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Age Differences in the Effects of Semantic Context on Speech Perception: The Role of Uncertainty.

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by
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Abstract of the Dissertation

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by

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Professor Mitchell Sommers, Chairperson

Recent experiments have shown that semantic context effects on spoken word recognition differ between young and older adults (Rogers, Jacoby & Sommers, 2012; Sommers et. al, in prep). These experiments have shown that older adults provide significantly more incorrect responses than young adults when context predicts a phonological competitor that is semantically more likely than the actual target item. Incorrectly responding with the semantically predicted item rather than the true target item, with high confidence, is referred to as false hearing. The general design used in the studies reported for this dissertation is to compare identification of sentence-final items (presented in noise) in three different conditions: (1) a condition in which target words were congruent with the preceding context; (2) a baseline condition in which no semantic context was presented; (3) an incongruent condition in which the target item was a semantically acceptable phonological competitor of the congruent trial target word.

The current work was conducted to see if reducing uncertainty would decrease age differences in false hearing. Uncertainty was manipulated in three different ways. Experiment 1 compared open to closed-set response formats to investigate if age differences would still emerge when uncertainty in responses was reduced by only having two responses to choose from relative to an open-set design. Results indicated that reducing uncertainty by limiting the number of responses did not reduce age differences in false hearing rates. Experiment 2 compared young and older adults' false hearing when the signal-to-noise ratio (SNR) was manipulated to either increase or decrease level of stimulus degradation. Results of Experiment 2 demonstrated that regardless of how much uncertainty was increased (by making the SNR harder), older adults' performance when context was congruent did not change. Experiment 3 manipulated uncertainty by presenting a validity cue ("likely predictive" or "likely misleading") prior to sentence presentation. The results showed that even when told an incongruent trial was likely to be misleading older adults' performance was no different than when presented a neutral cue. These results are discussed within the context of age differences in cognitive control as a contributing proof to differences in false hearing.

Chapter 1: Introduction

Uncertainty in our perceptions and judgments is part of every individual's life. We can be uncertain about a recent memory such as what we had for dinner last night, or uncertain about hearing a talker's statement correctly due to ambient noise in a restaurant. Within the domain of speech perception, a listener can reduce uncertainty about what's being said by asking the talker to "speak up" (hence improving signal-to-noise ratio). The listener can also use environmental cues to reduce uncertainty. If the listener was uncertain about whether the talker had said 'rest' or 'test', for example, having an exam in front of the listener can act to bolster certainty that the word presented was 'test'. Approaches used by individuals attempting to reduce these uncertainties need not be the same. For example, young and older adults may differ in the extent to which they use certain sources of information in attempting to reduce uncertainty. How uncertainty affects younger and older adult speech perception is important because it can inform researchers about differences in speech perception that are not based on peripheral hearing differences. This dissertation is focused on age differences in speech perception that stem from differences in cognition, not peripheral hearing. Age differences in speech perception in this dissertation are proposed to be caused by differential bases for responding when given meaningful semantic context.

Speech is almost always heard in the context of meaningful contextual information. Most of the time when we speak to others we are attempting to convey meaning, and thus each word in a sentence helps constrain the perceptual candidates for the next word. Simply put, when hearing "the dog" the listener knows that certain words are more likely than others to follow (e.g., items like sniffed or barked). This logic follows for each upcoming candidate. If the listener hears “the dog chased the” the listener knows to select for words dogs commonly chase (e.g., cats or cars). When a semantically meaningful context is provided spoken word recognition performance is similar between young and older adults, but without meaningful semantic context (e.g., presenting words in isolation) older adults show large decrements in performance relative to young adults (Pichora-Fuller, Schneider & Daneman, 1995; McCoy et al., 2007). This has lead many researchers to question why there is such a differential benefit when including meaningful semantic context, compared to when meaningful context is non-predictive or absent, to spoken word recognition for older adults, relative to young adults.

When meaningful semantic information is provided, spoken word recognition judgments can be made on the basis of two, not mutually exclusive, sources of information, sensation (the physical signal) and context (the semantic context). For example, if a talker were to say “he was employed by a large firm”, the spoken word ‘firm’ could be recognized by a listener from the acoustic properties of the word or because the meaningful semantic context leads to that word. One possibility to account for older listeners, compared to young adults, differential benefits of semantic context to spoken word recognition is that older adults over-utilize context as a basis for responding. Thus, when no meaningful semantic context is present older adults struggle to correctly identify items, but, because they utilize context to a greater extent, when context is included they perform similarly to their young counterparts.

Older adults’ increased benefits in spoken word recognition when meaningful semantic context is provided, relative to young adults, supports the differential basis of responding account for age differences (Hutchinson, 1989). The differential basis of responding account states that age differences in the benefits of semantic context are caused by one age group using one basis of responding more than the other age group. This account for age differences in the benefits of semantic context relies on the assumption that there are two processes (i.e., dual processes) that individuals can use for making judgments, and was developed from the dual process framework used in other areas (Jacoby, et al., 2011; Rogers, Jacoby & Sommers, 2012). Dual process models propose two different processes that can mediate a given function or ability, such as memory. For example, memory judgments can be based on an intentional attempt to recall an item from memory (i.e., recollection) or on a vague sense of having encountered an item before (i.e., familiarity). The differential basis of responding theory posits that one age group may use one of these processes to a greater extent when making judgments than another age group. The bases for making judgments can differ depending on the psychological domain (i.e., memory, vision or hearing). Within the domain of memory these bases of responding are familiarity and recollection. In vision these bases have been called perceiving and knowing, whereas in audition they have traditionally been labeled sensory and context. Although each domain has termed these bases of responding differently, each is addressing two similar central processes. Familiarity, knowing and context all involve using prior associations to make judgments, whereas recollection, perceiving and sensation involve responding based on a high fidelity encoding of the stimulus. Furthermore, familiarity, knowing and context are largely automatic whereas recollection, perceiving and sensation are more effortful in that they engage controlled processes. Thus, although the terminology may differ, the underlying concept remains the same across these distinct domains. The goal of this dissertation is to attempt to explain the observed increased reliance on context by older, relative to young, listeners as a preferred basis for responding in speech perception. The experiments in this dissertation are specifically aimed at testing age differences in context effects when uncertainty in the stimulus is manipulated. These uncertainty manipulations are designed to expose age differences in speech perception that are caused by cognitive differences between age groups, not peripheral hearing differences.

Uncertainty here refers to any aspect of the experimental design or stimuli that might reduce the ambiguity of the stimuli. Thus, uncertainty could be reduced by limiting the number of responses possible (e.g., moving from open-set responding to closed-set), decreasing the signal-to-noise ratio (i.e., making the information easier to encode), increasing the resolution of a picture, providing item probability prior to presentation, or any number of other possible ways in which the stimulus becomes less ambiguous. Each type of uncertainty manipulation acts on the bases for responding in different ways. For example, manipulating signal-to-noise ratios affects primarily sensory based responding, because context is unaltered. Decreasing the number of response candidates decreases the lexical search required, which could affirm a listeners' response should the listener see a word he or she heard. Decreasing the number of response candidates could then influence responses that were based on context. The important aspect of manipulating uncertainty to note is that it introduces new ways to theoretically exaggerate or reduce the effects of an age difference in bases for responding. These age differences can be used to support and extend the differential bases of responding account by uncovering how resilient context effects are after uncertainty has been reduced. If older adults are able to eliminate context effects when uncertainty is reduced, perhaps they don't over-use context as a basis for responding when other sources of information (other than sensory information) are present. However, if older adults continue to use context, despite being provided additional information, then older adults' differential use of context maybe far more persistent than we originally thought.

This dissertation will begin by discussing how dual process models have explained age differences in memory, where dual process models were first established. The dissertation discusses the process dissociation framework in memory as it forms the basis of the experiments in this dissertation. The dissertation discusses dual process models in perception beginning with vision as well as the age differences in performance resulting from the proposed dual processes. An overview of the specific uncertainty manipulations used in the experiments herein was included prior to sections for the methods, results and discussions for each experiment individually. Lastly, the dissertation concludes with a general discussion of the findings and the relation these findings have to experiments outside audition. Although the memory and perception sections will review the basic age differences in each domain, no explanation of biological differences will be discussed in detail as they are beyond the scope of this dissertation. Some analysis methods, specifically detailed explanations of receiver operator curves, will not be discussed at length as good introductions to the topic are already available (Macmillan & Creelman, 2004).

Age differences in memory

Memory declines have been well documented in the aging literature, and the range of tasks and paradigms showing these declines is extensive (for a review chapter on memory see Craik & Salthouse, 2008, p. 251-310). Researchers in memory have relied heavily on recall and recognition tasks for obtaining a metric of memory performance. Recall tasks provide individuals with stimuli that are to be remembered for a memory test later. At time of test the individual is asked to provide as many of those to-be remembered stimuli as he or she can. Methods and stimuli used in recall tasks vary immensely, but the key point is that no information is provided at time of test to assist in retrieval of target stimuli. In contrast to recall tasks, recognition tasks provide information at time of test that can be used to assist memory retrieval. This usually takes the form of asking individuals to make "old" or "new" judgments for a presented stimulus. Perhaps one of the most commonly seen age differences in memory performance is that older adults perform worse on recall tasks than do younger adults (Craik & Salthouse, 2008; Perfect & Stollery, 2007; Perlmutter, 1979) but differ much less, if at all, in recognition tasks. Memory researchers have often explained this age difference in recall versus recognition task performance within a dual process framework (Jacoby, 1991; Jacoby, 2007; Yonelinas, 2001).

Familiarity and recollection

Dual process distinctions within memory retrieval have long been posited to contain *familiarity* process as well as a *recollection* process (Atkinson & Juola, 1974; Mandler, 1980; Tulving, 1985; Jacoby, 1991; Jacoby, 2007; Yonelinas, 2001). Central to theories making this distinction is that memory judgments can be made using two distinct processes: *recollection* and *familiarity*. Under this framework, familiarity is an automatic process whereas recollection would be considered a controlled process. The *familiarity* process reflects judging the memory of a stimulus based on the strength or experimental familiarity for that stimulus. Specifically, each time an individual encounters a stimulus (face, building, etc.) the strength of that memory can be increased (i.e., a friend's face has a stronger memory trace than a stranger). As prior exposure to a stimulus gives rise to familiarity to the stimulus, individuals are more willing to accept a stimulus he or she is familiar with as studied relative to a novel stimulus. Using familiarity as the basis for responding is thought of as automatic process. It does not require the individual to search memory for any specific information, instead relying primarily on associative strength. In contrast, the *recollection* process is used by an individual when he or she can recall some aspect of the study event, and this additional information can then be used to serve as evidence for making a judgment. Using *recollection* processes is thought to require intentional use, where the individual actively engages recall. This distinction between recollection and familiarity has subsequently given rise to researchers making distinctions between these two processes as bases for responding, and researchers have argued that the over-utilization of familiarity as a basis for responding leads to age differences in false memory (Balota et al., 1999; Hay & Jacoby, 1999).

Age differences in false memory

Recollection and *familiarity* have been used to account for age differences in the prevalence of false memories as measured using the Deese-Roediger-McDermott (DRM) paradigm. Within the DRM paradigm individuals are exposed to a list of semantically related words (e.g., *pillow*, *rest*, *bed*, etc.) (Roediger & McDermott, 1995). These words strongly relate to a non-presented, critical lure word (e.g., *sleep*) which is then presented in a subsequent recognition and/or recall task. The major finding from these experiments is that individuals often falsely recognize and recall the critical lure word (e.g., *sleep*) (Roediger & McDermott, 1995; Yonelinas, 2001). Of specific interest is that research using the DRM paradigm consistently finds that older adults are more likely to falsely remember the critical lure words than are younger adults (Butler, et al., 2004; Norman & Schacter, 1997). Researchers have proposed that age differences in false memory occurrences arise due to automatic and consciously controlled processes, which form two alternate bases for responding (Balota et al., 1999; Hay & Jacoby, 1999). Under this account, false memories occur when recollection fails which, in turn, leaves familiarity unopposed. Since older adults use familiarity to a greater extent, relative to young adults, during memory testing they then exhibit a higher susceptibility to memory for foils (e.g., *sleep*) compared to young adults (Dywan & Jacoby; 1990).

Dywan and Jacoby (1990) demonstrated age differences in automatic and consciously controlled processes using an alternative to the DRM false memory paradigm called the fame judgment task. The fame judgment task was developed to measure the influence of *familiarity* processes on memory. In this study young and older adults were asked to read a list of names that were non-famous, and were informed that these names were, in fact, not famous. Individuals were told they were reading these names as part of a pronunciation task. However, the true purpose in reading these non-famous names was to build familiarity with each name. The previously studied non-famous names that young and older adults studied were then mixed with a list of new names which contained both new famous and new non-famous names. Young and older adults were then asked to decide whether or not the names on this new list were, or were not famous. Using *recollection* as a basis for responding leads to correctly calling non-famous names from the first list "non-famous", whereas using familiarity as a basis for responding leads to calling non-famous names from the first list "famous" (recollection has failed but familiarity strength is still great enough to elicit a response). Dywan and Jacoby predicted that older adults, compared to young adults, would be less successful at using recollection as a basis for responding causing them to rely on familiarity as a basis for responding. Using familiarity as a basis for responding would then increase the number of previously presented non-famous names reported as famous in the test phase for older adults compared to young adults. As was expected, Dywan and Jacoby found that reading a list of non-famous names increased the likelihood of calling the non-famous names ‘famous’ in the subsequent fame judgment task significantly more for older adults than for young adults. These findings could be explained if older adults, compared to young adults, use familiarity more as the basis for responding.

Applying a differential basis of responding framework provides one account for age differences in some types of memory. However, one difficulty faced in making distinctions between alternative bases for responding has been that measures of memory are typically not process pure (Yonelinas, 2012). The idea is that although certain tasks might favor an individual’s reliance on *familiarity* or *recollection* processing as a basis for responding to a greater or lesser extent (e.g., recall and recognition tasks) each process is still engaged to some degree. Thus, for example, tasks that favor using familiarity as a basis for responding might still be “contaminated” by intentional use of recollection. Conversely, tasks that could favor using recollection as a basis for responding might be contaminated by the use of familiarity. The inability to measure one basis for responding separate from the other limits any possibility to estimate the separate contributions of recollection and familiarity in memory. The realization of this limitation led to the seminal study of what has come to be termed ‘the process dissociation framework’; a paradigm designed to allow such processes’ contributions to become distinguishable (Jacoby, 1991).

The process dissociation framework

The dual process model proposed by Jacoby (1991) posited two separate processes involved in memory retrieval: automatic and controlled. In this model *familiarity*, also sometimes called habit, is an automatic processes, whereas *recollection* is a controlled process.

The goal of the process dissociation framework was to create a procedure that could provide estimates of the contribution of each process to memory performance, but it is important to this dissertation because the design used an opposition procedure. Central to the framework is that procedures must include ones in which automatic processes (i.e., familiarity) facilitate as well as reduce accurate memory responses. Automatic processing and controlled processes can converge on the same response and facilitate accurate responding when item familiarity is high (due to prior exposure) and the individual can recollect the item. However, automatic processes can also act in opposition to controlled processes. As was shown in the false fame studies, familiarity with a non-famous name (produced by exposing individuals to these names prior to fame judgments) can cause individuals to incorrectly identify a non-famous name as famous when familiarity is used as the basis for responding. Because the process dissociation framework considers both retrieval performance when recollection and familiarity processes are in concert as well as in opposition this allows for simple mathematical equations to solve for the separate contributions of automatic and controlled processes. Jacoby (1991) explains, "The rationale underlying the process dissociation procedure can be understood in terms of solving simultaneous equations, where the variables in the equations refer to processes that contribute to performance of a task: "*A*" refers to automatic processing whereas "*I*" refers to intentional processing. For example, consider the following equations: $A + I = 10$; $A - I = 4$. Those equations are easily solved to yield a solution of $A = 7$ and $I = 3$ (p. 518)."

To test these claims, Jacoby (1991) had individuals study two lists of words where items on List 1 were either to be read or solved as anagrams (e.g., 'dowry' given yodrw; only letters that were not underlined were to be rearranged). After participants studied List 1 words (by reading/solving anagrams), Jacoby presented the participants with a second list of all new words and asked participants to simply listen proof these words (List 2). In the final phase, individuals' memory for items was tested by administering an 'old'/'new' recognition memory test. This final phase demonstrates the utility of the process dissociation logic by having one group selecting for inclusion (e.g., both List 1 and List 2) and the other selecting for exclusion (e.g., excluding 'old' responses to items from List 2 only) of items where recollection is the basis for responding. In the inclusion test condition individuals were instructed to call an item 'old' if it had been read in List 1, had been a solution to an anagram in List 1 or been heard in List 2. In the exclusion condition individuals were instructed to call an item 'old' only if it had been heard in List 2. Therefore, if participants could recollect that an item had been presented in list 1, they would know to call it new. The exclusion condition therefore requires individuals to consciously recollect a word from List 1, or consciously recollect a word's absence from List 2, in order to exclude them as 'old' responses. In most recognition research both recollection and familiarity are used in combination to make judgments. However, Jacoby's (1991) procedure requires individuals to recall to reject in the exclusion condition (e.g., select against items remembered in List 1) versus recall to confirm in the inclusion condition (e.g., selecting for items remembered in List 1 or 2) which allows one to measure the relative contributions of recollection and familiarity by comparing inclusion and exclusion conditions. Thus, the exclusion condition places familiarity and recollection in opposition. The designs of the experiments in this dissertation are based on the opposition procedure used in Jacoby (1991), and this procedure has been used to examine age differences in memory. Placing dual processes in concert and opposition within a single experiment has allowed researchers to investigate possible age differences in reliance on familiarity and recollection as a basis for responding.

Age differences in memory based on familiarity and recollection

Research on age differences in memory using the process dissociation paradigm produce similar results with those from memory studies that do not rely on the opposition procedure. For example, using the process dissociation procedure it is generally found that older adults' recollection based performance is lower than that of younger adults (Hay & Jacoby, 1999; Jacoby et al., 2005). Furthermore, older and younger adults seem to be able to perform similarly when using automatic processes such as habit or *familiarity* (Hay & Jacoby, 1999; Jacoby, Debner & Hay, 2001). However, the true advantage to the process dissociation procedure is that it allows researchers to compare situations in which both processes converge on the same response with those in which processes are in opposition. When familiarity and recollection are in opposition, and an individual inappropriately uses familiarity as the basis for responding, false alarms/memories arise. The probability of producing false alarms in these experiments differs between age groups.

In these experiments, the way false memories are defined differs slightly from the way they have been defined in previous studies such as those using the DRM procedure. Specifically, false memories in experiments investigating familiarity and recollection refer to responding that the item was encountered despite the fact that the item should have been excluded due to task instructions. For example, in the Jacoby (1991) study previously described, if a word read from Phase 1 was called 'old' in the exclusion condition, this would be a false alarm due to the fact that instructions explicitly asked only for read items in the second list to be called old. Each way of defining false memories generally involves errors of commission as opposed to errors of omission.

To demonstrate age differences in false memories, Jacoby et al. (2005) used a paired associate memory task. The procedure began by presenting individuals with paired associates for study (e.g., *knee bone*). Both older and younger adults' memory performance was then tested by being presented with the left-hand member of each pair with the right-hand member requiring fragment competition (e.g., *knee b_n_*). However, prior to each cued recall pair presented for responding, a prime word was presented to individuals. The prime word manipulation is central to understanding the age differences in false memory because the prime word varied on whether or not it was a word that had been presented as a pair earlier or was an alternative that could be completed with the same fragment structure. For some trials, the prime word did not vary from previously studied items (a *congruent* trial, e.g., *bone*). On incongruent trials, the prime was not previously studied but could be completed with the same word fragment as the previously studied item (an *incongruent* trial, e.g., *bend*). Lastly, some trials were neutral, non-word primes (a *baseline* trial, e.g., *&&&&*). Utilizing process dissociation procedures, Jacoby et al. (2005) created congruent trials in which the two bases for responding, familiarity and recollection, act in concert as well as incongruent trials in which they act in opposition.

Figure 1 presents the basic findings from Jacoby et al. (2005). When recollection and familiarity converged on the same response, performance was equated between young and older adults. Thus, on congruent trials a correct fragment competition (e.g., *bone*) could occur as a result of recollection of the study pair (e.g., presented *knee bone* as a study pair) or from the familiarity/accessibility bias of the congruent prime (e.g., primed with *bone*). In contrast, when presented with an incongruent trial, correct identifications result solely from use of recollection as the basis for responding, because familiarity/accessibility bias now favors an alternate response (e.g., *bend*). Results demonstrated that both young and older adults were susceptible to

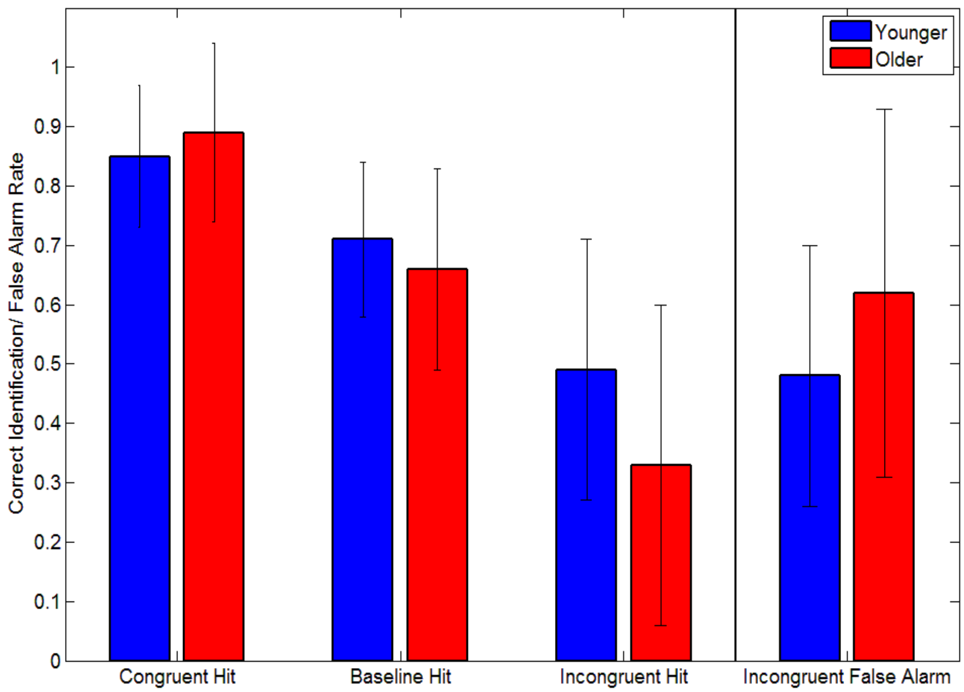

Figure 1: Proportion of correctly recalled study items and incongruent false alarms in Jacoby et al. (2005).

false memories; however older adults had a differentially greater probability of producing false memories compared to young adults. These findings converge with those previously described, demonstrating that older adults' overutilization of familiarity as a basis for responding made them more susceptible to errors of commission (i.e., saying an item previously studied was present when it wasn't). Thus, age differences arise from a differential reliance on the two bases for responding, in which older adults over use familiarity as a basis for responding relative to young adults.

Dual process models of memory explain a great deal of the differences seen in task performance (recall versus recognition), as well as age differences in memory (older adults' false memory susceptibility). The result of such dual process modeling has begun to be used to address aspects of perception (mainly vision and hearing). Although the field is just starting to examine dual processes in perception, the data have begun to offer support for a controlled and automatic process that shares some similarities to those proposed in memory, as well as age differences associated with these processes. The following sections this dissertation will address these dual process models, as well as experimental data relevant to age differences associated with these two processes.

Age differences in perception

When given two similar, but nevertheless different, photographs an observer might be able to accurately find the differences, other times the observer will fail. Some perceptual differences are simply more distinguishable than others, and it is the strength of these perceptual differences to be noticed that has traditionally been understood as the basis for which perceptual judgments are made. However, as previously discussed, memory researchers have suggested that a single process is insufficient to describe memory, giving rise to dual process models of *familiarity* and *recollection* (Jacoby, 1991; Hay & Jacoby, 1999; Yonalinas & Jacoby, 2012). Researchers in perception have likewise begun to suggest that a single process is insufficient to describe perceptual decision making (Aly & Yonelinas, 2012).

In perception researchers have made distinctions between *seeing* and *sensing* or *perceiving* and *knowing* as the dual processes for which judgments can be based on. The *seeing* and *sensing* dual process model and the *perceiving* and *knowing* dual process model. S*eeing* and *perceiving* refer to decisions based on high fidelity sensory information (similar to using discriminatory cues), whereas *sensing* and *knowing* refer to decisions based upon a global environment match (i.e., the match of the visual field at any moment to the moment(s) previous).

Although the perceptual dual processes are not the same as memory dual processes, the processes do share some important similarities. *Familiarity* processes are automatic and based on prior associations. *Sensing* and *knowing* in perception function similarly in that these processes use how objects are globally associated to one another. *Recollection* processes in memory are intentionally controlled and brought to explicit awareness. *Seeing* and *perceiving* processes are also posited to be brought to explicit awareness. Thus, although there are differences across domains there are some important qualities that are shared.

Perceiving and knowing in visual perception

The two bases for responding within the domain of vision originally proposed were *sensing* versus *seeing*. Parallels with memory are quite direct in which *sensing* refers to "the processing of visual information without accompaniment by visual experience, or by conscious awareness at all" (Rensink, 2000, p. 1478). This is very similar to the concept of 'knowing' (i.e., familiarity) proposed by Tulving, in which conscious recollection was not required when using this basis for responding. In contrast, *seeing* refers to a consciously attended representation of the environment. Seeing then shares similarities with the "remember" (i.e., recollection) basis for responding in the dual process model proposed by Tulving, in that it is based on conscious experience. One paradigm used to investigate seeing versus sensing has been implicit perception designs in which small changes are made to an image. Specifically, individuals are asked to identify if an image has changed from original to test, or if an item in the test image has the same angle, color, etc. as the item did in the original image. Using this methodology Rensink (2004) tested his dual process theory by having participants view a series of images. The flicker design presented an original image A and an altered image A' in a sequence A, A, A', A', A, A….. as well as catch trials in which the image is never altered throughout the sequence. Participants were asked to respond when they believed the image had changed in the sequence, and if they could, then state the nature of this change when asked to do so. Trials in which participants correctly identified the change as well as were able to describe what that change was were classified as '*seeing*' responses. Results from this study as well as the general finding in studies of this type show that, although observers often cannot actually identify a specific change, they are still able to correctly state if an image, or item within an image, has changed (Fernandez-Duque & Thornton, 2000; Rensink, 2000; Rensink, 2004; Simons, Nevarez & Boot, 2005). Rensink argued that because participants could accurately distinguish when pictures had changed despite not being able to report the nature of this change demonstrated the sensing process. The seeing versus sensing dual process model of perception closely resembles the dual process model of memory proposed by Tulving, but Aly and Yonelinas (2012) have proposed a dual process model that more closely resembles the Jacoby memory dual process model.

Aly and Yonelinas (2012) developed the strength and state dual process model of perception based on previous familiarity and recollection dual process models of memory. This model of perception posits a state process of *perceiving* which is analogous to recollection in that both provide high fidelity, high-resolution information to explicit awareness. It also posits an independent strength process of *knowing*, which is analogous to familiarity in that both provide a signal of low-resolution representation of the global environment. To reiterate, *perceiving* refers to a state process in which highly detailed sensory information is processed whereas *knowing* refers to a strength process in which low detail information of the overall match is processed. The *perceiving* process shares similarities to the recollection process in memory in that they both rely heavily on controlled processes, whereas the *knowing* process is similar to familiarity processes as they both rely heavily on automatic processes. Specifically, when an individual notices a change, attention is controlled to focus on whatever that change is. Conversely, global changes to the visual representation engage automatic processes which cause the individual to have a sense that something has changed, but they are unable identify what. It is important to note that Aly and Yonelinas distinguished perceiving and knowing processes not on the basis of automatic versus controlled processes, but, instead based on consciousness. They argued that *perceiving* and *knowing* are associated with different forms of consciousness. *Perceiving* reflects the consciousness of what has changed (e.g., noticing that the color of a plant is different between two images), whereas *knowing* reflects the consciousness that there has been a change (e.g., feeling that something is differing between two images but unable to identify what). Although the claims made by Aly and Yonelinas are strong, especially regarding the independence of these processes, their dual process model makes predictions that are supported by the data.

Aly and Yonelinas (2012) demonstrated the independence of perceiving and knowing using a change detection paradigm in which images were altered to form a pair of images that differed on either a global or discrete manner. Global changes between a pair of images were made by contracting the image slightly in one image and expanded slightly in the other. Discrete changes between the two images were made by adding or subtracting a single feature from one version. Figure 2A visually demonstrates the changes made to the images. Participants were presented with two images simultaneously for 1500 ms and asked to judge whether the images were the same or different. After deciding if the images were the same or different, participants were asked to provide their confidence concerning the accuracy of the same/different judgment.

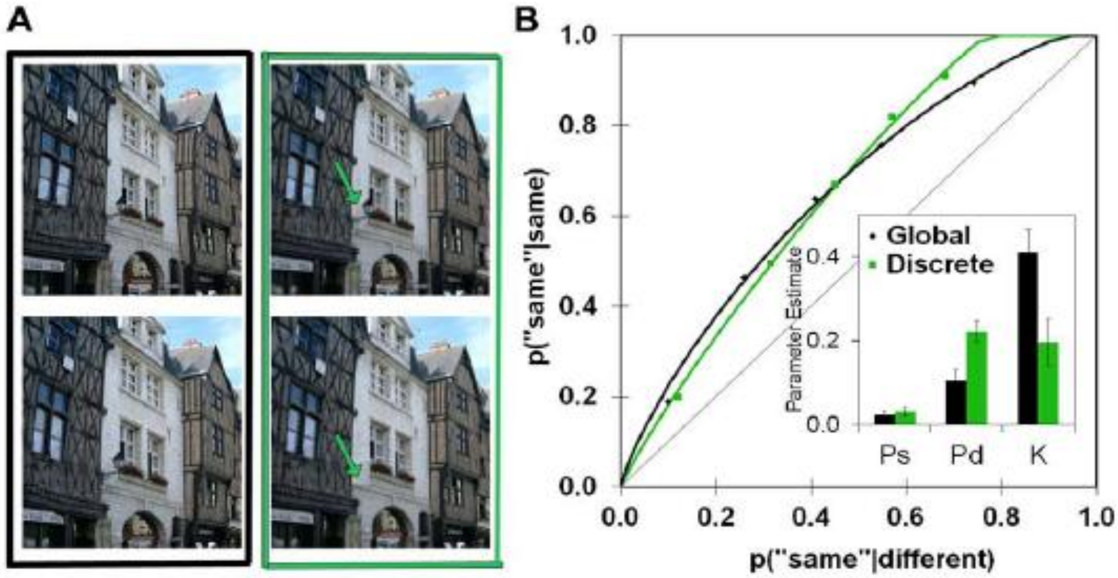

Figure 2: (A) Examples of the global (left) versus discrete (right) changes made between a pair of images used. (B) ROCs and parameter estimates revealing the crossover dissociation. (Aly & Yonelinas, 2012)

Using the confidence judgments as plot points, the probability of hits and false alarms for 'same' judgments was plotted to form receiver operating characteristic curves (ROC). Parameter estimates were obtained using a modified Independence Remember/Know procedure (Yonelinas & Jacoby, 1995; Aly & Yonelinas, 2012). The modified Independence Remember/Know procedure takes "perceived" responses, and subtracts the probability of incorrect responses from the probability of correct responses to obtain an estimate of *perceiving*. The estimate of *knowing* changes, compared to global changes, and global changes were associated with higher levels of knowing relative to discrete changes. Figure 2B from Aly and Yonelinas shows this double dissociation clearly in the parameter estimates where perceiving same (Ps) and different (Pd) refer to the *perceiving* processes and knowing (K) refers to the *knowing* process.

Implications of perceptual dual process models on differential bases of responding

Dual process models are important to differential bases of responding accounts, because the different bases of responding are typically the two processes. For example, researchers in memory posited dual processes of *recollection* (controlled process) and *familiarity* (automatic process). These two processes could be used when an individual is making a memory judgment. The reliance on these two bases for responding is not the same between age groups, as was argued by Jacoby et al. (2005). Likewise, in visual perception *perceiving* and *knowing* have been proposed as dual processes. These two processes are then the different bases of responding that individuals can use when making perceptual decisions. Just as was the case in familiarity processes in memory, it is possible that older adults use the *knowing* process in perception to a larger extent than do young adults. Thus, using the experimental design from Aly and Yonelinas (2012), one might find that older adult's perform similarly to young adults on *knowin*g judgments of change, but perform worse on *perceiving* judgments of change. Although this specific study has yet to be conducted there are similar studies that begun to shed light on differential bases of responding in perception which will be discussed in the coming sections.

In the memory and visual perception domains, the two bases for responding are the two processes proposed for that domain. Thus, in memory the dual processes were *familiarity* and *recollection* and the different bases for responding were *familiarity* and *recollection*. The dual processes in vision, *perceiving* and *knowing*, can be used as the dual processes in audition. However, these two processes have not traditionally been used as the different bases for responding in audition. The two different bases of responding that have commonly been used are sensory signals and context. This dissertation will continue to address sensory signals and context as the bases for responding, but it is important to note that these two bases of responding share similarities to the *perceiving* and *knowing* processes. The *perceiving* process uses high fidelity information that is brought into awareness, which is similar to using sensory signals because sensory signals are high fidelity information about speech. Sensory information is also similar to using *perceiving* processes in the model proposed by Aly and Yonelinas (2012), because sensory information is high fidelity information that the listener brings to awareness. Likewise, the *knowing* process in visual perception uses global (association based) information that is automatically activated which shares similarities to context, because context consists of associations the words share with one another which are automatically activated.

Context has been utilized in either a prior presentation method or a semantic and syntactic probability method, and each methodology will be discussed separately in this dissertation. In the prior presentation method for creating associations, probability increases as a function of exposure. For example, if the word 'BOOK' is only paired with the word 'CHEF', and is done so frequently, over time when seeing the word 'BOOK' the perceiver can assume a higher probability that the paired word will be 'CHEF' as opposed to another word. The paired associates are always seen in the context of one another and thus create the contextual source of information required for dual process perceptual experiments. The semantic and syntactic method uses existing probabilities and associations. For example, when presented with the partial sentence "the plumber was fixing a _____" the perceiver can assume a higher probability that the proceeding word will be 'SINK' as opposed to a lower probability word like 'POSTER'. Thus, the semantic and syntactic method uses pre-existing contextual associations to form the contextual source of information required for dual process perceptual experiments.

Age differences in bases for responding: prior presentation

One of the first studies to examine age differences in the bases for responding in visual perception was conducted by Jacoby et al. (2011). To support the theory of a differential basis for responding between age groups, Jacoby et al. (2011) adapted the process dissociation procedure used in Jacoby et al. (2005) investigating age differences in bases for memory responses. In this experiment, individuals were visually presented with a prime word prior to a very brief presentation of a target word (making it difficult to perceive) that included both a forward and backward visual mask. After the second mask, individuals were asked to complete a word fragment with the target word that was presented between the visual masks, and report how confident he or she was in this response (i.e., saying the target was 'seen', 'known' or 'guessed'). Jacoby et al. used four different prime-target pair conditions: congruent, incongruent, baseline and guessing. Figure 3 displays the procedure schematically for each of these conditions. On a congruent trial, the prime (e.g., DART) was the same word as the target. On incongruent trials the target word was an orthographic neighbor of the prime word differing only in a single letter (e.g., DIRT). For the baseline trials the prime was unrelated to the target word (e.g., CHEW). Lastly, guessing trials presented no target word at all, and instead individuals were actually presented a blank screen. After viewing the prime and target words individuals were given a fragment completion task in which the goal was to fill in the missing letter he or she believed was the target word (e.g., d_rt). Jacoby et al. (2011) thought it possible that older adults would rely more on expectations (e.g., the prime) simply due to older adults' poorer vision compared to young adults. To control for this, Jacoby et al. allowed the duration

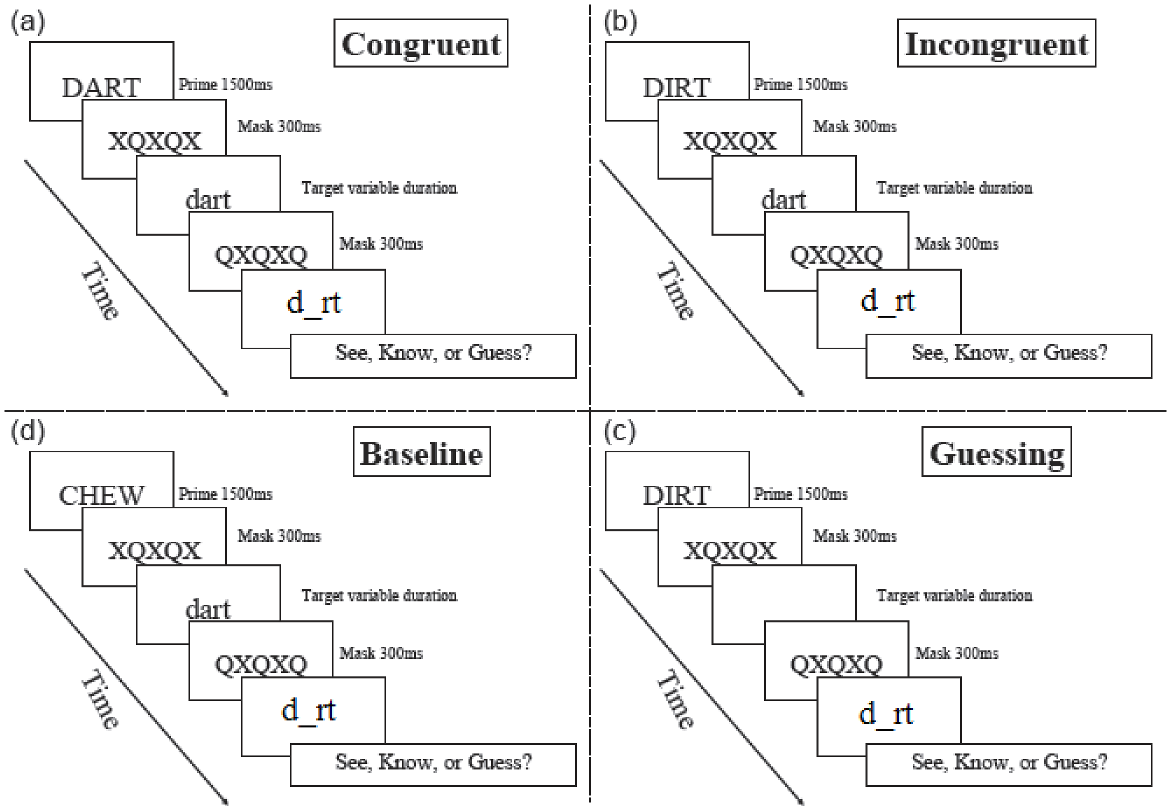

Figure 3: The procedure schematic for Jacoby et al. (2011).

the target item was present to vary individually. Specifically, the duration that the target word was present on the screen was titrated for each individual such that equal performance between young and older adults on baseline trials was obtained.

Jacoby argued that if older adults have a differential basis for responding, one would expect large age differences on incongruent trials where older adults would be more likely to complete the fragments with the primed words' letter than young adults (e.g., the letter "i" for prime "dirt"). He argued that an increase in incongruent false alarms (e.g., reporting 'dirt' when the target was in fact 'dart') in older adults, relative to young adults, would be a consequence of relying more heavily on the prime (i.e., the knowing process). Jacoby et al. (2011) reported that older adults produced significantly more incongruent false alarms than young adults. This finding supports the claim that older adults are using the knowing process to a greater extent as, when perceiving and knowing act in opposition (e.g., incongruent trials), older adults are more likely to falsely see the target item as the prime.

More compelling evidence for the differential use of contextually based responding came from trials in which individuals were not presented a target word at all (guessing trials). On these trials, individuals should simply be guessing what the target word was because no target was actually provided. Under these conditions, older adults reported seeing the primed word in the blank screen on 34% of the trials, whereas young adults reported the primed word only 8% of the time. Thus, the overutilization of the knowing (i.e., familiarity) basis for responding by older adults led to seeing the target word predicted by prior presentation of the prime, despite the fact that this target word was never actually presented, significantly more than young adults.

The dual process model of perception has also been applied to the auditory domain with results converging strongly with those seen in the visual domain as well as in memory. Rogers, Jacoby and Sommers (2012) investigated age differences in bases for responding using a paired associate procedure. Investigating age differences in auditory perception can be difficult because older adults traditionally have poorer peripheral functioning relative to young adults (Humes et al., 1994; Wingfield et al., 2005) that is more difficult to correct than age-related reductions in visual acuity. To deal with age differences in spoken word recognition due purely to degraded hearing acuity in older adults, compared to younger adults, Rogers, Jacoby and Sommers equated audibility between young and older adults using a titration phase. This procedure determined a signal-to-noise ratio (SNR) that generated fifty percent accuracy for both age groups in the baseline condition and participants were then tested using these individually determined SNRs. In the experimental phase, individuals first learned semantically related word pairs (e.g., BARN-HAY) so that pairings would become strongly associated (i.e., activating the familiarity/knowing processes). Once an individual was able to recall all of the pairs (as assessed by providing the first item and asking for the second) he or she then received a perceptual test. This perceptual test phase presented individuals with a cue word (e.g., BARN) followed by a target word masked by white noise (at the SNR determined in the titration procedure) which was to be identified by the individuals. Three different conditions were used: congruent, incongruent and baseline. On congruent trials, the word presented in noise was the same as the trained associate (e.g., HAY in the BARN-HAY example), whereas on incongruent trials the presented word was a phonological neighbor of the trained associate (e.g., PAY). Lastly, baseline trials (the control condition) presented an unrelated word (e.g., FUN) in noise. After individuals identified the word in noise, metacognition was measured by obtaining confidence judgments (0-100%) regarding how certain the word they provided was in fact the word in noise.

Rogers, Jacoby and Sommers (2012) postulated that, in the case of contextually congruent word pairs (e.g., BARN-HAY), both young and older adults should demonstrate high levels of confidence and word recognition, because both bases of responding (context and sensory signal) converge on the same response (e.g., HAY). In contrast, incongruent trials place bases for responding in opposition in which the sensory signal leads to a ‘PAY’ response and context leads to a ‘HAY’ response. The researchers hypothesized that if young and older adults differ in their bases of responding, with older adults utilizing context sources of information to a greater extent (i.e., knowing process) than sensory sources of information, older adults should exhibit not only more incorrect responses on incongruent trials – where they respond ‘HAY’ to the initial item ‘BARN’, even though ‘PAY’ was actually presented – but they should provide very high confidence measures on those incorrect responses. Consistent with this prediction, the experimenters reported that older adults were significantly more likely than young adults to respond incorrectly on incongruent trials by using the word predicted by prior association, and confidence on those incorrect responses was significantly higher for older compared to young adults. Furthermore, older adults produced a significantly greater proportion of dramatic false hearing occurrences (cases in which individuals were 100% confident in their incorrect responses) than did young adults, 27% versus 7% respectively. Thus, Rogers, Jacoby and Sommers argued that if confidence ratings reflect the subjective hearing experience, then older adults falsely heard a word not presented on over 25% of all incongruent trials. These findings are consistent with the proposal that older adults, compared to young adults, are using context as a basis for responding to a greater extent, and that they are having the subjective experience of hearing the congruent item on incongruent trials.

Age differences in bases for responding: semantic and syntactic probability

Differences between young and older adults' spoken word recognition have been well documented (Pichora-Fuller, Schneider & Daneman, 1995; Sommers & Danielson, 1999), with the general finding that older adults' performance is poorer than young adults. What is somewhat unexpected, however, is that, when a semantically meaningful context (i.e., increasing the semantic information) is provided, age differences in spoken word recognition can be attenuated or eliminated (Pichora-Fuller, Schneider & Daneman, 1995; McCoy et al., 2007). That is, both young and older adults are more accurate identifying a word (e.g., SINK) if it is presented in a meaningful context (e.g., "The plumber was fixing a ____") than if the identical signal is presented without meaningful context (e.g., "she might discuss the ____"), but older adults show greater improvements than young adults when a meaningful semantic context is provided. For example, Hutchinson (1989) found that age differences in spoken word recognition were 5.6% when words were presented in a low predictability context but 0.2% when they were presented with highly predictable semantic context. This pattern of findings is consistent with dual process models of perception because under conditions in which individuals can use only sensory information (low-predictability sentences), or the perceiving process as the basis for responding, older adults perform worse than young adults. The age difference in performance reflects both the fact that older adults have degraded sensory abilities (i.e., presbycusis) and older adults use the contextual sources of information, or the *knowing* process, as the basis of responding to a greater extent than do young adults. Thus, since low predictability trials have little context for older adults to take advantage of semantic context, performance suffers relative to young adults. However, when provided meaningful semantic context both bases of responding converge on the correct response. This framework would then explain the general finding that older and young adults' performance on spoken word recognition is similar when meaningful semantic context is available (Nittrouer & Boothroyd, 1990; Pichora-Fuller, 2008) compared to when such contexts are absent. Thus, a differential basis for responding account would explain older adults' poorer performance on spoken word recognition when low-predictability context was used as being caused by age related hearing loss (i.e., older adults can only use sensory information). Conversely, older adults can often perform similarly to young adults when semantic context is highly predictable because in this condition older adults can use their preferred base of responding, context.

Evidence that older adults differentially use semantic context as a basis for responding more so than young adults has been found in both vision and auditory domains using Speech Perception in Noise (SPIN) sentences (Bilger, Nuetzel, Rabinowitz & Rzeczkowski, 1984). SPIN sentences vary on the predictability of the final word of a sentence. High-predictability sentences (e.g., “The plumber was fixing a sink”) are ones in which the preceding context is strongly predictive of the sentence-final word whereas in low-predictability sentences (e.g., “Mrs. White spoke about the rod”) the final word is not predictable from the preceding context. Speranza, Daneman and Schneider (2000) examined age differences in the use of context as a basis for responding in older adults using a visual version of the SPIN sentences. In this experiment, young and older adults were shown SPIN sentences masked by a visual noise, and were asked to identify the final word of the sentence. Researchers reported that both young and older adults benefited when given high predictability contexts relative to low predictability contexts. However, as a differential basis for responding theory predicts, older adults benefited from highly predictable context to a greater degree than did young adults.

Experiments conducted by Sommers et al. (in prep) were the first to use the process dissociation procedure to investigate age differences in the basis of responding using SPIN sentences, presented in the auditory modality. In this study, young and older adults were presented with sentences in which all but the final word was presented in the clear, and the target (sentence-final) item was presented at individually adjusted signal-to-noise ratios (to equate audibility differences between the age groups by setting SNRs to obtain approximately 50% in baseline conditions). The experiments used three different contextual conditions: congruent, incongruent and baseline. On congruent trials, unmodified versions of the SPIN high-predictability sentences (e.g., "The plumber was fixing a sink") were used. On incongruent trials, modified versions of the high-predictability sentences were used in which the target item was replaced by a plausible, but less predictable, phonological neighbor (e.g., "The plumber was fixing a drink"). Finally, on baseline trials, individuals heard low-predictability versions of the SPIN sentences (e.g., "Paul heard they asked about the rice"). Low predictability trials therefore, contained little contextual information, and, consequently, correct responding could only be done on the basis of sensory information. Conversely, both congruent and incongruent trials would allow individuals to respond using both sensory (*perceiving* process) and context (*knowing* process) as the bases for responding, but only on incongruent trials would context act in opposition to sensory based responding. After individuals identified the word in noise, confidence judgments (0-100%) were obtained asking the participants how certain they were that the word they reported hearing was the word heard in noise.

Sommers et al. (in prep) hypothesized that older adults would be more likely than young adults to provide an incorrect, but context consistent, response in the incongruent condition (i.e.,

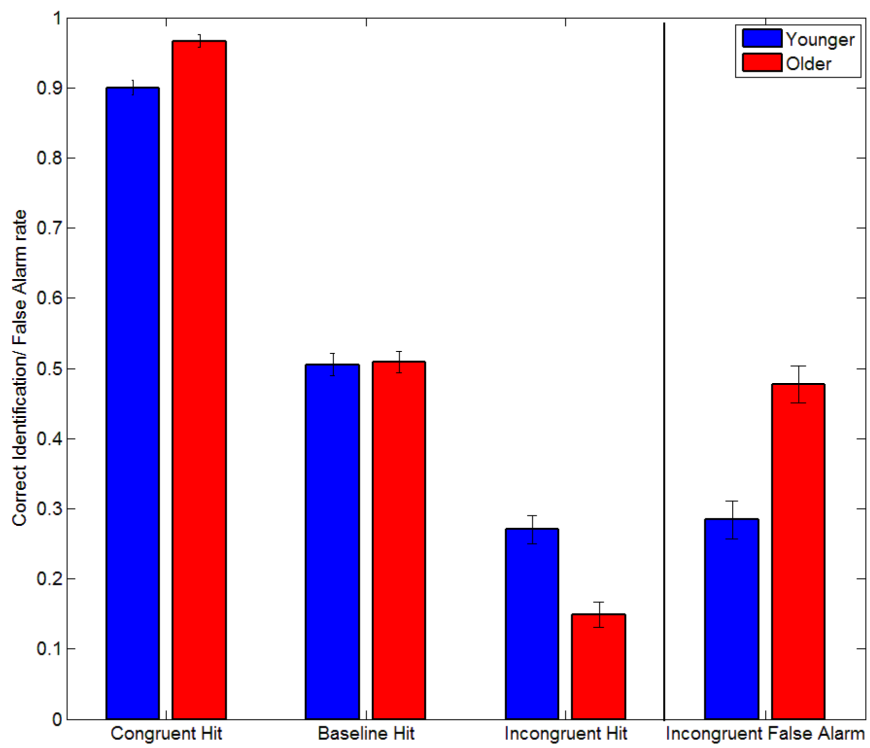

Figure 4: Mean proportion correctly identified sentence final words for each trial type and false alarms on incongruent trials in Sommers et al. (in prep).

responding "sink" when provided the sentence "the plumber was fixing a drink"). Figure 4 presents the main findings for this experiment. Note that although both young and older adults' performance is better when context is congruent, older adults benefit more than young adults. This older adult congruency advantage is shown in Figure 4 in the proportion correctly identified on congruent trials. Figure 4 also demonstrates that false alarms on incongruent trials (false alarms are defined here as trials in which the participant responds with the contextually predicted item despite the fact that the phonological neighbor was actually presented) were significantly greater for older adults compared to young adults. Furthermore, older adults produced a significantly greater proportion of dramatic false hearing occurrences than did young adults, 20% versus 1% respectively. Recall that dramatic false hearing is defined as providing the (incorrect) response favored by context with a confidence rating of 100% (i.e., cases in which individuals were 100% confident in their incorrect responses). If it is assumed that dramatic false hearing occurrences reflect the subjective experience of having heard the non-presented word on incongruent trials, then young adults have an extremely low probability of falsely hearing, whereas older adults falsely hear 20% of the time. These data suggest that, when sensory and contextual bases for responding are in opposition, older adults continued to use context as the primary basis for responding, which caused increases in false hearing.

The results from Sommers et al., (in prep) are quite similar to those reported in Rogers, Jacoby and Sommers (2012), but the experimental designs have some important differences. First, the study conducted by Rogers, Jacoby and Sommers (2012) used paired associates while the study conducted by Sommers et al., (in prep) used sentences. The advantage to using sentences as opposed to paired associates is that it resembles speech communication outside of a laboratory to a greater extent. Using sentences could increase the number of false hearing occurrences due to context sentences being stronger stimuli than paired associates. In fact, when comparing the two experiments, incongruent false alarms increase approximately 10% when using context sentences compared to paired associates. The second advantage to using sentences, as opposed to paired associates, is that it begins to separate false hearing effects from semantic priming effects. Semantic priming refers to the observation that a response to a target is faster when it is preceded by a semantically related prime (Neely, 1977). In the paired associate design, all of the cue-target pairs were semantic associates so priming could be the result of pre-existing semantic relationships. Thus, if presented with incongruent paired associate (e.g., BARN-PAY), a false alarm could arise out of the first word of the pair semantically priming the second (e.g., BARN-HAY), and lead the participant to respond with the semantically primed word (e.g., 'HAY'). However, semantic priming is less able to explain false hearing when there is intervening context between two words, because semantic priming is fast acting. How long an associated word can be activated varies somewhat in the literature, but researchers have posited that it is around 400 to 800 ms (Lupker, 1984; Schreuder, d'Arcais and Glazenborg, 1984; Nelly, 1991). Thus, if a listener is presented with the sentence "the shepherd watched his sheath", the word 'shepherd' would semantically prime the word sheep, but this activation would no longer be present at the sentence final word (e.g., 'sheath'). Alternatively, we posit that false hearing when using semantically meaningful sentences is due to the expectation of a semantically predicted final word. In this account false hearing occurs due to meaningful semantic context building the expectation of the semantically predicted word, which then requires resisting the prepotent response. Thus, another advantage to using semantically meaningful sentences, compared to paired associates, is that it allows researchers to investigate if false hearing is due to semantic expectation as opposed to semantic priming.

Cognitive control as a common factor in false seeing, false hearing, and false memory

Cognitive control is an umbrella term for a large number of abilities used in planning and executing a range of tasks. It is important to the differential bases of responding account because it provides a possible mechanism for the observed age differences. A cognitive control deficit argument posits age differences as a result of older adults' inability to resist prepotent responses. Thus, older adults are more easily captured by context (i.e., less able to resist prepotent responses) than are young adults, leading to increases in false hearing. Cognitive control is a possible unifying mechanism that explains why in such divergent domains as memory, vision and hearing all results reflect the same findings; older adults are more likely to respond on the basis of context than are young adults.

Here the basic account is that older adults are captured by context more than young adults because of age related declines in the ability to control responding on the basis of what is presented rather than what is expected (i.e., prepotent responding). Importantly, in many of the experiments described previously participants are explicitly informed that many of the trials will be incongruent (i.e., misleading) (Jacoby et al., 2011; Rogers, Jacoby & Sommers, 2012; Sommers et al., in prep). Despite this knowledge these studies still find that older adults are unable to resist the prepotent response and false hear/see more than young adults (Jacoby et al., 2011; Rogers, Jacoby & Sommers, 2012; Sommers et al., in prep). Cognitive control has implications for age differences stemming from differential bases of responding because most of the experiments investigating differential bases of responding require participants to resist prepotent candidates for response. For example, listeners need to resist being captured by context when hearing "I was attacked by a lark", which leads to the prepotent response 'shark'. Thus, the listener must engage cognitive control processes so that less probable response candidates can be considered. Older adults' ability to resist prepotent responses has been demonstrated to be considerably lower than young adults (Hasher, Zacks & May, 1999; May & Hasher, 1998). One such demonstration of older adults' inability to resist prepotent responses was found by May and Hasher (1998). In this experiment, participants were trained on a simple categorization task in which participants were tasked with making a keypress when a certain exemplar (e.g., chair) matched a certain category (e.g., furniture). After training, participants were told that on certain trials a tone would be presented, which indicated that they were not supposed to make a keypress on this trial. Thus, control was measured as the ability to resist the keypress. May and Hasher found that older adults were significantly less able to resist the prepotent, keypress response compared to young adults. Results of this nature suggest that older adults have diminished cognitive control relative to young adults, and are less flexible at shifting response patterns.

Thus, cognitive control is a strong candidate for the unifying mechanism that can explain why older adults are more likely to falsely remember (Hay & Jacoby, 1999; Jacoby et al., 2005), falsely see (Jacoby et al., 2011) and falsely hear (Rogers, Jacoby & Sommers, 2012; Sommers et al., in prep) compared to young adults. Each study demonstrated that older adults used automatic familiarity/knowing processes to a greater extent than did young adults, which was reflected by the increased proportion of incongruent false alarms. In other words, older adults falsely hear, see and remember more than young adults because they are less able to resist prepotent responding.

Effects of changing uncertainty

How reducing or increasing uncertainty might alter age differences in use of context as a basis for responding is unknown, but reducing or enhancing uncertainty in stimuli does have some promise to inform researchers about differential bases of responding accounts. There are many ways to reduce or increase the uncertainty of a stimulus which could include altering the background noise (i.e., making the stimulus easier to encode), altering the duration of presentation, or manipulating whether responding is in an open or closed-set. The experiments that form the basis of this dissertation make use of three manipulations: a) comparing open-set to closed-set responding, b) increasing or decreasing the signal-to-noise ratio, and c) cuing individuals to the validity of the context. Each of these uncertainty manipulations affects the access to, or the availability of, sensory information, and the effects of these alternations to signal-based information will be examined.

Open-set responding refers to requiring participants to identify target stimuli without providing any response alternatives to chose from, whereas closed-set responding provides a set of response alternatives from which participants are asked to chose. In spoken word recognition, open-set responding, at least in principle, requires a comparison of the entire mental lexicon to find a best match representation with the incoming signal. In contrast, closed-set responding only requires that the incoming stimulus be compared with the set of provided response alternatives Thus, closed-set responding considerably reduces uncertainty in spoken word recognition relative to open-set responding. In young adults, the general finding is that spoken word recognition is better under closed-set responding than open-set responding (Sommers, Kirk & Pisoni, 1997; Trout, 2005), reflecting the benefits of closed-set response formats.

A second method for manipulating uncertainty is by altering the signal-to-noise ratio. All stimulus degradation techniques increase uncertainty by decreasing the fidelity of sensory sources of information. Of importance to the differential bases of responding account is whether changes in the signal-to-noise ratio (SNR) cause systematic increases in recognition performance between age groups as the SNR difficulty decreases. In a peripheral hearing loss account for age differences in spoken word recognition, one would expect systematic performance changes regardless of context predictability. For example, when manipulating SNR, it would not be surprising to find that, moving from an easier to harder SNR causes systematic decrements in performance. Thus, congruent hits, for example, might decrease for both older and young adults when the SNR difficulty is increased. However, if the differential bases of responding accounts for unequal performance benefits for older adults when semantic context is added then older adults should be relatively unaffected by changes in the SNR difficulty when meaningful semantic context is present. The differential bases of responding account would predict that moving from a less to a more favorable SNR should, for example, lead to little or no change in congruent hits for older adults, whereas young adults should show a systematic increase in congruent hits as the SNR is made more favorable. In other words, the differential bases of responding account asserts that because older adults overuse contextual sources of information, relative to young adults, they might show reduced changes in congruent hits, relative to young listeners, as SNR becomes more difficult. In the extreme case of complete use of context as a basis for responding by older adults, variations in the SNR of the target word should have little effect given that such changes affect only sensory based information.

The overuse of context as a basis for responding for older adults should also affect incongruent performance such that older adults' incongruent hits increase less than young adults as the SNR becomes easier. The continued overuse of context as a basis for responding, even when uncertainty is reduced, could reflect older adults' deficit in cognitive control. Specifically, if older adults' ability to resist prepotent responding is poorer than young adults then they should continue to use contextual sources of information to a larger degree than young adults even when uncertainty is reduced (increasing the SNR).

A final manipulation that was used to investigate uncertainty was by cuing individuals to the validity of the context. Here cuing individuals to the validity of the context refers to providing information, prior to presentation of a stimulus, that can be used to aid in providing listeners with information regarding the validity of context on each trial. Thus, cuing can considerably reduce uncertainty so long as it conforms to the expectation it fosters. For example, Jaeger, Cox and Dobbins (2012) designed a recognition memory experiment in which participants were cued to the validity of certain trials. In this experiment, participants were presented with words and instructed to decide if the word had more than one syllable. Following this incidental encoding phase, participants were given a recognition memory test and instructed to indicate if a presented word was previously presented in the encoding task (e.g., "old") or not (e.g., "new"). However, prior to the presentation of the word, participants were cued with a probe "likely old" or "unlikely old". Seventy-five percent of the cues were valid and 25% of the cues were invalid. Participants were made aware of the valid and invalid percentages. Results demonstrated that when cuing was valid the proportion of correct responses was significantly greater than when the cues were invalid. Thus, when participants were given valid cues they were able to use this reduction in uncertainty to increase performance. This uncertainty manipulation is of special interest to differential bases of responding account because if overuse of context as a basis for responding continues for older adults, despite being informed that the trial likely violates expectations, it would demonstrate a decrement in performance even when additional information is provided to aid hearing judgments. Conversely, if presenting informative cues to older and younger adults equates performance on incongruent hits/false alarms then informing older adults to the validity of the context can be one way of reducing age differences in false hearing.

Overview of experiments

The goal of Experiment 1 was to determine how false hearing rates differ in a closed-set response format compared to an open-set response format using a within-participants design. We wanted to know if restricting the responses available, relative to an open-set response format, would alter the pattern of age differences in spoken word recognition. Experiment 1 used the same stimuli and basic procedures used in the Sommers et al. (in prep) study, but modified from the completely open-set design in that half the trials (blocked) were open-set response format and the other half used a two-alternative forced-choice (closed-set) response format. In the open-set block, participants heard sentences (final word in noise) and then were asked to repeat that word back to the experimenter. In the closed-set block participants heard sentences (final word in noise), were presented with two responses options (the correct target and a phonological neighbor), and asked to select the word he or she heard in noise. In both blocks, after participants responded with the word they heard in noise, they were asked to report their confidence (0-100%) that the response they provided was the word actually presented in noise. There were two main hypotheses for Experiment 1. First, we hypothesized that both young and older adults would increase their correct responding for incongruent trials in the closed- compared with the open-set design, but that the increase would be greater for older listeners.

That is, we predicted that reducing uncertainty would be more beneficial for older than for young listeners. Older adults might benefit more from the reduction in uncertainty on incongruent trials because older adults already rely less on sensory based information, which is the favored basis for responding on incongruent trials. Since older adults' incongruent hits are significantly lower than young adults in an open-set design (Sommers et al., in prep), it is possible that restricting response options would provide older adults with more opportunities to turn missed incongruent items into correct responses; producing a larger percentage increase in incongruent hits for older adults than young adults.

The second hypothesis for Experiment 1 was that the proportion of incongruent false alarms would be greater for older adults than young adults in both open and closed-set responding. If a differential basis of responding accounts for age differences in false hearing, then regardless of response format older adults should be captured by context more than young adults. This would be reflected in older adults having significantly more incongruent false alarms in both open and closed-set formats. Thus, Experiment 1 predicted that although older adults would benefit more from a reduction in uncertainty than would young adults, older adults would still be unable to decrease their false hearing occurrences to the levels of young adults, as they are less able to resist prepotent responding.

The goal of Experiment 2 was to examine the effects of reducing or increasing uncertainty by varying signal-to-noise ratio (SNR). All materials and procedures for Experiment 2 were the same as those used in the closed-set format of Experiment 1 with the exception of how uncertainty was manipulated. In Experiment 2, uncertainty was manipulated by making stimuli easier or harder to hear for listeners, relative to the individuals' age-equated SNR value. Four SNR values (easy, intermediate, hard and clear) were used in blocked presentation. The average SNR for baseline hits for each age group was used as the intermediate SNR value for Experiment 2, as baseline performance at this SNR was known to be equal from Experiment 1. The harder SNR condition increased the SNR by 4 dB (i.e., the masker was made 4-dB more intense relative to the intermediate SNR), and the easier SNR condition decreased the SNR by 4 dB (i.e., the masker was made 4-dB less intense relative to the intermediate SNR). Finally, we included a condition in which no noise was present (clear condition) so that age group performance could be compared when uncertainty in the stimuli has been reduced as much as possible.

Experiment 2 was conducted to investigate if congruent and incongruent trial performance increased systematically as the SNR difficulty is decreased. If older adults do not show systematic increases for congruent or incongruent trials, as SNR difficulty is decreased, it would support a differential bases of responding account. The differential bases of responding account predicts that moving from a more difficult SNR to an easier SNR should lead to systematically greater numbers of incongruent hits for young adults, whereas older adult performance might remain relatively invariant (since they might continue to use context even when SNR is made easier). In other words, because the differential bases of responding account asserts that young adults use sensory information to a greater extent, relative to older adults, they should benefit more than older adults by having a higher fidelity sensory signal. Unlike incongruent hits, congruent hits should systematically decrease for young adults, but not for older adults, as the SNR difficulty is increased. If young adults are using sensory information more than older adults, having a more difficult SNR should lower young adult performance systematically. Conversely, older adults should show little to no change in performance as SNR is made more difficult on congruent trials as they use context as the primary basis for responding.

Experiment 3 was conducted to see how reducing or increasing uncertainty by providing information about the validity of the context affects age differences in false hearing. Using the closed-set design (i.e., 2AFC), participants were presented with the same sentence materials as were used in Experiments 1 and 2. However, on congruent and incongruent trials, cues stating "likely misleading" or "likely predictive" were displayed just prior to participants being presented with the sentence. Twenty-five percent of the congruent trials were paired with a cue stating "likely misleading", 50% were paired with a cue stating "likely predictive", and 25% of congruent trials contained a neutral cue (asterisks). Conversely, 25% of the incongruent trials were paired with a cue stating "likely predictive", 50% with a cue stating "likely misleading", and 25% contained a neutral cue (asterisks). After hearing the sentence, as with the closed-set trials in Experiment 1, participants were presented with two words, and were asked to select the word presented in noise. As in Experiments 1 and 2, participants were asked to provide their confidence (0-100%) that the word he or she selected was the word in noise.

We hypothesized that only young adults would respond to the presentation of the cues on congruent and incongruent trials. If older adults are unable to resist using context we should see that regardless of cue type, older adults respond with the contextually predicted word. This would essentially produce flat performance across cue types for older adults. If young adults are not as reliant on context then they might demonstrate a significant decrease in congruent hits when the "likely misleading" cue is presented, as they might be more willing to act against context. Also of interest, is whether older adults continue to over-use context as the basis for responding on incongruent trials even when cues specifically state the trial is "likely misleading". If older adults ignore the cue, despite the cue considerably reducing uncertainty about the validity of context in the subsequent sentence, and still respond with the word predicted by context, this finding would offer considerable support that older adults use context to a greater extent. We predict that young adults will benefit more from this reduction in uncertainty than older adults as evidenced by young adults significantly decreasing incongruent false alarms when the cue states "likely misleading", relative to when no cue is presented, compared to older adults.

Chapter 2: Experiment 1

Methods for Experiment 1

Participants

A total of 24 undergraduate students (17 female and 7 male) were recruited through the Washington University subject pool, and received either ten dollars or one course credit per hour. These young adults ranged in age from 18 to 24 years (*M* = 20.38, *SD* = 1.77). A total of 26 older adults (19 female and 5 male) were recruited through the Research Participation Registry, and received ten dollars per hour of participation as well as five dollars for travel expenses. Of these 26 older adults, two were excluded, one due to a computer error and the other to correct an error in counterbalancing. The remaining older adults ranged in age from 65 to 86 years (*M* = 69.08, *SD* = 5.34). Participants were tested on the Vocabulary subset of the Shipley Institute of Living Scale (Shipley, 1967). The mean score was significantly higher for older adults (*M* = 35.42, *SD* = 3.2) compared to younger adults (*M* = 33.33, *SD* = 2.63), $t(46) = 2.46$ $p < .01$. None of the older participants reported taking medications or having health conditions that would affect cognitive function. All participants reported normal or corrected-to-normal vision.

Materials

A critical issue for any study comparing speech perception in older and young adults is that older adults typically have reduced audibility of spoken words due to presbycusic hearing loss. To control for individual differences in hearing in the open-set response format, we used a modified version of the ASHA speech reception threshold (SRT) titration procedure (ASHA, 1998). In this procedure, signal-to-noise ratio (SNR) was varied adaptively to determine the SNR value that produced 50% correct identification for words in a low-predictability context. A set of 52 low predictability sentences that were not used in the main experiment were created and used as stimuli for the calibration procedure.

To control for individual differences in hearing in the closed-set response format, the calibration procedure for open-set responding was adapted to display two response options on the screen. In this procedure, one of four preselected, age specific, SNR values was selected randomly for each trial. At the end of calibration, the average proportion of correct responses was displayed for each of the four SNR values to determine the SNR value that produced 75% (or as close to as possible) correct identification for sentence final words. A set of 48 novel low predictability sentences (12 per SNR value) were created and used as stimuli for the calibration procedure.

A total of 126 sentences were taken or modified from the SPIN sentence test (Bilger, Nuetzel, Rabinowitz & Rzeczkowski, 1984), and used for the study. Six of these sentences (two sentences per trial type) were used for practice prior to beginning experimental trials (3 each in the open and closed-set response formats) in order to ensure that each participant had a sufficient understanding of the task at hand. Of the remaining 120 sentences, 40 were used as baseline trials, 20 were used as congruent trials and 60 were used as incongruent trials. These trials were then equally divided between open- and closed-set response formats. The congruent condition used unmodified versions of high-predictability SPIN sentences in which the final word was highly predictable from the prior semantic context (e.g., the plumber was fixing a <u>sink</u>). The baseline condition used unmodified versions of low-predictability SPIN sentences in which the context provides minimal information about the sentence-final item (e.g., Paul heard they asked about the <u>rice</u>). Finally, the incongruent condition used modified versions of the SPIN sentences in which the final (target) word was replaced by a phonological competitor (i.e., rhyming word) confusable with the original target item, but that still produced a meaningful sentence (e.g., The plumber was fixing a <u>drink</u>). Across the three conditions, final target items were equated for frequency, neighborhood density and word duration. Table 1 displays the descriptive statistics for the final words used in the sentences. In addition, for the congruent and incongruent conditions, presentation of intact or modified high-predictability sentences was counterbalanced across participants such that an equal number received each version of a sentence (i.e., half heard the 'sink' ending for the sentence context "the plumber is fixing a _______" and half received the 'drink' ending). No participant received both versions of any of the sentences.

Word Stimuli (N = 120)	Baseline	Congruent	Incongruent
Log Frequency	8.61 (1.37)	8.72 (1.21)	8.72 (1.21)
Neighborhood Density	20.28 (6.97)	21.13 (7.81)	22.09 (7.46)
Word Duration	1286.72 ms (194.19)	1274.78 ms (176.14)	1231.76 ms (159.78)

Table 2: Descriptive Statistics for the sentence final words used in Experiments 1, 2 and 3.

All of the auditory stimuli were spoken versions of the above sentences recorded at 48,000 Hz with a 16-bit resolution, using a table-mounted microphone (Shure PG27) in a double-walled sound attenuating booth. Sentences were spoken by a male speaker with a standard American dialect. Root-mean-square (RMS) amplitude of the stimuli was equated. Stimuli were then down sampled to 11,025 Hz using Adobe Audition for presentation in the experiment.

The auditory stimuli were masked (full word in calibration phase and final word in sentence tests) using a 6-talker babble. The babble was captured from the Iowa Auditory visual Speech Perception Laserdisc (Tyler, Preece, & Tye-Murray, 1986) using a 16-bit converter at a sampling rate of 44,100Hz and then down sampled to 11,025 Hz using Adobe Audition. A different random sample of the babble was used for each presentation.

Procedure

Calibration. The procedure in the experiment was broken into two main counterbalanced phases: the open-set response phase and the closed-set response phase. Within each phase, participants were given a calibration task followed by the test task. The calibration phase for the open-set response format differed from the calibration phase for the closed-set response. In the open-set response format, the calibration phase was used to find a signal-to-noise ratio (SNR) that produced 50% accuracy for word identification using a modification of the American

Speech-Language-Hearing Association's recommended procedure (ASHA, 1998) for obtaining a Speech Reception Threshold. That is, the goal of the calibration phase was to equate audibility by determining the SNR that would produce 50% correct identification of low predictability sentence final words. During the calibration phase, participants were seated in a testing room, and stimuli were presented binaurally over headphones (Sennheiser HD 518). Each stimulus presented the contextual portion of the sentence without any background noise, and the sentence final word in background noise. Participants were told to repeat the word presented in noise back to the experimenter and that if he or she had no idea what the word was to give the best possible guess. For each correctly identified word the signal-to-noise ratio was decreased by 2dB SPL, and for each incorrectly identified word the signal-to-noise ratio was increased by 2dB SPL. Calibration was completed when participants' responses stabilized such that if the signal-to-noise ratio was decreased he or she would incorrectly identify the word, but when the signal-to-noise ratio was increased he or she would correctly identify the word. After task completion the average dB level for each point at which a participant switched to a correct response from an incorrect response(s) or switched to an incorrect response from a correct response(s) was obtained to be used in the perception test phase. Stimuli were randomly presented from the total calibration word list.

The calibration task for the closed-set format was similar to the open-set format except it did not adaptively vary SNR, and participants were given two response candidates to select from. Four SNR values, based on pilot tests, were chosen separately for young and older adults. The values selected were those closest to the average SNR value that produced 75% correct recognition performance for low predictability sentence final words. For young adults, those SNR values were -3, -5, -7 and -9 dB. For older adults, those SNR values were +5, +3, +1 and -1 dB. Participants were randomly presented low predictability sentences with the background noise randomly selected between the four SNR values for an age group. After listeners heard each sentence, they were presented with two-alternative forced choice responses and asked to select which of the two was the word presented in noise. If the listener couldn't identify the word, he or she was instructed to make the best possible guess between the two choices. After task completion, the computer program indicated to the experimenter what the average proportion of correct responses was for each SNR value, and the experimenter chose the SNR value closest to 75% to be used in the perception test phase. To select the SNR closest to 75% the experimenter would examine the proportion correct for each four SNR values tested. If one value clearly was closest to 75%, this value was used during the test phase. If two or more SNR values were close to 75%, the SNR value was selected based on the performance in the other SNR condition(s).

Perception Test. Perceptual tests were divided between the open and closed-set response formats. Both the open and closed-set response tests included 60 trials with equal amounts of congruent, incongruent and baseline trials between the two formats. Trials of each type were presented in a single block with the restriction that no more than three trials of a given type were presented consecutively. Participants were seated facing the computer screen in the same testing room used for the calibration phase. Participants were informed that they would be hearing a series of sentences with the final word in a babble-background noise. Participants were told that the masking noise would sound like when you first walk into a room with several people talking at once. In the open-set response format, participants were told that their task would be to repeat the final word of this sentence back to the experimenter, and that if they had no idea what this word was, to respond with the best possible guess. In the closed-set response format, participants were told they would see two response options on the screen and they were to select the alternative that matched the word presented in noise. If they couldn't identify the word, they were to select the best possible guess between the two response options. Participants were warned that there would be three types of sentences: predictive sentences like, "the plumber fixed the <u>sink</u>", misleading sentences like, "the plumber fixed a <u>drink</u>", and sentences that would have no predictive qualities at all like, "Mr. White is thinking about the <u>drink</u>". Because of this, participants were instructed to respond on the basis of what they heard in noise, not what the context of the sentence may or may not lead them to believe.

After participants provided the target word identification, they were instructed to indicate how confident they were that the response provided was in fact the word presented in noise. Participants gave this confidence rating using a 0-100 percent scale. Participants in the open response format provided the rating aloud, and participants in the closed-set response format keyed in the confidence. During both open and closed-set tests, participants were encouraged to use the full range of the scale. As with the identification judgments, participants were instructed to make their confidence judgments only on the basis of what they heard in noise.

After participants received all instructions for the perceptual test phase, they were asked to explain the procedure in their own words. Participants' reports had to include (a) the identification judgment, (b) the confidence rating (0-100), and (c) the potential misleading nature of sentence context. The experimenter verbally repeated instructions and questioned participants until the participants' procedure report was complete. All participants' procedure reports were complete before the beginning of the perception test phase.

The timing for each trial was as follows: 200 ms before the sentence was presented over the headphones a single asterisk "*" was presented visually in the top center portion of the screen until the onset of the aurally presented sentence. The babble-background noise began approximately 50 ms before the target item and ended with the offset of the target word. Participants were given no time limit with regards to reporting the target word or confidence.

Experiment 1 Results and Discussion

Correct Identifications and False Alarms

Identification accuracy was measured as the proportion of trials on which participants correctly identified the target word in noise. The proportion of correctly identified trials as well as the proportion of incongruent false alarms between young and older adults can be seen in Figure 5. A mixed-model analysis of variance (ANOVA) with age (young, older) as an

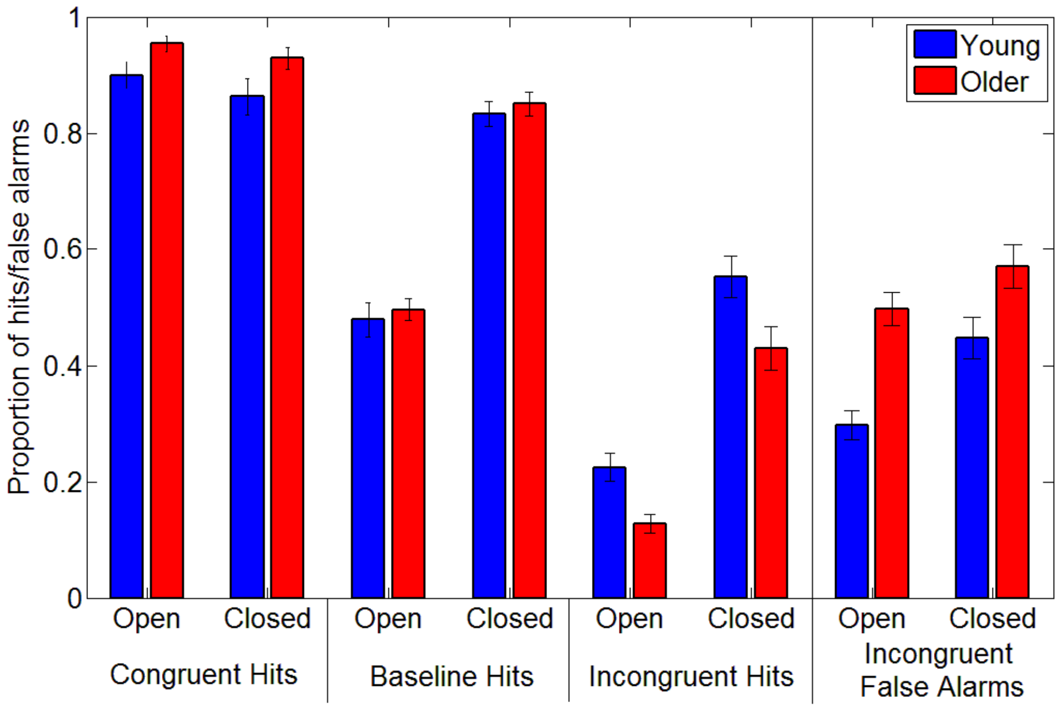

Figure 5: Young and older adults' proportion of hits and false alarms for open and closed-set responding. False alarms are presented to the right of the dividing line.

independent measures factor, response format (open-set, closed-set) as a repeated measures factor and trial type (baseline, congruent, incongruent) as a repeated measures factor indicated that participants had different proportions of correctly identified words depending on the trial type as indicated by the main effect of trial type, $F(2, 92) = 563.38$, MSE = .014, $p < .001$, $\eta_p^2 = .925$. Participants also performed better in the closed-set response format compared to the open-set format as evidenced by a significant main effect of response format, $F(1, 46) = 165.86$, MSE = .02, $p < .001$, $\eta_p^2 = .783$. There was no main effect of age, $F(1, 46) = .43$, MSE = .021, $p <.75$, $\eta_p^2 = .009$. The ANOVA revealed a significant age x trial type interaction ($F(2, 92) = 13.2$, MSE = .014, $p < .001$, $\eta_p^2 = .223$) and a significant trial x response format interaction ($F(2, 92) = 96.59$, MSE = .02, $p < .001$, $\eta_p^2 = .667$). There was no significant interaction between age and response format, indicating that restricting response options did not benefit older adults more than young adults, $F(1, 46) = .02$, MSE = .02, $p < 1$, $\eta_p^2 = .001$. No significant three way interaction was found between age x response format x trial type, $F(2, 92) = .212$, MSE = .011, $p < 1$, $\eta_p^2 = .005$.

Correct Identifications with Open-set Responding: Recall that the ANOVA revealed a significant age by trial type interaction. To determine the source of this interaction, I conducted separate analyses for each trial type in both the open- and closed set response formats. Consider first, the baseline condition for the open-set response format in which context is entirely non-predictive of the sentence-final item. A Bonferroni corrected comparison of performance for open-set responding in this condition did not differ significantly between young and older adults and overall accuracy was very close to the targeted 50% correct rate, $F(1,46) = .226$, $p > .05$. This indicates that performance was properly equated between age groups when context was non-predictive.

Next, consider open-set response format results for the congruent condition in which both context and sensory information converge on the same response (e.g., “the plumber was fixing a sink”). As can be seen in Figure 5, congruent trial performance on both open and closed-set response formats was near ceiling and higher than any other trial type. This is not surprising as both young and older adults benefit from having contextual and sensory sources of information converging on the same response. What was somewhat surprising was that older adults' proportion of congruent hits was significantly greater than young adults in open-set responding, $F(1,46) = 4.28$, $p < .05$.

Moving to incongruent trial performance in open-set responding, results demonstrated that young adults outperformed older adults. Bonferroni-corrected pairwise comparisons indicated that older adults ($M = 0.12$, $SD = 0.08$) had significantly fewer incongruent hits than young adults ($M = 0.22$, $SD = 0.12$), $F(1,46) = 11$, $p < .01$. Thus, when meaningful semantic context is taken away, older adults' performance is significantly worse than young adults.

Correct Identifications with Closed-set Responding: Recall that the omnibus ANOVA revealed an age by trial type interaction. To determine if the same age differences revealed from the pairwise comparisons in the open-set response format were present in the closed-set format, Bonferroni-corrected pairwise comparisons were conducted on baseline, congruent and incongruent trials. Performance for closed-set responding on baseline trials did not differ significantly between age groups, and accuracy was close to the targeted 75% correct identification rate, $F(1,46) = .314$, $p > .05$. Thus, baseline conditions indicate that the procedures used for equating audibility between age groups were successful.

As was the case in the open-set response format, performance on congruent trials was near ceiling in the closed-set response format. Although older adults, compared to young adults, demonstrated a numerically higher proportion of hits on congruent trials, the Bonferroni-corrected comparison only approached significance in closed-set responding, $F(1,46) = 3.48$, $p = .07$.

Performance on incongruent trials using a closed-set response format converged with the results from the open-set response format. A Bonferroni-corrected pairwise comparison revealed that older adults ($M = 0.43$, $SD = 0.18$) had significantly fewer incongruent hits than young adults ($M = 0.55$, $SD = 0.18$) for closed-set responding, $F(1,46) = 5.75$, $p < .05$. Thus, when context is not predictive, older adults perform significantly worse in the incongruent condition than young adults even when uncertainty is reduced by restricting the number of response options.

Incongruent False Alarms: False alarms on incongruent trials were examined, and the proportion of incongruent false alarms can be seen in Figure 5 (right of the dividing line). An incongruent false alarm occurs when the participant responds with the contextually predicted word (e.g., 'sink') when the item actually presented was a phonologically confusable neighbor (e.g., 'drink'). A 2 (age: young, older) x 2 (response format: open-set, closed-set) mixed-model ANOVA was conducted and revealed main effects of age group ($F(1, 46) = 17.98$, MSE = .035, $p < .001$, $\eta_p^2 = .281$) and response type ($F(1, 46) = 20.6$, MSE = .015, $p < .001$, $\eta_p^2 = .309$). There was no interaction between age and response format, $F(1, 46) = 2.4$, MSE = .015, $p < .15$, $\eta_p^2 = .05$. Thus, our hypothesis that older adults' incongruent false alarms would differentially decrease compared to young adults as a result of reducing uncertainty proved false.

Age differences in the proportion of false alarms for the open-set response format were investigated and are shown in the far right panel of Figure 5. As was indicated by the main effect of age, older adults have significantly more incongruent false alarms than young adults.

Bonferroni-corrected pairwise comparisons on incongruent false alarms in the open-set response format confirmed that older adults (*M* = 0.5, *SD* = 0.14) had a significantly greater proportion of incongruent false alarms than did young adults (*M* = 0.3, *SD* = 0.12), $F(1,46) = 27.23$, $p < .001$.

False alarms for the closed-set response format are plotted to the right of the dividing line in Figure 5. Within a two alternative forced choice design, incongruent false alarms are the complement of incongruent hits (because there are only two choices) which means older adults had significantly more incongruent false alarms than young adults, $F(1,46) = 5.75$, $p < .05$. Confirming our second hypothesis, the results from incongruent false alarms demonstrate that even when uncertainty is reduced by limiting the number of response alternatives older adults still false hear more than young adults.

Confidence data

Figure 6 shows the mean confidence ratings assigned to correct identifications in the congruent, baseline, and incongruent conditions as well as the confidence in false alarms for incongruent trials (to the right of the dividing line) for each response format type. Confidence in hits and incongruent false alarms were used to investigate how confidence varied between age groups. To investigate confidence results a mixed-model ANOVA with age (young, older) as an independent measures factor, response format (open-set, closed-set) as a repeated measures factor and trial type (baseline, congruent, incongruent) as a repeated measures factor was conducted. The only significant main effect revealed was trial type, indicating that participants' performance varied depending on how semantic context was manipulated, $F(2, 92) = 118.41$, MSE = 232.11, $p < .001$, $\eta_p^2 = .72$. A significant trial type x response format interaction was also found demonstrating that participants trial type performance varied as a function of response format, $F(2, 46) = 12.63$, MSE = 306.9, $p < .001$, $\eta_p^2 = .215$. A significant age x response type

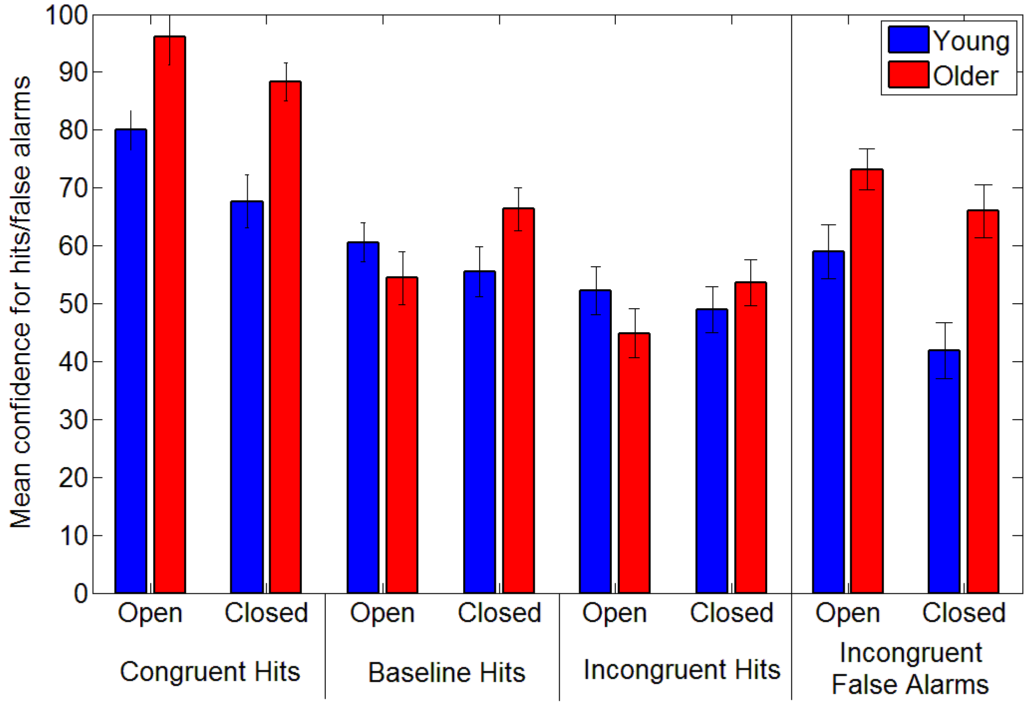

Figure 6: Young and older adults' confidence in hits and false alarms for open and closed-set responding. False alarms are presented to the right of the dividing line.

interaction in the ANOVA was revealed, and indicated that age groups varied in how response format effected overall trial confidence, $F(1,46) = 7.98$, MSE = 306.9, $p < .01$, $\eta_p^2 = .148$. Thus, young adult confidence was considerably lower in closed-set responding compared to open-set responding, whereas older adult confidence was considerably lower in open-set responding compared to closed-set responding. Demonstrating that age groups differed in how confident they were between the trial types, a significant age x trial type interaction was found, $F(2, 92) = 10.79$, MSE = 232.11, $p < .001$, $\eta_p^2 = .19$. Lastly, the omnibus ANOVA revealed no significant three way interaction between age x response format x trial type, $F(2, 92) = 2.14$, MSE = 113.7, $p < .25$, $\eta_p^2 = .044$.

Returning to the age x trial type interaction, to determine the source of the interaction Bonferroni-corrected pairwise comparisons were conducted separately for each response format.

Consistent with older and young adults being restricted to sensory information as a basis for responding in the baseline condition, confidence did not differ as a function of age for either open ($F(1,46) = 1.16$, $p > .05$) or closed-set ($F(1,46) = 3.62$, $p > .05$) response formats.

If the differential basis of responding account for age differences in spoken word recognition is correct, then older adults' greater usage of context as a basis for responding should lead to increased confidence, relative to young adults, when context is predictive. Bonferroni-corrected pairwise comparisons showed participants' average confidence on congruent hits was significantly higher for older than for young adults for open-set responding, $F(1,46) = 7.47$, $p < .01$, as well as closed-set responding, $F(1,46) = 13.26$, $p < .001$. These findings demonstrate that older adults are more confident than young adults when context is predictive and support the claim that increased confidence is caused by older adults using context to a greater extent, relative to young adults. Analysis of the confidence in hits on incongruent trials revealed no age differences in confidence for open ($F(1,46) = 1.57$, $p > .05$) or closed-set ($F(1,46) = 1$, $p > .05$) response formats.

Confidence in incongruent false alarms is of particular importance in the present experiment as false alarm confidence addresses age group's differences in context use. With regards to open-set responding, we predicted that if older adults use context to a greater extent than do young adults, when an older adult responds with the word predicted by context incorrectly (e.g., the sentence was "the plumber was fixing a drink", but the participant responds 'sink') he or she should be significantly more confident in this incorrect response. To investigate this, a mixed-model ANOVA with age (young, older) as an independent measures factor and response format (open-set, closed-set) as a repeated measures factor was conducted. The ANOVA revealed a main effect of age indicating that older adults were more confident in their false alarms than young adults, $F(1,46) = 11.65$, MSE = 755.73, $p < .01$, $\eta_p^2 = .202$. The ANOVA also revealed a main effect of response format which showed that participants were more confident in their false alarms on the open-set response format, $F(1,46) = 18.96$, MSE = 187.61, $p < .001$, $\eta_p^2 = .292$. Although approaching significance, there was no significant age by response format interaction, $F(1,46) = 3.19$, MSE = 187.61, $p < .1$, $\eta_p^2 = .065$. To examine the main effect of age, Bonferroni-corrected pairwise comparisons were conducted, and revealed that when using the open-set responding format older adults were significantly more confident in their incongruent false alarms than were younger adults, $F(1,46) = 5.91$, $p < .05$. The Bonferroni-corrected pairwise comparison of incongruent false alarms in the closed-set format demonstrated that older adults also had significantly higher confidence on their incongruent false alarms than did younger adults, $F(1,46) = 13.05$, $p < .001$. Thus, as predicted, when context is misleading older adults are more confident in their incorrect responses than are young adults.

Dramatic False Hearing

In the differential basis of responding account, incongruent false alarms are caused by using context as a basis for responding to a greater extent than sensory sources of information. Thus, older adults show significantly more incongruent false alarms because they use context to a greater extent. Of interest, is whether the context actually alters the subjective hearing experience or merely is a way of increasing the chances of correctly identifying a word when sensory information fails. It is possible that incongruent false alarms occur because the listener misses the word in noise, and, when asked to respond, chooses the word predicted by context. In this situation, choosing the word predicted by the semantic context would be a good strategy to increase the chances of being correct as saying a word predicted by context has a higher probability of being correct than a random guess. On the other hand, incongruent false alarms might reflect actually hearing the contextually predicted word due to top down processes. To examine if there are age differences in the subjective hearing experience of incongruent false alarms, we investigated occurrences of dramatic false hearing as a function of age. Dramatic false hearing (DFH) we define as providing the (incorrect) response favored by context with a confidence rating of 90% or more (i.e., cases in which individuals were 90-100% confident in their incorrect responses). If we consider 90-100% confidence as an indicator of the subjective hearing experience, then these data should reveal if there are age differences in the subjective hearing experience of incongruent false alarms. A 2 (age: young, older) x 2 (response format: open-set, closed-set) mixed-model ANOVA was conducted to investigate age differences in DFH occurrences. There was no main effect of response format on DFH occurrences ($F(1,30) = 0$, MSE = .029, $p < 1$, $\eta_p^2 = 0$), or a significant age by response format interaction ($F(1,30) = .008$, MSE = .029, $p < 1$, $\eta_p^2 = 0$). Older adults demonstrated more DFH occurrences than young adults as shown by a main effect of age, $F(1,30) = 7.24$, MSE = .026, $p < .05$, $\eta_p^2 = .194$.

Figure 7 displays the proportion of DFH occurrences for young and older adults. As the main effect of age indicated, older adults had significantly more DFH occurrences than young adults. This age difference in the proportion of DFH occurrences can be seen in Figure 7. These data suggest that older adults subjectively hear the contextually predicted word on incongruent trials significantly more than young adults, and that this is due to older adults using context to guide perception to a greater extent. Furthermore, as the non-significant interaction suggests, older adults continue to produce more DFH occurrences than young adults even when

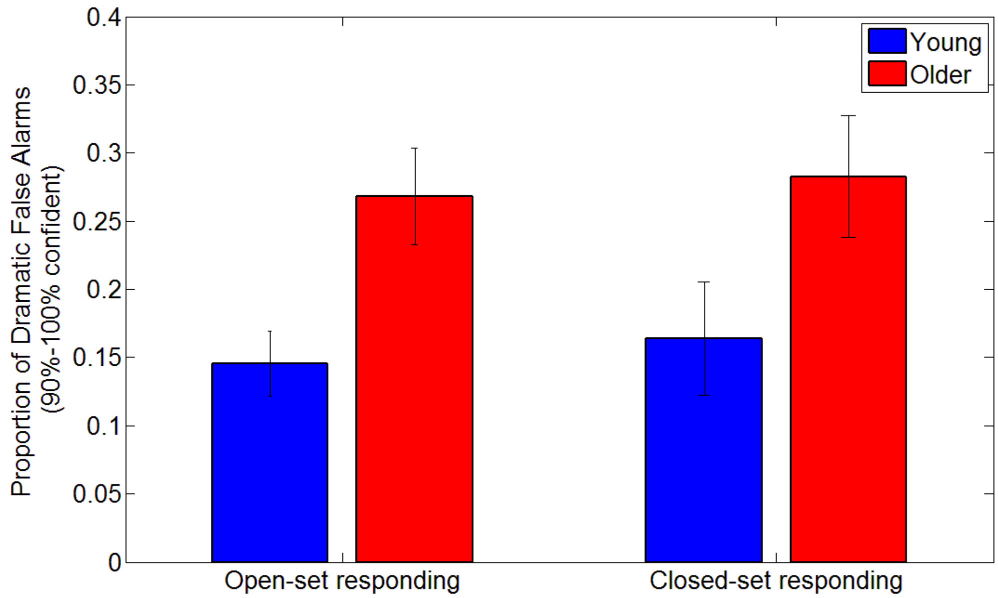

Figure 7: The proportion of dramatic false hearing occurrences for young and older adults.

uncertainty is reduced by limiting the number of response options relative to an open-set response format.

The ANOVA conducted revealed a main effect of age. However, we also wanted to determine the how age groups differed in the proportion of DFH occurrences for each specific response format. To do so, independent samples *t*-tests were conducted separately for both the open-set and closed-set response formats. The result of this tests revealed that older adults (M = 0.25, SD = 0.18) demonstrated significantly more occurrences of DFH in the open-set response format compared to younger adults (M = 0.09, SD = 0.1), $t(46) = 3.89$, $p < .001$. The independent samples *t*-test investigating age differences in DFH in the closed-set response format, also revealed that older adults (M = 0.25, SD = 0.21) had significantly more DFH occurrences than younger adults (M = 0.08, SD = 0.12), $t(46) = 3.43$, $p < .001$. Thus, regardless of response format older adults continue to produce more DFH occurrences than young adults.

Resolution

Resolution is a measure of metacognitive monitoring that assesses the extent to which confidence in a response is related to accuracy. Resolution was measured using gamma correlations, which reflect the item-level correspondence between confidence and accuracy (Goodman & Kruskal, 1954). Gamma correlations range from +1 to -1, where a strong positive value on this scale refers to cases in which confidence judgments distinguish between correct versus incorrect responses. We expected participants' resolution to be high on congruent trials, moderate on baseline trials, and poor on incongruent trials. However, we expected age differences in resolution such that age groups' resolution is equated in baseline trials, but older adults' resolution is significantly lower than young adults on incongruent trials.

When participants used only one point on a confidence scale or achieve either 0% or 100% accuracy, a gamma correlation could not be calculated. The congruent condition often produced 100% accuracy leading to about half of the participants' gamma correlations for the congruent condition to be incalculable. Due to such a large number of participants not having a congruent condition gamma correlation we calculated only baseline and incongruent gamma correlations. All gamma correlations were transformed to z-scores using Fishers *r* to *z* transformation so that statistical tests could be conducted.

Figure 8 shows the resolution data for all participants' baseline and incongruent trials. To investigate if there were age differences in resolution depending on trial type, a 2 mixed-model analysis of variance (ANOVA) with age (young, older) as an independent measures factor, response format (open-set, closed-set) as a repeated measures factor and trial type (baseline, incongruent) as a repeated measures factor was conducted. Participants' gamma

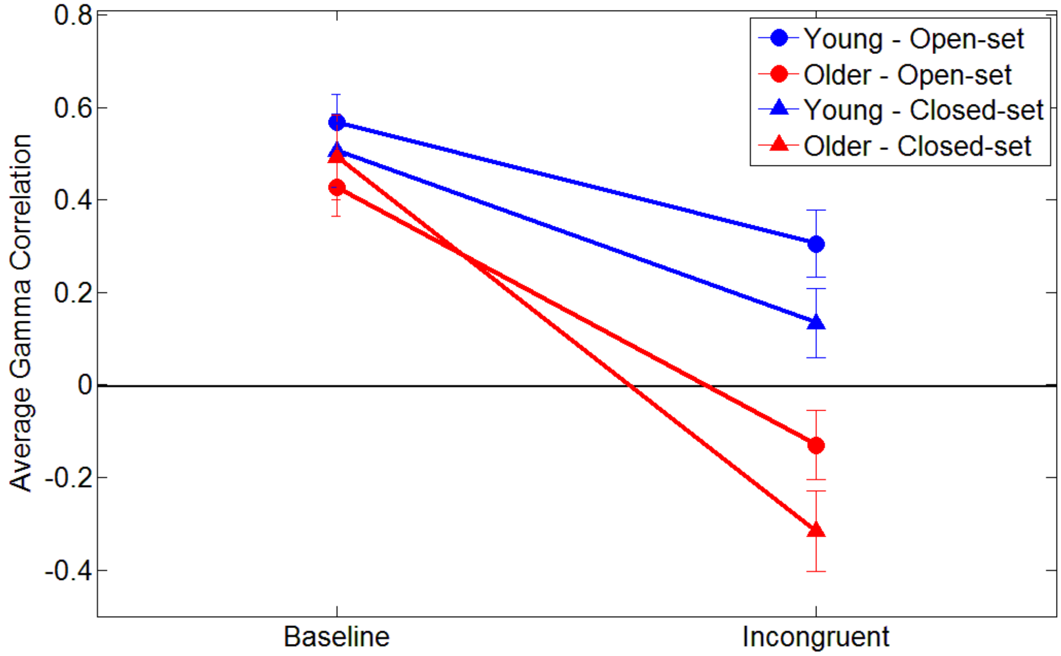

Figure 8: Young and older adults average gamma correlations for open and closed-set responding.

correlations were higher on baseline trials compared to incongruent trials as was indicated from the main effect of trial type, $F(1, 42) = 38.66$, MSE = .691, $p < .001$, $\eta_p^2 = .479$. There was no main effect response format, $F(1, 42) = 1.79$, MSE = .38, $p < .75$, $\eta_p^2 = .003$. Older adults' averaged gamma correlations were poorer than young adults, indicated by the main effect of age, $F(1, 42) = 13.11$, MSE = .873, $p < .001$, $\eta_p^2 = .238$. The ANVOA did not reveal a significant age x trial type interaction, $F(1, 42) = 1.79$, MSE = .691, $p < .25$, $\eta_p^2 = .041$. No significant interaction was found between age group and response format, $F(1, 42) = .063$, MSE = .38, $p < 1$, $\eta_p^2 = .002$. Participants gamma correlations were worse on closed-set responding than open-set responding on incongruent trials but not baseline trials as indicated by the significant trial type x response format interaction, $F(1, 42) = 6.36$, MSE = .321, $p < .05$, $\eta_p^2 = .131$. Lastly, no significant interaction was observed in the age x trial type x response format analysis, $F(1, 42) =$

.09, MSE = .321, $p < .75$, $\eta_p^2 = .002$. As can be seen in Figure 8, baseline resolution was equal between age groups for both response formats, *p*'s > .05. As Figure 8 displays, in the incongruent condition, resolution was noticeably reduced for both groups compared to baseline conditions, but only older adults show a negative gamma correlations in the incongruent trials. A negative gamma means that the more confident the older adult was in his or her response, the more likely he or she was to provide an incorrect response.

Summary

Experiment 1 investigated age differences in false hearing when uncertainty in the response is reduced by limiting the number of response candidates. Participants were given an open-set response format in which they repeated back the sentence final word, and a closed-set response format which reduced uncertainty by displaying only two responses options. Results demonstrated that older adults had significantly more congruent hits and incongruent false alarms supporting accounts that there are age differences in the basis for responding. The first hypothesis was that older adults would differentially decrease false alarms, relative to young adults, between open and closed-set response formats. Suggesting against this hypothesis, no significant response format by age group interaction was found for incongruent false alarms. Confirming the second hypothesis that older adults would false alarm more than young adults, older adult false alarms were significantly greater than young adults in both response formats. The results indicate that older adults use context as a basis for responding to a greater extent than do young adults. Confidence data converged on the same interpretation, as older adults were significantly more confident on their congruent hits and incongruent false alarms. Older adults also demonstrated significantly more dramatic false hearing occurrences (incongruent false alarms with confidence of 90% or more) than did young adults. Finally, gamma correlations were obtained to measure age differences in resolution, and it was found that older adults had significantly poorer resolution. Thus, even when uncertainty is reduced, it appears that older adults remain more likely than young adults to use context as the primary basis for responding.

Experiment 1 manipulated uncertainty in the responses by decreasing the number of response candidates possible, relative to open-set responding, but this is only one way that uncertainty is present in everyday hearing situations. One of the more common ways uncertainty is increased or decreased in our everyday experience is how noisy or loud the surrounding environment is. When we are in a noisy environment, we are less certain about what we are hearing from a given talker relative to when we are in a quiet room. Experiment 2 was conducted to investigate how uncertainty caused by manipulating the signal-to-noise ratio (SNR) affects age differences in false hearing.

Chapter 3: Experiment 2

Methods for Experiment 2

Participants

A total of 24 undergraduate students were recruited through the Washington University subject pool, and received either ten dollars or one course credit per hour. These young adults (15 female and 9 male) ranged in age from 18 to 21 years (M = 19.46, SD = 1.1). A total of 24 older adults (17 female and 7 male) were recruited through the Research Participation Registry, and received ten dollars per hour of participation as well as five dollars for travel expenses.

These older adults ranged in age from 65 to 77 years (*M* = 68.17, *SD* = 3.95). Participants were tested on the Vocabulary subset of the Shipley Institute of Living Scale (Shipley, 1967). The mean score was significantly higher for older adults (*M* = 33.92, *SD* = 3.11) compared to young adults (*M* = 30.17, *SD* = 3.63), $t(46) = 3.85$ $p < .001$. None of the older participants reported taking medications or having health conditions that would affect cognitive function. All participants reported normal or corrected-to-normal vision.

Materials & Procedure

All materials and procedures for Experiment 2 were the same as those used in Experiment 1 for the closed-set responding task with the exception of how uncertainty was manipulated. In Experiment 1, uncertainty was reduced by using a closed-set design compared to an open-set design. In Experiment 2, uncertainty was manipulated by manipulating signal-to-noise ratio (SNR). The 120 test stimuli were equally divided into four different groups (30 trials per SNR condition) containing equal numbers of congruent, baseline and incongruent trials for each SNR condition. Unlike Experiment 1, a calibration phase was not included as the SNR values used during testing needed to remain constant within an age group (i.e., all individuals in a group were tested using the same 4 SNRs). Since age group performance on baseline trials in the closed-set response format was equated in Experiment 1, the average SNR used for each age group was obtained from Experiment 1. The mean SNR value for baseline stimuli in each group was then specified as the intermediate SNR value in Experiment 2 (- 3 for younger adults and +1 for older adults). Three additional SNR values were used to increase or decrease uncertainty in the sentence final words. First, a harder SNR condition in which noise levels were increased by 4 dB (i.e., SNR was made 4 dB harder) from the intermediate value. Secondly, an easier SNR condition in which noise levels were decreased by 4-dB relative to the intermediate value (i.e., SNR was made 4 dB easier). Finally, a condition in which no noise was present (clear condition) was used so that age group performance could be compared when uncertainty in the stimuli has been reduced as much as possible. Each SNR condition was presented in a block and counterbalanced such that approximately equal numbers of participants were given the hard, intermediate, easy or clear SNR condition first. The procedure for Experiment 2 did not differ from that of the closed-set response format test in Experiment 1 except it did not use a calibration phase.

Experiment 2 Results and Discussion

Correct Identifications

Identification accuracy was measured as the proportion of trials on which participants correctly identified the target word in noise. Figure 9 displays the proportion of correct identifications for each trial type as well as the confidence in those responses. The three upper panels of Figure 9 show the proportion of correctly identified target words for young and older adults by trial type. Analyses were conducted separately for the clear SNR condition as hearing could not be equated between age groups in that condition. To investigate if there were age differences in correct identifications, a mixed-model ANOVA with age (young, older) as an independent measures factor, SNR difficulty (high, medium, low) and trial type (baseline, congruent, incongruent) as repeated measures factors was conducted. The analysis revealed a main effect of trial type, indicating that correct identifications differed depending on the semantic context of the trial types, $F(2, 92) = 111.29$, MSE = .033, $p < .001$, $\eta_p^2 = .708$. Participants' correct identifications also differed significantly between SNR levels, as indicated by a main effect of SNR, $F(2, 92) = 40$, MSE = .015, $p < .001$, $\eta_p^2 = .465$. The main effect of SNR demonstrates that as SNR becomes more difficult, performance decreases, confirming that increasing or decreasing uncertainty (i.e., increasing/decreasing SNR) affects overall performance. No main effect of age was found, $F(1, 46) = .22$, MSE = .046, $p < .75$, $\eta_p^2 = .005$. No interactions between trial type, SNR difficulty or age group achieved significance, p's > .05. Lastly there was no three way interaction between age, SNR level and trial type, $F(4,92) = 1.48$, $p > .05$.

Beginning with baseline trials, Figure 9 shows that group SNR adjustments were successful at equating performance between young and older adults across all three SNR levels.

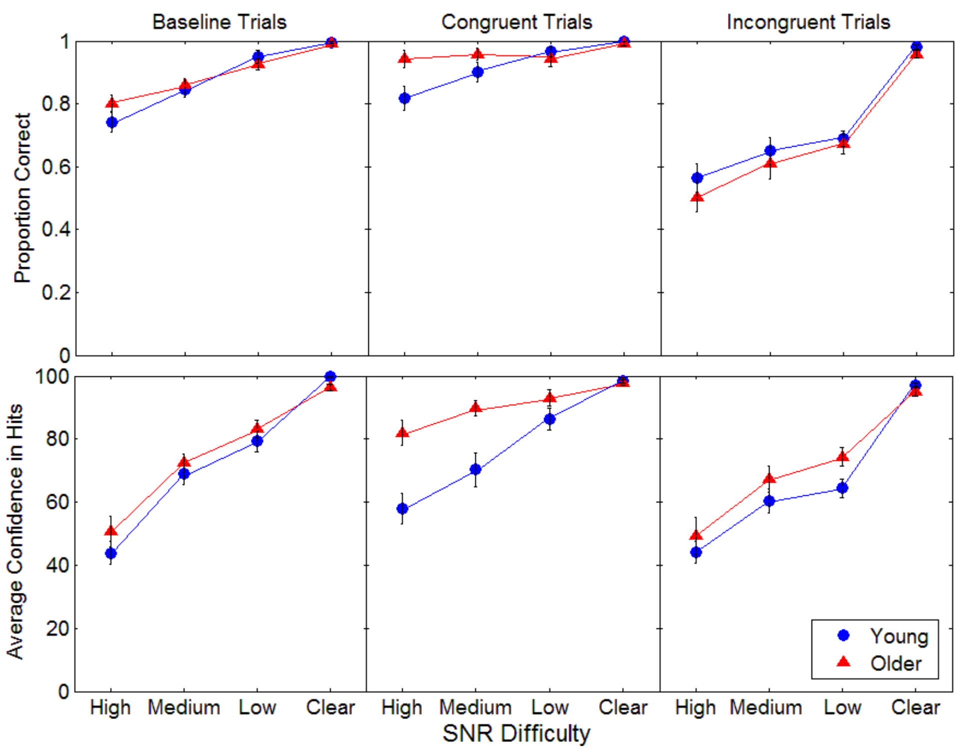

Figure 9: Top panel displays young and older adults' proportion of hits for each SNR condition. The bottom panel displays the average confidence in those hits.

Although no interaction between trial type and SNR difficulty was found in the ANOVA, it is important that at each SNR level age groups' performance on baseline conditions did not differ. If young and older adults' baseline accuracy were to differ significantly in a harder SNR, for example, this would mean that any age differences seen on congruent or incongruent conditions with a harder SNR would need to take that baseline difference into account. To ensure that age groups' baseline accuracy was equated in every SNR condition, a Bonferroni-corrected comparison was conducted on age groups' baseline performance for each SNR difficulty, and these comparisons confirmed there were no significant differences between age groups' baseline performance in all three SNR types, p's $> .1$. Thus, baseline conditions indicate that the procedures used for equating audibility between age groups were successful.

The top, middle panel of Figure 9 displays the proportion of correctly identified target words on congruent trials (e.g., "the plumber was fixing a sink"). As can be seen, performance on congruent trials is the highest of all three trial types for both older and young adults. Despite near ceiling performance one notable relationship is clear to the naked eye: older adults' congruent performance is invariant to SNR type. In Experiment 2, we hypothesized that older adults' performance would remain invariant as SNR difficulty was increased for both congruent and incongruent conditions, but young adults' performance would show systematic decreases for both congruent and incongruent conditions as SNR difficulty increased. Thus, even though the omnibus ANOVA failed to produce a significant interaction, we planned to examine the specific age by SNR difficulty interaction for congruent trials. To determine if older adults would remain invariant to SNR difficulty in the congruent condition, a mixed-model ANOVA with age (young, older) as an independent measures factor and SNR difficulty (high, medium, low) as a repeated measures factor was conducted. Older adults performed better than young adults, as indicated by a significant main effects of age, $F(1, 46) = 5.1$, MSE = .02, $p < .05$, $\eta_p^2 = .1$. Participants performed better as the SNR difficulty was decreased, as demonstrated by a main effect of SNR difficulty, $F(2, 92) = 4.19$, MSE = .017, $p < .05$, $\eta_p^2 = .083$. Importantly, there was a significant SNR by age group interaction, indicating that young adults' performance systematically changed as SNR difficulty decreased whereas older adults performance did not, $F(2, 92) = 4.06$, MSE = .068, $p < .05$, $\eta_p^2 = .081$. Thus, as was reported in Experiment 1, older adults performed significantly better than young adults when meaningful semantic context is provided. Extending this finding, Experiment 2 showed that when uncertainty is increased or decreased (i.e., increasing or decreasing SNR) on congruent trials older adults do not show decrements or improvements. These data suggest that older adults do not show decrements in congruent performance when SNR is made more difficult, because they do not rely on sensory information to a large degree. Thus, making the SNR more difficult only influences sensory sources of information, and, if, as the data suggest, older adults don't rely heavily on sensory sources of information, than making the SNR more difficult has little affect on performance.

The right, top panel of Figure 9 displays older and young adult performance on incongruent trials (e.g., "the plumber was fixing a <u>drink</u>"). In Experiment 2, we hypothesized that older adults performance would remain invariant as SNR difficulty was increased for both congruent and incongruent conditions. To determine if older adults would remain invariant to SNR difficulty in the incongruent condition a mixed-model ANOVA with age (young, older) as an independent measures factor and SNR difficulty (high, medium, low) as a repeated measures factor was conducted. Participants performed better when SNR difficulty was decreased, as indicated by a main effect of SNR difficulty, $F(2, 92) = 9.9$, MSE = .027, $p < .001$, $\eta_p^2 = .177$. There was no main effect of age, $F(1, 46) = .78$, MSE = .07, $p < .5$, $\eta_p^2 = .017$. Contrary to our hypothesis, the age by SNR difficulty interaction was not significant, $F(2, 92) = .22$, MSE = .027, $p < .85$, $\eta_p^2 = .005$. Thus, although young adults have numerically more incongruent hits than older adults in all SNR levels, no significant differences were found. This finding was surprising as we predicted that older adults would continue to use context to a greater extent, causing older adults to show consistent incongruent hit rates across SNR difficulty.

Lastly, Experiment 2 included trials that presented the items in clear (i.e., no background noise). These trials produced ceiling performance across both age groups and all trial types. To investigate possible age differences in trial performance when items were presented in the clear, a 2 (age: young, older) x 3 (trial type: baseline, congruent, incongruent) repeated measures ANOVA was conducted. A main effect of trial type was revealed to be significant, indicating that participants performance differed depending on the semantic context provided, $F(2, 92) = 7.28$, MSE = .001, $p < .01$, $\eta_p^2 = .137$. Older adults' correct identifications also were significantly lower than young adults, indicated by a main effect of age, $F(1, 46) = 4.93$, MSE = .001, $p < .05$, $\eta_p^2 = .097$. As audibility was not equated between age groups, a main effect of age is likely due to declines in peripheral hearing acuity. There was no age x trial interaction, $F(2, 92) = .756$, MSE = .001, $p < .5$, $\eta_p^2 = .016$.

Confidence data

The bottom panel of Figure 9 displays the average confidence in hits for young and older adults for each type of SNR used as a function of sentence context. Again, clear SNR condition performance was analyzed separately because audibility was not equated between age groups. To analyze age differences in confidence, a mixed-model ANOVA with age (young, older) as an independent measures factor, SNR difficulty (high, medium, low) and trial type (baseline, congruent, incongruent) as a repeated measures factors was conducted. This analysis revealed a main effect of trial, indicating that the proceeding semantic context had an effect on performance, $F(2, 88) = 84.61$, MSE = 155.89, $p < .001$, $\eta_p^2 = .658$. There was also a main effect of SNR indicating that confidence decreased as SNR difficulty increased, $F(2, 88) = 77.99$, MSE = 279.88, $p < .001$, $\eta_p^2 = .639$. The ANOVA also revealed a main effect of age demonstrating that older adults were more confident in their responses compared to young adults, $F(1, 44) = 4.94$, MSE = 1753.02, $p < .05$, $\eta_p^2 = .101$. Age groups did not differ in how SNR difficulty affected confidence, as indicated by a non-significant age by SNR difficulty interaction, $F(2, 88) = 1.3$, MSE = 279.88, $p < .3$, $\eta_p^2 = .029$. Demonstrating that confidence on the trial types varied as a function of SNR difficulty, the ANOVA revealed a SNR difficulty x trial type interaction, $F(4, 176) = 7.29$, MSE = 127.62, $p < .001$, $\eta_p^2 = .142$. There was significant age x trial type interaction indicating that age groups' confidence varied as a function of trial type, $F(2, 88) = 8.46$, MSE = 155.89, $p < .001$, $\eta_p^2 = .161$. Although not significant, the age x SNR difficulty x trial type interaction approached significance, $F(4, 176) = 2.27$, MSE = 127.62, $p < .07$, $\eta_p^2 = .049$.

Starting with the left, bottom panel in Figure 9, mean confidence on baseline hits for older and young adults appears to be equated between age groups. Having confidence in baseline hits equated between age groups would further suggest that audibility had been equated between age groups. To investigate if age groups' confidence on baseline hits was equated in every SNR condition, a Bonferroni-corrected comparison was conducted on age groups' confidence in baseline hits for each SNR difficulty. These comparisons confirmed there were no significant differences between age groups' baseline performance in all three SNR types, p's >

.2. Thus, confidence on baseline hits suggests that the procedures used for equating audibility between age groups were successful.

Next, consider the bottom, middle panel of Figure 9, which displays confidence in congruent hits. Similar to what was seen when investigating congruent condition hits, there is a visible difference between older and young confidence in the congruent condition. It appears that having predictive context increases the accuracy on congruent trials as well as the confidence in those hits, relative to young adults. Recalling that the omnibus ANOVA revealed a significant age by trial type interaction, we investigated the source of the age by trial type interaction using separate, post-hoc, ANOVAs for confidence in congruent hits and confidence in incongruent hits. A 2 (age: younger, older) x 3 (SNR difficulty: high, medium, low) repeated measures (ANOVA) was conducted on confidence on congruent hits, which produced significant main effects of age ($F(1, 46) = 14.65$, MSE = 682.46, $p < .001$, $\eta_p^2 = .242$) and SNR difficulty ($F(2, 92) = 21.48$, MSE = 218.04, $p < .001$, $\eta_p^2 = .318$). As with congruent hits, confidence in congruent hits differed between age groups as SNR difficulty increased evidenced by a significant interaction between age and SNR difficulty, $F(2, 92) = 4.49$, MSE = 218.04, $p < .05$, $\eta_p^2 = .089$. The results of congruent accuracy and the confidence in congruent hits converge, suggesting that older adults do not adjust their confidence in hits when uncertainty is increased or decreased as long as predictive semantic context is present. Thus, as a differential basis for responding account for age differences in spoken word recognition predicts, older adults use context to a greater extent than young adults and using context increases older adults confidence relative to young adults.

Moving on to the bottom right panel of Figure 9, older and young adults confidence on incongruent hits (e.g., “the plumber was fixing a drink”) is plotted as a function of SNR. Recall that the omnibus ANOVA revealed a significant age by trial type interaction. To further examine this interaction, a mixed-model ANOVA with age (young, older) as an independent measures factor and SNR difficulty (high, medium, low) as a repeated measures factor was conducted. Participants confidence on incongruent hits was higher when SNR difficulty was decreased, as indicated by a main effect of SNR difficulty, $F(2, 88) = 28.28$, MSE = 172.97, $p < .001$, $\eta_p^2 = .391$. There was no main effect of age, $F(1, 44) = 3.24$, MSE = 720.9, $p < .1$, $\eta_p^2 = .069$. Similar to the pattern of results for incongruent hit accuracy, age groups' confidence on incongruent hits did not differ as a function of SNR difficulty, as indicated by the non-significant age by SNR difficulty interaction, $F(2, 88) = .26$, MSE = 172.97, $p < 1$, $\eta_p^2 = .001$

Lastly, Experiment 2 included trials that presented the items in clear (i.e., no background noise). As these trials produced ceiling performance across both age groups and all trial types confidence in these hits is, not surprisingly, near ceiling as well. To investigate age differences in confidence across clear condition trial types a 2 (age: younger, older) x 3 (trial type: baseline, congruent, incongruent) was conducted. There was a main effect of trial type demonstrating that participants confidence in hits was higher on congruent trials than incongruent trials, $F(2, 92) = 4.8$, MSE = 13.86, $p < .05$, $\eta_p^2 = .094$. Although approaching significance, the ANOVA revealed no main effect of age, $F(1, 46) = 3.8$, MSE = 38.18, $p < .06$, $\eta_p^2 = .076$. There was no age by trial type interaction, $F(2, 92) = 1.55$, MSE = 13.86, $p < .25$, $\eta_p^2 = .033$.

Confidence in False Alarms

Of particular interest to differential bases of responding account, is how different age groups differ in their confidence in false alarms even when uncertainty has been reduced. In a false alarm, a listener has incorrectly responded on an incongruent trial with the word that is predicted by context. Thus, these occurrences represent times at which the participant has been captured by context, and should show large age differences in confidence. Confidence for incongruent false alarms in the clear SNR condition were excluded from analysis as they occurred so rarely (i.e., ceiling performance), and this would have been too few data points to reliably test. Figure 10 displays the average confidence in incongruent false alarms for both young and older adults. A 2 (age: younger, older) x 3 (SNR difficulty: high, medium, low)

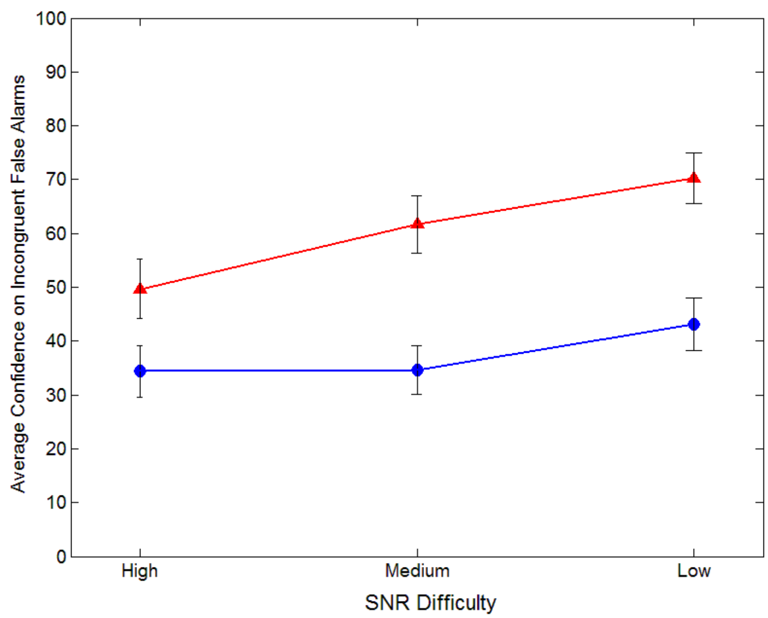

Figure 10: Young and older adults' average confidence on incongruent false alarms for each SNR type.

mixed-model ANOVA was conducted on confidence on false alarms and revealed a main effect of SNR difficulty indicating that as SNR difficulty increased confidence decreased, $F(2, 88) = 7.45$, MSE = 308.09, $p < .001$, $\eta_p^2 = .145$. Older adults were more confident in their incongruent false alarms than were young adults as evidenced by a main effect of age, $F(1, 44) = 17.8$, MSE = 1102.76, $p < .001$, $\eta_p^2 = .288$. There was no interaction between SNR difficulty and age, $F(2, 88) = 1.34$, MSE = 308.09, $p < .5$, $\eta_p^2 = .03$. Thus, the main effect of age indicates that when older adults responded incorrectly on incongruent trials, they do so with a significantly higher confidence regardless of the SNR used.

Dramatic False Hearing

As in Experiment 1, we were interested in age differences in high confidence errors on incongruent trials (e.g., hearing, "the plumber was fixing a <u>drink</u>" and responding 'sink'), as they indicate what the subjective experience of hearing the contextually predicted word was. In order to examine if there were age differences in the subjective hearing experiences, we compared dramatic false hearing (DFH) (responding incorrectly with the word favored by context with confidence levels between 90-100%) rates for younger and older adults. As was the case for confidence in false alarms, there were too few data points for dramatic false alarms in the clear SNR condition and, thus, those data were excluded.

Figure 11 displays the proportion of dramatic false hearing occurrences for young and older adults for each SNR type. A 2 (age: young, older) x 3 (SNR difficulty: high, medium, low) mixed-model ANOVA was conducted on DFH occurrences, and revealed no main effect of SNR difficulty on DFH occurrences ($F(2,92) = .98$, MSE = .011, $p < .5$, $\eta_p^2 = .021$), or a significant age by SNR difficulty interaction ($F(2,92) = .21$, MSE = .011, $p < 1$, $\eta_p^2 = .004$). Importantly, a

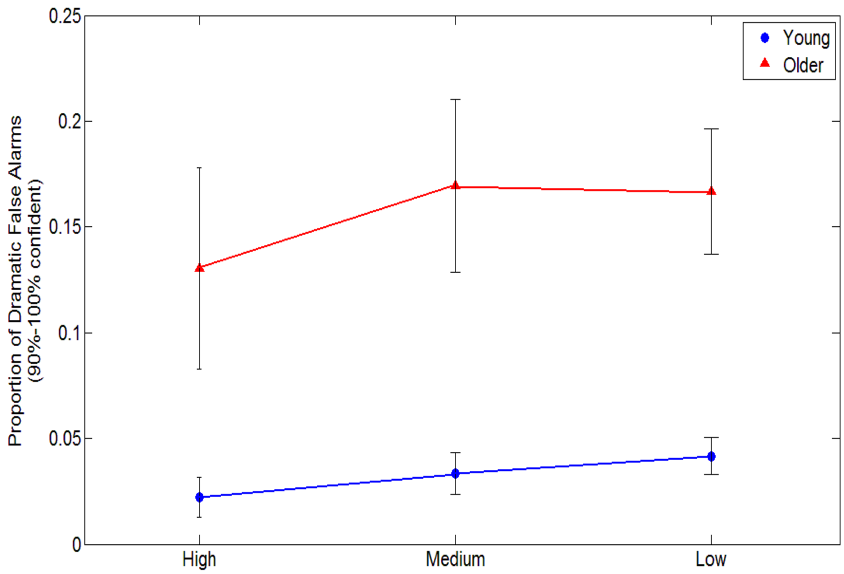

Figure 11: Proportion of DFH occurrences by SNR type for young and older adults.

significant main effect of age confirmed that older adults produce more DFH occurrences than young adults, $F(1,46) = 33.3$, MSE = .038, $p < .001$, $\eta_p^2 = .237$. Thus, as was the case in Experiment 1, older adults have significantly more high confidence errors on incongruent trials than young adults. This coincides with the claims that older adults use context to a greater degree than do young adults, causing older adults to be more confident in their incorrect responses when the responses are predicted by context.

Resolution

As in Experiment 1, resolution was measured using gamma correlations (Fisher *r* to *z* transformed). The congruent condition often produced 100% accuracy, leading to about two-thirds of the participants' congruent gamma correlations being incalculable. Due to such a large number of participants not having a congruent condition gamma correlation, we calculated only baseline and incongruent gamma correlations. When investigating gamma correlations for low difficulty baseline trials a similar issue emerged in which about two-thirds of participants' baseline gamma correlations could be calculated. Due to such a large number of participants not having gamma correlations these data were excluded, leaving only medium and high SNR difficulty to be analyzed.

We predicted that gamma correlations would be similar to those found in Experiment 1, in which age groups would differ in incongruent trial gamma correlations. Furthermore, to examine how uncertainty interacted with incongruent trial resolution, gamma correlations were obtained for each different incongruent SNR type. If differential bases of responding accounts for age differences in context effects, then we expected that older adults would not show increases on incongruent gamma correlations as the SNR becomes easier due to the fact that older adults would continue to be captured by context. Because older adults use context to a greater extent than young adults, they should benefit less when sensory sources of information are improved in a condition that allows older adults to use their preferred basis of responding.

Figure 12 shows the resolution data for all participants' baseline and incongruent trials for each SNR difficulty. Recall that low difficulty baseline gamma correlations were only obtainable for one-third of the participants. To deal with this issue, both low difficulty baseline and low difficulty incongruent gamma correlations were excluded for the final analysis. A mixed-model ANOVA with age (young, older) as an independent measures factor, SNR difficulty (high, medium) as a repeated measures factor and trial type (baseline, incongruent) as a repeated measures factor was conducted to investigate age differences in how trial performance was effected by SNR difficulty. There was a main effect of trial type indicating that participants resolution was higher in baseline trials than incongruent trials, $F(1, 31) = 5.21$, MSE = 1.88, $p <$

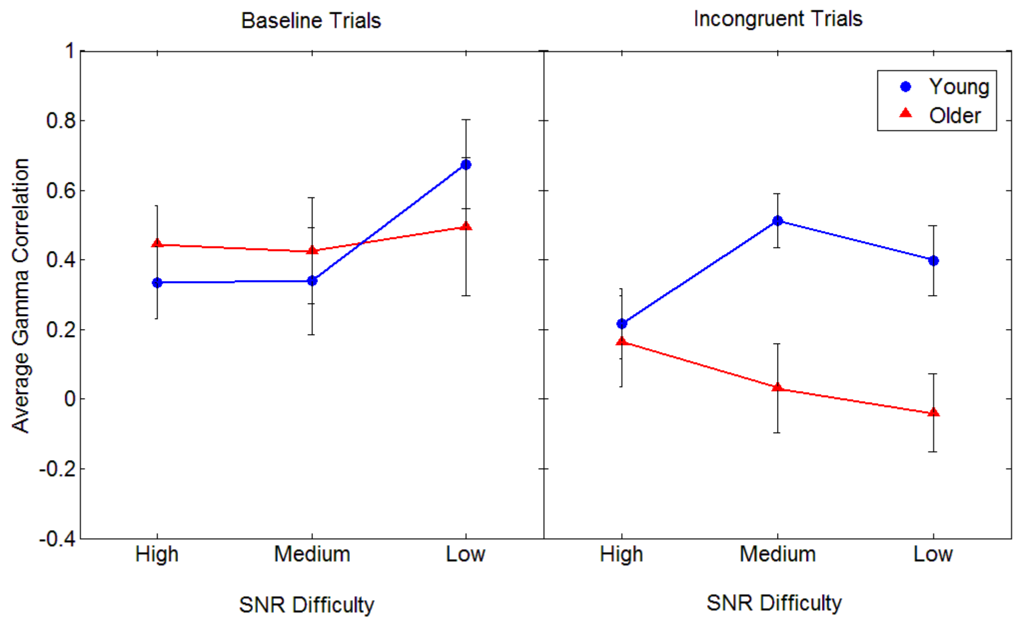

Figure 12: Average gamma correlation for young and older adults for baseline and incongruent trials

.05, η_p^2= .144. No main effect of age was revealed, *F*(1,31) = .16, MSE = 1.32, $p < .75$, η_p^2 = .005. No significant interaction was found between SNR difficulty and age (*F*(1,31) = .17, MSE = 1.48, $p < .75$, η_p^2 = .005), or between trial type and SNR difficulty (*F*(1,31) = .23, MSE = 1.58, $p < .75$, η_p^2 = .007). The ANOVA demonstrated that older adults' gamma correlations are worse than young adults on incongruent trials, as was indicated by a significant age x trial type interaction, *F*(1,31) = 5.91, MSE = 1.88, $p < .05$, η_p^2 = .16. Lastly, the age x SNR difficulty x trial type interaction was found to be non-significant, *F*(1,31) = .23, MSE = 1.58, $p < .75$, η_p^2 =.007.

To determine the source of the significant age by trial type interaction, pairwise comparisons were conducted to examine the nature of this interaction. Bonferroni-corrected pairwise comparisons on baseline trials demonstrated no age differences between high and medium difficulty SNR, p's > .05. Bonferroni-corrected pairwise comparisons on incongruent trials revealed that older adults' incongruent gamma correlations did not differ from young adults when SNR was highly difficult, $F(1,31) = 2.2$, $p > .05$. However, when SNR was improved in the medium difficulty SNR, young adults gamma correlations improved and were found to be significantly larger than older adults' gamma correlations, $F(1,31) = 5$, $p < .05$. Thus, when uncertainty was reduced by making the SNR easier, only young adults showed improvements in resolution.

Summary

Experiment 2 investigated age differences in context effects on spoken word recognition when uncertainty in the stimulus was increased or decreased by altering SNR. Listeners were tested on a two alternative forced choice task which contained four different SNR blocks. Baseline performance did not differ between age groups at any SNR difficulty which indicates that audibility was properly equated between age groups. Confirming our hypothesis, results demonstrated that there was a significant age by SNR type interaction on congruent trials. The proportion of correctly indentified congruent trials for older adults was invariant with regards to SNR difficulty, which suggests that older adults rely on context to such a large degree that when SNR is made more difficult they do not suffer decrements in performance. Confidence data converged on the same interpretation, as older adults were significantly more confident than young adults on their congruent hits and incongruent false alarms. Older adults also demonstrated significantly more dramatic false hearing occurrences (incongruent false alarms with confidence of 90% or more) than did young adults in all three SNR conditions. Lastly, resolution measures demonstrated that older adults' metacognitive monitoring was worse than young adults on incongruent trials, and that making the SNR easier only benefited young adults' resolution on incongruent trials.

The results from Experiments 1 and 2 showed that older adults were unable resist prepotent responding and continued using context as the primary basis for responding. Manipulating uncertainty by restricting response options relative to an open-set response format (Experiment 1) still produced an older adult disadvantage on incongruent trials, which reflects an older adult differential usage of context. Manipulating uncertainty by increasing or decreasing the SNR (Experiment 2) actually led to an older adult advantage on congruent trials, but this advantage still suggests that older adults were using context to a greater extent than young adults. In Experiment 3, we reduced uncertainty by providing a validity cue prior to presenting congruent or incongruent sentences. The validity cues displayed "likely misleading", "likely predictive" or "*****" (neutral cue), and provided participants with information that could be used reduce uncertainty that he or she was hearing a congruent or incongruent trial. Doing so might allow older adults to restrict the number of incongruent false alarms, and, in doing so, equate young and older adults' performance on incongruent trials. If older adults ignore the cue, despite the cue considerably reducing uncertainty of the subsequent sentence, and still respond with the word predicted by context, this finding would suggest that older adults are unable to benefit from reductions in uncertainty.

Chapter 4: Experiment 3

Methods for Experiment 3

Participants

A total of 26 undergraduate students were recruited through the Washington University subject pool, and received either ten dollars or one course credit per hour. Data from two younger adults were excluded from the final analysis due to a computer error that caused stimuli to be played without a background noise. The remaining 24 young adults (18 females, 6 males) ranged in age from 18 to 22 years (M = 19, SD = 1.1). A total of 30 older adults were recruited through the Research Participation Registry, and received ten dollars per hour of participation as well as five dollars for travel expenses. Six of these older adults' results were excluded from the final analysis due to the same computer error that caused stimuli to be played without a background noise. The remaining older adults (18 females, 6 males) ranged in age from 65 to 92 years (M = 72.7, SD = 7.09). Participants were tested on the Vocabulary subset of the Shipley Institute of Living Scale (Shipley, 1967). The mean score was significantly higher for older adults (M = 34.83, SD = 2.46) compared to young adults (M = 31.58, SD = 3.82), $t(46) = 3.5$ $p < .001$. None of the older participants reported taking medications or having health conditions that would affect cognitive function. All participants reported normal or corrected-to-normal vision.

Materials & Procedure

All materials and procedures for Experiment 3 were the same as those used in Experiment 2 except a cue was added prior to the presentation of a trial and the signal-to-noise ratio remained constant at an individually calibrated level. Unlike earlier experiments, Experiment 3 manipulated uncertainty by presenting a cue, prior to stimulus presentation, that indicated either the trial's context would likely be predictive (e.g., "likely predictive"), would likely be misleading (e.g., "likely misleading") or was a neutral cue (e.g., "*****"). The cues were presented for 2 seconds prior to the 50ms trial preparation tone. Baseline trials were only paired with neutral cues since baseline trials do not contain any predictive or misleading context to begin with. One quarter of the congruent trials were paired with cues stating "likely misleading" (i.e., the cue was invalid), 50% of the trials were paired with the cue stating "likely predictive" (i.e., the cue was valid), and 25% used the neutral cue. Conversely, 25% of the incongruent trials were paired with the cue stating "likely predictive" (i.e., the cue was invalid), 50% were paired with the cue stating "likely misleading" (i.e., the cue was valid), and 25% used the neutral cue. In order to control for age differences in audibility, Experiment 3 used the same titration procedure as was used in the two alternative forced choice portion of Experiment 1. The desired baseline trial performance for the titration phase was set to 75%, the same as in Experiment 1, and the SNR value that produced accuracy closest to this value was used as the SNR for the sentence final words in the testing phase.

Experiment 3 Results and Discussion

Overall Correct Identifications

Experiment 3 was conducted to examine the effects of validity cues on age differences in spoken word recognition performance. First, however, we examined overall performance without regard to cue type. Doing so allowed us to see whether the basic age difference trends from Experiment 1 and the work by Sommers et al. (in prep) replicated, and allowed us to investigate all trial types. All trial types cannot be examined when cue type is included because baseline trials do not contain all three cue types (since they contain no predictive context they are only paired with neutral cues). In order to determine if there was an age by trial type interaction when all trial types are included, overall performance was analyzed. Identification accuracy was measured as the proportion of trials on which participants correctly identified the target word in noise. Figure 13 displays the proportion of correct identifications for each trial type. To confirm age differences, correct identifications were analyzed using a mixed-model ANOVA with age (young, older) as an independent measures factor and trial type (baseline, congruent, incongruent) as a repeated measures factor was conducted. This ANOVA revealed a main effect of trial type indicating that participants performance varied as a function of trial type, $F(2, 92) = 64.85$, MSE = .015, $p < .001$, $\eta_p^2 = .585$. There was no main effect of age, $F(1, 46) = 1.08$, MSE = .021, $p < .5$, $\eta_p^2 = .023$. Age groups differed in performance between trial types as the ANOVA also revealed a significant age x trial type interaction, $F(2, 92) = 6.5$, MSE = .015, $p < .01$, $\eta_p^2 = .124$.

To determine the source of the age by trial type interaction pairwise comparisons were conducted on baseline, congruent and incongruent trial types. Figure 13 shows that age groups

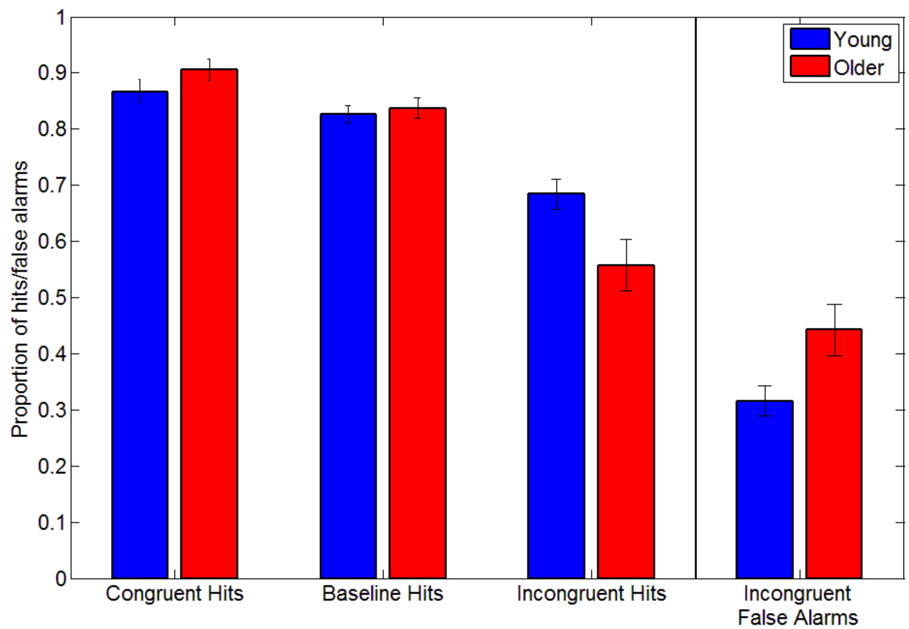

Figure 23: Young and older adults overall hits and false alarms by trial type. False alarms are shown to the right of the dividing line.

did not differ in baseline performance, suggesting that audibility differences were equated. A Bonferroni-corrected pairwise comparison was performed, confirming there was no significant difference between age groups' baseline performance, $F(1, 46) = .25$, $p > .05$. Thus, baseline conditions indicated that the procedures used for equating audibility between age groups were successful.

As is displayed in Figure 13, overall performance on congruent trials demonstrated that both young and older adults did best when context was predictive of the sentence final word, but that older adults actually performed better than young adults. As was found in the two-alternative forced choice task in Experiment 1, although older adults performed better than young adults the Bonferroni-corrected pairwise comparison did not reach significance, $F(1, 46) = 1.92$, $p > .05$.

Incongruent hits were analyzed to ensure that age differences in incongruent hits persisted even when presenting validity cues. To confirm that incongruent hits differed across age groups, a Bonferroni-corrected pairwise comparison revealed that young adults had significantly more incongruent hits than older adults, $F(1, 46) = 5.64$, $p < .05$. The age difference in incongruent hits can be seen in Figure 13. The second panel of Figure 13 displays incongruent false alarms. Incongruent false alarms are the reverse of incongruent hits on a two-alternative forced choice format; thus, age differences on incongruent false alarms also differed significantly.

Overall Confidence data

Confidence in hits and false alarms were collected after each trial and used to examine age differences in confidence for baseline, congruent and incongruent correct responses. Figure 14 displays the overall confidence in hits and false alarms for congruent baseline and incongruent trial types. As with overall hit performance, we also wanted to ensure that the general findings in confidence for trial types replicated as well as investigate age by trial type interactions when baseline trials are included in the ANOVA. To see if confidence in hits varied by trial type for the two age groups, a mixed-model ANOVA with age (young, older) as an independent measures factor and trial type (baseline, congruent, incongruent) as a repeated measures factor was conducted, and revealed a main effect of age, $F(1, 46) = 8.88$, MSE = 589.39, $p < .001$, $\eta_p^2 = .162$. The main effect of age indicates that older adults were significantly more confident in their hits than were young adults. The ANOVA also revealed a main effect of trial type trial, indicating that participants were more confident in congruent hits than incongruent hits, $F(2, 46) = 43.7$, MSE = 87.18, $p < .001$, $\eta_p^2 = .487$. No significant age x trial

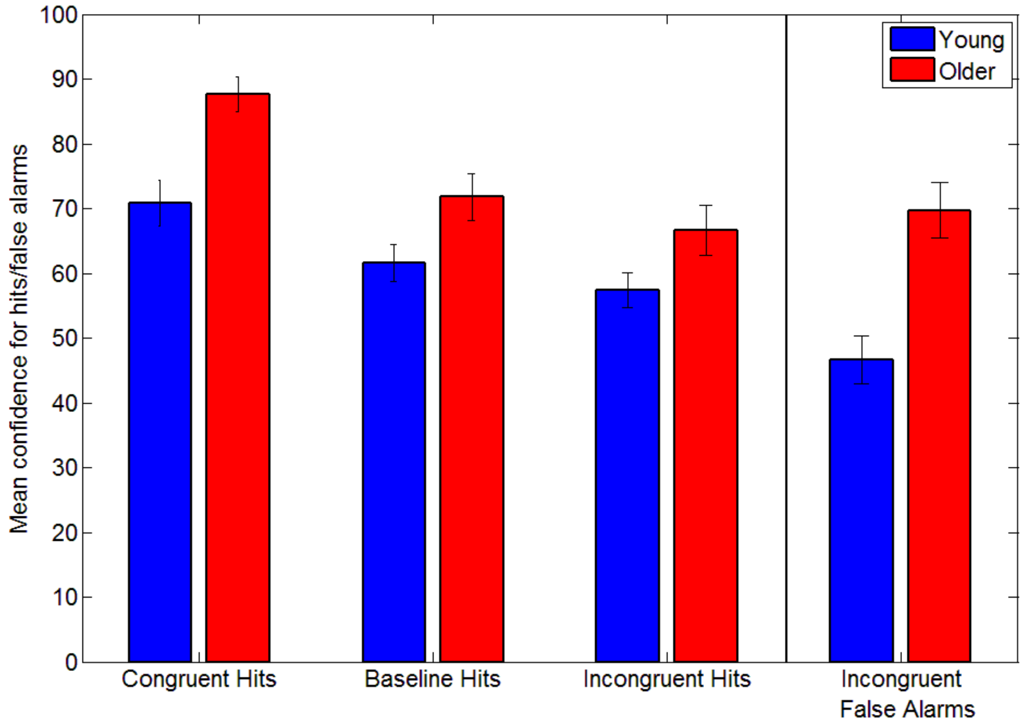

Figure 14: Young and older adult average confidence in hits and false alarms. False alarms are shown to the right of the dividing lines.

type interaction was found, $F(2, 46) = 2.35$, MSE = 87.18, $p < .25$, $\eta_p^2 = .05$. Overall confidence in incongruent false alarms was analyzed separately using an independent samples *t*-test, which revealed that older adults were significantly more confident in incongruent false alarms than young adults, $t(46) = 4.05$, $p < .001$. The results of these analyses confirm that the general findings from Sommers, et al. (in prep) replicated when the cues were included.

Age Groups' Correct Identifications by Cue Type

To examine how predictive cues would affect age groups' correct identifications, the proportion of congruent and incongruent hits were examined by cue type. Because baseline trials contain no predictive context, cues in baseline trials are always neutral. Because of the fact that baseline trials don't contain all three cue types, including them in a within participants design ANOVA would be inappropriate. For this reason, baseline trial performance was excluded from the mixed-model ANOVA conducted with age (young, older) as an independent measures factor, trial type (congruent, incongruent) as a repeated measures factor and cue type (neutral, “likely predictive”, “likely misleading”) as a repeated measures factor. The ANOVA revealed a main effect of trial type indicating that participants did better on congruent compared to incongruent trials, $F(1, 46) = 65.77$, MSE = .075, $p < .001$, $\eta_p^2 = .588$. Participants’ correct identifications differed depending on the cue type, as was indicated by the main effect of cue, $F(2, 92) = 10.52$, MSE = .025, $p < .001$, $\eta_p^2 = .186$. The main effect of cue type revealed that participants did better when the cue indicated “likely predictive”, did worse when the cue indicated “likely misleading”, and performance was intermediate when shown a neutral cue. There was no main effect of age, $F(1, 46) = 1.38$, MSE = .064, $p < .25$, $\eta_p^2 = .029$. There was also a marginally significant interaction between trial type and cue type demonstrating that cues affected performance differently for trial types, $F(2, 92) = 3.07$, MSE = .012, $p = .051$, $\eta_p^2 = .063$. This finding is not surprising as cue labels change validity between congruent and incongruent trials (i.e., a likely predictive cue is valid on a congruent trial but invalid on an incongruent trial). Age groups’ combined congruent and incongruent performance was similar for the cue types as there was no interaction between age and cue type, $F(2, 92) = 2.04$, MSE = .025, $p < .25$, $\eta_p^2 = .042$. There was a significant age x trial type interaction, indicating that older adults performed worse on incongruent trials, $F(1, 92) = 6.53$, MSE = .075, $p < .05$, $\eta_p^2 = .124$. Lastly, there was no age x trial type x cue type interaction, $F(2, 92) = 2.37$, MSE = .012, $p < .1$, $\eta_p^2 = .049$.

Congruent Trial Correct Identifications: Experiment 3 was conducted to see if providing a cue that indicated the validity of a trial would reduce age differences in context effects. Our hypothesis for Experiment 3 was that older adults’ congruent trial performance would remain invariant, regardless of cue type, but that young adults’ congruent trial performance would vary as a function of cue type. If older adults chose to rely on the sentence context when making responses, ignoring the cue, then older adults' performance would remain constant regardless of cue type. On the other hand, if young adults are less captured by context the "likely misleading" cue might cause a decrease in congruent hit performance.

As can be seen in Figure 15, older adults' performance doesn't change as a function of cue type, but young adult performance does. The congruent condition in Experiment 2 led us to believe that age groups might differ on how reductions in uncertainty affect congruent trial performance. Furthermore, the main hypothesis for Experiment 3 was that older adults' performance on congruent and incongruent trials would remain invariant regardless of cue validity, but young adults' performance would vary (demonstrated by age differences between

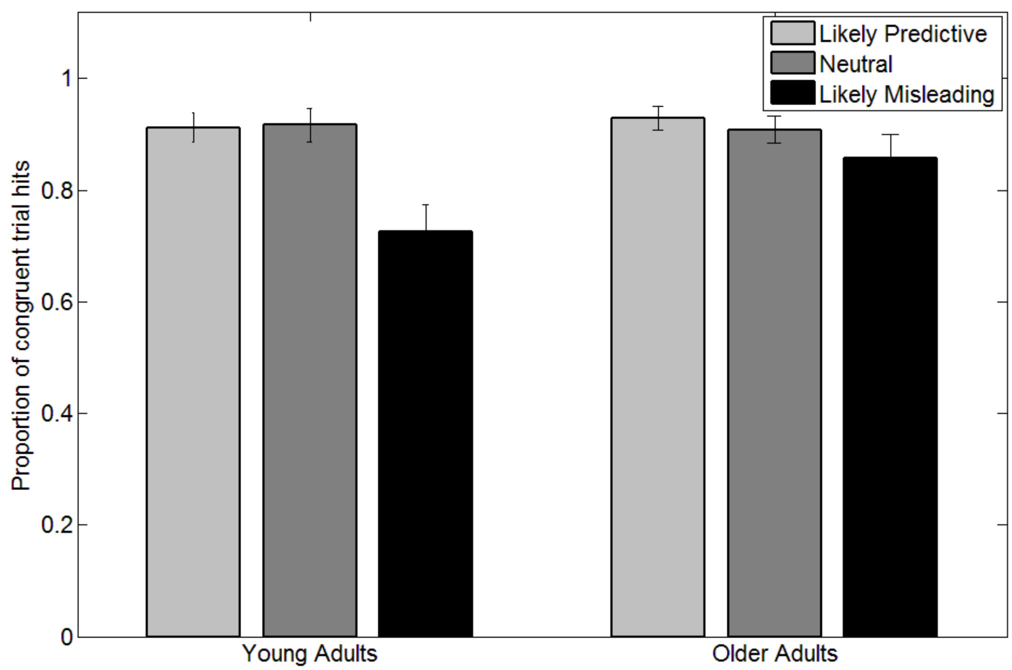

Figure 15: Young and older adults' proportion of congruent hits by cue type.

"likely predictive" and "likely misleading" cues). Thus, despite the omnibus ANOVA reveling no significant three way interaction we examined age by cue type effects separately for both congruent and incongruent hits. To examine age by cue type effects in congruent trails, a mixed-model ANOVA with age (young, older) as an independent measures factor and cue type (neutral, "likely predictive", "likely misleading") as a repeated measures factor was conducted. Participants performance was better when cues were valid as was revealed from the significant main effect of cue type, $F(2, 92) = 11.23$, MSE = .022, $p < .001$, $\eta_p^2 = .196$. There was no main effect of age, $F(1, 46) = 2.31$, MSE = .035, $p < .25$, $\eta_p^2 = .048$. Lastly, the age x cue type interaction was marginally significance indicating that age groups' performance differed on congruent trails as a function of cue validity, $F(2, 92) = 3.072$, MSE = .022, $p = .051$, $\eta_p^2 = .063$. Bonferroni-corrected pairwise comparisons were performed to determine the source of the marginally significant age x cue type interaction, and revealed that there were no significant differences in congruent hits between young and older adults when presented a neutral or "likely predictive" cue, p's > .05. However, young adults had significantly fewer congruent hits when presented with the "likely misleading" cue than older adults, $F(1,46) = 4.34$, $p < .05$. Thus, it appears that on congruent trials only younger adults' performance changes as a function of validity cues. The fact that older adults performance doesn't change at all as a function of cue type suggests either that they continue to use context as a basis for responding regardless of having new information that increases or decreases uncertainty.

Incongruent Trial Correct Identifications: One of the major goals of Experiment 3 was to see if reducing uncertainty by cuing participants that a trial was "likely misleading" would decrease age differences on incongruent hits/false alarms. Perhaps older adults were using context to a greater extent, but, if given information prior to hearing a misleading sentence, maybe they would increase their incongruent hits to levels seen in young adults. Thus, we measured the proportion of incongruent hits for each cue type by age group. These data are plotted in Figure 16, and demonstrate that older adults did not reduce or enhance incongruent trial performance as a function of cue type. At first glance, the data in Figure 16 show some indication that young adults benefits when uncertainty on incongruent trials is reduced (i.e., when presented with a "likely misleading" cue). Relative to the neutral cue, young adults' performance increased when the cue correctly identified the context ("likely misleading") and young adults' performance decreased when the cue incorrectly identified the context ("likely predictive").

The main hypothesis for Experiment 3 was that older adults' performance on congruent and incongruent trials would remain invariant regardless of cue validity, but young adults'

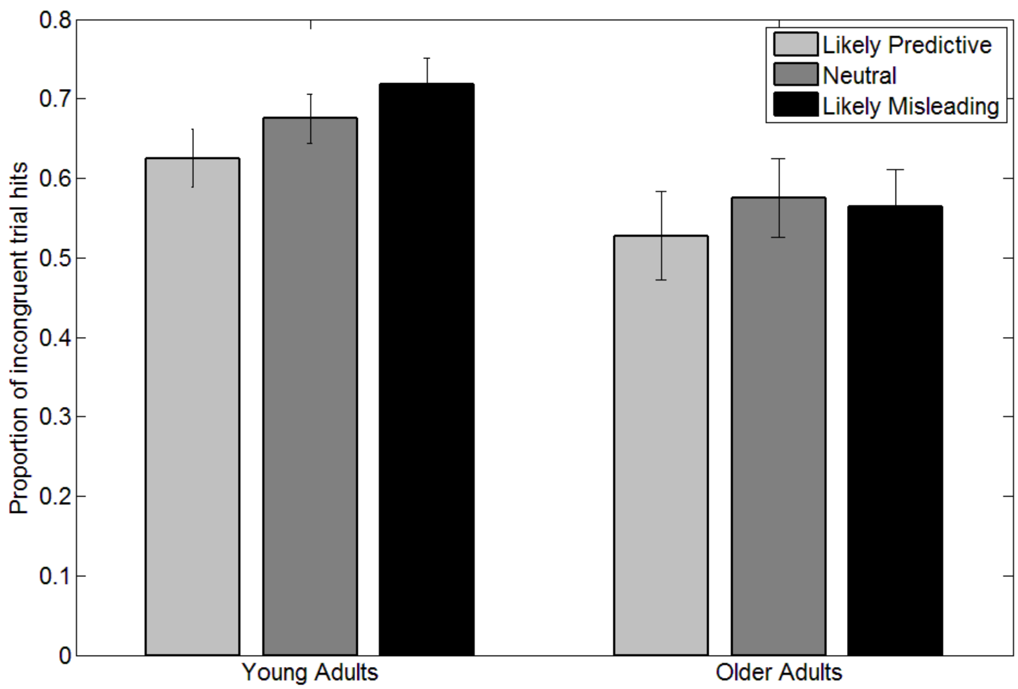

Figure 16: Young and older adults' proportion of incongruent hits by cue type.

performance would vary (demonstrated by age differences between "likely predictive" and "likely misleading" cues). To examine this relationship in incongruent trial performance, a mixed-model ANOVA with age (young, older) as an independent measures factor and cue type (neutral, "likely predictive", "likely misleading") as a repeated measures factor was conducted. The ANOVA revealed a main effect of age demonstrating older adults' incongruent hit performance was worse than young adults, $F(1, 46) = 4.77$, MSE = .103, $p < .05$, $\eta_p^2 = .094$. Participants' performance was significantly better when the cue correctly matched sentence validity (i.e., "likely misleading") relative to when the cue incorrectly matched as was indicated by a main effect of cue type, $F(2, 92) = 3.53$, MSE = .015, $p < .05$, $\eta_p^2 = .071$. However, this ANOVA revealed no significant interaction of cue type on age groups incongruent hits, $F(1, 92) = .8$, MSE = .015, $p < .5$, $\eta_p^2 = .017$. Thus, contrary to what a glance at Figure 16 would indicate, any benefits young adults have over older adults by using cues appear to be minor. Similar to the pattern of results found in Experiment 2, not finding a significant interaction between age groups' incongruent condition performance by cue type was unexpected. Recall that our hypothesis was that older adults' incongruent performance would remain invariant as a function of cue validity, but young adults would not. Whereas, older adults did remain invariant, it also appears that young adults don't vary performance to a large degree.

Taken together with the effect of the "likely misleading" cue on congruent hits, it appears that only young adults are responsive to the cues more when context is congruent than when it is incongruent. Older adults remained unresponsive to these cues regardless of whether the context was congruent or incongruent with expectation of the sentence final word. It is unclear if the fact that older adults don't benefit from the presentation of validity cues is due to older adults using the cues, and then deciding to use context, or if they are simply ignoring the cues altogether. Thus, even though instructed that the cues can aid in correctly identifying items, older adults may have decided to ignore the cues altogether. Regardless, older adults don't utilize these cues and this causes them to continue to show increased false hearing relative to young adults. Importantly, there was an overall age by trial type interaction which demonstrated that older adults were producing significantly different performance depending on whether or not context was predictive. The ANOVA conducted on incongruent trials alone revealed a main effect of age, whereas the ANOVA conducted on congruent trials alone did not reveal a main effect of age. Thus, the overall significant age by trial type interaction appears to be driven by large differences in incongruent hits in which older adults perform significantly worse than young adults.

Age Groups' Confidence in Correct Responses

Confidence responses were collected at the end of each response, and were analyzed to see if there were age differences for confidence on correct responses. To investigate how cue type influenced young and older adults' confidence on baseline, congruent and incongruent trials, a mixed-model ANOVA with age (young, older) as an independent measures factor, trial type (congruent, incongruent) as a repeated measures factor and cue type (neutral, "likely predictive", "likely misleading") as a repeated measures factor was conducted. As was the case when analyzing correct identifications, baseline trials were excluded from the analysis, because baseline trials do not contain three levels of cue type (i.e., baseline trials don't have "likely predictive" or "likely misleading" cues). The omnibus ANOVA of confidence revealed a significant main effect of age indicating that older adults were more confident than young adults,

$F(1, 44) = 9.54$, MSE = 1261.45, $p < .01$, $\eta_p^2 = .178$. Participants were more confident on congruent hits than incongruent hits evidenced by a main effect of trial type, $F(1, 44) = 47.21$, MSE = 345.6, $p < .001$, $\eta_p^2 = .518$. There was no main effect of cue type on confidence, $F(2, 88) = .32$, MSE = 92.57, $p < .75$, $\eta_p^2 = .007$. The age x cue type interaction was not significant ($F(2, 88) = .2$, MSE = 92.57, $p < 1$, $\eta_p^2 = .005$), and, although approaching significance, the age x trial interaction was also not significant ($F(1, 44) = 3.81$, MSE = 345.6, $p = .06$, $\eta_p^2 = .08$). There was a significant trial x cue type interaction, $F(2, 88) = 6.79$, MSE = 106.09, $p < .01$, $\eta_p^2 = .134$. This significant interaction showed that participants' confidence on congruent and incongruent trials differed as a function of the cue type. Lastly, older and younger adults' confidence was similar with each cue type for congruent and incongruent trials as was indicated by a non-significant age x trial type x cue type interaction, $F(2, 88) = .88$, MSE = 106.09, $p < .5$, $\eta_p^2 = .02$.

Age Groups' Confidence in Incorrect Responses

As confidence in incongruent misses/false alarms are of specific interest, we also measured participants mean confidence on incongruent misses/false alarms by cue type. The data depicting the average confidence on incongruent misses is shown in Figure 17. To investigate if cue type effected age groups differently on their incongruent miss/false alarm confidence, a mixed-model ANOVA with age (young, older) as an independent measures factor and cue type (neutral, "likely predictive", "likely misleading") as a repeated measures factor was conducted. Older adults were significantly more confident in their incorrect responses than were young adults on incongruent trials as was revealed by a main effect of age, $F(1, 45) = 16.55$, MSE = 1170.88, $p < .001$, $\eta_p^2 = .269$. There was no main effect of cue type meaning that participants confidence in incorrect responses did not vary depending on cue validity, $F(2, 90) =$

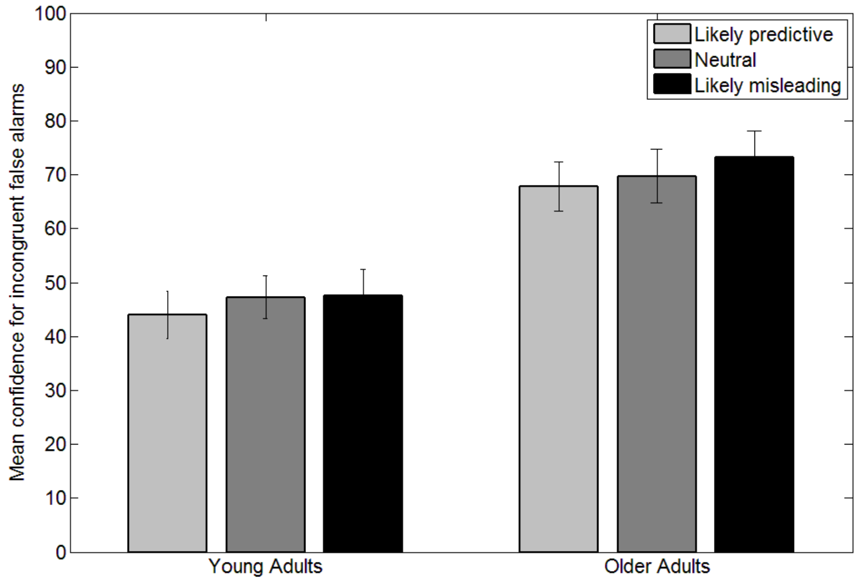

Figure 17: Young and older adults mean confidence on incongruent misses/false alarms by cue type

1.41, MSE = 187.61, $p < .25$, $\eta_p^2 = .03$. Lastly, the age x cue type interaction was not significant, $F(2, 90) = .26$, MSE = 187.61, $p < 1$, $\eta_p^2 = .006$. The main effect of age found in the ANOVA is not surprising, given past studies. Numerous studies within this dissertation as well as the previous literature (Sommers et al., in prep) have shown that older adults are significantly more confident in their incongruent false alarms. Thus, the increased level of confidence following incorrect incongruent responses expresses the overutilization of context as a basis for responding for older adults relative to young adults.

Dramatic False Hearing

Dramatic false hearing (DFH) occurrences were extremely important to the current study as they strongly suggest the false subjective experience of hearing the word predicted by context. Recall that dramatic false hearing refers to extremely high confidence (90-100%) errors on incongruent trials (e.g., hearing, “the plumber was fixing a drink” and responding ‘sink’). Figure 18 displays the proportion of DFH occurrences by cue type, observed on incongruent trials.

To examine what effect cue types had on young and older adults’ DFH rates, a 2 (age: young, older) x 3 (cue type: neutral, “likely predictive”, “likely misleading”) mixed-model ANOVA was conducted. This ANOVA revealed a main effect of age indicating that older adults (M = .47, SD = .3) produced more DFH occurrences than young adults (M = .11, SD = .09), $F(1, 45) = 36.06$, MSE = .144, $p < .001$, $\eta_p^2 = .445$. DFH rates were consist across cue type as was confirmed by a non-significant main effect of cue, $F(2, 90) = .78$, MSE = .027, $p < .5$, $\eta_p^2 = .017$. There was no age x cue type interaction, $F(2, 90) = .53$, MSE = .027, $p < .75$, $\eta_p^2 = .012$. Thus, as was observed in Experiments 1 and 2, older adults produce significantly more DFH

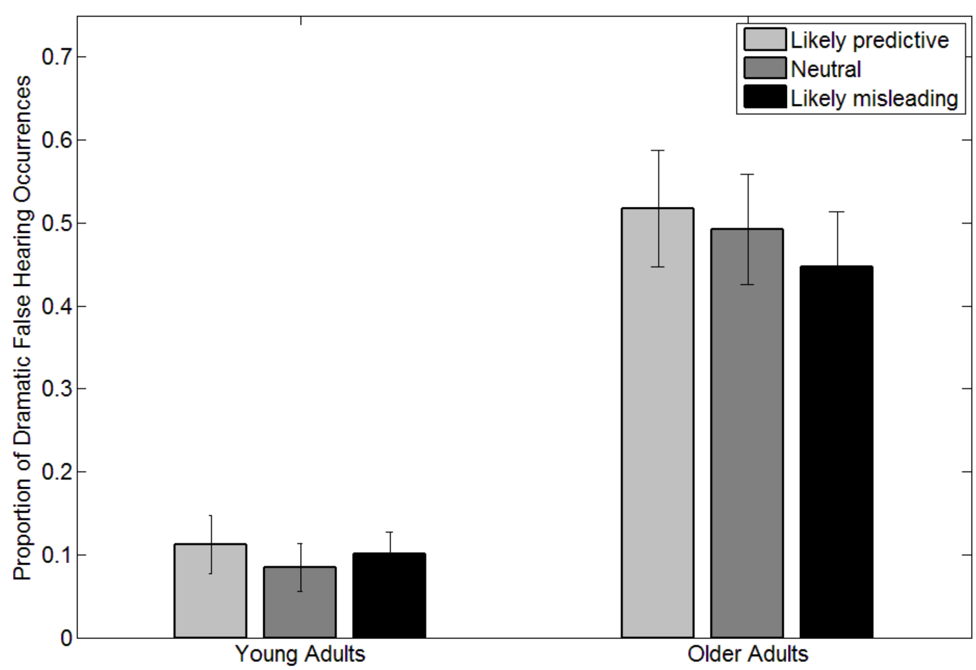

Figure 18: Young and older adults’ proportion of Dramatic False Hearing occurrences (90-100% accuracy).

occurrences than young adults. These findings suggest that older adults are having the subjective hearing experience of hearing the word predicted by context.

Resolution

Experiment 3 also allowed us to examine the relationship between confidence and accuracy, and to determine if there were age differences in these correlations. To do so, we examined resolution, which assesses the extent to which confidence in a response is related to accuracy. As with previous the experiments, resolution was measured using, Fisher *r* to *z* transformed, Gamma correlations. As was an issue with previous experiments, the congruent condition often produced 100% accuracy. This meant that a large number (11 out of 48) of participants' gamma correlations were incalculable in the congruent condition. Furthermore, a disproportionate amount of the incalculable gamma correlations came from older adults leaving over a third of older adults' gamma correlations unusable. Due to such a large number of participants not having a congruent condition gamma correlation, we calculated only baseline and incongruent gamma correlations.

As in Experiments 1 and 2, we predicted that gamma correlations in the baseline condition would be equal across age groups, but that gamma correlations in the incongruent condition would be significantly lower for older adults, compared to young adults. Figure 19 displays the average gamma correlations for young and older adults for baseline and incongruent conditions. As can be seen, older adults performed worse on incongruent trials compared to young adults, and older adults actually produced a negative gamma correlation. This negative gamma correlation indicates that the more confident an older adult was on an incongruent trial the more likely he or she was to provide an incorrect response. To investigate if the correlations produced an age by trial type interaction, a mixed-model ANOVA with age (young, older) as an independent measures factor and trial type (baseline, incongruent) was conducted. There was a significant main effect of age, in which older adults performed worse than young adults, $F(1, 46) = 5.3$, MSE = .536, $p < .05$, $\eta_p^2 = .103$. Participants resolution was better on baseline trials than incongruent trials as was indicated by a main effect of trial, $F(1, 46) = 21.12$, MSE = .693, $p < .001$, $\eta_p^2 = .315$. There was no interaction between age and trial type, $F(1, 46) = .69$, MSE = .693, $p < .5$, $\eta_p^2 = .015$. Thus, this experiment only showed that older adults' gamma correlations were worse than young adults in Experiment 3.

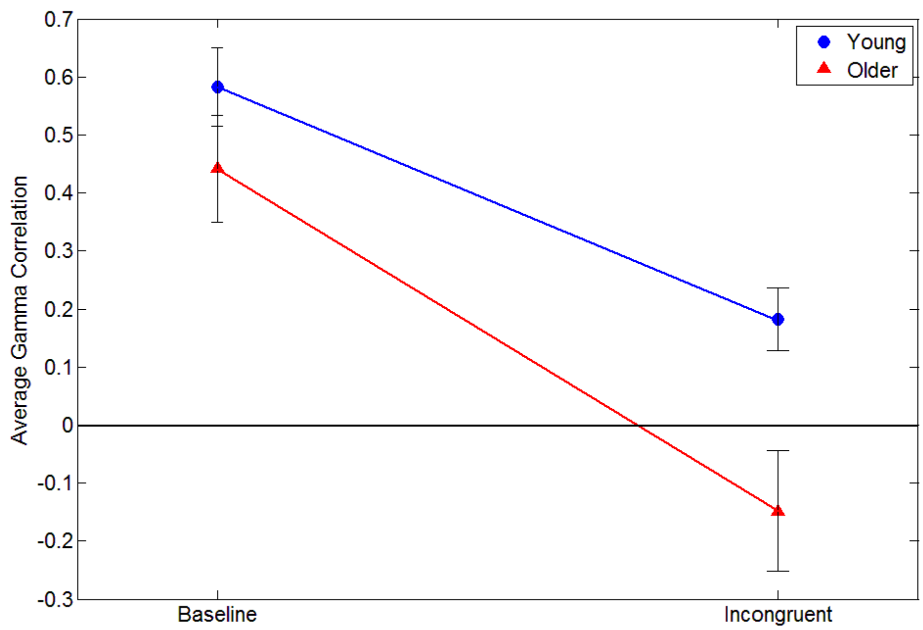

Figure 19: Young and older adults average gamma correlations for baseline and incongruent trials.

Summary

Experiment 3 was conducted to see if validity cues presented prior to hearing sentences would affect age differences in spoken word recognition and false hearing. Overall, Experiment 3 produced results consistent with prior studies (Sommers, et al., in prep), as well as the other experiments within this dissertation. Older adults had significantly more incongruent false alarms than young adults. When performance was investigated within each cue type, results demonstrated that regardless of cue type older adults' performance did not change on either congruent or incongruent trials. In contrast, young adults did show differences in congruent trial performance as a function of cue type. The marginally significant age by cue type interaction was found on congruent trial performance; in which young adult performance dropped significantly when the cue was invalid (i.e., "likely misleading"). Contrary to our hypothesis that there would be a significant age by cue type interaction on incongruent trial performance, no significant interaction was obtained. Although it is interesting that performance on incongruent trials increased for young adults from an invalid cue (i.e., "likely predictive"), to a neutral cue, and again to a valid cue (i.e., "likely misleading"), these increases seem to be minor. Thus, the results of Experiment 3 indicate that reducing or increasing uncertainty by informing participants about the predictive or misleading nature of these sentences doesn't change older adults' performance, while it can for young adults. It appears that older adults are sufficiently captured by context to such a degree that they disregard the additional cue information or choose to not use the cue altogether. Further support for older adults' overuse of context was found in the Dramatic False Hearing (DFH) occurrences as well. Older adults had significantly more DFH occurrences than young adults, demonstrating that they are highly confident in their incorrect, but contextually predicted, responses.

Chapter 5: General Discussion

The results of this dissertation revealed some interesting findings regarding age differences in context effects in spoken word recognition. Experiment 1 compared false hearing rates between age groups when responses were restricted by comparing open-set responding to closed-set responding. Results from Experiment 1 demonstrate that reducing uncertainty by changing from open to closed-set responding does not reduce age differences in false hearing. The closed-set responding condition still produced significantly more false hearing occurrences for older adults than young adults. Furthermore, older adults were more confident on these incongruent false alarms than young adults. Experiment 2 furthered the investigation of the role uncertainty has on use of semantic context during spoken word recognition by manipulating signal-to-noise ratio (SNR). Experiment 2 revealed that when context is predictive (i.e., congruent), older adults' accuracy does not change as a function of increasing or decreasing the SNR. Thus, even when moving across an 8-dB difference in SNR, older adults' performance remained invariant. Rarely do researchers find that older adults outperform young adults, let alone a task where our data indicate that, as SNR is made more difficult, age differences increase with an older adult advantage. Experiment 3 provided participants with a probabilistic cue prior to presenting a baseline, congruent or incongruent sentence. The results of Experiment 3 demonstrated that older adults continue to use contextual sources of information to a greater extent than young adults, regardless of uncertainty being reduced considerably. In fact, both conditions in which context is present (congruent and incongruent trials) showed no changes in performance as a function of cue type for older adults. The cue types did affect young adults' performance on congruent trials, but did not on incongruent trials. Thus, Experiment 3 revealed evidence supporting age differences in use of context as a base for responding on congruent trials, but inconclusive evidence to supporting an age differences in bases of responding account for incongruent trials.

Effects of uncertainty on spoken word recognition with semantic context

The goal of this work was to investigate age differences in semantic context effects during spoken language processing when uncertainty was manipulated. The experiments conducted by Rogers, Jacoby and Sommers (2012) shared many similarities with the experiments in this dissertation, but there were some important distinctions. First, the experiments in this dissertation used semantically meaningful sentences as opposed to paired associates. However, the most important difference between these studies is that the experiments in this dissertation were conducted to specifically manipulate uncertainty. Understanding how uncertainty can modulate semantic context effects during spoken word recognition differently for young and older adults is important, as it can inform researchers as to possible directions to limit false hearing occurrences. Although no experiment in this dissertation directly replicates the ways in which uncertainty is reduced in everyday communication, the uncertainty manipulations in the experiments were designed to act similar to some of the ways uncertainty is reduced in daily life.

Experiments 1 and 3 reduced uncertainty in the same way that listeners reduce uncertainty in everyday life by knowing the likely word candidates in a given environment. When we are speaking with co-workers at the office we predict different word possibilities than when speaking with friends at a zoo. If the listener hears the word ‘frog’ while at a zoo with friends, the environment of the zoo can reduce the uncertainty the word heard in the noise was in fact ‘frog’. Likewise if the word ‘frog’ is heard in a sentence while the listener is at the office, the listener’s uncertainty might increase as ‘frog’ is an uncommon word candidate for the workplace. Similarly, Experiment l limited the response candidates in the two-alternative forced choice condition relative to the open-set response condition. Experiment 3 reduced uncertainty in a similar manner, providing a validity cue that could be used to reduce uncertainty in two-alternative forced choice responding. Reducing uncertainty by using word probabilities offers a way to investigate the role of uncertainty has in false hearing. The results of Experiment 1 suggest that even when uncertainty is reduced by limiting the response candidates, older adults continue to false hear more than young adults. Likewise, Experiment 3 demonstrated that providing validity cues did not reduce age differences in false hearing. Thus, reducing uncertainty by limiting responses or by providing validity cue was not an effective way to reduce false hearing in older adults.

Experiment 2 manipulated uncertainty by increasing or decreasing the signal-to-noise ratio (SNR). One of the simplest ways to reduce uncertainty in everyday communication is to attempt to reduce the background noise or increase the signal. For example, a listener can move closer to a speaker when noise is overcoming the speech signal. Experiment 2 attempted to partially recreate such a situation by varying the SNR. Although not a direct reflection of how individuals reduce uncertainty in noisy situations in everyday communication, it did allow the examination of how age groups respond when uncertainty in the signal is manipulated. Results of Experiment 2 revealed that older adults' performance doesn't change as a function of SNR difficulty when context is congruent with what is semantically predicted. The implication being, that when context is predictive older adults can be reasonably confident they will correctly perceive speech; surprisingly, even more than young adults. All three Experiments results converge, and demonstrate that reducing older adults' over-use of context is not possible with any uncertainty manipulation used within this dissertation.

Convergence of experiments' results to the broader literature

The results of the experiments in this dissertation converge with the broader literature on age differences in hearing, vision and memory. In Experiments 1 and 2, results showed that on incongruent trials (when context is misleading) older adults falsely heard the contextually congruent word significantly more often than did younger adults. This finding is consistent with those reported in the hearing domain by Rogers, Jacoby and Sommers (2012) and Sommers et al. (in prep), in which older adults were also significantly more likely to demonstrate incongruent false alarms than young adults. The greater amount of older adult incongruent false alarms, relative to young adults, in Experiments 1 and 3 also converges with similar experiments in the visual domain by Jacoby et al. (2011) that reported older adults produced more incongruent false alarms than young adults. Thus, across both the hearing and visual domains of perception, a similar pattern of results emerges; older adults are more susceptible to false seeing and hearing. The results of this dissertation also converge with results from similar experiments examining age differences in memory. For example, in a study conducted by Jacoby et al. (2005)

researchers presented individuals with paired associates for study (e.g., knee bone). Both young and older adults' memory performance was then tested by being presented with the left-hand member of each pair with the right-hand member requiring fragment competition (e.g., knee b_n_). However, prior to each cued recall pair presented for responding, a prime word was presented to individuals that could be congruent (bone) or incongruent (bend). Results demonstrated that both young and older adults were susceptible to false memories; however, older adults had a differentially greater probability of producing false memories relative to young adults. The convergence of these results to those in hearing, vision, memory and the experiments conducted in this dissertation, suggest a commonality(s) between the three different domains.

Dual process models could account for this commonality(s) by postulating an association driven automatic process and a controlled process. Originally argued for in memory, many experiments have been conducted examining the dual processes in memory with results supporting a controlled process (e.g., *recollection*) and an automatic process (e.g., *familiarity*) (Jacoby, 1991; Hay & Jacoby, 1999; Jacoby et al., 2005). A common finding in such experiments is that older adults' recollection based performance is lower than that of young adults, but both age groups perform similarly when using automatic processes (i.e., *familiarity*) (Hay & Jacoby, 1999; Jacoby, Debner & Hay, 2001). In the dual process model approach, *recollection* processes and *familiarity* processes serve as alternative bases for cued recall. Thus, with *recollection* processes in decline, older adults may use familiarity to a greater extent than young adults.

Dual processes have also been postulated in vision. Aly and Yonelinas (2012) postulated a state process of *perceiving* that both provides high fidelity, high-resolution information to explicit awareness, and a strength process of *knowing* that provides a signal of low-resolution representation of the global environment. As with the dual processes in vision and memory, hearing could contain dual processes that share important similarities across domains. In audition one process could provide high fidelity sensory signal information to explicit awareness (i.e., *perceiving*), and the other process could provide association driven information automatically (i.e. *knowing*). The convergence of the results in this dissertation with those from other experiments investigating age differences could support such claims (Jacoby et al., 2011). Thus, it may be that as individuals age, they use association driven automatic processes to a greater extent than young adults, and this overuse of associative driven processes could explain the convergence of data showing that older adults false hear, see and remember more than young adults. This overuse of associative driven processes by older adults may be caused by underlying age differences in cognitive control, which will be discussed.

False hearing: Implications for differential bases for responding

The results of the experiments in this dissertation have implications for the differential bases of responding account of age differences in spoken word recognition. Recall that the differential bases of responding account asserts that older adults' differential benefit when provided meaningful semantic context, relative to non-predictive context, is due to older adults using context to a greater extent than young adults. The account would have predicted many of the results in the experiments conducted in this dissertation. If older adults use context to a greater extent than young adults, one would predict older adults to false hear more than young adults when context is incongruent with the expectation from context. This was found in both open and closed-set responding in Experiment 1 and Experiment 3. The differential bases of responding account would also predict that congruent correct identifications would be greater for older adults, which was also found in the open-set response format task in Experiment 1. In Experiment 2, performance over a change of 8-dB in the SNR resulted in no performance changes on congruent trials for older adults, but did show systematic declines for young adults as SNR difficulty increased. The lack of change in older adults' congruent performance over this 8-dB shift would also support a differential bases of responding account for age differences in spoken word recognition. The data from all three experiments' dramatic false hearing (high confidence errors on incongruent trials) occurrences showed that older adults had significantly more high confidence errors than young adults, as a differential bases of responding account would posit. Although the results of the three experiments support a differential bases of responding account, there were findings that would not support a differential bases of responding account. Recall in Experiment 2 that there was no age difference between incongruent hits at any SNR difficulty. Although young adults had numerically more incongruent hits, the differential bases of responding account would have predicted a main effect of age which was not found. Similarly, Experiment 3 also failed to reveal a significant interaction between age groups performance on incongruent hits between cue types. It is unclear why age groups performed similarly on incongruent trials in Experiment 2, and further experiments should aim to answer this question.

False hearing: implications for cognitive control

As was addressed in the introduction of this dissertation, cognitive control refers to a large number of controlled processes such as inhibitory control, planning, reasoning, task flexibility, etc. Cognitive control has implications for false hearing as we posit that age differences in false hearing are a reflection of older adult declines in cognitive control, leading older adults to use context to a greater degree. For our purposes here the most important aspect of cognitive control is inhibitory control (i.e., resisting prepotent responses), because we propose that age differences in false hearing are partly due to age differences in cognitively controlling prepotent responding. Although other processes related to cognitive control, such as task flexibility, are likely to influence false hearing we posit that older adults' decreased inhibition is a major contributor. This account has support from the literature in that older adults' ability to resist prepotent responses (i.e., default) is significantly worse than young adults (Hasher, Zacks & May, 1999; May & Hasher, 1998). Thus, older adults continue to false hear even when uncertainty is reduced, because they are less able to resist having the contextually predicted, non-presented, word activated. The reduced ability of older adults to resist prepotent responding could account for why older adults did not show changes in performance as a function of cue type in Experiment 3. Thus, it is possible when older adults are presented with a cue informing them to the validity of a trial they are unable to inhibit the activated contextually predicted word even when the cue information could be a benefit to perception. It would also account for why performance on congruent hits in Experiment 2 did not change as a function of shifts in the signal-to-noise ratio (SNR). This is to say that as SNR became more difficult, older adults' performance didn't suffer, because they didn't have to resist a prepotent response; which, in this case, lead to differentially better performance. Importantly, older adults' inability to resist prepotent responding occurred despite the fact that each participant was explicitly informed that contextual sources of information cannot be fully trusted prior to testing in all three experiments within this dissertation. Thus, even after being told about the misleading nature of some of these sentences older adults still were unable to control prepotent responding.

Is false hearing just semantic priming?

As previously mentioned the experiments in this dissertation closely resemble the experiments conducted in Rogers, Jacoby and Sommers (2012). However the key difference between the two paradigms is that Rogers, Jacoby and Sommers (2012) used paired associates whereas we used semantically meaningful sentences to demonstrate age differences in false hearing. The use of sentences was partly to investigate if rates of false hearing would increase when stimuli more closely resembled how context functions in speech communication. However, we were also interested in using methodologies that differ from methods common in semantic priming experiments. Recall that Semantic priming refers to the observation that a response to a target is faster when it is preceded by a semantically related prime (Neely, 1977). In the paired associate design, all of the cue-target pairs were semantic associates so priming could be the result of pre-existing semantic relationships. Thus, falsely hearing 'HAY' when presented the word pair 'BARN-PAY', could be due to the word 'BARN' priming 'HAY' since they are strongly associated. Semantic priming can account for the pattern of results seen in Rogers, Jacoby and Sommers (2012), but becomes a less clear account for results using semantically meaningful sentences.

The stimuli used in Sommers et al., (in prep) and in the experiments in this dissertation were sentences in which the prime word was not directly paired with the target word. For example, when presented "The shepherd watched his <u>sheep</u>", the word 'shepherd' would prime the word 'sheep'. However, there are intervening words between the prime and the target word which causes a problem for semantic priming, because semantic priming is fast acting and has a short duration. Although the length of this activation is not fully agreed upon, it is usually around 400 to 800 ms (Lupker, 1984; Schreuder, d'Arcais and Glazenborg, 1984; Nelly, 1991). Thus, when finally arriving at the word pair containing the target word (i.e., 'sheep'), priming from the associated word (i.e., 'shepherd') would presumably have ended during the intervening words. Although a semantic priming explanation cannot be completely ruled out, it seems far more likely that false hearing using semantically meaningful sentences is due to expectations to the sentence final words. We explain the age differences in false hearing in the experiments herein as being caused by the expectation of the semantically predicted sentence final words. Thus, when hearing the sentence "the shepherd watched his sheep", the listeners' expectation that the final word will be 'sheep' increases as sentence context unfolds. If this expectation is violated (i.e., presenting 'sheath' as the final word), individuals may false hear the word actually presented for the word that was congruent with expectations.

Is using context a bad technique?

The experiments in this dissertation have shown that older adults falsely hear more than young adults even when baseline performance was equated. We have argued that this age difference in false hearing is caused by older adults' overutilization of contextual sources of information when making spoken word recognition judgments. All this would make using context sound like a poor strategy for the listener, but this is not our contention. In everyday life, a talker's context is quite useful to the listener and rarely is misleading. It is important to note that both young and older adults show a benefit to performance when context is congruent compared to baseline trials. Thus, using context is going to benefit the listener in almost every real-world circumstance. In fact, many experiments in this dissertation produced significantly higher congruent performance for older adults than young adults; meaning overutilization of context was actually a benefit. So if using context as a basis for responding isn't a bad thing what should the reader take away from this dissertation? We argue that its judicious use of context.

Judicious use of context here refers to using context, but doing so after examining all the possible options. As we have seen, older adults tend to disregard additional sources of information, and focus solely on context. In Experiment 3, older adults' performance on both congruent and incongruent trials did not change as a function of cue type. Thus, when we offered additional sources of information to make judgments on, older adults ignored these cues. Our experimental results suggest that listeners, especially older adults, should be attempting to determine the validity of different sources of information. By doing so, these listeners might be better able to reduce false hearing occurrences.

Limitations of the current research

The current research contains some limitations that should be addressed. All three experiments were conducted to investigate how manipulating uncertainty effects spoken word recognition with meaningful semantic context. Although the experiments were designed to loosely follow how listeners reduce uncertainty in everyday communication the experiments should not be interpreted as a direct comparison to how listeners reduce uncertainty. Everyday communication is quite different from any perceptual tests conducted in this dissertation or those referenced.

Experiment 1 manipulated uncertainty by investigating open-set and closed-set response formats. Experiment 1 is limited in its ability to make comparisons between test types. Although when designing the experiment great care was taken to be able to equate baseline performance between the two response formats, equating these two response formats is not possible. In an open-set response format, baseline condition chance performance is near zero, but, in a two-alternative forced choice design, baseline condition chance performance is at 50%. We calibrated baseline performance in the open-set task to 50% for young and older adults, which increased performance above a near zero chance performance by 50%. We calibrated the baseline performance in the closed-set task to 75% for young and older adults in the closed-set task, which increased performance above a 50% chance performance by 50%. Although we attempted to equate performance in baseline trials between test types there is no way to be certain that, for example, a 50% performance on an open-set response format truly equals a 75% performance on a closed-set response format. Thus, when making comparisons across response formats researchers should be aware of this limitation.

Experiment 3 supports that older adults did not use the validity cues to assist spoken word recognition performance. At least two accounts for this might exist. (1) Older adults considered the cues, but, when selecting between response alternatives, opted to ignore the cue in favor of using context as a basis for responding. (2) Older adults ignore the cues altogether and this results in the lack of change over cue type. The first account, where older adults disregard the cue, would have substantial implications for false hearing, indicating that older adults use context to such a degree that they are willing to disregard useful information. The second account, where older adults ignore the cues altogether, would imply that older adults refuse to use other sources of information when making perceptual decisions. Data in the Experiment 3 are limited in the ability to resolve these two possibilities.

Results from Experiments 1, 2 and 3 did not always reveal significant age by condition interactions. For example, resolution measures in Experiment 1 revealed no significant age by trial type interaction. In Experiment 2 there was no three way interaction between age, SNR difficulty and trial type. In Experiment 3 the three way interaction between age, cue type and trial type was not significant although approaching. Each experiment in this dissertation contained 24 participants per age group, and this number was based on previous studies showing age differences in correct identifications (Sommers et al., in prep). However, the experiments in this experiment may have been limited by not including a large enough participant sample leading to underpowered results. In future experiments a larger number of participants should be used when including more levels of repeated measures into the model.

Future directions

Due to the similar pattern of results in false hearing, false seeing and false memory experiments there is reason to believe that there is a common cause. We have argued that older adults' inhibitory deficits in cognitive control are a major contributor to false hearing, false seeing and false memories. Future directions should focus on directly demonstrating how poor inhibitory control leads to increased false hearing, seeing and remembering. Such an experiment would begin by separating older adults based on high and low ability to resist prepotent responses using methods similar to those used in the experiments conducted by May and Hasher

(1998). If the ability to resist prepotent responses is responsible for false hearing, seeing and remembering, then older adults in the low inhibition group should show more false hearing, seeing and remembering intrusions than older adults in the high inhibition group. This finding would strongly suggest that the ability to resist prepotent responding contributes a major role to false hearing, seeing and remembering. Such work could inform researchers about a specific ability to train in order to reduce intrusions.

This dissertation has focused on the relation dual process models have to a differential bases of responding account for age differences in spoken word recognition in the presence of meaningful semantic context. Although we have outlined some possible ways these dual processes might function in audition, we have not explicitly defined how such processes might function in a specific manner. There is likely a process for dealing with high fidelity acoustical speech signal information which is controlled and brought to explicit awareness. Likewise, there would be a process for dealing with global, associative, information (i.e., context) which is automatically activated. Future research should investigate how these processes should be defined in audition specifically. Research should be conducted to test for the existence of these processes using similar techniques to those used by Aly and Yonelinas (2012) that tested for dual processes in the visual perception domain. False hearing methodology could offer one measure of these processes. Using a change detection paradigm, researchers could place use pairs of baseline, congruent and incongruent sentences, and ask participants if the sentence had changed. For example, when context contains low predictability (baseline-baseline pair) correctly detecting change would be due predominately to controlled processes as there is little to no context to drive activation of automatic processes. However, when context is semantically meaningful it could have large effects on association driven, automatic processes, particularly in the elderly. Thus, when presenting a congruent – incongruent sentence pair incorrectly calling the sentence final word the same reflects use of association driven, automatic processes. Age differences in the detection of change in these types of stimulus materials would reflect age differences in the use of dual processes. Thus, future research should focus on using change detection paradigms to investigate age differences in dual processes in audition.

Furthermore, it is possible that false hearing could offer a method to uncover early onset of Alzheimer's disease (AD). There has been recent work to suggest that the proportion of incongruent false memories can differentially classify normal aged adults from those with very mild dementia of the Alzheimer's type (Tse, et al., 2010). In this experiment, young, older and older adults with very mild dementia of the AD type, were given two lists and received different incidental encoding instructions (read aloud or rate for pleasantness). One list contained distractor items and the other list contained target items. This allowed researchers to place *recollection* processes in opposition to *familiarity* processes. The result of placing recollection and familiarity processes in opposition was that false alarms (indicated by the number of incorrectly recalled distractor items) were greater for AD older adults than either young or healthy older adults. Similarly, the false hearing paradigm places contextually based responding in opposition to sensory based responding. Thus, Experiments comparing young, healthy older and older adults with mild dementia of the AD type, in the false hearing paradigm, might demonstrate increased false hearing for older adults with AD type dementia. Such a paradigm could be quite useful for metric of diagnosing AD early in onset.

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