Music-Dependent Memory: The Roles of Tempo Change and Mood Mediation

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Music-dependent memory was obtained in previous literature by changing from 1 musical piece to another. Here, the phenomenon was induced by changing only the tempo of the same musical selection. After being presented with a list of words, along with a piece of background music, listeners recalled more words when the selection was played at the same tempo than when it was played at a different tempo. However, no significant reduction in memory was produced by recall contexts with a changed timbre, a different musical selection, or no music (Experiments 1 and 2). Tempo was found to influence the arousal dimension of mood (Experiment 3), and recall was higher in a mood context consistent (as compared with inconsistent) with a given tempo (Experiment 4). The results support the mood-mediation hypothesis of music-dependent memory.

Context-dependent memory (CDM) refers to a change in context or environment that causes some of the material learned in the original context to be forgotten. McGeoch (1952) first formally proposed the principle, calling it altered stimulus conditions. The CDM effect has been obtained with various context manipulations, including place (e.g., Godden & Baddeley, 1975; Smith, 1979; Smith, Glenberg, & Bjork, 1978), olfactory cues (Cann & Ross, 1989; Schab, 1990), time of day (Holloway, 1978); gender of speaking voice (Geiselman & Gleny, 1977), alcohol or drug states (e.g., Eich, 1980), and mood states (e.g., Bower, Monteiro, & Gilligan, 1978; Eich, 1995b; Eich & Metcalfe, 1989; Lewis & Williams, 1989). Despite the variety and number of studies reporting CDM, however, the reliability of these effects has been questioned (Bjork & Richardson-Klavehn, 1989). For instance, Fernandez and Glenberg (1985) did not find place-dependent memory, and Bower and Mayer (1989) and Mueller, Grove, and Thompson (1991) did not report reliable mood-dependent memory effects.

Background music has recently been found to affect memory, thus joining the list of CDM contexts (Balch, Bowman, & Mohler, 1992; Smith, 1985). In these studies, performed with typical CDM procedures, a series of words was presented along with a particular selection of music. Later, recall for the words was tested. Participants recalled fewer words when a different piece as compared with the same piece was played.

This type of CDM (i.e., music-dependent memory) is the particular concern of the present research. Our central purpose is to explain why music-dependent memory occurs. However, the key issues addressed in this study are also relevant to CDM effects obtained by the manipulation of other contexts, such as mood (e.g., Eich, 1995b) or place (e.g., Smith et al., 1978).

The first issue addressed here is the identification and testing of specific contextual changes that might induce music-dependent memory. In previous studies, the CDM effect has generally been obtained with procedures involving a number of simultaneous changes in context. For instance, Balch et al. (1992) and Smith (1985) induced the effect by playing one musical selection—called the presentation or learning context—during presentation of the words and a different selection during recall. The presentation and recall contexts thus differed in the sense of their overall identities and presumably in a multiplicity of specific musical features or dimensions. Some of these changes include differences in the tempo, the timbres of the instruments playing the music, the harmonic sequences, and the probably the moods induced by the music.

Compound differences have also been used in obtaining CDM effects with other contexts: In place-dependent memory studies, researchers have used different rooms with different furnishings (e.g., Smith, 1979), differently furnished rooms containing different olfactory cues (Dalton, 1993), or different geographical environments such as land versus underwater (e.g., Godden & Baddeley, 1975), and in mood-dependent memory studies, researchers have used different pieces of music expressing different moods and accompanied by different mood instructions (e.g., Eich, Macaulay, & Ryan, 1994; Eich & Metcalfe, 1989).1

1 Regarding the mood-dependent memory studies cited, multiple-feature differences are involved with respect to the procedures and stimuli used in establishing the moods, though not necessarily with respect to the internal mood states themselves.
The use of these multiple-feature changes in CDM studies is consistent with the theoretical view of context as the combined contributions of several sources of information (e.g., Bower, 1972; Tulving, 1983). This view has recently been called the mental-context hypothesis (Smith, 1995). One implication of this hypothesis is that the more contextual changes that are made, the greater the CDM effect. In regard to this point, Eich et al. (1994, p. 203) have suggested that simultaneous changes in two effective dimensions of mood (e.g., pleasantness and arousal) may increase mood-dependent memory, as compared with the effect induced by either single-dimensional change. However, they note that so far this hypothesis has been based mainly on correlational evidence (Eich & Metcalfe, 1989; Eich et al., 1994).

Although varying several aspects of context simultaneously is possibly the most effective method of inducing CDM, this procedure does not clarify what manipulations might be sufficient causes of CDM. One such manipulation might be a change in tempo. For instance, Balch et al. (1992) found that changing to a different piece having a different tempo lowered recall (compared with using the same musical selection). However, changing to a different piece having the same tempo did not induce this effect.

Therefore, tempo may be a specific dimension closely associated with music-dependent memory. However, more direct evidence for this hypothesis would be obtained if CDM could be induced by an experimentally controlled tempo change. To this end, Experiments 1 and 2 both include (a) a same-context condition, in which the same piece is played at the same tempo during recall and (b) a different-tempo condition, in which the identical selection is played at a faster or slower tempo. A recall difference between these two conditions would show that a controlled tempo change is sufficient to induce music-dependent memory. In other words, tempo-dependent memory would be demonstrated.

Several other contextual manipulations are also tested for their effects on recall. Experiment 1 includes a different-selection condition, in which a different piece is played at the same tempo during recall. If recall is lower in this context than in the same-context condition, then a change in overall musical context—without altering tempo—can induce music-dependent memory. This type of change was not found to be effective by Balch et al. (1992) but is tested again here.

In Experiment 2, a different-timbre condition is introduced to isolate and test the effect of a change in timbre on music-dependent memory. For instance, a selection originally played with a piano timbre is played with a brass timbre. As in the different-tempo condition, the different-timbre context represents a controlled change in a single musical dimension. However, tempo and timbre changes need not influence recall in the same way. Therefore, both tempo-dependent and timbre-dependent memory are tested in Experiment 2.

In addition, a no-context condition is included in this experiment. This type of context change is a test for what Smith (1985) has called contextual cuing, referring to superior recall obtained with a same-context condition as opposed to a null recall context. Although most CDM studies have reported better memory for the same (as compared with a different) context, it has been more difficult to show that recalling in the same context serves as a facilitative recall cue and actually improves memory relative to a no-context control (Rowe-Collie, Earley, & Stafford, 1989, p. 149; Ucros, 1989). For background-music contexts, contextual cuing was found by Smith (1985) but not by Balch et al. (1992) or by Thaut and de l'Etoile (1993).

A second issue was motivated by our finding tempo-dependent memory in Experiments 1 and 2. This issue relates to the mechanisms that might underlie the effect of tempo changes on recall. We focus on the hypothesis that tempo changes may induce mood alterations and that these mood differences may in turn induce CDM. A similar viewpoint has been expressed in connection with other CDM effects and is known as the mood-mediation hypothesis (Bower, 1981; Eich, 1995a; Eich & Birnbaum, 1988). This hypothesis, along with other possible mechanisms, is tested in Experiments 3 and 4.

**Experiment 1**

Experiment 1 compared word recall after a 1-min retention interval under three recall-context conditions: same context (identical to the presentation context), different tempo (the same piece played at a different tempo than during presentation), and different selection (a different piece played at the same tempo as during presentation). If fewer words were recalled with the different-tempo context than with the same context, this result would demonstrate tempo-dependent memory and indicate that changing tempo is a sufficient condition for CDM. If fewer words were recalled with the different-selection context than with same context, this finding would suggest that changing a variety of other musical features (i.e., musical selection) can induce music-dependent memory.

**Method**

**Participants.** Volunteers for this experiment were 168 undergraduates enrolled in introductory psychology courses at the Altoona and University Park campuses of The Pennsylvania State University. Equal numbers of students from each campus made up each experimental group, and all participants received a small amount of academic credit for their services.

**Materials and apparatus.** The words used for all conditions of this experiment were 24 common (A-frequency) two- and three-syllable nouns taken from Spreen and Schulz's (1966) norms (e.g., furniture, cousin, etc.). All words were originally presented together with one of two selections of background music: an excerpt (Mozart, 1953) from the Rondo (third movement) of a Mozart piano sonata in C major (K. 309) or “Jazz Holiday,” a piano composition (Nevin, 1957). These pieces are designated here as the classical and jazz selections, respectively. We chose pieces representing two different genres because we wished to use selections that were not likely to sound similar to participants in the different-selection condition. In addition, neither piece was considered likely to have been heard frequently by most of the participants in the experiment.

These selections were originally played by William R. Balch on a Korg SG-1D keyboard and digitized on a 386-SX computer with sequencing software (Master Tracks Pro 5). For both selections, a piano timbre was simulated by means of a Roland U-220 Sound Module (timbre program 001 on that unit). Each piece was played in C major (requiring no transcription of the classical [C] piece but requiring the jazz [J] piece to be transcribed one whole tone higher by
computer). Two audiocassette recordings were made from each selection, one at a slow (S) tempo (60 quarter notes per minute) and the other at a fast (F) tempo (140 quarter notes per minute). All recordings had a duration slightly longer than the time required for word presentation (250 s). If the end of a selection occurred during recording, the computer continued playing from the beginning.

Thus, four recordings were used in each experiment: SC, FC, SJ, and FJ. In comparing the fast and slow versions of either the classical (SC vs. FC) or the jazz (SJ vs. FJ) selection, note that each version was identical except for the tempo.

**Design.** The first two independent variables were selection (classical [C] or jazz [J]) and tempo (slow [S] or fast [F]). Together, these variables generated the four possible presentation contexts: SC, FC, SJ, or FJ. In other words, each presentation context was based on either the classical or the jazz selection, played at either the slow or the fast tempo (60 or 140 quarter notes per minute, respectively).

The third independent variable was recall context. This variable consisted of three conditions: same context, different tempo, or different selection. For the same-context condition, the same recording was used for both the presentation and recall contexts. For the different-tempo condition, the recordings used for these contexts were based on the same selection but different tempos. For the different-selection condition, on the other hand, presentation and recall contexts were based on a different piece played at the same tempo.

Fourteen different participants were randomly assigned to each of the 12 experimental groups. In terms of presentation and recall contexts, the four same-context groups can be designated as SC-SC, FC-FC, SJ-SJ, and FJ-FJ. The four different-tempo groups were SC-FC, FC-SC, SJ-FJ, and FJ-SJ. Finally, the four different-selection groups were SC-SJ, FC-FJ, SJ-SC, and FJ-FC.

The dependent variable was the number of words (out of 24) correctly recalled during the recall phase of the experiment.

**Procedure.** An individual session was conducted with each participant, who was told that the purpose of the experiment was to rate words for pleasantness. Participants were then given a pencil and a booklet for rating the words on a 6-point scale: 1 for very unpleasant, 2 for moderately unpleasant, 3 for slightly unpleasant, 4 for slightly pleasant, 5 for moderately pleasant, and 6 for very pleasant. To make the rating task more enjoyable, participants were told, background music would be played while the words were shown.

Typed words were presented visually on index cards, 1 word per card. To help give the participants sufficient exposure to the material, two different random orders of the 24-word list were run consecutively to generate a complete 48-word sequence. During the instructions, participants had been informed that each word would be repeated somewhere in the sequence and that they should rate each presented word according to their impression of its pleasantness at the moment. One of two different 48-word sequences was assigned to half the participants in each group.

After the instructions, the experimenter started the recording of the assigned musical context. After 10 s, he or she began showing words at the rate of one every 5 s. This presentation phase lasted about 250 s. The musical recording was stopped at the end of presentation, and the participant's rating booklet was taken.

Next, a piece of "distraction music" was played: a technique adopted from Balch et al.'s (1992) study (their Experiment 3). This procedure was intended to help equate the otherwise different distraction levels that might be involved in the various recall-context conditions. Immediately changing to a different context (as in the different-tempo and different-selection conditions) might have startled or distracted participants more than playing the identical recording again (as in the same-context condition). This extra distraction might have disrupted attention and impaired recall performance in a manner uninteresting from a memory standpoint. An intentionally distracting piece inserted between presentation and recall, however, should have helped eliminate such differences in the degrees of distraction produced by the recall contexts.

The distraction piece was an excerpt from Shirabe-Sagaribe (1980). (The title is translated, "The Sound of Wind Through Bamboo Leaves.") This essentially atonal music was played on several oriental instruments, including a bamboo flute, and was chosen to be distractingly different from both the classical and jazz contexts.

After 30 s of distraction music, the recall-context recording was started. Participants were handed a piece of paper and asked to write down, in any order, as many of the presented words as they could recall. The interval between the end of presentation and the beginning of recall was about 1 min. Two minutes were allowed for the recall session itself, and then participants were debriefed.

**Results and Discussion**

An alpha level of .05 was used for the statistical tests reported in all the present experiments.

The results of Experiment 1 are illustrated in Table 1, which gives the mean recall scores and standard deviations for the various conditions. The table shows the scores for the three recall contexts: the same context, the different-tempo context, and the different-selection context. Average recall across the presentation conditions was highest for the same context (12.38), lowest for the different tempo (10.98), and intermediate for the different selection (11.75). This outcome appears to be consistent with the hypothesis that a tempo change per se is sufficient to induce music-dependent memory.

To check the statistical significance of these results, $2 \times 2 \times 3$ (Selection $\times$ Tempo $\times$ Recall Context) independent-groups analysis of variance (ANOVA) was performed. As expected, the main effect of recall context was significant, $F(2, 156) = 6.83$, $MSE = 3.99$, $p < .01$. Neither of the other main effects and none of the interactions were significant ($ps > .10$).

The music-dependent memory effects can be assessed by multiple Bonferroni comparisons between the same-context mean and each of the other recall-context means. The 1.40

<table>
<thead>
<tr>
<th>Presentation context$^a$</th>
<th>Same context</th>
<th>Different tempo</th>
<th>Different selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classical selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>12.50</td>
<td>11.21</td>
<td>11.64</td>
</tr>
<tr>
<td>$SD$</td>
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<td>$SD$</td>
<td>1.69</td>
<td>1.45</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>Jazz selection</td>
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<td></td>
</tr>
<tr>
<td>Slow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>12.35</td>
<td>11.21</td>
<td>11.86</td>
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<tr>
<td>$SD$</td>
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<tr>
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<td>11.07</td>
<td>10.71</td>
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<tr>
<td>$SD$</td>
<td>1.60</td>
<td>2.13</td>
<td>2.76</td>
</tr>
</tbody>
</table>

Note. Each participant's recall score was the number of correct words out of 24; $n = 14$ for each entry.

$^a$All presentation contexts were played with the piano timbre.
difference in recall between the same-context (12.38) and different-tempo conditions (10.98) was significant, $t(165) = 3.73, p < .002$. However, the 0.63 difference between recall in the former-context and different-selection conditions (11.75) was not significant, $t(165) = 1.73, p > .10$.

Thus, changing tempo induced music-dependent memory. However, changing to a different selection played at the same tempo did not. Tempo, in particular, appears to be a dimension of musical context that has significant memory consequences. However, because Experiment 1 was designed to test the individual effects of changing tempo or selection, no statistical inference is made concerning the comparison between the tempo-dependent and selection-dependent effects.

**Experiment 2**

In Experiment 2, word recall in the same-context condition of Experiment 1 was compared with recall under each of three changed contexts. First, the different-tempo context, which was found to reduce recall in Experiment 1, was tested again. This time, however, a second controlled and single-dimensional change was also tested: different timbre (in which only timbre was altered). To test for contextual cuing, a further context manipulation was introduced: a no-context condition (in which no musical selection was played during recall).

A significant drop in recall under the different-tempo context would replicate the finding obtained in Experiment 1 that changing tempo is a sufficient cause for music-dependent memory. Decreased recall under the different-timbre context would show an analogous effect for a timbre change. Finally, a memory decrement under the no-context condition would demonstrate contextual cuing.

**Method**

**Participants.** Participants were 128 undergraduates who took part in this experiment for extra credit. As in Experiment 1, half of the participants in each condition were from the Altoona campus of The Pennsylvania State University, and half were from the University Park campus.

**Materials and apparatus.** The same word list, musical selections, and tempos used in Experiment 1 were applied again in Experiment 2. Likewise, the same four recorded contexts used in the previous experiment—all in the piano timbre—were used here. These contexts were designated SC-P, SJ-P, and so forth (P indicates the piano timbre). An additional set of four comparable contexts was recorded in a brass timbre created by the Roland U-220 Sound Module (timbre program 042 on that unit): SC-B, SJ-B, and so forth (B indicates the brass timbre).

**Design.** Because of the introduction of the brass timbre, the presentation-context variables were expanded from two in Experiment 1 to three in Experiment 2: selection (classical [C] or jazz [J]), tempo (slow [S] or fast [F]), and timbre (piano [P] or brass [B]). Thus, eight presentation contexts were generated: SC-P, SC-B, FC-P, FC-B, SJ-P, SJ-B, FJ-P, and FJ-B.

The recall-context variable included two contexts from Experiment 1 (same context and different tempo) and two additional contexts (different timbre and no context). These conditions were explained in the introduction to Experiment 2 and are briefly illustrated now. The presentation-context/recall-context sequences were as follows: for the eight same-context groups: SC-P/SC-P, SC-B/SC-B, and so forth; for the different-tempo context: SC-P/FC-P, SC-B/FC-B, and so forth; for the different-timbre context: SC-P/SC-B, SC-B/SC-P, and so forth; and for the no-context condition: SC-P/N, SC-B/N, and so forth (N designates no musical selection during recall).

Four different participants were randomly assigned to each of the 32 combinations of the eight presentation contexts and four recall contexts.

**Procedure.** All of the same procedures used for conducting experimental sessions in Experiment 1 were applied in Experiment 2. In the no-context condition, though, no selection was played during recall. The retention interval for all conditions was again 1 min, and the same distraction music was used.

**Results and Discussion**

A preliminary $2 \times 2 \times 2 \times 4$ (Selection $\times$ Tempo $\times$ Timbre $\times$ Recall Context) independent-groups ANOVA revealed that musical selection was not significant as a main effect, nor was it included in any significant interactions with the other variables ($p > .10$). Therefore, the results were collapsed across musical selections.

Table 2 gives the mean recall scores and standard deviations for the conditions in Experiment 2. The table shows the scores for the four recall contexts: the same-context, the different-tempo context, the different-timbre context, and the no-context conditions. Average recall across the presentation conditions was higher for the same context (12.06) than for the different-tempo context (10.19). These scores appear to be reasonably similar to the comparable numbers found in Experiment 1 (12.38 and 10.98, respectively). Again, changing only tempo seems to be sufficient to induce music-dependent memory. However, average recall in the different-timbre (12.59) and no-context conditions (12.53) was about the same as that obtained for the same context (12.06). Therefore, there seems to be no evidence for the timbre-dependent memory or contextual-cuing effects.

To test the statistical significance of the results, a $2 \times 2 \times 4$ (Tempo $\times$ Timbre $\times$ Recall Context) independent-groups ANOVA was performed. As expected, the main effect of recall context was significant, $F(3, 112) = 10.49$, $MSE = 3.89$, $p < .001$. None of the other main effects and none of the interac-

<table>
<thead>
<tr>
<th>Presentation context</th>
<th>Same context</th>
<th>Different tempo</th>
<th>Different timbre</th>
<th>No context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow-piano</td>
<td>M 11.88</td>
<td>10.38</td>
<td>12.75</td>
<td>13.00</td>
</tr>
<tr>
<td></td>
<td>SD 2.19</td>
<td>1.28</td>
<td>1.08</td>
<td>1.89</td>
</tr>
<tr>
<td>Slow-brass</td>
<td>M 12.13</td>
<td>9.38</td>
<td>12.38</td>
<td>12.63</td>
</tr>
<tr>
<td></td>
<td>SD 1.90</td>
<td>2.36</td>
<td>1.89</td>
<td>2.14</td>
</tr>
<tr>
<td>Fast-piano</td>
<td>M 12.13</td>
<td>11.38</td>
<td>13.38</td>
<td>12.38</td>
</tr>
<tr>
<td></td>
<td>SD 1.57</td>
<td>1.95</td>
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<td></td>
<td>SD 1.62</td>
<td>1.91</td>
<td>2.54</td>
<td>2.82</td>
</tr>
</tbody>
</table>

**Note.** Each participant's recall score was the number of correct words out of 24. The results are collapsed across musical selections, and $n = 8$ for each entry.
tions were significant (ps > .05). However, the main effect of timbre—as a presentation context—was nearly significant, F(1, 112) = 3.21, MSE = 3.89, p < .10, with average recall lower for the brass (11.53) than for the piano (12.16) contexts.

Music-dependent memory effects were assessed with multiple Bonferroni comparisons between the same-context mean and each of the other recall-context means. The 1.88 difference in recall between the same-context (12.06) and the different-tempo conditions (10.18) was significant, t(124) = 4.16, p < .002. However, the 0.53 recall difference between the former-context and the different-timbre conditions (12.59) was not significant, t(124) = 1.07, p > .10, nor was the 0.47 difference between the same-context and the no-context conditions (12.53) significant, t(124) = 0.90, p > .10.

As in Experiment 1, then, changing tempo significantly reduced recall. Yet there was no significant effect of changing timbre, suggesting that music-dependent memory is selective with respect to the musical dimension being manipulated. So far, however, there is no assurance that the tempo and timbre changes were approximately equivalent in any functional sense. This problem of comparability between the different musical changes is addressed by certain results obtained with the mood-rating measures used in Experiment 3.

In Experiment 2, we did not find contextual cuing (i.e., better recall for the same-context than for the no-context condition). This result is consistent with the fact that Balch et al. (1992) and Thaut and de l'Etoile (1993) did not obtain a similar effect and also with the assessment that contextual cuing is generally difficult to demonstrate in CDM studies (Rovee-Collier et al., 1989; Uncros, 1989). Only Smith (1985) found contextual cuing with background music. With this exception, then, that effect has been difficult to obtain. This point is discussed further in connection with the mood-mediation hypothesis in the General Discussion section.

As in Experiment 1, Experiment 2 was designed to test the individual music-dependent memory effects. In this case, these effects were tempo change, timbre change, and contextual cuing. Again, however, no statistical inferences are made concerning the comparisons between the individual CDM effects.

Considered together, Experiments 1 and 2 establish tempo change as a sufficient cause of music-dependent memory. Yet why should changes in tempo and not the other contextual changes studied so far induce significant music-dependent memory? One view is that altering tempo changes mood and that mood change is the key determinant of music-dependent memory. This hypothesis, an application of the mood-mediation hypothesis (Eich, 1995a; Smith, 1995), is tested in Experiments 3 and 4.

Experiment 3

Experiment 3 was designed to test the effects of three musical variables—tempo, timbre, and musical selection—on two measures of mood. To obtain these measures, participants rated the mood into which a musical context put them in terms of either arousal or pleasantness. If the tempo-dependent memory effects obtained in Experiments 1 and 2 were mediated by mood, there should be a mood difference generated by a given musical selection played at two different tempos. Thus, there should be an effect of tempo on mood arousal, mood pleasantness, or both. However, the other musical variables—timbre and musical selection—need not have an effect on mood.

Method

Participants. Participants were 64 undergraduates who took part in this experiment for extra credit. Half the participants in each condition were from the Altoona campus of The Pennsylvania State University, and half were from the University Park campus.

Materials and apparatus. The same musical selections, tempos, and timbres used in Experiment 2 were used in Experiment 3. The purpose of this experiment was simply to measure the effect of music on mood; therefore, word lists and distraction music were unnecessary. However, a mood-rating sheet was used so that participants could record their levels of mood arousal and mood pleasantness by circling a number on a scale from 10 (marked either lowest arousal or lowest pleasantness, respectively) to 10 (marked either highest arousal or highest pleasantness, respectively).

Design. The independent variables were selection (classical [C] or jazz [J]), tempo (slow [S] or fast [F]), and timbre (piano [P] or brass [B]). Thus, as in Experiment 2, eight musical contexts were generated: SC-P, SC-B, FC-P, FC-B, SJ-P, SJ-B, FJ-P, and FJ-B. Eight different participants were randomly assigned to each of the eight musical contexts. In each condition, the order of the scales on the mood-rating sheet was counterbalanced: The mood-arousal scale appeared first for half the participants; for half, the mood-pleasantness scale appeared first.

Procedure. In contrast to the procedures of Experiments 1 and 2, no word list, distraction music, or recall test was used in Experiment 3. In individual sessions, participants were instructed that the purpose of the experiment was to find out how music makes them feel; then, they were given the aforementioned mood-rating sheet. Next, they were told that they would listen to a piece of music for 2 min and afterward would rate the mood that the piece put them into on two different dimensions—arousal and pleasantness—in the order that the scales appeared on the mood-rating sheet.

A recording of the assigned musical context was then played for 2 min. Then the recording was turned off, and each participant rated the music on the mood-rating sheet. After completing the two mood ratings, participants were debriefed and dismissed.

Results and Discussion

Mood-arousal ratings. The top half of Table 3 shows the means and standard deviations of the arousal ratings for each of the musical contexts. These arousal-rating means range from −0.88 to −6.13 on a scale of −10 to +10 and average −3.44. Apparently, none of the musical contexts was very arousing to participants.

Of main interest, however, is the effect of tempo on arousal. Table 3 shows that the arousal ratings for fast musical contexts were generally higher (i.e., less negative) than those for slow contexts. The average rating for the fast contexts was −2.13; for the slow contexts, it was −4.75. Tempo apparently influences the arousal dimension of mood. This result supports the assumption, made by the mood-mediation hypothesis, that tempo is related to mood.

On the other hand, neither musical selection nor timbre appear to influence arousal as much. Regarding musical selection, the average arousal rating for the classical contexts
was $-3.13$, and for the jazz contexts, it was $-3.75$. With respect to timbre, the piano contexts averaged $-4.16$, and the brass contexts averaged $-2.71$.

To test for the statistical significance of the results, a $2 \times 2 \times 2$ (Tempo \times Timbre \times Selection) independent-groups ANOVA was performed on the mood-arousal ratings. Only the main effect of tempo was significant, $F(1, 56) = 7.59, MSE = 14.53, p < .01$. None of the other main effects and none of the interactions between the variables were significant, $F_s < 1$ except for the main effect of timbre, $F(1, 56) = 2.28, MSE = 14.53, p > .10$. Thus, the ANOVA supports the conclusion that tempo is related to the arousal dimension of mood; ratings were significantly lower for slow than for fast contexts.

Mood-pleasantness ratings. The bottom half of Table 3 shows the means and standard deviations of the mood-pleasantness ratings for each musical context. On the basis of a scale of $-10$ to $+10$, these ratings range from $0.75$ to $3.38$ and average $1.58$.

There appears to be little effect of tempo on mood pleasantness (means of $1.81$ for fast-tempo and $1.34$ for slow-tempo contexts). Neither do selection (means of $1.78$ for classical and $1.38$ for jazz) and timbre ($1.31$ for piano and $1.84$ for brass) seem to make much difference. Apparently, none of the musical variables manipulated here influence the pleasantness dimension of mood.

To check the statistical significance of the results, a $2 \times 2 \times 2$ (Tempo \times Timbre \times Selection) independent-groups ANOVA was performed on the mood-pleasantness ratings. None of the main effects or interactions between the variables were significant ($F_s < 1$). Therefore, the ANOVA reveals no relations between the present musical variables and mood pleasantness.

The similar mood-pleasantness levels induced by the various musical contexts suggest at least one type of functional equivalence among the musical changes being studied here: tempo, timbre, and musical selection. This issue of comparability was raised in the Results and Discussion section of Experiment 2 and is considered further in the General Discussion.

**Experiment 4**

In Experiment 3, a relation between tempo and mood arousal was demonstrated. The effect of this relation on memory was tested in Experiment 4. As in the first three experiments, words were presented along with a musical context. Word recall was tested, however, in a mood context that did not involve music. Either a relaxed or an active mood was induced with verbal instructions and an audio "mood tape" on which a spoken scenario was heard. The relaxed context was designed to be consistent with the mood induced by the slow-tempo musical context, whereas the active context was intended to approximate the mood of the fast-tempo context.

The hypothesis tested in Experiment 4 was that tempo-dependent memory, obtained in Experiments 1 and 2, is mediated by mood. If this is so, word recall in the relaxed mood should be better when the musical context was presented at a slow (vs. fast) tempo. However, recall in the active mood should be better when the tempo of the musical presentation context was fast (vs. slow). In other words, there should be an interaction between the tempo context during word presentation and the mood context during recall.

Note that this interaction cannot be explained in terms of any alternative hypothesis that attributes tempo-dependent memory to mediation by specifically musical characteristics. For instance, level of phrase repetition might mediate the effect: Faster tempos generate a higher frequency with which musical phrases are repeated. Likewise, the rate of tempo may provide a rhythmic framework for the encoding of associated verbal material. Thus, a change in tempo might disrupt retrieval by making the recall context inconsistent with the original pace of encoding. We shall call this latter view the *temporal-frame hypothesis*. Because there is no musical context during recall, any interaction between presentation tempo and recall mood could not have been mediated by the temporal frame or by other musical means. The only apparent link between presentation and recall contexts is mood.

**Method**

Participants. Participants were 48 undergraduates who took part in Experiment 4 for extra credit. Half the participants in each condition were from the Altoona campus of The Pennsylvania State University, and half were from the University Park campus. In addition, 20 normative participants from the Altoona campus rated the mood tapes.

Materials and apparatus. The word list and word orders were the same as those used in Experiments 1 and 2. However, only two musical
contexts were used: the slow and fast versions of the classical selection, both played in the brass timbre (SC-B and FC-B, respectively). The classical brass contexts were chosen because of the mood-arousal ratings in Experiment 3: −4.88 for SC-B and −0.88 for FC-B (see Table 3). This 4-point difference in arousal levels between slow and fast tempos was larger than the comparable differences for the classical piano context or the jazz contexts.

For the classical brass contexts used here, mean mood pleasantness was slightly higher for the fast context (3.38) than for the slow (1.13) context (see Table 3). However, this 2.25 difference (on a scale from −10 to 10) was not significant, \( r(14) = 0.84, p > .10 \).

**Mood tapes.** To help induce a relaxed or an active mood during recall, two different scenarios were written by William R. Balch. Then they were recorded, again in William R. Balch's voice, on audiocassette. Each scenario lasted about 2 min and was spoken at the same word/minute rate. Both scenarios described a sequence of events for the participants to imagine themselves a part of, beginning with the statement: "I would like you to imagine yourself on a Saturday afternoon."

The relaxed-mood tape was meant to approximate the mean arousal level (−4.88) of the slow musical context (SC-B). The scenario included the following events: relaxing in a lounge chair by a lake, hearing a bird sing in a nearby tree, listening to the rippling of the lake against the shore, feeling a light breeze, hearing leaves rustle, seeing a chipmunk standing by a tree, and looking at a patch of flowers growing by the lake.

The active-mood tape was intended to approximate the arousal level (−0.88) of the fast musical context (FC-B) and described the following events: going out the door to do some errands, driving to a shopping area in moderate but smoothly flowing traffic, driving home, taking a walk around the neighborhood, giving directions to a passing motorist, greeting a friend, and doing the friend a favor by walking his dog.

To check the arousal levels induced by the mood tapes, each tape was rated by a different group of 10 participants. These normative participants were asked to listen to a given tape and then rate their mood on an arousal scale from −10 to 10. The mean ratings were −6.15 for the relaxed-mood tape and +1.20 for the active-mood tape. Thus, the relaxed and active tapes approximated the arousal levels of the slow (−4.88) and fast (−0.88) tempos, respectively. For the mood tapes, however, the contrast between the arousal levels was greater than the contrast for the tempos.

**Design.** The independent variables were presentation tempo (slow [S] or fast [F]) and recall mood (relaxed [R] or active [A]). Twelve different participants were randomly assigned to each of the four combinations of the two presentation tempos and two recall moods. Thus, the groups in Experiment 4 were S–R, F–R, S–A, and F–A.

**Procedure.** The word-presentation phase followed the same procedure that was used in Experiments 1 and 2. At the end of this phase, participants were told that they were going to do another task, involving mental images and moods. Then they were instructed that they would hear a tape in which the speaker would suggest a scenario for them to imagine themselves a part of. They were to follow the described events mentally, letting images come to mind and getting themselves into the mood intended by the scenario.

Participants in the relaxed-mood contexts were asked to put themselves into a mood that was "well relaxed: that is, significantly more relaxed than a neutral or normal mood." After a while, they were told their moods would be checked by having them record their arousal levels on a scale of −10 (lowest arousal) to 10 (highest arousal). They were asked to try for a mood of −5 or lower.

Participants in the active-mood contexts were asked to aim for a mood that was "active but comfortable and not overly excited." Again, they were told that their mood would be checked later by having them record their arousal levels on a scale from −10 to 10. They were asked to try for a mood in the range between 0 and 5.

These instructions were intended, like the mood tapes, to help participants attain moods that approximated—though with greater contrast between the moods—the arousal levels of the slow or fast tempos.

After the assigned mood tape was played for 90 s, the tape was paused, and the participant rated his or her arousal level. Participants whose moods were in the prescribed range were asked to continue in that mood. Participants who were out of range by no more than 1 point on the scale were asked to try to adjust their moods slightly to get within the requested range. (Six participants who missed the range by more than a point were excused from further participation.) Then, the remaining 30 s of the scenario were heard.

Participants were then asked to maintain their mood. They were instructed that doing so would help them during the last task of the experiment: a task that involved the words they rated for pleasantness earlier. As in Experiments 1 and 2, they were asked to write on a sheet of paper as many of these words as they could, in any order. Again, 2 min were allowed for recall. Halfway through this recall period, participants were reminded to continue in the same mood.

The procedures described above resulted in a retention interval of about 5 min between the end of word presentation and the beginning of recall. Unlike the procedure for Experiments 1 and 2, no distraction music was used because the recall contexts were not musical.

**Results and Discussion**

Table 4 shows the means and standard deviations of the recall scores for the tempo and mood contexts of Experiment 4. Note that participants in the relaxed mood recalled more words when the presentation tempo was slow (12.41) as compared with fast (9.33). However, participants in the active mood recalled more words when the tempo was fast (10.75) as compared with slow (9.08).

To assess the statistical significance of the results, a 2 × 2 (Tempo × Mood) ANOVA was performed on the recall scores. As main effects, neither tempo \((F < 1)\) nor mood, \(F(1, 44) = 2.91, MSE = 3.79, p < .10\), was significant. However, a significant Tempo × Mood interaction was found, \(F(1, 44) = 17.86, MSE = 3.79, p < .001\). Looking at each mood separately, recall in the relaxed mood was significantly better for the slow (12.41) than for the fast (9.33) presentation tempo, \(F(1, 22) = 10.68, MSE = 5.34, p < .01\). However, recall in the active mood was significantly better for the fast (10.75) than for the slow (9.08) presentation tempo, \(F(1, 22) = 7.45, MSE = 2.24, p < .05\). (See Table 4.)

This pattern of results is consistent with the hypothesis that tempo-dependent memory is mediated by mood. Apparently,

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Recall Scores for the Tempo and Mood Contexts in Experiment 4</th>
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<tbody>
<tr>
<td>Mood</td>
<td>Slow</td>
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<tr>
<td>---------</td>
<td>------</td>
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<tr>
<td>Relaxed</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>12.41</td>
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<tr>
<td>SD</td>
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<tr>
<td>Active</td>
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<tr>
<td>M</td>
<td>9.08</td>
</tr>
<tr>
<td>SD</td>
<td>1.08</td>
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*Note.* Words were presented in a musical-tempo context and recalled in a mood context; \(n = 12\) for each condition.
participants recall more when they are put into a mood that matches, rather than mismatches, the mood induced by the tempo of the musical presentation context. This experiment shows that the recall context need not be musical, as in Experiments 1 and 2. Thus, what underlies the CDM effect found in Experiment 4 is mood, rather than musical variables such as phrase repetition or beats per minute. Note that the latter was specified as the operative variable in the temporal-frame hypothesis.

General Discussion

Considered together, the present experiments support the mood-mediation hypothesis of music-dependent memory. Experiments 1 and 2 show that changing tempo, but not musical selection (Experiment 1) or timbre (Experiment 2), significantly reduces recall. In Experiment 3, tempo—but again, not selection or timbre—was found to influence the arousal dimension of mood. Experiment 4 linked tempo and mood together in terms of memory. Tempo was manipulated in the musical presentation context; however, in recall, a mood context was manipulated strictly by verbal means. During recall, more was remembered in mood contexts that matched the moods of the original presentation tempos. Therefore, this CDM effect was mediated by the one presumably common property of the matching presentation and recall contexts: mood arousal.

In explaining CDM effects, an alternative to the mood-mediation view is the mental-context hypothesis. According to Smith (1995), this latter hypothesis considers “mood, place, mental set and other factors as components of one’s mental context, any of which can serve to cue the representation of mental context at test” (p. 309). According to this view, any one or a combination of many specific contextual changes could be a sufficient cause of CDM.

The tempo manipulation, tested in Experiments 1 and 2, significantly influenced recall. Thus, tempo change is clearly a sufficient cause of music-dependent memory. However, we did not induce CDM with the other contextual changes. Thus, our results provide no evidence that music-dependent memory can have multiple causes, an idea expressed by the mental-context hypothesis.

We acknowledge that there may be causes of this CDM effect—other than tempo—that we simply have not found. Even variations of the timbre or the selection changes that we tested here might have the potential to induce music-dependent memory. Though the brass and piano timbres sounded quite different to us, for instance, there may be other contrasting timbres that would have induced stronger CDM. Moreover, the two tempos used here were purposely chosen to be very distinct (60 vs. 140 beats per minute), and the contrasts involved in our other musical variables may not have been functionally equivalent in every relevant way. The 60 beats-per-minute pace may also have rendered the slow-tempo contexts less discriminable from each other, compared with the greater distinctiveness of each fast context. Note that the fast tempo is closer to those tempos originally intended for the jazz and classical compositions used here.

However, we can cite one type of functional equivalence. In Experiment 3, all of the musical contexts were rated about the same in the mood pleasantness they induced. Pleasantness represents one type of encoding that could be relevant to the present memory task, especially because the words to be remembered were rated for pleasantness during presentation. Yet there were no obvious differences in the effects of tempo, timbre, or selection on the mood-pleasantness ratings of the musical contexts.

Still, we acknowledge that there may be changes in timbre, selection, or other musical characteristics that would be more comparable with the tempo manipulation we used. Therefore, we conclude only that the tempo change used here is a single and sufficient manipulation that induces music-dependent memory. We do not claim that this manipulation is necessary to induce the effect. By the same token, we do not dismiss the notion that several simultaneous contextual changes might induce greater CDM than any single change (Eich et al., 1994, p. 203). More research in the various CDM areas needs to be addressed to systematic changes in context, both single and multiple.

Though tempo change may be an external cause of music-dependent memory, Experiments 3 and 4 show that this effect seems to be best explained in terms of an internal mediator: mood arousal. In addition, Experiment 4 helps resolve an issue raised by Smith (1995) concerning the mood-mediation hypothesis. He points out an ambiguity in Eich’s (1995a) research on the mediation of place-dependent memory by the happy–sad dimension of mood (Eich’s Experiment 3). Because Eich used only one presentation context (a pleasant place), recall in the mismatched-mood context might have been worse because of the sad-mood procedure rather than because of the mismatched mood (Smith, 1995, p. 309). However, in the present Experiment 4, presentation tempos and recall moods were counterbalanced. Thus, the CDM we found appears to arise from matched or mismatched moods rather than from the particular recall contexts used.

In light of the above consideration, our findings clarify and extend Eich’s (1995a) support of the mood-mediation hypothesis. Note that Eich was concerned with place-dependent memory and an evaluative dimension of mood (i.e., pleasant—happy vs. unpleasant—sad). Our own experiments have been focused on tempo change and the arousal dimension of mood. If mood mediation proves to be the key mechanism for a variety of CDM effects, it seems plausible that the particular mood dimension underlying any given effect will depend on the type of CDM in question.

The present findings also have some implications concerning the question of reliability, which has plagued most CDM effects (e.g., Bjork & Richardson-Klavehn, 1989). For instance, Eich (1995a) has summarized the phenomena of place-dependent and mood-dependent memory as having had “mercurial histories, with the mostly positive results reported in the 1970s giving way to mostly negative results in the 1980s, leading theorists in the 1990s to wonder whether either PDM [place-dependent memory] or MDM [mood-dependent memory] even exists” (p. 305).

The mood-mediation view, which is supported by the present research, helps explain such reliability problems. For instance, several studies have not found place-dependent
memory (e.g., Fernandez & Glenberg, 1985). However, in an early study by Godden and Baddeley (1975), a 46% difference in recall between same- and different-place contexts was obtained with scuba divers as participants. This large effect may well have been due to the choice of contexts: on land or underwater. Because these two locations were likely to have evoked very different moods, place-dependent memory could have been mediated by this difference. (See Eich, 1995a, for a more detailed discussion of this point.)

Certain reliability problems have also surfaced in music-dependent memory research. For instance, contextual cuing (i.e., a recall difference between same-music and no-music contexts) was found by Smith (1985). However, no contextual cuing for background music was found in the present Experiment 2 or in the studies by Balch et al. (1992) and Thaut and de l’Etoile (1993).

Mood mediation may explain why contextual cuing has been difficult to demonstrate with background music. Although a different-music condition could disrupt mood and induce CDM, the no-music recall context should not prevent participants from mentally reinstating the mood they had experienced during the presentation music. Therefore, this null context—unlike a different-music context—should not interfere with recall. In other words, contextual cuing would not be expected. This interpretation seems plausible in light of recent theoretical discussions of spontaneous context reinstatement (e.g., Bjork & Richardson-Klavehn, 1989).

Reliability has generally not been a problem for music-dependent memory induced by different-music contexts. This effect, obtained in the present Experiments 1 and 2, reinforces similar effects found by both Smith (1985) and Balch et al. (1992). Different-music contexts have apparently not induced CDM only when the tempo was purposely kept the same as that of the presentation music, as in the following cases: the different-selection context of Experiment 1, the different-timbre context of Experiment 2, and the same-tempo context in Balch et al.'s (1992) study in which a different selection was played at the original presentation tempo (their Experiment 2). The preceding observations are consistent with the view that tempo change and mood mediation figure importantly in music-dependent memory.

To what degree is the present research congruent with everyday examples of music-dependent memory? Our results seem generally consistent with several aspects of practical musical experience. For instance, consider the familiar notion that old songs brings back associated memories. In this case, musical context appears to have memory consequences that occur in everyday life as well as in experimental studies. In songs, music can also influence the recognition of lyrics (Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986), illustrating a related type of memory consequence.

One aspect of musical experience is more difficult to explain in terms of experimental research. In some naturally occurring cases, music-dependent memory may involve the kind of contextual cuing not found in the present Experiment 2 or in most CDM studies. As already mentioned, decreases in memory due to an altered context have been easier to demonstrate than facilitation due to the same context. Yet sometimes a few bars of an old melody appear to cue memories that might have been difficult to retrieve otherwise. If so, several influences might contribute to this phenomenon: many pairings of the musical context and the associated material to be remembered, for instance, or the personal significance of the music and material to the individual involved. The range of conditions possible in natural occurrences of CDM far exceeds even the broad variety now encountered in laboratory studies.

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Musk-Dependent Memory


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