The Effects of Age and Experience on Memory for Visually Presented Music

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Increased age is often associated with lower levels of performance in tests of memory for spatial information. The primary question in the current study was whether this relationship could be moderated as a function of one's relevant experience and/or knowledge. Stimulus materials consisted of short (7–11 note), visually presented musical melodies and structurally equivalent nonmusical stimuli. Participants (N = 128) were recruited from a wide range of age and experience levels. Although there were strong main effects of age and experience on memory for music, there was no evidence that the age-related differences in memory for these stimuli were smaller for individuals with moderate to large amounts of experience with music.

ONE important question in the aging literature that has yet to result in a definite answer concerns the relations among age, experience, and performance on domain-relevant tasks. Although age effects in the direction of lower performance in older adults have been reported on many types of memory tasks (see Smith, 1996; Craik & Jennings, 1992, for reviews) and other cognitive tasks (see Craik & Salthouse, 1992; Blanchard-Fields & Hess, 1996, for reviews), the positive effects of experience on domain-relevant tasks might be expected to moderate these age-memory relations. A finding of this type would suggest that normal age differences may be minimized or eliminated on domain-relevant tasks with high levels of experience in that domain.

Prior research investigating relations of age and experience on domain-specific memory has yielded inconsistent results. For instance, in a study of memory for chess positions, Charness (1981a) found significant effects of age and skill (and presumably experience) and an interaction of age and skill on a measure of the mean number of chunks recalled per position, but the interaction was not significant on the proportion of chess pieces recalled. Experience did not eliminate age differences in pilots recalling aviation narratives, or recalling route, altitude, speed, and frequency commands, but there was an attenuation of age differences with experience for pilots recalling air traffic control message heading commands (Morrow, Leirer, & Altieri, 1992; Morrow, Leirer, Altieri, & Fitzsimmons, 1994).

Studies including tasks other than recall have also been inconsistent with respect to whether relevant experience can reduce the magnitude of age differences. For instance, older experienced typists are able to maintain a high level of overall typing speed although they are slower in tapping rates and choice reaction times than younger typists of the same net typing speed (Salthouse, 1984; Bosman, 1993). This maintenance of skill across age may be a result of preserved ability to execute typing-related movements despite age differences in the translation component of typing (Bosman, 1994). Clancy and Hoyer (1994) also reported a significant interaction of age and experience such that experience attenuated the negative effects

of age in visual search of pathology slides. However, significantly lower performance with increased age has been found in the spatial abilities of architects, despite a large correlation between age and presumably relevant job experience (Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990). Salthouse and Mitchell (1990) also found little evidence for an Age × Experience interaction in measures of spatial ability in a sample of unselected adults.

In the domain of music, Krampe and Ericsson (1996) recently reported a study in which the effects of age (younger/older) and piano expertise group (amateur/expert) were investigated on several musical and nonmusical tasks. The results of their study were mixed as to whether expertise can attenuate age differences in musical performance. On two speeded motoric tasks, a significant interaction of age, expertise group, and task type (musical/nonmusical) was found such that greater expertise was associated with smaller age differences on the musical but not on the nonmusical task. However, on performance force variation and musical interpretation, two measures claimed to be "critical factors that reflect musical knowledge to a high degree" (p. 334), no interactions of age and expertise group were reported. A significant interaction might have been expected on these measures because they are presumably sensitive to musical knowledge and thus may have been more domain-relevant than the motoric tasks. Because of this inconsistent pattern, no strong conclusions can be reached from the Krampe and Ericsson (1996) study regarding the role of expertise in minimizing age differences in musical performance.

The effects of musical expertise and age have also been studied on cognitive musical tasks. Halpern, Bartlett, and Dowling (1995) studied the effects of experience (musician/nonmusician), age (younger/older), and tonality (tonal/atonal) on the auditory recognition of transposed melodies. In only one of four experiments did they find a significant interaction of age and experience in the direction of smaller age differences in musicians than nonmusicians, and there was no evidence for the attenuation of age effects with experience on an old/new recognition task. Thus, there was only weak evidence in their

study for experience-based attenuation of age differences on the recognition of musical melodies.

It is possible that failure to find an age by experience interaction in the Halpern et al. (1995) and other studies is a result of differing levels of domain-relevancy in the tasks. Morrow and his colleagues (Morrow et al., 1994) have suggested that "expertise (domain knowledge) can compensate hypothesized age declines in the cognitive resources necessary to perform pilot tasks when both materials and procedures are highly relevant to piloting" (p.145). Therefore, although the materials used by Halpern and her colleagues (i.e., aurally presented melodies) were presumably domain-relevant, the music transposition recognition task may not have been highly relevant to experience with music.

In particular, their recognition task may not have been highly domain-relevant because it did not draw heavily on knowledge acquired through experience. One piece of evidence that supports this conclusion is the absence of an Experience × Tonality interaction on recognition performance in that study. If musical experience leads to a greater knowledge of the tonal structure of Western music, then experienced musicians might be expected to outperform less experienced musicians on the tonal melodies. That is, an Experience × Stimulus Type interaction would be predicted such that experienced participants are able to use their knowledge of musical structure to recognize those excerpts consistent with their knowledge, but are less successful at recognizing excerpts that are inconsistent with their knowledge. The absence of this interaction in the Halpern et al. (1995) study makes it difficult to eliminate the possibility that the musically experienced were relying solely on their experience with aurally presented music, rather than on an acquired knowledge of the tonal structure of Western music. Thus, although there were experience effects on this task, the greater amounts of experience may not have been accompanied by increased levels of domain knowledge necessary to compensate for the negative effects of age. Alternatively, experienced participants may have possessed the relevant domain knowledge, but the constraints of the task might have been such that it was not necessary to use it to perform the task.

One of the most convincing ways to establish that stimulus materials and experimental tasks are relevant to a particular domain is to demonstrate a relation between performance on the critical task and experience in that domain while demonstrating little relation between experience and performance on tasks not relevant to the domain. Two preliminary studies were therefore conducted to investigate possible experiential effects on a task involving memory for visually presented musical melodies and formally similar nonmusical stimuli (see Meinz, 1996, for a more complete description of the studies). The musical stimuli are domain-relevant because with a few exceptions, exposure to printed music is involved in almost all musical experiences, and the task might be considered domain-relevant because short-term memory for visually presented music is most likely a component in musical sight-reading.

All participants in these initial studies were college students because the goal was to examine relations of experience to performance on the experimental tasks. The musical stimuli in each study were visually presented 7- to 11-note melodies, and the nonmusical stimuli consisted of meaningless symbols on a background of concentric circles (see Figure 1). In both cases, memory was assessed by immediate written reproduction of the stimulus patterns after each of four brief (5-second) presentations. Questionnaires containing a wide variety of items concerned with type and frequency of experience with music were also administered to all participants in the preliminary studies.

The major result in both studies was a significant interaction of experience and stimulus type such that the effects of musical experience were much larger in the memory for musical stimuli than for nonmusical stimuli. Moderate positive correlations between the index of musical experience and memory for musical stimuli (i.e., $r = .56$ in Preliminary Study 1, and $r = .47$ in Preliminary Study 2) but not for nonmusical stimuli (i.e., $r =$ in Preliminary Study 1 = .28, and $r = .22$ in Preliminary Study 2) were also found in both studies. In addition, in the second preliminary study, a brief test of musical notation knowledge was administered. Performance on this test was highly correlated with experience ($r = .80$), and additional analyses indicated that the effects of musical experience on recall were largely mediated through this measure of knowledge. This finding, along with the interactions of experience and stimulus type and the strong correlations between experience and memory for musical stimuli, suggested that the combination of these stimuli and the immediate recall task were highly domain-relevant. These materials and similar procedures were therefore used in the study to be reported in which a moderately large sample of adults were recruited with a wide range of age and musical experience.

Although most memory tasks involve a single recall attempt with each stimulus, three successive attempts were allowed in the current study. One reason for allowing multiple recall attempts was a desire to obtain sensitive measures of performance, and we were concerned that the average level of performance might be very low on the first recall attempt, especially in those participants with little musical experience. The second reason for requiring three successive recall attempts with the same stimuli was to investigate possible interactions of attempt with age or experience. This is potentially informative because, for example, if older adults are simply slower at encoding the information, then one might expect the age differences in memory performance to decrease across successive recall attempts because of the additional opportunities for effective encoding. Alternatively, the age differences might increase across attempts as in a study by Charness (1981b) in which there were greater age-related differences in recall performance with increased study time.

To summarize, participants of a wide age and experience range were studied to investigate the moderating effects of experience on the relations between age and spatial memory performance. Of particular interest was a possible interaction of age and experience on the recall of musical stimuli, such that experienced individuals would show little or no age differences on these stimuli, whereas in keeping with reports of age-related spatial memory decline (Cherry & Park, 1993; Park, Cherry, Smith & Lafronza, 1990; Salthouse, 1995), individuals with little or no experience would show substantial age-related differences. A three-way interaction of musical experience, age, and stimulus type might also be expected if experience attenuated the effects of age on memory for musical but not for nonmusical stimuli.

Because time limitations were anticipated, all participants completed the musical stimuli portion of the testing, and only those finishing in sufficient time also performed the recall task with nonmusical stimuli. The tasks were administered on computers to provide greater control of the testing environment and to facilitate subsequent scoring and analyses.

METHOD

Participants

One hundred forty-one participants were tested. However, the data from 13 participants were not analyzed because of incomplete data attributable to failure to follow directions, failure to complete the session, or computer malfunctions. Therefore, the analyses to be described are based on 128 participants. The participants were recruited through general newspaper ads, through special recruiting at schools of music and music retail stores, and through a local musicians' union.

Participants ranged in age from 18 to 83, and their self-reported number of years participating in musical activities on a primary instrument ranged from 0 to 60. Special efforts were made to recruit pianists because the visual memory task was presumed to be similar to both sight-reading and memorization, both of which may be especially important to the development of a pianist. Fifty percent of the participants listed piano as their primary instrument, with the primary instruments of the remaining participants listed as either brass, woodwind, string, or percussive instruments. Background characteristics of the participants performing the musical memory task, and of the 53 participants who also performed the nonmusical memory task, are summarized in Table 1. A series of t-tests were conducted to compare the subsample performing both the musical and nonmusical tasks ($N = 53$) with the subsample only performing the musical task ($N = 75$) on the variables listed in Table 1. There were no significant ($p<.01$) differences between the groups except on age, such that the subgroup completing both tasks was younger ($M = $

40.8, $SD = 13.0$) than the subgroup completing only the musical task ($M = 49.8$, $SD = 16.2$). In addition, none of the correlations between age and the variables was significantly different between the subgroups.

Materials

Musical experience was assessed by analyzing responses to a questionnaire containing questions concerned with the frequency and type of experience with music. A newly devised test of musical notation knowledge was also administered to all participants. This test was designed to assess knowledge of written music, with portions of the test querying knowledge of pitch, rhythm, key signatures, and chords. The test was in matching form, that is, the correct answers were selected from a set of between 5 and 10 alternatives, and had a maximum score of 42. Participants were asked to identify the names of musical notes on the bass and treble staves; to identify the number of beats indicated by different note symbols; to identify major key signatures; and to identify major, minor, diminished, and augmented chords. The reliability of the test, computed by Cronbach's alpha, was .98. Descriptive statistics on the individual questionnaire items and the musical notation test are listed in Table 2.

All musical stimuli were melodies between 7 and 11 notes long, and were adapted from 7-note sequences described by Dowling (1991). These melodies were "tonally strong items that started and ended on the tonic, that constituted clearly tonal patterns in the key, and that were 'melodious' in the sense of using relatively small pitch intervals" (Pechstedt, Kershner, & Kinsbourne, 1989, cited in Dowling, 1991). The 7–11 note melodies were constructed by adding notes within the key structure to the melodies taken from the Dowling work and adding rhythm by assigning values to the pitches. No measure had fewer than two or greater than six notes. Melodies were in common time and were drawn from all possible major keys.

Rhythms were randomly assigned from all possible combinations of a specified number of notes. The possible note val-

Table 1. Participant Characteristics: Complete Sample and Sample with Nonmusic Data

Variable	Entire Sample			Participants with Nonmusic Data		
	Mean	SD	Age r	Mean	SD	Age r
n	128	—	—	53	—	—
Age	46.1	15.6	—	40.8	13.0	—
% Female	66.4	—	—	60.4	—	—
Education	15.7	2.9	−0.16	16.4	2.9	−0.14
Health rating	1.9	0.9	−0.06	2.0	1.0	0.21
Vocabulary	13.4	5.0	0.13	13.3	5.1	0.34
Years of musical activity- primary instrument	12.5	15.1	0.15	12.0	13.6	0.14
Hours/week musical activity- currently	4.6	8.7	−0.18	6.4	10.7	−0.14
Hours/week musical activity- most active time	14.9	15.8	−0.24*	16.7	19.1	−0.18
Self-rated musical ability	2.7	1.3	−0.26*	2.8	1.4	−0.30
Musical notation knowledge test	19.3	14.5	−0.21	20.7	14.4	−0.21

Note: Education refers to years of formal education, and health rating is a self-assessment on a scale ranging from 1 = excellent to 5 = poor. The vocabulary score is the sum of the number of correct responses (maximum = 20) across synonym and antonym multiple choice tests. Self-rated musical ability is based on a 1 (poor) to 5 (excellent) scale.
*$p < .01$

ues included dotted half (3 beats), half (2 beats), dotted quarter (1½ beats), quarter (1 beat), eighth (½ beat), and sixteenth (¼ beat). None of the melodies were assigned the same sequence of rhythms. The order of note values was assigned in such a way that the combination of melody and rhythm seemed typical of Western music, as judged by two individuals with greater than 10 years of music experience each. Key and time signatures as well as clef were provided to the participant.

The nonmusical background was constructed to be similar in all of its components to the musical staff. The musical staff consists of five lines divided into two measures, and the nonmusical background was five concentric circles divided into two equal halves. The symbols were also constructed to be similar to musical notation, but not recognizable as music. There was a nonmusical stimulus paired with each musical stimulus, such that a 1:1 mapping could place symbols on both the staff and circle. Extra symbols were included on the circle to parallel the key and time signatures on the musical stimuli. The nonmusical stimuli were, however, arranged according to a different pitch order than the music. For example, the D in a musical stimulus corresponded to an E in the nonmusical stimulus. The pattern in which the nonmusical stimuli were arranged was composed so as to reduce the possibility of encoding by any tonal music strategy. An example of a musical stimulus and the corresponding nonmusical stimulus are shown in Figure 1.

Design and Procedure

In the single session lasting between 2 and 2.5 hours, participants completed a consent form, a demographic information sheet, two brief vocabulary measures (multiple-choice synonym and antonym tests described in Salthouse, 1993), the musical notation test, and the musical experience questionnaire. They then received supervised practice using the computer interface to reproduce the musical melodies. There were three practice melodies, with the first provided to the participant on a piece of paper so that he or she could practice using the interface without relying on memory. Informal comments collected by participants indicated that three practice trials were sufficient to be comfortable in using the interface. Two blocks of six melodies each followed the practice trials, and an additional block of six nonmusical stimuli on the circular, nonmusical background was administered if time permitted. The stimuli in this last block were formally identical to those in the first block of musical stimuli, but converted to nonmusical stimuli. The presentation order was always practice (music), music, music, practice (nonmusic), nonmusic. Two sets of melodies were used, each with equal numbers of melodies of differing lengths. Set one was used in the first music condition and the nonmusical condition, and set two in the second music condition.

Participants viewed the stimulus presented on a computer screen for 5 seconds, and then attempted to reproduce the ob-

Table 2. Descriptive Statistics on Experience Measures (N = 128)

Experience Measure	Mean	SD	Range	% minimum responses	Component Loading			
					C1	C2	C3	C4
Years of musical activity-primary instrument	12.5	15.1	0–60.0	12.5	0.66	0.38	0.10	−0.16
Years of musical activity-secondary instrument	4.7	8.8	0–41.0	44.5	0.60	0.32	0.27	−0.44
Years of private study-primary instrument	4.8	5.6	0–24.0	28.1	0.59	0.39	−0.30	0.28
Years of private study-secondary instrument	1.2	2.7	0–16.0	64.8	0.48	0.31	0.12	0.06
Number of paid performances	245.7	774.2	0–5000.0	64.8	0.46	0.53	0.55	0.13
Number of solo recital performances	12.8	26.9	0–150.0	35.9	0.43	0.36	−0.25	0.39
Number of accompanying performances	47.7	163.9	0–1300.0	67.2	0.48	0.29	0.10	0.61
Number of ensemble performances	238.6	620.1	0–3500.0	35.2	0.50	0.53	0.49	−0.15
Hours/week alone practice-currently	2.1	4.5	0–30.0	64.1	0.73	−0.57	0.14	0.01
Hours/week alone practice-most active time	9.3	9.9	0–45.0	13.3	0.82	−0.07	−0.40	−0.23
Hours/week deliberate alone practice-currently	1.5	3.9	0–30.0	68.0	0.66	−0.63	0.20	0.06
Hours/week deliberate alone practice-most active time	7.3	8.9	0–42.0	15.6	0.78	−0.07	−0.30	−0.28
Hours/week total musical activity-currently	4.6	8.7	0–45.0	53.9	0.78	−0.27	0.28	0.11
Hours/week total musical activity-most active time	14.9	15.9	0–70.0	11.7	0.87	0.12	−0.20	−0.03
Hours/week sight reading-currently	0.8	2.2	0–20.0	67.2	0.61	−0.63	0.14	0.00
Hours/week sight reading-most active time	3.1	4.4	0–24.0	27.3	0.57	−0.20	−0.24	−0.00
Hours/week memorization-currently	0.7	1.6	0–10.0	77.3	0.57	−0.57	0.35	0.17
Hours/week memorization-most active time	3.0	4.3	0–20.0	34.4	0.67	−0.15	−0.30	0.19
Self-rated musical ability	2.7	1.3	1.0–5.0	22.7	0.73	0.24	−0.03	−0.15
Self-rated sight reading ability	2.3	1.3	1.0–5.0	38.3	0.70	0.26	−0.27	−0.09
Eigenvalues					8.37	2.99	1.60	1.11
Proportion of variance accounted for					0.42	0.15	0.08	0.06
Correlation with age					−0.12	0.04	0.15	−0.10
Correlation with corrctly placed musical stimuli (third attempt)					*0.63	0.21	0.02	0.03
Correlation with correctly placed nonmusical stimuli (third attempt)					0.04	−0.20	0.03	−0.03
Correlations with subjective overall similarity rating					*0.65	0.21	0.00	0.03
Musical notation knowledge test — Descriptives and correlations with the components	19.3	14.5	0–42.0	12.5	*0.75	0.19	0.05	0.02

*p < .01

served pattern on a musical staff or nonmusical background that appeared on the computer screen. The recall attempts were produced by pressing arrow keys to position the desired note on the staff, and then using the arrow keys to identify which type of note (i.e., quarter, half, eighth) was to be placed in the chosen position. An example of the computer interface is illustrated in Figure 2. After the participants had placed all of the notes they could remember, the "Enter" key was pressed to view the stimulus again for five seconds. The second stimulus presentation was followed by a second recall attempt in which the previously placed notes were displayed and could be added to, changed, or deleted. A total of three presentations and recall attempts were administered in this manner for each stimulus. Participants were thoroughly debriefed following the testing.

Scoring

Each symbol placed on the staff was assigned one of four score types: correct, correct placement, correct symbol, or incorrect. Correct scores were those that were correct both in placement as well as in symbol type. A correct placement score was assigned to responses in which the vertical position on the musical staff or nonmusical background was correct, but the symbol chosen was incorrect. Those correct symbols with in-

correct vertical or horizontal positioning were designated as correct symbol, and those with incorrect symbol type and placement were designated as incorrect. Although it was possible for participants to correct their incorrect responses across repeated recall attempts, no significant decreases in the number of errors across attempts occurred for any error type. Additionally, the frequency of errors was quite low in all cases (i.e., means of less than 1.1), and thus the error analyses will not be discussed further.

Two criteria were used to score the reproduction responses. The conservative criterion began scoring each response symbol at the beginning of the melody, matching sequentially, so that, for example, the third symbol in the response melody was scored against the third symbol in the stimulus. This criterion is conservative because it does not account for possible insertions or omissions.

The liberal criterion also began scoring each response symbol at the beginning of the melody, however, when it reached a symbol that was incorrect (i.e., not matching on symbol or placement), a serial search was performed until an item matching on either symbol type or vertical position was found. Once a match was found, the search continued with the next symbol from the stimulus note that was last matched. If no match was

Figure 1. Example of a musical stimulus and the corresponding nonmusical stimulus.

Figure 2. Illustration of musical and nonmusical stimuli computer interface.

found, the symbol was scored as incorrect, and the scoring resumed at the next symbol. This scoring criterion is more liberal than the conservative criterion because it takes insertions and omissions into account on the scoring. However, the correlation between these two criteria was very high ($r = .99$), and consequently all subsequent analyses were performed using the conservative criterion.

A subjective scoring method was also used with the musical stimuli to evaluate possible qualitative dimensions of recall performance. The final response attempt for each of the 1536 (i.e., 128 × 12) response patterns was independently rated on four criteria by a musician with over 15 years of musical experience: tonality, rhythm, contour, and overall similarity to the stimulus melody. The ratings ranged from 1 (completely dissimilar) to 5 (identical). Inter-rater reliability, assessed by comparing the ratings on a subset of 96 stimuli with a second independent rater, was high ($r = .94, .95, .97,$ and $.96$ for overall similarity, rhythm, contour, and tonality, respectively).

As one might expect, the correlations among the ratings for these attributes were high (i.e., $r > .84$). Correlations between the four rating scales and the computer-derived scores were also quite high. To illustrate, the correlations between number of symbols correctly placed (conservative criterion) and ratings of overall similarity, rhythm, contour, and tonality were $.97, .93, .88,$ and $.93$, respectively. Because these high correlations imply that the different types of scores were very similar, all subsequent analyses were based on the computer-derived (conservative) scores.

For the following analyses, correct scores from each attempt on the musical stimuli were averaged across the 12 stimulus patterns, and the correct scores from each attempt on the non-musical stimuli were averaged across the 6 stimulus patterns. Reliability of the musical recall, computed by using the Spearman-Brown formula to boost the correlation between the average correct scores on the final attempt for the two blocks, was greater than .99.

RESULTS

Musical experience

A principal components analysis was performed on the experience questionnaire items to transform them into a few, more general variables that could parsimoniously account for the variance in the original questionnaire items. Each component represents a weighted linear composite of the questionnaire items and accounts for the greatest possible proportion of the variance in the items that is distinct from the variance already explained by the preceding components. Loadings of the questionnaire items on the four components with eigenvalues greater than 1.0 are listed in Table 2.

The first principal component, C1, was chosen as the primary measure of musical experience because it was associated with a large proportion of the total variance (42%), and because all of the questionnaire items had fairly high loadings on this component (> 0.4). Although each of the remaining components had some items with high loadings, they were not easily interpretable and may have been indicators of professional musical experience (i.e., accompanying, ensemble performance, and paid performances). In addition, each of these components accounted for considerably smaller amounts of variance than the first (15% or less) and none correlated significantly with musical recall. Correlations of the experience components with age, musical notation knowledge, and recall on the two stimulus types are reported in Table 2.

Domain-Relevance

Stimulus type effects. — Before proceeding to more complex analyses, it was first necessary to confirm that the performance measure in this task was relevant to musical experience. One way to do this was to determine whether the Experience × Stimulus Type interaction was significant. Only those participants who completed the recall task with both stimulus types were included in this analysis. Characteristics of this subsample ($N = 53$) are contained in Table 1, and correlations among experience, musical knowledge, age, and recall for this sample are listed in Table 3. Note that although the subsample was somewhat younger than the total sample, the subsample still had a wide range of age and was comparable with the total sample on most relevant characteristics.

Using only the subsample's data for both musical and non-musical stimuli, regression analyses were conducted with stimulus type and experience as predictors of recall accuracy. Recall attempts were largely cumulative, and the range of scores was larger with successive attempts, and thus, this analysis was performed on the final recall attempt only. There were significant main effects of stimulus type, $F(1,51) = 133.72$, (Ms [and SDs] = 4.7(2.6), and 1.9(1.4) for musical and nonmusical stimuli, respectively), and experience, $F(1,51) = 29.44$, but these effects were qualified by an interaction of stimulus type and experience, $F(1,51) = 70.80$. As expected, this interaction was attributable to significant effects of experience on the musical stimuli (i.e., $F(1,51) = 64.96$, $\beta = .75$) but not on the nonmusical stimuli (i.e., $F(1,51) = .07$, $\beta = .04$).

Table 3. Correlations Among Experience, Musical Notation Knowledge, Memory Performance, and Age

	1	2	3	4
1. Age		−0.12	−0.17	−0.43*
2. Experience[a]	−0.11		0.75*	0.63*
3. Musical notation knowledge test	−0.21	0.85*		0.81*
4. Musical memory	−0.31	0.75*	0.87*	
5. Nonmusical memory	−0.35	0.04	0.18	0.34

Note: Above the diagonal are correlations for all subjects (N = 128). Below the diagonal are correlations for only those with nonmusical data (N = 53).
[a]Experience refers to the first principal component from the analysis of the experience questionnaire.
*$p < .01$.

Musical knowledge. — Another indication that performance measures are domain-relevant is sensitivity to domain knowledge. Indeed, it was argued earlier that the absence of an Experience × Tonality interaction in the Halpern et al. (1995) study could be attributable to weak experience-knowledge relations. Thus, it is our argument that experience alone is not sufficient to produce strong experience-performance relations; rather, experienced individuals must possess higher levels of relevant knowledge, presumably acquired through relevant experience, and the performance measure must be sensitive to this knowledge to be considered domain-relevant.

Therefore, another analysis was performed predicting recall performance on the final attempt, this time with knowledge (i.e., score on the musical notation test) and stimulus type as predictors. There was a significant main effect of knowledge, $F(1,51) = 70.73$, but not of stimulus type, $F(1,51) = .13$. Most importantly, the interaction of stimulus type and knowledge was significant, $F(1,51) = 99.63$, which was attributable to significant main effects of knowledge on the musical stimuli, $F(1,51) = 162.68$, $\beta = .87$, but not on the nonmusical stimuli, $F(1,51) = 1.79$, $\beta = .18$.

These two sets of results clearly indicate that the measures of musical memory in the current study are sensitive to experience with music and to knowledge about musical notation that is presumably acquired with experience. Subsequent analyses, therefore, focused on the interrelations of age and experience on these measures.

Age and Experience Effects

Nonlinear relations. — Initial analyses were conducted to determine the magnitude of any nonlinear effects of age and experience on the musical recall measure (final attempt). Hierarchical regression analyses were used for this purpose with the quadratic age or quadratic experience term introduced after first controlling for the linear effects of that variable. The results did not reveal a significant quadratic effect of age, $F(1,125) = .26$, $\beta = .24$, after control for the significant linear effect of age; however, there was a significant quadratic effect of experience, $F(1,125) = 14.99$, $\beta = -.37$, after control of the linear experience effect. The significant quadratic effect of ex-

perience reflected a tendency for the relations between experience and memory performance to be stronger with greater amounts of experience. Although the nonlinear pattern was significant, the proportion of variance associated with the quadratic trend was small relative to that associated with the linear trend (i.e., $R^2 = .04$ vs .40), and consequently the nonlinear relations were ignored in subsequent analyses.

Age × Experience × Attempt. — Table 4 contains the mean number of symbols correctly recalled as a function of experience level, age decade, and attempt number. A repeated measures regression analysis was conducted on these data with age, experience, and attempt number as predictors of musical recall. Scores on successive attempts were largely cumulative because, for example, the symbols from Attempt 1 were included in the score from Attempt 2 unless symbols were deleted by the participant. The main effects of attempt, $F(2,248) = 164.48$, age, $F(1,124) = 29.33$, and experience, $F(1,124) = 30.59$, were qualified by interactions of attempt and age, $F(2,248) = 35.26$, attempt and experience, $F(2,248) = 12.20$, and experience and age, $F(1,124) = 7.65$. The three-way interaction of age, experience, and attempt was not significant, $F(2,248) = 2.50$, $p = .09$.

Examination of the means involved in these relations revealed that participants placed significantly more correct notes on each successive trial (Ms and $SDs = 1.4(1.1)$, $2.9(2.1)$, and $4.0(2.5)$ for the first, second, and third attempts, respectively), and that this increase in correct placements was greater for experienced than inexperienced participants and lesser for older than for younger participants. The discovery that the benefits of repeated presentations were greater for experienced and young individuals suggests that the poorer performance of older and inexperienced individuals was not simply attributable to a slower or less effective initial encoding of the stimuli, because there was no tendency for the deficits to be remediated with repeated presentations. Because analyses revealed similar patterns of results on each attempt, and because recall attempts were largely cumulative, all subsequent analyses were performed using performance from the final attempt as the measure of recall.

The significant interaction of experience and age was not in

Table 4. Mean Number of Musical Symbols Correctly Placed Presented by Age Decade, Experience Level, and Attempt Number

| | Age Decade | | | | | | | | | | | |
| | 20 | | 30 | | 40 | | 50 | | 60 | | 70 | |
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Inexperienced												
N	9		10		16		16		11		5	
Attempt 1	1.3	0.4	0.9	0.4	0.8	0.4	0.8	0.5	0.6	0.4	0.8	0.9
Attempt 2	2.6	0.9	1.9	0.9	1.7	0.8	1.6	1.0	1.0	0.7	1.5	1.8
Attempt 3	4.0	1.8	2.9	1.1	2.6	1.0	2.4	1.6	1.3	0.9	2.3	2.8
Experienced[a]												
N	14		13		15		8		10		4	
Attempt 1	2.5	1.1	1.9	1.2	2.3	1.1	2.5	1.5	1.2	0.8	1.3	0.9
Attempt 2	5.1	2.1	4.0	2.4	4.4	2.0	4.6	2.3	2.5	1.3	1.6	0.8
Attempt 3	7.0	2.0	5.6	2.7	6.0	2.2	5.9	2.1	3.7	1.5	2.1	1.3

Note: The mean number of symbols across the 12 melodies was 8.83, and thus, this is the maximum possible in each cell.
[a]Experience level was obtained by dichotomizing experience by the median score on the first principal component from the experience questionnaire.

the predicted direction because experienced musicians did not show smaller age differences on recall of the musical stimuli than inexperienced participants. Instead, the opposite appears to be true, in that there were smaller age differences among inexperienced than among experienced musicians, most likely because of floor effects in the older, inexperienced participants. Figure 3 illustrates this trend with data from the final attempt, with experience dichotomized by dividing the sample into high and low groups at the median of the composite index of experience. The low experience group in this illustration corresponds to a mean of 2.6($SD = 2.8$) years of musical activity on a primary instrument, a mean of 0.3($SD = 0.9$) hours per week of current musical activity, and a mean of 0.1($SD = 0.6$) current hours per week of practice alone. The high experience group corresponds to means of 22.3($SD = 15.9$), 9.0($SD = 10.6$), and 4.1($SD = 5.6$) on these activities, respectively.

Additional Analyses Conducted for Interpretation of the Age × Experience Interaction

Other measures of experience. — Although the results summarized in Table 2 indicate that most of the experience questionnaire items had moderate to high loadings on the first principal component, separate analyses were conducted using each

Figure 3. The Age × Experience (dichotomized by median score on the first principal component from an experience questionnaire) interaction for musical stimuli. Maximum mean number of symbols correctly placed = 8.83. The mean age was 47.9 ($SD = 14.1$) for the low experience participants and 44.2 ($SD = 16.8$) for the high experience participants, with ranges of 22–79 and 18–33 years, respectively.

individual item as the experience measure. Individual experience item correlations with musical memory varied from .16 to .60, but with none of the experience measures was the interaction of age and experience significant in the direction of smaller age differences in the more experienced participants.

Moderation versus mediation. — The primary focus in this study was on the moderating effects of experience on the relations between age and memory, but small negative correlations between age and some experience measures (see Tables 1 and 2) raise the possibility that lower levels of experience in the older sample might have actually mediated some of the negative age relations. If this were the case, the age differences should be substantially attenuated after statistical control of musical experience. Although the effects of age on musical recall were reduced after controlling for experience, i.e., $R^2 = .19$ for age alone and .14 after control of the first experience component, the residual effect of age was still significantly greater than zero. Repeating the regression analyses with a sample consisting of only the upper half of the experience distribution also revealed no evidence for moderation of age effects with experience, $F(1,60) = 3.15, p > .07$, or for a smaller age correlation with musical recall ($r = -.48$). Thus, the age differences observed in musical recall were most likely not attributable to lower levels of experience in the older participants.

Recency of experience. — Because of the rather high correlation between age and years since musical activity ceased (i.e., $r = .44$), it was possible that the lack of the predicted age by experience interaction was due to variations in recency of experience. Indeed, Ericsson and Charness (1994), in discussing the existence of age-related decline across experience levels, have suggested that "much of the age-related decline in performance may reflect the reduction or termination of practice" (p.744). Moreover, Krampe and Ericsson (1996) reported that an important predictor of alternate hand tapping speed in pianists was the amount of deliberate practice in which a pianist was engaged during the past 10 years. Thus, maintenance of domain-relevant skills may depend on the degree to which relevant deliberate practice is continued in later years.

Given this interpretation, one might expect a significant three-way interaction of age, experience, and recency of experience in the direction of larger experience-based moderation of the age relations for individuals with greater amounts of recent experience. However, regression analyses revealed that the interaction of age, experience, and recency of experience (the number of years since musical activity ceased) was not significant, $F = 1.78, p = .19$, and furthermore, there was still a negative correlation between age and correct recall (i.e., $r = -.53$) when the sample was limited to only recently active participants (i.e., those with musical activity within the past 3 years, $N = 61, M_{age} = 45.9(15.1)$). Therefore, the results of these analyses do not provide support for a moderation of experience effects by recency of experience. Additionally, it does not appear that older adults change their patterns of musical engagement such that they spend most of their time playing familiar pieces rather than sight-reading, because when the sample was restricted to include only those participants who reported that they currently spent time sight-reading in an av-
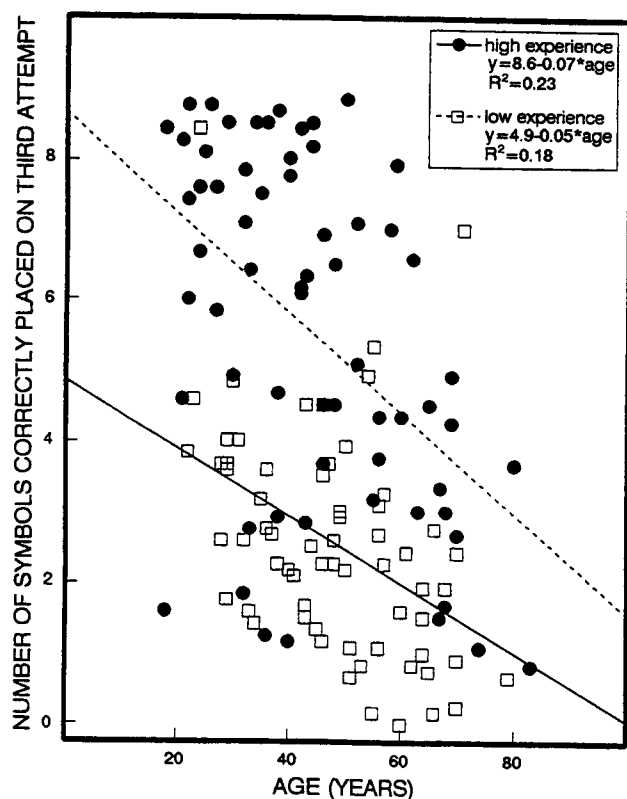
erage week, the correlation between age and correct music recall was still significantly negative (i.e., $r = -.54$).

Instrument analyses. — Although special efforts were made to recruit pianists for this study, those listing piano as a primary or secondary instrument comprised only 67% of the sample; therefore, the results might have been moderated by instrument effects. If instrument effects moderated the effects of experience on recall, then an interaction of experience and instrument might be expected when predicting musical recall from primary instrument (piano/nonpiano), experience, and age. In addition, if instrument effects moderated the effects of age on recall, then an interaction of age and experience might be expected. However, there was no evidence to suggest that there was an effect of instrument on correct recall of musical stimuli, $F(1,120) = .06$, that experience effects were moderated by type of instrument, $F(1,120) = 1.39$, or that age effects were moderated by type of instrument, $F(1,120) = .06$. The three-way interaction of age, experience, and instrument type was also nonsignificant, $F(1,120) = 2.47$.

Response bias. — Because there was a significant correlation between age and the average number of symbols placed in the final attempt regardless of accuracy ($r = -.34$), there might have been an age-related response bias in that relative to young adults, older adults could have been less inclined to guess when uncertain. Nonetheless, when the total number of symbols placed (correct and incorrect) was used as a covariate in the Age × Experience analysis, the pattern of results in this analysis was identical to that of the initial analysis. Also, it does not appear that certain individuals concentrated more on pitch values (vertical position) than rhythms (note type), because when all responses with correct pitch values were used as the dependent measure, the pattern of results was similar to that of the initial analyses with the exception of a nonsignificant interaction of age and experience (i.e., $F(1,124) = 1.91$).

Relations Between Experience and Knowledge

To further explore the relationship between domain experience and knowledge, and to investigate the possibility that the effects of experience on tasks within a domain are mediated through knowledge about that domain, the effects of experience were examined before and after control of the musical notation knowledge measure. Hierarchical regression analyses with experience and score on the notation test as predictors of musical recall revealed that there were no additional significant effects of experience on recall performance after performance on the musical notation test was held constant. The F and R^2 values associated with experience were 142.95 and .40, respectively, when experience was the only predictor, but only .74 and .00 after control of the knowledge variable. This pattern of results suggests that the effects of musical experience on this task were almost entirely mediated through the measure of musical notation knowledge.

It could be argued that the current musical recall task is qualitatively different for those who have no musical background because for those individuals the stimuli would consist of meaningless configurations of unfamiliar stimuli, whereas individuals with a background in music would be able to code the musical symbols as meaningful notes. To investigate this

possibility, similar analyses were performed using only those participants who scored above 19 on the notation knowledge test. Even when using this more select sample ($N = 59$), however, the same pattern of results emerged in that there was no significant effect of musical experience on musical recall after controlling for knowledge, $F(1,56) = .13$. Furthermore, the pattern of age effects on musical recall in this sample was similar to that of the entire sample, with a significant negative correlation between age and musical recall ($r = -.60$).

DISCUSSION

The major result of this project was the failure to find an attenuation of the negative effects of age on memory for domain-relevant stimuli with increased experience. Although the results of previous studies have been inconsistent as to whether experience can reduce age differences on domain-relevant tasks, attenuation was predicted because the current task was believed to be highly domain-relevant on the basis of the significant relations between experience and recall performance in the preliminary studies and in the primary study. Additional evidence for the relevance of the stimuli was in the form of a significant Knowledge × Stimulus Type interaction on recall, which is important given the argument that experience effects alone may not be a sufficient condition for establishing the relevance of a task to a domain.

Despite strong effects of experience and of knowledge on recall of the musical stimuli, and strong age-related effects on memory for both musical and nonmusical stimuli, there was no evidence in this study that greater amounts of experience moderated the effects of age on performance in a domain-relevant task. Several possible explanations for this finding were explored, but the absence of the predicted Age × Experience interaction could not be accounted for by recency of experience, reductions in sight-reading activity, response biases, or instrument effects. Moreover, although the brief exposure period (5 seconds) might have been a disadvantage for the older adults, the presence of an Age × Attempt interaction, in which age differences were actually larger with more attempts, indicates that older adults were not able to capitalize on the repeated exposures to the stimuli. Finally, the possibility that some of the negative effects of age might have been mediated by decreased amounts of experience was explored, but there was little attenuation of age-related effects after control of the available measure of experience.

A discovery of a significant Age × Experience interaction on musical recall would have been consistent with the view that older adults were able to maintain high levels of performance in a domain-relevant spatial memory task despite lower levels of performance on general spatial memory tasks because of the positive effects of experience. In other words, because people often continue to engage in musical activities late into life, they might have been expected to somehow circumvent declining abilities to maintain high levels of performance in tasks relevant to their experience. However, despite the use of a task in which moderately large experience effects have been established, even considerable experience with music (up to 60 years) was unable to compensate for the age-related differences in memory performance on this particular task.

One factor that may have contributed to the observed age differences in this study was that the computer interface could

have placed a large burden on the working memory of participants. Age-related working memory limitations have been well-documented (e.g., Salthouse, 1994), and thus the use of an unfamiliar computer interface could have contributed to the poor performance of older adults. Several efforts were made to minimize the influence of this factor. First, the interface was relatively simple and included the use of only six different keys with no time pressure. Second, extensive guided practice was given, usually lasting around 15 minutes, and feedback from the participants indicated that they were comfortable with the interface by the end of the third practice trial. Nonetheless, although the same pattern of experiential relations was found in preliminary studies with undergraduate participants using paper-and-pencil versions of this task, we cannot rule out the possibility that older adults were differentially penalized by the computerized nature of this task. That is, older adults might have found the conversion of the stored stimulus information to a novel interface difficult because of working memory limitations. Also, because of this slower conversion, older adults might have had a longer interval between the presentation of the stimulus and the time taken to recall the stimuli, which would necessitate holding the presented stimuli in working memory for a longer period of time. One means by which this interpretation might be investigated would involve repeating the study with a different type of response mode, such as recognition or actual reproduction of the melody on an instrument.

The results of this study are also relevant to the issue of how experience exerts its effects on cognitive performance. That is, an interpretation suggested by the current results is that the effects of experience on a task might be explained by the specific knowledge and skills gained through experience. The discovery that most of the effects of experience on the present task were mediated through the measure of musical notation knowledge is clearly consistent with this view. However, we suspect that other types of knowledge or skills would be needed to account for the effects of experience on more complex musical activities. For example, the recall of longer, more complex melodies might draw on more detailed knowledge of musical notation or of relations among musical notes.

In conclusion, this project capitalized on the breadth of musical experience, musical knowledge, and age in the general population in illustrating the skilled memory effect in music, documenting relations among experience, knowledge, and domain-relevant memory, and in examining the effects of experience on the relations between age and domain-relevant recall performance. Because no attenuation of the age differences with increased amounts of experience was found in this study, the challenge remains to characterize tasks in which there are little or no age-related differences and to identify the processes that allow older adults to maintain high levels of performance despite lower levels of functioning in many cognitive abilities.

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