Tune In or Tune Out: Age-Related Differences in Listening to Speech in Music

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Objective: To examine age-related differences in listening to speech in music.

Design: In the first experiment, the effect of music familiarity on word identification was compared with a standard measure of word identification in multitalker babble. The average level of the backgrounds was matched and two speech-to-background ratios were tested. In the second experiment, recognition recall was measured for background music heard during a word identification task.

Results: For older adults, word identification did not depend on the type of background, but for younger adults word identification was better when the background was familiar music than when it was unfamiliar music or babble. Younger listeners remembered background music better than older listeners, with the pattern of false alarms suggesting that younger listeners consciously processed the background music more than older listeners. In other words, younger listeners attempted to “tune in” the music background, but older listeners attempted to “tune out” the background.

Conclusions: These findings reveal age-related differences in listening to speech in music. When older listeners are confronted with a music background they tend to focus attention on the speech foreground. In contrast, younger listeners attend to both the speech foreground and music background. When music is familiar, this strategy adopted by younger listeners seems to be beneficial to word identification.

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TUNE IN OR TUNE OUT: AGE-RELATED DIFFERENCES IN LISTENING TO SPEECH IN MUSIC

Older adults often have difficulty in understanding speech in complex or noisy acoustical environments. The auditory and cognitive challenges encountered in such environments affect even older adults whose hearing is considered to be clinically normal in the speech range and even though they have little difficulty listening in simple, quiet environments (for a review see Pichora-Fuller & Souza, 2003). In most research, it has been assumed that speech is the wanted or relevant target sound and that any competing sound is unwanted or irrelevant. Unwanted competing sounds menace the target speech either because the competitor masks the acoustical cues in speech that are important for understanding, distracts attention from the primary task of understanding what is being said, or both. Despite the assumptions about everyday listening that have inspired many experiments concerning speech understanding in noise, the reality is that listeners often need or wish to attend the various non-speech signals while they are listening to speech.

Music is a ubiquitous part of everyday life for people of all ages, and its psychological significance may be even greater for older adults than for middle-aged adults (Cohen, 2002; Gabrielsson, 2002). Music is generally thought as a foreground signal, but it is often encountered in the background. Background music is an extremely common component of sound tracks in films and television programming, as well as being a common device for creating ambiance in a wide range of situations where older adults find themselves, such as shopping malls and restaurants. Because speech is often heard in sound environments featuring background music, it seems important to investigate how music affects the ability of listeners to understand speech, yet previous research on this topic seems to be largely nonexistent.

Effects of Attention, Masking, and Familiarity with Music on Word Identification

Modern research on speech communication has been strongly influenced by Cherry’s (1953) watershed article on the “cocktail party” phenomenon. An important but often overlooked distinction made by Cherry is the difference between foreground and background listening (for a discussion see Wingfield & Tun, 2007). Although a listener may be attending to a particular conversation in the foreground, he or she may still be aware of informational signals (e.g., speech or music or both) in the background. The distinction between foreground and background may also be thought of in terms of levels of attention.
The focus of attention is directed at the foreground signal, but that is not to say that no attention is directed at the background signal. In addition, there may be shifts in the focus of attention. Cherry (1953, pp. 979) states that “when listening to and repeating concurrently a message received in one ear whereas a different message is being presented to the other ear, it is found that a short time interval is required to transfer the attention from the one ear to the other”. From this perspective, listening in a cocktail party may be regarded as a dynamic listening experience involving divided attention and the occasional shift in the focus of attention. For example, a listener will readily shift the focus of attention on hearing his or her own name in a background conversation.

A competing speech signal may be particularly challenging for speech perception because it provides both energetic and informational masking (Watson, 1987). Energetic masking is thought to occur in the auditory periphery because of stimulation of the same auditory filters, resulting in a degraded neural representation of the sound source target. In contrast, informational masking is thought to be because of limitations in central processing, despite a veridical representation of sound in the auditory periphery. Informational masking has been likened to camouflage insofar as the acoustical target and background signals are both audible, but they cannot be differentiated easily as separate objects.

The ability to identify a target in a background will be influenced by the degree of similarity between the target and the background. In general, both energetic and informational masking will be high when the target and masker have similar structure; for example, when both are speech (see however, Oxenham, et al., 2003). The energy of background speech will inevitably be concentrated in frequency regions that overlap with the energy of foreground speech. Background speech also competes for central or higher-level processing resources because it shares linguistic structural properties with foreground speech (Freyman, et al., 1999; Li, et al., 2004).

Music and speech share many acoustic and structural properties (Besson & Schon, 2001; Chasin & Russo, 2004; Patel, 2005; Patel, et al., 2006) and seem to rely on shared resources for processing syntax (Koelsch, et al., 2002; Maess, et al., 2001; Patel, et al., 1998). However, music differs from speech with regard to other acoustical and structural properties and should lead to less masking than speech itself in terms of both energetic and informational masking.

Importantly, because music is meaningful and temporally organized, it may demand attention; that is a listener may be motivated to divide his or her attention between music and speech, even when the focus of attention is ostensibly speech. Neural and behavioral evidence suggests that dividing attention will reduce attention-based streaming ability (Alain & Izenberg, 2003; Carlyon, et al., 2001). A reduction in attention-based streaming ability could have a negative effect on word identification when there is a music background.

Familiarity with a piece of music is likely to be an important factor in determining the extent to which a shift in attention will occur. Familiar sounds (such as one’s name) are known to trigger automatic shifts in attention. In real world settings, music can be highly familiar, perhaps even more so than speech or other organized acoustic signals. For example, music possesses style rules that may be highly familiar (e.g., tonality). In addition, there may be familiarity with a specific piece of music (e.g., a jazz standard) and even familiarity with a particular recording (e.g., performance nuances).

In many cases, popular recordings have been heard dozens of times and in numerous contexts. These factors may converge so as to yield a highly predictable signal that may temporarily shift attention away from a speech target. In such highly familiar cases, it is possible that enough attention will be drawn to the music so as to generate strong and accurate expectancies about future events in the music. Specific knowledge-based (or veridical) expectancies (Bharucha, 1987) may be generated in as few as five notes, which is the number of notes required to accurately identify a highly familiar melody (e.g., Scholkind, et al., 2003). More general schema-driven and bottom-up expectancies are generated in as few as two notes, regardless of familiarity (e.g., Cuddy & Lunney, 1995; Schellenberg, et al., 2002). Compared to listening to a less predictable masker, if expectancies are focused on key points in time (e.g., at points in the music heard concurrently with the target word), then a brief attention shift may actually be beneficial to the listener, leading to a net improvement in word identification. Additional improvement in word identification may also be owed to retroactive filtering of the familiar musical signal at key points in time (Bregman, 1990; Grossberg, 1998, 1999).

Finally, familiarity with a piece of music may also influence the listener’s cognitive load regardless of whether or not shifts in attention occur. Specifically, if some attention is always allocated to background music because it is a meaningful and organized signal, but the amount of attention varies with the listener’s familiarity with the music, then processing demands associated with listening to the background should be relatively lower in the case of
music that has a pre-existing internal representation (i.e., familiar music). In turn, lower processing demands imposed by the background should lead to enhanced processing of the foreground.

Effects of Perceptual and Cognitive Aging on Word Identification

Older adults have more trouble than younger adults in identifying words in the presence of competing sounds. Age-related differences in word identification occur when the competing sound is another talker or multiple talkers (e.g., Pichora-Fuller, et al., 1995; Tun, et al., 2002; Wingfield & Tun, 2001), and to a lesser extent when speech is heard in nonspeech backgrounds such as white noise (e.g., Duquesnay, 1983a, b). In general, differences between younger and older adults are exaggerated when the competing sound is fluctuating and complex (e.g., Gordon-Salant & Fitzgibbons, 1993, 1995; Stuart & Philips, 1996). These problems may be attributed to auditory and cognitive aging.

The most well known characteristic of auditory aging is threshold elevation for high-frequency sounds resulting from damage to the inner ear. Clearly, depending on the degree of clinically significant audiometric hearing loss, important aspects of speech acoustics will be rendered inaudible and consequently speech perception will be reduced. However, difficulty in understanding speech in noise has been reported even for older adults whose audiometric thresholds remain within normal clinical limits in the speech range (for reviews see CHABA, 1988; Willott, 1991). Neural degeneration resulting in alterations in auditory temporal processing at various levels of the auditory system seems to be the most likely basis of age-related differences in ability to listen in complex acoustical environments (Divenyi & Simon, 1999; Frisina, et al., 2001; Mills, et al., 2006; Pichora-Fuller & Souza, 2003; Schneider & Pichora-Fuller, 2001).

Attention and memory are two aspects of cognitive aging which may influence how well older adults listen to and understand language spoken in complex acoustical environments. Age-related reductions in ability to inhibit irrelevant stimuli (for reviews see Hasher, 2006; Hasher, et al., 1988) and age-related reductions in ability to divide attention (for a review see McDowd & Shaw, 2000) may disproportionately disadvantage older listeners when the acoustical environment is complex with many potentially distracting or attention-diverting streams of auditory input arising from different sources. Age-related reductions in working memory during language processing (for a review see Wingfield & Stine-Morrow, 2000) may also contribute to the disproportionate difficulties encountered by older adults when they must comprehend spoken language in challenging listening situations. For example, when listening becomes effortful in acoustically adverse conditions, working memory resources may be allocated preferentially to listening and away from storage of the information that has been heard, thereby diminishing the ability of older adults to fully integrate the meaning of and remember the speech that they heard (e.g., Pichora-Fuller, et al., 1995; see also Surprenant, 2007).

Overview of Experiments

Two experiments were conducted to examine age-related differences in listening to speech in music. In experiment 1, accuracy of word identification was measured in the presence of music or babble backgrounds. Accuracy was compared across background conditions and across age groups. In experiment 2, recognition memory for background music was measured to assess the extent to which background music had been consciously processed when the listening task was word identification. Recognition memory was compared across background conditions (familiar versus unfamiliar music) and across age groups. To our knowledge, this set of experiments is the first empirical study of the effects of music on speech processing. The pattern of findings should help to illuminate issues concerning cognitive and auditory processing in complex listening environments in younger and older listeners.

Experiment 1: Word Identification Test

In experiment 1, we tested word identification in the presence of familiar music, unfamiliar music, and multitalker babble. Because speech is more similar to multitalker babble than to music, we expected more informational masking from multitalker babble than from music. If familiarity with a music background influences the extent to which it becomes the focus of attention (i.e., conscious processing), familiar music may be better attended than unfamiliar music. This additional attention may lead to the generation of expectancy, which in turn could be helpful in stream segregation. Moreover, the processing demands imposed by familiar music should be less than those imposed by unfamiliar music. Therefore, in the case of younger adults, the expected hierarchy of word identification performance would be best performance when the background is familiar music, followed by unfamiliar music, followed by multitalker babble. In the case of older adults, differences because of background were expected to be less pronounced because of reduced capacity to divide attention.
Methods

Participants • Sixteen participants were recruited from the university community. All had participated in previous listening studies, but none had heard the test sentences previously. Eight participants with ages ranging from 18 to 30 yrs were recruited for the younger adult group (M = 21.1 yrs, SE = 1.5 yr). Eight participants with ages ranging from 65 to 78 yrs were recruited for the older adult group (M = 69.4 yrs, SE = 0.7 yr). The number of years of formal education completed was not statistically different for younger (M = 14, SE = 0.4) and older adults (M = 15, SE = 0.8), t (7) < 1. In addition, the scores on the Hill Mill Vocabulary test were not statistically different for younger (M = 14/20, SE = 1.1) and older adults (M = 14.8/20, SE = 0.4), t (7) < 1. All participants had normal audiometric thresholds (i.e., less than 25 dB HL from 0.25 to 3 kHz; see Table 1) and were native English speakers (English is the primary language spoken since age 5 or earlier). Finally, all participants provided informed consent and received financial remuneration for their participation.

Procedure • Each participant was tested individually in a total of six conditions: each of the three different backgrounds (multitalker babble, 1950s music, 1990s music) was presented in each of two different speech-to-background ratio conditions, (+4 and 0 dB S:B). In each condition, listeners were tested first in the more favorable +4 dB S:B condition and then in the more challenging 0 dB S:B condition. Tests were conducted using a digitized version of the eight original audio-taped 50-sentence lists of the Revised Speech Perception in Noise Test (SPIN-R; Bilger et al., 1984; also see Kalikow et al., 1977). The order of lists was arranged across participants such that each of the eight lists was presented once in each of the six test conditions and no lists were repeated for a given listener. The listener’s task was to report the last word of each sentence immediately after its presentation. Word identification accuracy in each condition was measured by scoring the number of sentence-final target words that the participant correctly reported after the presentation of each sentence in the 50-sentence form used in that condition.

Apparatus and Stimuli • Sentences were those of the SPIN-R test. Each list of the SPIN-R consists of an audio-recording of 50 sentences on one channel and accompanying multitalker babble on a second channel. The speech and babble are presented monaurally, with the average level of each adjusted to achieve the desired signal-to-background ratio (S:B). In half of the sentences in each form of the test, the last word is predictable from the sentence context (e.g., The wedding banquet was a feast.) and in the other half it is not predictable (e.g., We could consider the feast.)

Speech sentences were presented in three different backgrounds. One background was the multitalker babble from the SPIN-R test. Two music backgrounds, one with 1950s music and the other with 1990s music, were prepared and aligned to the SPIN-R sentences. The music backgrounds were composed of carefully selected segments drawn from 32 different Karaoke versions of popular recordings (nonvocal instrumental versions of recordings that had ranked highly in the Billboard charts in the respective decade; see Table A1 and A2 for details). Music segments were selected so as to vary minimally with regard to variability in local root-mean-square. Additional data on envelope modulation was determined by calculating the crest factor for each background music selection (ratio of peak amplitude to root-mean-square amplitude). The crest factor has been used to predict loudness and forward masking. For complex tones, a higher crest factor leads to higher loudness but paradoxically, lower masking effectiveness (Gockel et al., 2003). Although the crest factors for 1990s music (M = 6.73 dB) and 1950s music (M = 6.13 dB) were similar, the difference was statistically significant, t (399) = 4.30, p < 0.0001, which raises the possibility of an acoustical advantage for speech processing in a background of 1990s music if a higher crest factor in music also leads to lower masking effectiveness (The average crest factor for babble was 16.07 dB). The sentences and the three backgrounds were digitized at a sampling rate of 20 kHz (16-bit), mixed, and presented monaurally over TDH-50P earphones using a Tucker-Davis Technology System II for digital-to-analog conversion and to control sentence and background levels.

The average sound levels of the speech and background signals were calculated and used to set the presentation levels. A comparison of the spectra of

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Younger Mean (SD)</th>
<th>Older Mean (SD)</th>
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</thead>
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<td>5.6 (1.99)</td>
<td>9.4 (3.19)</td>
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<td>500</td>
<td>1.9 (1.32)</td>
<td>8.1 (2.66)</td>
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<tr>
<td>1000</td>
<td>0.0 (0)</td>
<td>7.5 (1.34)</td>
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<td>1500</td>
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<td>6.3 (2.27)</td>
</tr>
<tr>
<td>2000</td>
<td>0.6 (0.63)</td>
<td>7.5 (2.5)</td>
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<td>3000</td>
<td>0.6 (0.63)</td>
<td>14.4 (1.13)</td>
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<tr>
<td>4000</td>
<td>0.6 (0.63)</td>
<td>18.8 (2.95)</td>
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<tr>
<td>6000</td>
<td>6.9 (1.88)</td>
<td>30.6 (5.04)</td>
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<tr>
<td>8000</td>
<td>3.8 (1.83)</td>
<td>41.9 (8.07)</td>
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TABLE 1. Mean (and standard error) of pure-tone thresholds in dB HL for younger and older listeners in experiment 1 at audiometric test frequencies from 250 to 8000 Hz.
the three different backgrounds relative to the speech spectrum is shown in Figure 1 and illustrates that sound energy was distributed similarly across frequencies for all three backgrounds, with the average sound pressure level in the speech range (from 0.1 to 4 kHz) for the three backgrounds differing by less than 0.5 dB*. The level of the speech was set at 50 dB above the listener’s threshold for babble. The backgrounds were adjusted to achieve the two different S:B conditions. All testing was conducted in a double-walled sound-attenuating International Acoustics Company sound booth.

**Results**

Figure 2A illustrates the basic pattern of results for sentences in multitalker babble in the current and an earlier study (Pichora-Fuller, et al., 1995). Figures 2B, C illustrate the basic pattern of results for sentences in 1950s and 1990s music, respectively. Consistent with previous work, word identification in babble was better for sentence-final target words in high-context sentences (M = 90.52, SE = 1.08) than for words in low-context sentences (M = 54.08, SE = 1.44), and it was better in the 4 dB S:B condition (M = 78.68, SE = 1.16) than in the 0 dB S:B condition (M = 65.92, SE = 1.17). Furthermore, greater benefit from high context was found when the S:B condition was more challenging, and conversely greater benefit from increasing S:B was found when the context condition was less supportive. Collapsing across backgrounds, the percentage of words correctly identified did not differ between the younger (M = 71.64, SE = 1.76) and older age groups (M = 72.96, SE = 1.24). Note that the older adult participants in the current study performed similarly to those in earlier studies using these materials with the standard multitalker babble background, but the younger adult participants in the current study did not perform as well as has been found previously.

The new finding from the present study is that word identification was superior when the background was music (M = 73.64, SE = 1.32) compared with babble (M = 69.64, SE = 1.48). The benefit of listening to words in a background of music compared with babble was more pronounced in the more challenging listening conditions. Specifically, the benefit of listening with a music compared with a babble background was greater for words presented in low-context sentences (5.2%) than for words presented in high-context sentences (+2.8%), and in 0 dB S:B (+7.9%) than in 4 dB S:B (+0.1%). For younger participants, the advantage of music over babble as a background was particularly acute when the music was familiar (i.e., music from the 1990s). As shown in Figure 3, the type of background had a negligible influence on word identification for older adults, but it had a striking influence on word identification for younger adults, particularly in the low S:B conditions. For younger adults, word identification scores were higher when the background was music from the 1990s (M = 78.52, SE = 1.88) than when the background was music from the 1950s (M = 68.36, SE = 2.24) or when the background was babble (M = 68.0, SE = 2.24). For older adults, word identification scores varied minimally with background (M = 74.88, SE = 1.64;
These descriptions of our findings were confirmed by a mixed design analysis of variance (ANOVA) with age as the between-subjects factor (younger versus older) and context (high versus low), signal-to-background (0 versus 4 dB S:B) and background (1990s music, 1950s music, and babble) as within-subjects factors. There was no main effect of age,
1. There were significant main effects of context, $F(1, 14) = 704.50, p < 0.0001$, S:B, $F(1, 14) = 222.79, p < 0.0001$, and background, $F(2, 28) = 13.15, p < 0.0001$. The effect of background interacted significantly with age, $F(2, 28) = 4.19, p < 0.05$, context, $F(2, 28) = 7.89, p < 0.01$, and S:B, $F(2, 28) = 4.3, p < 0.05$ (A follow-up ANOVA using arcsine transformed scores yielded the same pattern of main effects and interactions). A post-hoc Student-Neuman-Keuls test of multiple comparisons confirmed that for younger adults, word identification was better when the background was 1990s music than when the background was 1950s music or babble ($p < 0.001$), but scores did not differ in the latter two conditions ($p > 0.1$). For older adults, word identification scores across background conditions were not significant different from each other ($p > 0.1$). There was a significant interaction between context and S:B, $F(1, 14) = 4.89, p < 0.05$. No other interactions were significant.

**Discussion**

The pattern of word identification scores in babble was consistent with previous work with the exception of the lack of an overall age effect in the current study. The lack of an age effect seems to be attributable to relatively poor performance by younger participants in the current study compared with previous studies. Differences in audiometric thresholds of younger participants in this present study compared with previous studies do not provide an explanation for the relatively poor speech performance we observed. Another possible explanation for the discrepancy may be that the language acquisition criteria were less strict in the present study. Adults who learned English after puberty are known to perform worse on speech in noise tests compared with monolinguals or those who learned English by the age of six, although early bilinguals may also function less well than monolinguals (Mayo, et al., 1997; Rogers, et al., 2006). In the present study, two of the younger participants were bilinguals who learned English before the age of 5 yrs and one of them was the worst performing younger adult. Although age of language acquisition has been found to contribute to speech performance in other studies, it does not seem to adequately explain the differences between younger participants in the current study and their peers in previous studies.

Our predictions about word identification in different background conditions were supported for the young adults. Specifically, word identification scores were better for music than for babble and they were better for familiar music than for unfamiliar music, but only for the younger participants.

The advantage to word identification performance realized in music backgrounds may be because of the lower level of similarity between the speech foreground and the music background compared with the similarity between the speech foreground and the babble background. This lower level of similarity may have led to less informational masking, thereby providing listeners with an opportunity to simultaneously track the foreground (speech target) and background (music).

Another possible explanation of the advantage of music over babble backgrounds concerns the degree of modulation. The time waveform of music has characteristic dips in the amplitude occurring at regular intervals. These dips may provide an opportunity for listeners to hear speech in the dips that is
not afforded by the more uniform time waveform of babble.

The advantage of music over babble backgrounds is consistent with recent work on the acceptable noise level (ANL) for speech. ANL has been proposed as an alternative measure for hearing aid success and has been defined as the maximum level of background noise that an individual is willing to accept while listening to speech. ANL's for backgrounds consisting of music tend to be better (i.e., closer to speech levels) than backgrounds consisting of multitalker babble, indicating that listeners are more willing to accept music as a background (Gordon-Hickey & Moore, 2007).

The advantage of familiar music for younger adults may be interpreted in at least two ways that are not mutually exclusive of each other. One possibility is that familiar music led to an advantage for younger adults because they were able to use knowledge about how a piece unfolds to generate expectancies. The generation of expectancies may have improved stream segregation because knowledge of the music background could have enabled selective filtering at strategic points in time (Expectancies may also have a retroactive effect within a limited window of time; see Grossberg, 2003). This streaming account posits that younger listeners may have intentionally shifted their focus of attention to the background for brief periods. In the case of familiar background music, conscious processing of the background music may have facilitated streaming, outweighing any potential loss resulting from shifting the focus of attention away from the target speech. In the case of unfamiliar background music, shifting the focus of attention may have had a punitive effect on word identification with minimal benefit from streaming (absence of veridical expectancies). With older adults, there was likely relatively little shifting of attention to the background music, or else relatively uncontrolled switching because of a failure of inhibitory control, so familiarity of the music would not have had much bearing on word identification.

In addition to its influence on attention, familiarity may influence memory. In dual-process models of memory, recognition, and recollection are regarded as functionally independent. Jacoby (1996) has suggested that recognition can occur automatically without attention at the encoding stage because of familiarity, whereas recollection requires conscious processing. Thus, if a listener who is closely attending to foreground speech is asked to make a recognition judgment concerning whether or not a particular music selection occurred in the background, they should display a high rate of false alarms; that is, judgments would likely be biased by familiarity. If however, the background music were consciously processed (even for a brief period), a listener could base their judgment on familiarity and on conscious recollection. Accordingly, recognition memory for background music may serve as a probe to assess the extent and nature of attention shifting. Experiment 2 used a surprise recognition memory test to determine whether younger adults consciously process background music to a greater extent than older adults.

### Experiment 2: Music Recognition and Familiarity Test

The primary objective in this experiment was to assess the extent to which nonvocal background music is consciously processed when the listener's task is to identify words in foreground speech. The extent of conscious processing of familiar and unfamiliar background music was assessed with a recognition memory test. The recognition memory test was administered after completion of a word identification task in which speech items were presented in a background of music.

Speech stimuli were drawn from the low-context sentences of the SPIN-R. Only low-context sentences were tested because the differences in word identification between music and babble backgrounds were observed for low-context sentences in experiment 1.

We predicted that all listeners would divide attention to some extent, resulting in above chance recognition memory for background music. However, we expected that younger listeners would be more likely to shift the focus of conscious attention to background music, thereby out-performing the older listeners in recognition memory for background music. This prediction assumes that not all cognitive resources would be allocated to the word identification task and that some resources would be allocated to listening to the music background, but that older listeners would need to allocate relatively more cognitive resources to listening to speech to compensate for age-related auditory declines. Furthermore, both age groups were expected to have better recognition memory for familiar music than for unfamiliar music. Although older adults generally benefit from familiarity to a greater extent than younger adults, we predict the reverse trend here because the familiarity in question is familiarity with the background rather than familiarity with the target. Thus, we expected that older listeners would have fewer cognitive resources available to be allocated to listening to the background compared with younger adults. Furthermore, if inhibitory
deficits resulted in older adults allocating attentional resources to listening to the background then they would have done so in a less controlled or conscious manner compared with younger listeners.

A secondary objective in this experiment was to validate the assumed familiarity of popular music from the different eras. Previous research has shown that listeners tend to be most familiar with music learned in late adolescence and early adulthood (Cohen, 2005; Schulkind, et al., 1999). This finding is consistent with the Plasticity Framework for Music Grammar Acquisition that asserts that exposure to music during a critical period (either the first or second) lays the foundation for which music will or will not be readily encoded in the future (Cohen, 2000). The first critical period is in childhood, laying the foundation for tonality. The second critical period is in late adolescence and early adulthood, laying the foundation for stylistic preferences (for a discussion see Cohen, 2000). Consistent with this framework, we expected that younger listeners would be most familiar with music from the 1990s and that older listeners would be most familiar with music from the 1950s.

Methods

Participants • Participants were recruited from the university community. All had participated in previous listening studies involving the SPIN-R materials, but none had participated in experiment 1 of the present study. Sixteen participants with ages ranging from 18 to 28 yrs were recruited for the younger adult group (M = 20.5, SE = 0.58). Sixteen participants with ages ranging from 65 to 80 yrs were recruited for the older adult group (M = 70.69, SE = 1.12). All participants had normal hearing in the speech range (see Table 2) and were native speakers of English (i.e., English was the primary language spoken since age 5 yrs or earlier). The number of years of formal education completed was not statistically different for younger (M = 14.81, SE = 0.52) and older adults (M = 15.28, SE = 0.89), t (30) = −0.45, p > 0.05. In addition, the scores on the Mill Hill Vocabulary test were not statistically different for younger (M = 14.2/20, SE = 0.23) and older adults (M = 15.3/20, SE = 0.68), t (30) = 1.57, p > 0.05. Finally, all participants provided informed consent and received financial remuneration for their participation.

Procedure • The experiment consisted of three tests: (1) mock word identification test; (2) music recognition test; and (3) music familiarity test. Participants had no advance knowledge that a recognition recall or familiarity test would take place. All participants were tested individually. All three tests were completed in a single session lasting less than 1 hr.

Test 1: Mock Word Identification Test • Participants were asked to report the final word of each of 25 sentences presented in a background of multitalker babble or music. The background for sentences 1 through 10 consisted of multitalker babble. The background for sentence 11 was music from the 1950s (practice trial). The background for sentences 12 through 25 also consisted of music, half from the 1950s and half from the 1990s. The order of the music background trials was fully randomized without blocking for era of music.

Test 2: Music Recognition Test • All participants were presented with the same 28 music selections in one of four predetermined random orders. Fourteen of the music selections (seven from the 1950s and seven from the 1990s) were drawn from those presented as background during the word identification test (test 1) and 14 were foils (seven from the 1950s and seven from the 1990s). For each music selection, participants were required to judge whether or not it had been presented in the background during the word identification test. One practice trial preceded the test phase. The music selection for the practice trial was drawn from the background during sentence 12 of the word identification test.

Test 3: Music Familiarity • Participants were asked to judge their degree of familiarity (before the day of testing) with each of the 28 music selections presented in test 2. For each participant, music selections were presented in one of four predetermined random orders with the provision that the orders between tests 2 and 3 being different. The participants judged their familiarity with each music selection on a 4-point scale (after Thompson & Russo, 2004), with higher numbers corresponding to greater familiarity:

| TABLE 2. Mean (and standard error) of pure-tone thresholds in dB HL for younger and older listeners in experiment 2 at audiometric test frequencies from 250 to 8000 Hz |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | 250             | 500             | 1000            | 1500            | 2000            | 3000            | 4000            | 6000            | 8000            |
| Younger         | 6.9 (1.20)      | 2.5 (0.65)      | 2.5 (0.79)      | 3.8 (1.16)      | 3.1 (1.28)      | 0.9 (0.50)      | 1.6 (1.56)      | 5.3 (1.85)      | 8.1 (3.68)      |
| Older           | 7.5 (1.44)      | 8.8 (1.68)      | 8.8 (1.48)      | 10.3 (1.25)     | 11.3 (1.74)     | 11.9 (2.18)     | 19.7 (2.21)     | 31.9 (4.21)     | 35.9 (4.31)     |
1. I’m NOT AT ALL FAMILIAR with this music selection;
2. I’m A LITTLE FAMILIAR with this music selection;
3. I’m SOMEWHAT familiar with this music selection;
4. I’m VERY FAMILIAR with this music selection.

Apparatus and Stimuli • In the present experiment, each of the 25 low-context sentences from list 1 of the SPIN-R was presented in one of three possible backgrounds. The backgrounds were the original multitalker babble from the SPIN-R test, selections of popular music from the 1950s, and selections of popular music from the 1990s (All music selections were drawn from those used in experiment 1). The sentences and the three backgrounds were digitized at a sampling rate of 20 kHz, and were presented monaurally over TDH-50P earphones using a Tucker-Davis Technology System II for digital-to-analog conversion and to control sentence and background levels.

The multitalker babble background was temporally aligned with the first 10 sentences as in the original SPIN-R test. Each popular music selection was aligned to 1 of the remaining 15 low-context sentences. The average sound levels of the speech and background signals were calculated and used to set the presentation levels. The level of the speech was set at 50 dB above the listener's threshold for babble. Based on the results of the individual participants in a previous study, the level of the background was adjusted for each listener to achieve the S:B where he or she was expected to score 75% correct on low-context items (following Schneider, et al., 2000). Note that although the speech signal levels were slightly higher for older listeners (M = 73.31 dB SPL, SE = 1.47) than for younger listeners (M = 67.25 dB SPL, SE = 0.62), t (30) = 3.8, p < 0.001, S:B levels were not significantly different between the two groups (M = 5.81 and 5.13 dB S:B, SE = 0.49 and 0.41, respectively), t (30) = 1.08, p > 0.05. Furthermore, for both groups the levels of presentation of the speech are typical of everyday conversational levels, and S:B is typical of a suburban living room (Pearson, et al., 1976).

For the recognition memory and familiarity phases of the experiment, the 14 music selections from the word identification phase (sentences 12 through 25) were presented along with 14 foils. The 14 foils consisted of seven additional selections of popular music from the 1950s and seven additional selections of popular music from the 1990s. For each participant, the average level of the music in the latter two phases of the experiment was identical to the average level of at which speech had been presented in the first phase of the experiment for the mock word identification test. The same average level was used for the selections of music to be recalled and the foils. All testing was conducted in a double-walled sound-attenuating International Acoustics Company sound booth.

Results and Discussion

Although familiarity ratings were collected last, the results are described first because they influenced the manner in which recognition recall accuracy was analyzed.

Familiarity • Figure 4 plots the mean familiarity rating for each 1950s and 1990s selection for each age group. Figure 5 plots familiarity as a function of musical era for all listeners in each age group. Younger listeners were less familiar with the 1950s music selections (M = 1.78, SE = 0.17) than with the 1990s music selections (M = 2.49, SE = 0.11), and older listeners were less familiar with the 1990s
music selections ($M = 1.71, SE = 0.11$) than with the $1950s$ music selections ($M = 2.65, SE = 0.18$). These
descriptions of our findings were confirmed by a
mixed design ANOVA with age as the between-
subjects factor and era of music as the within-
subjects factor.

Although no significant effects were observed for
age ($F = 1$) or era ($F = 1.90$), the interaction between
these two variables was significant, $F(1, 30) = 98.60, p < 0.0001$. A post-hoc Student-Neuman-
Keuls test of multiple comparisons confirmed that
for younger adults, $1990s$ music was more familiar
than $1950s$ music ($p < 0.001$), and for older adults,
$1950s$ music was more familiar than $1990s$ music
($p < 0.001$). The post-hoc test also confirmed that
the difference between younger listeners’ familiarity
with $1990s$ music and older listeners’ familiarity
with $1950s$ music was not significant. Thus, our
prediction about familiarity of music across age
groups was validated. Henceforth, in referring to
familiar music we refer to music from the $1990s$ in
the case of younger listeners and music from the
$1950s$ in the case of older listeners. We acknowledge,
however, that a piece of music that is familiar to an
older listener may not be equally accessible to mem-
ory as would be a piece of music that is familiar to a
younger listener because of differences in the length
of time since encoding.

Recognition • Participants’ responses on the rec-
ognition recall test were assessed using signal de-
tection theory (MacMillan & Creelman, 1991). As
seen in Figure 6, for younger adults, there was both
a higher hit rate and a lower false alarm rate
compared with older adults. Thus, subsequent rec-
ognition of the music selections from the earlier
mock word-identification phase, expressed as $d^'$,
was higher for younger adults ($M = 1.47, SE = 0.25$)
than for older adults ($M = 0.32, SE = 0.13$), $t(30) =
4.086, p = 0.001$. Nonetheless, as expected, both
younger and older adults performed better than
chance ($d^' = 0$), respectively, $t(15) = 5.88$ and $2.5$, $p < 0.05$.

It is doubtful that the striking advantage dis-
played by younger adults in recognizing music back-
grounds is attributable exclusively to age-related
differences in memory. Increasing evidence has been
accumulated suggesting that many aspects of short-
term memory (e.g., temporal order memory recogni-
tion and visual memory) are relatively unaffected by
aging (McIntosh, et al., 1999; Sekuler, et al., 2006).
The age-related differences observed are perhaps
better understood in terms of differences in attention. Specifically, younger listeners may intention-
ally switch their attentional focus to a meaningful
background more than older listeners, at least when
the primary task is speech perception.

To further assess age differences in attending to
background music, the false alarms rates for famil-
iar and unfamiliar music were determined for each
age group. As seen in Figure 7, for younger partici-
pants, false alarm rates were higher for unfamiliar
music ($M = 0.39, SE = 0.05$) than for familiar music
($M = 0.08, SE = 0.03$). This pattern is consistent
with the idea that younger adults may intentionally
switch their attentional focus to a meaningful, fa-
miliar background. However, for older participants,
false alarm rates were higher for familiar music
($M = 0.49, SE = 0.05$) than for unfamiliar music
($M = 0.34, SE = 0.05$). Jacoby (1996) has shown that
in the absence of conscious processing, memory for a
stimulus will be biased by its familiarity. Thus, for

Fig. 5. Mean rating of familiarity by era for all listeners in each
age group. Top panel includes all younger listeners and
bottom panel includes all older listeners.

Fig. 6. Mean and standard error of hit and false alarm rate
(displayed as percentage) in the recognition task for younger
and older listeners.

Recognition • Participants’ responses on the rec-
ognition recall test were assessed using signal de-
tection theory (MacMillan & Creelman, 1991). As
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($M = 0.34, SE = 0.05$). Jacoby (1996) has shown that
in the absence of conscious processing, memory for a
stimulus will be biased by its familiarity. Thus, for
older adults, the higher false alarms rate for familiar music than for unfamiliar music is consistent with the interpretation of minimal conscious processing of the music background during the word identification test.

These descriptions of our findings for false alarms were confirmed by a mixed design ANOVA that revealed a significant interaction between age and familiarity, $F(1, 30) = 33.63, p < 0.0001$. A post-hoc Student-Neuman-Keuls test of multiple comparisons confirmed that for older adults, false alarm rates were higher for familiar music than for unfamiliar music ($p < 0.05$), but for younger adults, false alarm rates were higher for unfamiliar music than for familiar music ($p < 0.001$).

The age-related differences in recognition memory found here are consistent with the findings of a similar study in which the background was speech from a foreign language. Tun et al. (2002, experiment 2) had younger and older listeners do a word identification task while presenting meaningful speech or nonmeaningful speech (foreign language) in the background. Results showed that younger adults were more likely than older adults to recognize meaningful speech items in a surprise recognition test of the background items. It seems likely that younger adults in both studies transferred the balance of attention to backgrounds more than did older adults.

In summary, although we found that both younger and older listeners process background music during a word identification task, their pattern of age-related differences suggest that younger and older listeners do not process background music in the same manner. First, younger listeners were better able to remember background music played during the prior word identification task than were older listeners. Second, the pattern of false alarms suggests that younger listeners were consciously processing background music to a greater extent than were older listeners, especially for familiar music.

**General Discussion**

In experiment 1, we found that for younger adults, word identification was better when the background was music than when it was babble, and it was better when the music was familiar than when it was unfamiliar. In contrast, for older adults, word identification was not influenced by the type of background. This pattern of findings suggests that younger and older adults listen to foreground speech in background music differently.

In experiment 2, we found that older listeners had more difficulty than younger listeners in remembering music that was heard during a prior word identification task. The pattern of false alarms suggests that younger listeners were consciously processing the task-irrelevant music background. Older listeners had a higher rate of false alarms, particularly for familiar music, suggesting that they were primarily basing recognition recall judgments on their familiarity with music before the experiment. In other words, it seems that younger listeners attempted to “tune in” to the music background, but that older listeners attempted to “tune out” the music background. However, because overall recognition performance for older listeners was above chance, it is not the case that older adults were suppressing the music entirely.

Younger listeners seem to be able to use the familiarity of music to their advantage. Specifically, by attending to familiar music, they are able to enhance performance on the word identification task. This apparent release from masking may have been achieved by an enhancement to streaming ability conferred by a well-attended signal (Alain & Izenberg, 2003). Increased attention would enable the generation of expectancies, leading to better segregation between speech and music. Similar benefits may have been conferred by unfamiliar music; however, the enhancement to streaming would be somewhat limited because there would be relatively less attention drawn to unfamiliar music and less veridical knowledge about how the piece unfolds.

The “tune out” approach adopted by older listeners may be part of a cascade of effects that originates with difficulty hearing speech in noisy environments. It is well known that expectancies have costs and benefits associated with signal detection (Posner, et al., 1980). An older adult with compromised ability to hear speech in adverse backgrounds may benefit from the generation of expectancies concern-
ing a speech target. Expectancies can guide attention resulting in improved streaming (Snyder, et al., 2006). The associated cost may be a reduction in ability to generate expectancies and retroactively filter events in the background.

The age-related differences observed in the present study and the attentional hypothesis may seem at first to run counter to a large body of theory and evidence concerning purported deficits in the abilities of older adults to inhibit attention to task-irrelevant information (Alain & Woods, 1999; Hasher & Zacks, 1988; Hasher, et al., 2006). However, in two recent reviews, Burke and colleagues have underscored the need to disentangle age-related changes in sensory and perceptual encoding of signals from the possibility of age-related inhibitory deficits post encoding (Burke & Osborne, in press; Burke & Shafot, 2007). If older adults “tune out” background music to a greater extent than younger adults, one might speculate that we have here an example of conditions in which older adults actually have enhanced ability to inhibit task-irrelevant information. An alternative and less controversial explanation is that the younger listeners were entertaining multiple objectives (i.e., tracking foreground and tracking background), whereas older listeners were focused on a single objective most clearly linked to the prescribed task (i.e., tracking foreground). Indeed, if one accepts the notion about the usefulness of attention to background, either tracking foreground and background or tracking foreground alone can be considered to be task-relevant. Task relevance and the balance of resources allocated to foreground and background are both influenced by perceptual and cognitive limitations (e.g., Kemper, et al., 2003).

Another possible source of the age-related differences observed in this study may concern cultural learning. Our older adult listeners would not have been exposed to as much background music in their youth as our younger adult listeners would have been (Schafer, 1977). These formative experiences may have shaped the way in which the respective adult groups choose to manage their auditory environments. Younger adults may be more likely (and have more opportunity) than older adults to intentionally introduce background music in contexts where music listening is not the primary objective. This type of experiential learning with complex acoustical environments may sharpen ability to divide and shift the focus of attention between foreground and background streams.

Our interpretation of the results uses a common framework to account for age-related differences in listening behavior. This framework considers the interplay of attention, expectancy, and streaming on listening outcomes. We propose that in both age groups, there is an initial separation of the auditory input by an automatic streaming mechanism. In younger listeners, this separation may be relatively successful, allowing for attention to be focused on either the speech or music streams. Attention on the music stream may facilitate expectancy generation and retroactive filtering, which may in turn further enable segregation of the independent streams. In older listeners, this preliminary separation may be relatively unsuccessful, encouraging focused attention on the speech stream.

In the current study, we show that for younger listeners, familiarity with a music background can be beneficial for understanding the foreground. We have suggested that this benefit was due in part to the generation of expectancies about the music background leading to improved streaming. It would be useful to investigate whether or not the benefit would persist in a music background specifically designed so as to deny expectancy for a musical event that was temporally overlapped with the target word in the speech stream. If younger listeners are selectively filtering out the music background on the basis of expectancy, an appropriately timed denial of musical expectancy should lead to a deficit in word identification. This type of experiment might also be useful in disentangling the extent to which the benefits of attending to a background may be attributed to top-down versus bottom-up expectancy.

In sum, younger and older adults seem to differ in their listening behavior when listening to speech in the presence of background music. This is not surprising insofar as older adults generally have greater difficulty understanding speech in complex acoustical environments. It seems that their solution to the challenges presented by a sound environment consisting of a music background is to focus attention on the speech foreground. In contrast, younger listeners choose to attend to both the speech foreground and music background. Other backgrounds that are both meaningful and predictable may present similar challenges and solutions that lead to age-related differences in listening outcomes in everyday life. Explanation of these differences may benefit from consideration of the dynamic interplay between attention, expectancy, and streaming.

Acknowledgments

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**TABLE A1. 1950s Music**

<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Artist</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>Jailhouse rock</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>That’ll be the day</td>
<td>Buddy Holly</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>All shook up</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>Jazzboss</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>Love me tender</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1957</td>
<td>Rockin’ pneumonia</td>
<td>Huey Smith and the Clowns</td>
<td>6</td>
</tr>
<tr>
<td>1956</td>
<td>Come go with me</td>
<td>Dell-Vikings</td>
<td>18</td>
</tr>
<tr>
<td>1956</td>
<td>Blue suede shoes</td>
<td>Elvis Presley</td>
<td>20</td>
</tr>
<tr>
<td>1956</td>
<td>Heart break hotel</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1956</td>
<td>Hound dog</td>
<td>Elvis Presley</td>
<td>1</td>
</tr>
<tr>
<td>1956</td>
<td>Be-bop-a-lula</td>
<td>Gene Vincent and his blue caps</td>
<td>7</td>
</tr>
<tr>
<td>1954</td>
<td>Shake, rattle &amp; roll</td>
<td>Joe Turner</td>
<td>7</td>
</tr>
</tbody>
</table>

*Year corresponds to first year of release; Title is the title of the track from which Karaoke versions were based; Artist is the performing artist or group; Peak is top position in Billboard Hot 100 Singles Charts (Billboard, 2007). Chart rankings are based on airplay and sales.*

**TABLE A2. 1990s Music**

<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Artist</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>What a girl wants</td>
<td>Christina Aguilera</td>
<td>1</td>
</tr>
<tr>
<td>1999</td>
<td>I need to know</td>
<td>Marc Anthony</td>
<td>3</td>
</tr>
<tr>
<td>1999</td>
<td>I want it that way</td>
<td>Backstreet Boys</td>
<td>1</td>
</tr>
<tr>
<td>1999</td>
<td>One week</td>
<td>Barenaked Ladies</td>
<td>1</td>
</tr>
<tr>
<td>1999</td>
<td>Livin’ La Vida Loca</td>
<td>Ricky Martin</td>
<td>1</td>
</tr>
<tr>
<td>1998</td>
<td>Slide</td>
<td>Goo Goo Dolls</td>
<td>8</td>
</tr>
<tr>
<td>1998</td>
<td>I’ll Be</td>
<td>Edwin McCain</td>
<td>5</td>
</tr>
<tr>
<td>1997</td>
<td>Zoot Suit Riot</td>
<td>Cherry Poppin’</td>
<td>32</td>
</tr>
<tr>
<td>1997</td>
<td>Every day is a winding road</td>
<td>Sheryl Crow</td>
<td>11</td>
</tr>
<tr>
<td>1997</td>
<td>Together again</td>
<td>Janet Jackson</td>
<td>1</td>
</tr>
<tr>
<td>1997</td>
<td>Foolish games</td>
<td>Jewel</td>
<td>2</td>
</tr>
<tr>
<td>1997</td>
<td>Truly madly deeply</td>
<td>Savage Garden</td>
<td>1</td>
</tr>
<tr>
<td>1996</td>
<td>I don’t want to wait</td>
<td>Paula Cole</td>
<td>8</td>
</tr>
<tr>
<td>1996</td>
<td>Where have all the cowboys gone</td>
<td>Paula Cole</td>
<td>11</td>
</tr>
<tr>
<td>1994</td>
<td>Kiss from a rose</td>
<td>Seal</td>
<td>1</td>
</tr>
<tr>
<td>1994</td>
<td>Kiss me</td>
<td>Sixpence None the Richer</td>
<td>1</td>
</tr>
<tr>
<td>1992</td>
<td>If I had a million dollars</td>
<td>Barenaked Ladies</td>
<td>1</td>
</tr>
</tbody>
</table>

*Year corresponds to first year of release; Title is the title of the track from which Karaoke versions were based; Artist is the performing artist or group; Peak is top position in Billboard Hot 100 Singles Charts (Billboard, 2007). Chart rankings are based on airplay and sales.*

*Although this is one of the band’s best-known songs and was ranked No. 2 on the Canadian Broadcasting Corporation’s “Top 50 Canadian Tracks in History”, it was never released as a US single and thus does not have an official Billboard peak position. The single was part of a live album released in 1997 that peaked at 86 in the Billboard.*

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**REFERENCES**


AUTHOR QUERIES

1—Dwyan & Jacoby, 1990; Hay & Jacoby, 1999; Jacoby, 1999; and Jacoby, et al., 2005 are not cited anywhere in the text. Kindly insert their citation at an appropriate place or delete the same.

2—Kindly update this reference, if possible.


4—Kindly check Grossberg, S. (1998b) in this reference has been deleted is OK.

5—Kindly confirm whether the affiliations are OK as typeset and provide division/department name for the third affiliation.