association between words. Prior to the main perceptual test phase participants received six practice trials to familiarize them with the task. None of these words was used in the main experiment.

Presentation of the experiment to the participant was conducted using E-Prime software (Psychology Software Tools, Pittsburgh, PA). The timing for each trial was as follows: 200 ms before the first member of a pair (the cue) was presented over the headphones, a single asterisk "*" was presented visually in the top center portion of the screen until the offset of the aurally presented word. Following a 1,000 ms interstimulus interval, two asterisks "**" were presented visually in the top center of the computer screen; 200 ms later the target word, masked by noise, was presented aurally. The asterisks were used so that participants would have a visual indication of which word was being played over the headphones, but were offset so that they did not distract the participants while the word was being played. Participants were given unlimited time to respond. Trials were presented in a pre-

[1]A secondary analysis was performed taking into account differences between the temporal orders of the phonemic substitution. This analysis revealed significant effects but did not show any differences in the pattern of age-related increases to false hearing. Details of the analyses are presented in Appendix B.

randomized order such that conditions were equally distributed throughout the test phase and that no condition appeared more that three times in a row.

Results

Unless otherwise indicated, we only report effects significant at the $p < .05$ significance level that were not involved in a higher-order interaction. After an interaction was revealed to be significant, we used post-hoc *F*-tests that applied the Bonferroni correction for reduction of Type I error. Mauchly's test of sphericity and Levene's test of homogeneity of variance were also calculated. If the assumption of sphericity was violated, the Greenhouse-Geisser correction for *MSE* and degrees of freedom was applied. If homogeneity of variance was violated, degrees of freedom were adjusted.

Baseline Trials

Baseline trials were separately examined to ensure that both age groups were presented age-appropriate noise masking on baseline trials. Performance was assessed by examining the proportion of correct responses (e.g., hit rate), mean confidence rating ascribed to a hit, and the probability of a hit subtracted from the probability of a hit given it was volunteered (called changes in accuracy from forced to free report; Koriat & Goldsmith, 1996). Table 1 shows there were no significant differences between young and older adults on baseline hit rates or changes from free to forced report [i.e. p(Hit|Vol)-p(Hit)]. One older adult was excluded from analysis for not volunteering any responses on baseline trials.

Congruent and Incongruent Trials

Figure 2 shows the pattern of identifications and confidence separated by whether responses were considered context- or sensory-based. Both congruent hits and incongruent false alarms were responses consistent with the semantic context, and were considered context-based[2]. Baseline and incongruent hits required successful use of the sensory information of the target, and were considered sensory-based.

Context-based responses are shown in the top left panel of Figure 2. While older adults trended toward having greater hits than young adults on congruent trials (Young $M = .84$, Older $M = .89$), $F(1, 34) = 3.47$, $MSE = .03$, $p < .08$, $\eta_p^2 = .09$, age group differences were greater on incongruent trials where older adults also had greater false alarms than young adults (Young $M = .46$, Older $M = .34$), $F(1, 34) = 11.63$, $MSE = .33$, $p < .01$, $\eta_p^2 = .26$. The *F*-tests were qualified by a 2 (Age group: Young, Older) × 2 (Trial-type: Congruent Hit, Incongruent False Alarm) × 3 (Presentation Count: 0x, 3x, 5x) mixed-model repeated measures ANOVA on context-based response rates that revealed a significant trial-type × age interaction, $F(1, 34) = 7.40$, $MSE = .26$, $p < .01$, $\eta_p^2 = .18$. Presentation count had no significant effect or interaction with respect to context-based responding.

[2]Participants often reported words that were neither correct nor the word favored by context in the incongruent condition. Participants made errors semantically consistent with the cue but without phonological overlap with the target at extremely low rates (<1% of responses). For an in-depth analysis of these types of "miss" responses, see Rogers & Wingfield (2015).

Sensory-based responses are shown in the top right panel of Figure 2. While young and older adults were matched on baseline trials, older adults had significantly fewer incongruent hits than young adults, as indicated by a 2 (Age group: Older, Young) × 3 (Presentation Count: 0x, 3x, 5x) mixed-model repeated-measures ANOVA on incongruent hit rates with a significant main effect of age, $F(1, 34) = 6.10$, $MSE = .37$, $p<.05$, $\eta_p^2 =.15$. An ANOVA revealed no main effect or interaction with presentation count. Thus, repeated presentations during familiarization did not modify the likelihood of sensory-based responding. A 2 (Trial-type: Baseline, Incongruent) × 2 (Age: Young, Older) mixed-model ANOVA comparing baseline hit rates with incongruent hit rates (collapsed across Presentation Count) revealed a significant interaction of Age and Trial-type, $F(1, 34) = 6.73$, $MSE = .05$, $p<.05$, $\eta_p^2 =.17$. Post-hoc *F*-tests revealed that older adults had significantly lower rates of sensory-based responding in the incongruent condition ($M = .34$), as compared to the baseline condition ($M = .48$), $F(1, 34) = 23.62$, $p<.001$, $\eta_p^2 =.41$. This pattern did not hold for young adults (Incongruent $M =.46$, Baseline $M =.49$), $F<1$, *ns*.

For confidence in context-based responses, the bottom left panel of Figure 2 shows that older adults were more confident than young adults in both their congruent hits and incongruent false alarms, as supported by a 2 (Age group: Older, Young) × 2 (Trial-type: Congruent, Incongruent) × 3 (Presentation Count: 0x, 3x, 5x) mixed-model repeated measures ANOVA that revealed a significant main effect of age, $F(1, 33) = 6.59$, $MSE = 5197.53$, $p<.05$, $\eta_p^2 =.17$. Age did not interact with any variable. Repetition priming did have an effect on confidence: participants were most confident in their congruent hits at 5x presentation count, but for incongruent false alarms were most confident at 0x presentation count, which resulted in a significant trial-type × presentation count interaction, $F(2, 66) = 4.23$, $MSE = 215.23$, $p<.05$, $\eta_p^2 =.11$.

The bottom right panel of Figure 2 shows that repetition priming had an effect on confidence in sensory-based responses as well. For both young and older adults, the more often an incongruent cue was presented during the familiarization phase, the more confidence increased in hits, as confirmed by a 2 (Age group: Older, Young) × 3 (Presentation Count: 0x, 3x, 5x) mixed-model repeated-measures ANOVA on mean confidence in incongruent hits that revealed a significant main effect of presentation count, $F(1.43, 45.68) = 3.80$, $MSE = 813.49$, $p<.05$, $\eta_p^2 =.11$. Post-hoc pairwise comparisons revealed that confidence in hits in the incongruent 0x condition ($M = 63$) was significantly lower than in the Incongruent 5x condition ($M = 68$), $p<.05$. Mean confidence in incongruent hits in the 0x condition also trended toward being lower than in the Incongruent 3x condition ($M=71$), $p<.08$. No other effects were found to be significant.

Lastly we report how well participants were able to strategically regulate their accuracy in the current study. Recall that changes in accuracy from forced to free report were assessed by subtracting the probability of a hit given that it was volunteered from the overall probability a hit [i.e. p(Hit|Vol)-p(Hit)]. Positive values indicated that participants improve their relative accuracy with the volunteer/withhold response option, whereas negative values indicated that given the option to volunteer/withhold items, participants volunteered a disproportionately high number of incorrect responses, relative to forced report. Across participants and conditions, confidence typically predicted the willingness to volunteer a response as both were strongly positively correlated (Pearson's r =.80). Young and older adults did not differ significantly with respect to changes in accuracy from forced to free report on baseline or congruent trials, however Figure 3 shows a different pattern for incongruent trials. A 2 (Age group: Older, Young) × 3 (Presentation Count: 0x, 3x, 5x) mixed-model repeated-measures ANOVA on changes in accuracy from forced to free report on incongruent trials revealed significant main effects of age, $F(1, 34) = 12.23$, $MSE = .21$, $p<.001$, $\eta_p^2 =.27$, and presentation count, $F(2, 68) = 9.82$, $MSE = .08$, $p<.001$, $\eta_p^2 =.22$. Older adults showed poorer gains in accuracy from forced to free report than young adults (Older $M = -.03$, Young $M= .06$). Also, pairwise comparisons revealed that accuracy gains were significantly poorer for incongruent 0x trials ($M = -.04$) than incongruent 3x trials ($M = .04$), $p<.01$, and incongruent 5x trials ($M = .05$), $p<.001$. Older adults had very poor performance on incongruent 0x trials, ($M=-.08$), where older adults significantly *decreased* their proportion correct from forced to free report, as a 1-sample t-test showed changes in proportion correct from forced to free report in that condition to be significantly less than 0, $t(17) = 2.64$, $p<.05$.

General Discussion

The current results inform two main areas. The first is whether semantic or repetition priming are responsible for the phenomenon of false hearing. The results show that repeated presentations did little to increase the kind of false hearing observed in prior work. To the contrary, context effects leading to false hearing were strongest when the cue-target pair was never presented during familiarization. This suggests that semantic priming is responsible for false hearing. Secondly, the results had implications for metacognition, where repetitions during familiarization had an effect on the subjective experience of hearing. These two sets of results are discussed in more detail below.

Having found that repeated presentations did not boost rates of false hearing came as a surprise, particularly in the 0x presentation count condition where rates of context- and sensory-based responding were equivalent to the 3x and 5x conditions. This surprise is based on the results of studies showing that repeated presentations of paired associates prior to a memory task can enhance veridical and false recall of the repeated response (e.g., Hay & Jacoby, 1999). That repetition had little effect on response rates suggests semantic priming, and not repetition priming, is responsible for false hearing. Semantic priming is also considered to be the dominant force in eliciting false memories using the Deese-Roediger-McDermott (DRM) paradigm (e.g., Roediger & McDermott, 1995), where the critical lure "sleep" is often falsely recalled when a study list includes items such as "bed", "rest", "night" and "pillow", (Roediger, Balota, & Watson, 2001). Using this paradigm, older adults are more likely to produce false memories than young adults (e.g., Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). Thus the current finding brings greater convergence between the phenomena of false hearing and false memory. It is also worthwhile to note that the age effects observed here cannot be attributed solely to age-related declines in access to sensory information, which was determined to be equivalent for young and older adults in the baseline condition, following a noise titration procedure.

Repeated presentations did have an effect on the subjective experience of hearing, but not in the direction consistent with context effects. In fact, the finding of a significant trial-type × presentation count interaction in the subjective measures suggest that with repeated presentations participants were more likely to shift towards basing their metacognition on sensory information. For example, participants were least confident in their incongruent false alarms when the cue had been presented five times during the familiarization phase. Likewise, participants were most confident in their incongruent hits in the 5x condition, compared to the 0x and 3x conditions. Age groups did not differ in this shift towards using sensory information with repeated presentations, as the interactions between age, trial-type, and presentation count were never significant.

The above finding is novel in demonstrating different forms of priming having differential effects on both accuracy and subjective experience, with semantic priming having effects on rates and confidence in context-based responses, whereas repetition priming had mostly opposite effects, increasing confidence in congruent and incongruent hits and decreasing confidence in incongruent false alarms. Those effects of repetition indicate that repetition priming may actually increase the availability of sensory information as a basis for responding. The shift towards sensory information could have arisen from an expectation, or an explicit memory representation of the phonological details of the heard word built during familiarization toward hearing the sensory details of the target word that was heard during familiarization. Violation of that expectation (e.g., presentation of an alternate word on incongruent trials) may have led to lower confidence when giving context-based responses on 3x and 5x trials as compared to 0x trials. A similar effect was described in Experiment 2 of Jacoby, Allan, Collins, and Larwill (1988), who found that prior repetitions of target words reduced subjective judgments of masking noise when those targets were heard again masked in noise, relative to when the targets were repeated following the noise or were mismatched. Further experimentation will be required to examine the nature of such an expectation. For example, repeated presentations during familiarization may facilitate an episodic representation of the semantically associated target word (e.g., Jacoby, 1999; see also Gupta, Lipinski, Abbs, & Lin, 2005, for an example of this in nonword learning). That episodic representation may contain sensory features of the specific utterance such as speaker information and prosody (e.g., Church & Schacter, 1995). If that information is changed during the perceptual test phase (e.g., different speaker), participants may not show such a shift towards sensory information with repeated presentations.

The shift toward sensory-based metacognition on 3x and 5x trials in the current study means that context effects in the 0x condition were maximally strong. Strikingly, older adults decreased their proportion correct from forced to free report on incongruent 0x trials, which has not been shown before in the metacognition literature. Koriat and Goldsmith (1996, Experiment 2) used deceptive general-knowledge questions (e.g., What is the capital of Australia?) that had devastating effects on free report relative to control items, but the change from forced to free report accuracy was still positive. This suggests that semantic priming alone can be a compelling basis for action, and, in the case of false hearing, can be highly detrimental to identification accuracy.

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Appendix A. Orthographic list of stimuli

Congruent/Incongruent Cue	Congruent Target	Incongruent Target	Baseline Cue	Baseline Target
front	back	bat	brace	dot
good	bad	bag	leash	mock
bounce	ball	doll	cement	kite
tub	bath	bass	jaw	pass
laser	beam	deem	strengthen	bead
grizzly	bear	dare	friction	bean
wager	bet	get	absent	bowl
small	big	bid	rigid	mud
pedal	bike	bite	blend	height
row	boat	goat	normal	bill
insect	bug	bud	sorrow	thud
hobo	bum	gum	bigot	bide
taxi	cab	tab	pillow	came
icing	cake	cape	acrobat	chick
auto	car	par	dreamed	cage
dog	cat	cap	hound	lop
effect	cause	pause	crawl	catch
cavern	cave	pave	calcium	calm
inexpensive	cheap	cheek	vapor	leak
miner	coal	pole	stable	kit
jacket	coat	cope	brief	lip

Congruent/Incongruent Cue	Congruent Target	Incongruent Target	Baseline Cue	Baseline Target
corn	cob	cod	hotel	rob
morse	code	toad	dance	veal
chef	cook	took	safe	cone
sofa	couch	pouch	summer	coach
saucer	cup	cut	brought	moat
calendar	date	bait	band	keys
dusk	dawn	gone	range	dull
alive	dead	bed	mode	boom
life	death	deaf	finally	suck
shallow	deep	beep	creature	bash
doe	deer	gear	circle	dig
knob	door	boar	grow	coil
up	down	gown	pull	hide
quack	duck	buck	oil	keen
flunk	fail	sail	carry	keel
handbag	purse	curse	explain	caught
skinny	fat	sat	solution	fine
touch	feel	seal	chance	foil
mist	fog	hog	party	bile
against	for	soar	result	folk
fuel	gas	gaffe	dark	leaf
gander	goose	goof	clear	chafe
pistol	gun	bun	water	but
brush	hair	fair	mind	faze
corridor	hall	fall	business	five
love	hate	fate	until	foul
hat	head	fed	tell	hone
there	here	fear	year	heard
steep	hill	fill	well	bang
house	home	foam	first	heed
hula	hoop	hoot	should	suit
cold	hot	hop	set	shop
embrace	hug	hub	end	lack
career	job	jog	service	nab
retain	keep	peep	found	curl
yarn	knit	nip	area	hit
tardy	late	lake	note	make
giggle	laugh	lass	become	roof
follow	lead	league	early	rid
arm	leg	led	pamper	lad
lamp	light	like	northward	neck
cabin	log	lob	allure	take

Congruent/Incongruent Cue	Congruent Target	Incongruent Target	Baseline Cue	Baseline Target
win	lose	luge	halter	bathe
atlas	map	mat	heartless	loop
calculus	math	mass	hedge	raise
tongue	mouth	mouse	clap	gaze
day	night	knife	washer	muck
hurt	pain	cane	sausage	keg
skillet	pan	tan	drip	pile
pencil	pen	ten	revert	pack
choose	pick	kick	bamboo	seam
chlorine	pool	tool	popcorn	pun
rich	poor	tore	spruce	tyke
rodent	rat	rap	tremor	gait
coral	reef	wreath	flurry	rise
left	right	ripe	maim	chat
street	road	robe	fume	load
stone	rock	rot	smother	rake
knot	rope	rote	razor	sack
thorn	rose	rove	stole	moss
happy	sad	sag	tender	seat
different	same	fame	colony	fit
buy	sell	fell	stern	cite
shepherd	sheep	sheet	pulse	pup
daughter	son	fun	assertion	fang
total	sum	thumb	powder	cub
wag	tail	pail	prayer	puck
short	tall	call	grace	kin
instruct	teach	peach	dice	peer
rip	tear	pair	weird	pap
thick	thin	fin	costume	fought
object	thing	sing	bloom	case
feet	toes	pose	slick	tip
bottom	top	taught	squad	gnat
run	walk	watt	pepper	might
strong	weak	weep	cotton	shake
scale	weight	wake	nurse	wick
black	white	wipe	extend	foot
half	whole	foal	motor	sash
better	worse	worth	shoulder	sock
socks	shoes	sues	fuchsia	shone
smooth	rough	rush	spot	heat
spider	web	wed	lenient	peak
carpet	rug	rub	procession	hack

Congruent/Incongruent Cue	Congruent Target	Incongruent Target	Baseline Cue	Baseline Target
blaze	fire	sire	fiend	sake
blackboard	chalk	chop	suburb	said
murder	kill	pill	refute	serve
butcher	meat	meek	rash	mess
hymn	song	thong	rim	shut
freckle	face	faith	slug	wish
ill	sick	sip	refund	hutch
chime	bell	dell	theft	hung
rhythm	beat	beak	comedy	shade
shove	push	puss	infant	sear
rescue	save	shave	trail	chic
lather	soap	hope	upset	hook
monopoly	game	dame		

Appendix B. Temporal order of word substitution analysis

As described in the methods of the current study, targets for the congruent and incongruent conditions differed only in substitution of either the word-initial or word-final consonant phoneme by place of articulation. Of these pairs, 56% were word initial substitutions (e.g., BOAT—GOAT), and 44% were word-final substitutions (e.g., RIGHT—RIDE). As indicated by a helpful reviewer, the word-initial and word-final pairs may differ in terms of their temporal pattern of lexical activation (Allopenna, Magnuson, & Tanenhaus, 1998). An incongruent target containing word-initial phoneme consistent with the semantic context may have built up a stronger context than an incongruent target with a word-initial phoneme that distinguishes it from the semantic context[3]. Thus, one would expect that context effects would be stronger for incongruent word-final substitutions than word-initial substitutions. The results of that analysis with respect to context-based responses, sensory-based responses, confidence in those responses, and changes in accuracy from forced to free report are reported below. However, due the low number of observations per cell, effects of presentation count could not be assessed. Observations were thus collapsed across presentation count conditions.

For context-based responding, offset substitutions led to greater rates of incongruent false alarms than onset substitutions (Onset $M = .31$, Offset $M = .53$). This was confirmed by a 2 (Age group: Older, Young) × 2 (Substitution: Onset, Offset) mixed-model repeated-measures ANOVA on incongruent false alarm rates that revealed a significant main effect of substitution, $F(1, 34) = 62.81$, $MSE = 0.86$, $p<.001$, $\eta_p^2 = .65$. As earlier reported and shown in panel A of Figure 2, older adults had higher rates of incongruent false alarms than young adults, $F(1, 34) = 11.99$, $MSE = 0.68$, $p<.001$, $\eta_p^2 = .26$, and this age group difference did not interaction with temporal order of substitution, $F<1$, *ns.* With respect to sensory-based responding (e.g., incongruent hits), word-initial substitutions were easier to detect (Onset M

[3]I would like to thank Joe Toscano for this helpful suggestion.

= .49, Offset *M* = .29), as ANOVA on incongruent hit rates revealed a significant main effect of substitution, $F(1, 34) = 43.41$, $MSE = 0.76$, $p<.001$, $\eta_p^2 =.56$. As with context-based responding, the pattern of age-related effects was the same as earlier reported where older adults had lower rates of incongruent hits than young adults, $F(1, 34) = 6.22$, $MSE = 0.25$, $p<.05$, $\eta_p^2 =.16$, and this age group difference did not interact with temporal order of substitution, $F<1$, *ns.*

Temporal order of substitution had no impact on confidence in sensory-based responses, as ANOVA on mean confidence in incongruent hits revealed no significant effects, all *F*'s <1.4, *ns*. The same was true for confidence in context-based responses, as ANOVA on mean confidence in incongruent false alarms revealed no significant effects aside from an already reported significant main effect of Age, $F(1, 34) = 6.44$, $MSE = 2144.30$, $p<.05$, $\eta_p^2 =.16$, all other *F*'s <1.5, *ns.* Changes in accuracy from forced to free responding were highly affected by temporal order of substitution, with offset substitutions shower fewer gains than for onset substitutions, (Onset $M = -0.11$, Offset $M = 0.12$), as ANOVA on changes in accuracy from forced to free report on incongruent trials revealed a significant main effect of substitution, $F(1, 34) = 38.94$, $MSE = 0.88$, $p<.001$, $\eta_p^2 =.53$. As already reported in Figure 3, older adults had poorer gains than young adults, but this age-related effect did not interact with temporal order of substitution, $F<1$, *ns.*

In summary, the pattern of results above reveal that misleading effects of context were stronger when the phonemic substitution of the incongruent target item was the offset consonant, rather than the onset phoneme. This appears to be consistent with the idea that context effects increase even during presentation of the to-be-identified word (e.g., Allopenna, Magnuson, & Tanenhaus, 1998). This effect did not appear to change confidence in sensory or context-based responses, however the strong effects on context-based responding had downstream effects on the gains made from forced to free report.

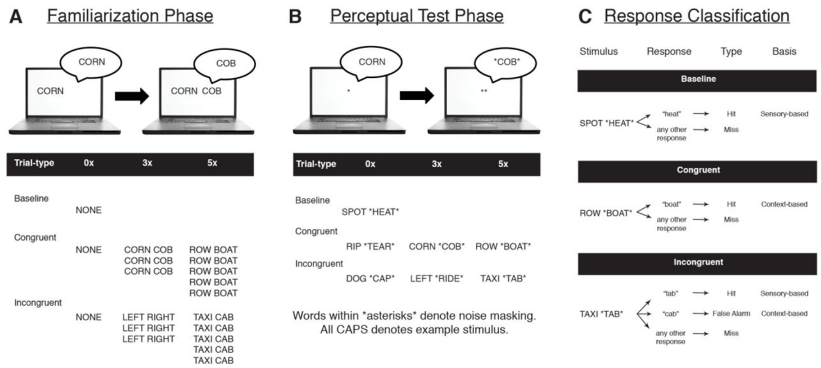

Figure 1.

Design figure describing the familiarization phase (A), perceptual test phase (B), and response classification (C) in the current study. During the familiarization phase, participants heard and saw semantically associated cue-target word pairs. For the 0x conditions and baseline conditions, no word pairs were presented. During the speech in noise task, participants heard a cue word in the clear, followed by a target in noise. Responses were logged by the experimenter then classified according to the rubric above.

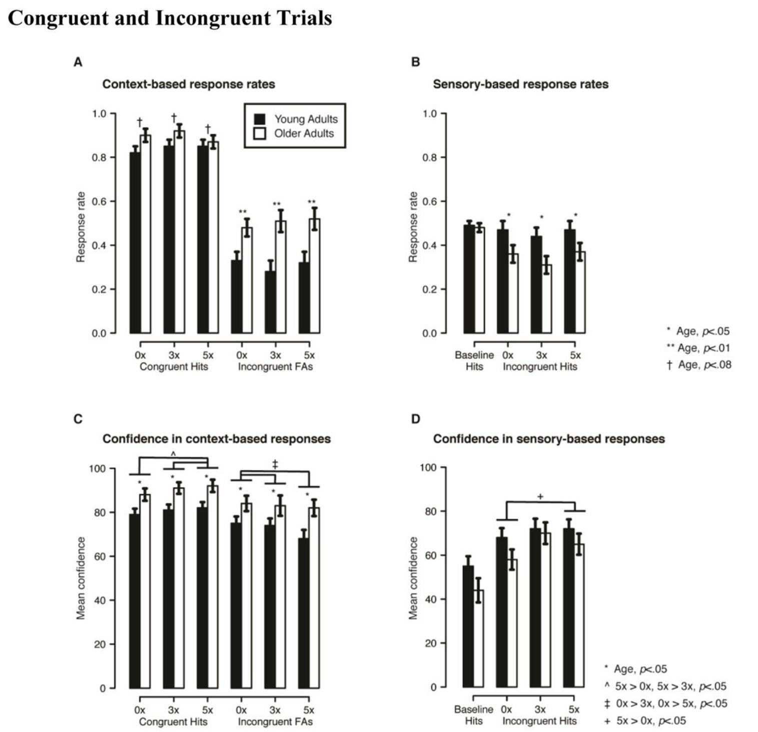

Figure 2.

(A) Context-based response rates, (B) sensory-based response rates, (C) confidence in context-based responses, and (D) confidence in in sensory-based responses as a function of trial-type and repetition. Error bars represent one standard error.

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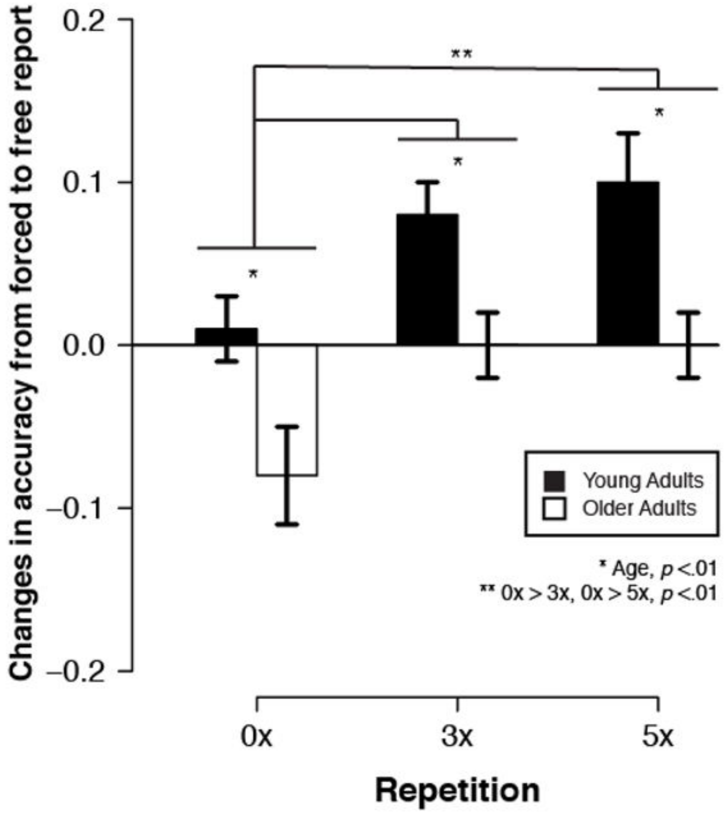

Figure 3.

Changes in accuracy from forced to free responding for incongruent trials as a function of repetition. Error bars represent one standard error.

Table 1

Hit rates, confidence in hits, and changes in accuracy from forced to free report [p(Hit|Vol)-p(Hit)] on baseline trials.

	Young		Older		Difference	
Baseline	***M***	***SE***	***M***	***SE***	***t* (df)**	***p***
Hit Rate	0.49	0.02	0.48	0.02	0.59 (34)	$p > 0.55$
Confidence in Hits	55	5	44	6	1.59 (34)	$p > 0.12$
p(Hit|Vol)-p(Hit)	0.17	0.05	0.12	0.03	0.91 (33)	$p > 0.36$