Laterality effects with visual perception of musical chords and dot patterns

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Using the paradigm denoting a contralateral relationship between visual field and brain hemisphere, laterality effects with music notation and dots were investigated. Two groups of readers of advanced piano music were selected, one good, one poor. Each group participated in two visual half-field experiments, one using random dot patterns and the other using musical chords. Significant opposite field effects were found for the two kinds of stimuli across reading groups, the left field for dots and the right field for chords. With dots, a significant sex effect emerged, with males superior to females across groups. The only significant group difference appeared in the chord experiment, in which the good group was superior. A practice effect also was found only with chords. Results suggest that the left hemisphere is more important for recognition of music notation than the right.

Most studies of musical perception, including those investigating brain laterality effects, have concentrated on auditory, rather than visual, input. Many have assumed or investigated processes common to language and music. Gates and Bradshaw (1977) relate that, at least for auditory processing of music, studies show that certain properties common to both music and language are controlled by the left hemisphere. However, when music alone is considered, normal subjects demonstrate varying degrees of asymmetry for its different components. For example, in clinical studies, tonal memory has been linked to the right hemisphere (Bogen & Gordon, 1971; Botez & Wertheim, 1959; Chase, 1967; Milner, 1956, 1961), while nonclinical studies of ear preferences in melodic recognition have also implicated the left hemisphere (Bartholomeus, 1974; Bever & Chiarello, 1974; Gordon, 1970; Cuyler, Note 1). Gates and Bradshaw believe that such studies suggest that the way musical information is processed may be an important determinant of hemispheric mediation.

According to Gardner (1975), it is unrealistic to expect a simple pattern of musical organization in the brain or a compact set of skills that can be compared across individuals. Deutsch (1978) believes that there is evidence that speech and music have specialized areas of the brain but still share common elements. In general, it seems that the nondominant hemisphere controls processing of the quality of musical sounds, while the dominant hemisphere controls processing of sequential relationships.

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When the input mode changes from auditory to visual, it is not clear that these same conclusions are warranted. The sight-reading of music for the purpose of performance on an instrument is more a problem of visual pattern recognition and motor expression. The process can perhaps be better compared to the oral reading of words. In his studies of oral reading, Geyer (1966, Note 2) postulated iconic storage as the basis for the eye-voice span in oral reading. He found that the span would remain relatively constant in smooth reading at the span of about 1 sec in duration. Wolf (1976) has proposed a pattern recognition model of piano sight-reading wherein good sight readers add preconceptions of what is to come to visual clues for a systematic assessment of notation. Important to the model is the time factor, which forces the collection of information and clues to be simultaneous with performing.

Sloboda (1977) tried to specify some sight-reading clues as physical and structural markers. Physical markers related to the look of the printed music, particularly the spaces between phrases; structural markers had largely to do with the harmonic construction of the musical phrase. Sloboda found that eye-hand span expanded when harmonic construction was redundant.

Chess is one area in which visual pattern chunking ability has been thoroughly investigated, and many conclusions of chess studies seem pertinent to investigations of music reading. In his chess experiments, de Groot (1965, 1966) found that Master-level chess players could recall virtually an entire chess position after seeing it for only 5 sec, whereas weaker players recalled very few pieces. Chase and Simon (1973) found that this ability disappeared when Masters were shown random configurations of pieces, thus ruling out the possibility that Masters have superior short-

term visual memories. Chase and Simon were further able to establish the nature of the perceptual patterns of the Master-level players. They concluded that stronger players are able to code positions into larger perceptual chunks, hold more chunks in recall, and organize chunks more efficiently for storage. This pattern memory is learned through years of experience with chess configurations.

The boundaries of notated musical chunks that good or poor readers perceive in one fixation have not been determined clearly. Studies vary on the number of notes recognized in a single fixation. Jacobsen (1926) reported six notes can be read, Weaver (1930) reported from one to two notes are fixated, and Bean (1938) believed that good reading depended on the ability to grasp patterns of three or more notes at a glance.

More recently, Sloboda (1976) demonstrated that musicians are superior to nonmusicians in immediate written recall of stimuli containing more than three notes, but only when stimuli are exposed for 150 msec or more. Sloboda hypothesized that musicians have a more permanent abstract coding process for music notation than nonmusicians. Additional experiments suggested that musicians probably do not use simple naming or pitching transformations to code visual input.

The present study used tachistoscopic presentation of musical chunks (chords) to investigate field preferences of readers of advanced piano music. The methodology follows an accepted paradigm for studying hemispheric effects, namely, that stimuli exposed in either the right or left visual field are projected contralaterally in the brain (Gazzaniga, Bogen, & Sperry, 1965; Levy-Agresti & Sperry, 1968; Teng & Sperry, 1973). A main purpose of the study was to investigate the assumption that music notation, being a visual representation of a nonverbal language, would be more easily perceived in the left visual field by readers of advanced piano music.

Studies using supposed nonverbal stimuli must consider several problems. For one, White (1969) cautioned that nonverbal percepts may be recalled by their verbal labels. For another, brain-damaged subjects have shown contradictory hemispheric functions (Shai, Goodglass, & Barton, 1972; Teng & Sperry, 1973). Apparently, stimuli thought to involve nonverbal right-hemisphere processing were processed in the left hemisphere when the right was not functioning. In addition, Sperry, Gazzaniga, and Bogen (1969) relate that even language ability is not confined to a single hemisphere, since the right hemisphere can read printed names of objects and spell simple three- or four-letter words.

Nonverbal laterality studies reflect the above ambiguities. Kimura (1966) found a left-field superiority for enumeration of dots and geometric forms, while no field differences were found for nonsense figures. McKeever and Huling (1970) also found a left-

field superiority for reproduction of dot figures. In an interesting memory experiment, Klatzky (1970) hypothesized that letters that were compared in terms of their physical configurations would be processed spatially, while pictures compared via verbal labels would be processed verbally. She found that, under these conditions, shorter reaction times did occur for letters processed in the right hemisphere and for pictures processed in the left hemisphere.

In other studies, Schell and Satz (1970) found a left-field superiority with block designs, while earlier, Paterson and Zangwill (1944) found no field superiority when subjects had to reproduce Kohs block designs. Gross (1972) found spatial stimuli (matrices) were processed faster in the left visual field. However, when error rate alone was considered, no significant field differences were found between spatial and verbal stimuli. Hines (1972) found blob designs were recognized better in the right field.

When musical stimuli are used, similar ambiguities arise. As previously noted, such ambiguities may arise from the existence of differing processing and organization patterns in the brain for various musical components. Oscar-Berman, Blumstein, and De Luca (1976) examined hemispheric differences in subjects presented visually with single musical notes and letters representing those notes. For notes, recognition threshold alone elicited a right-field superiority, while iconic memory, measured via a masking paradigm, functioned better in the left field. Greenberg and Graham (1970) examined EEG changes during the learning of speech syllables and piano notes. They concluded that the right hemisphere played a dominant role in the nonspeech discriminations. In a study already cited, Bever and Chiarello (1974) found that musically experienced listeners recognized simple melodies better in the right ear than in the left, while the reverse was true for musically naive listeners.

The nature of the stimuli in the present study also forced other factors to be considered in its design. The factor of sex seemed important, particularly since the design, in addition to using musical notation, included a control experiment using dot patterns found to have elicited left-field preferences (Kimura, 1966). Studies have found that males are more lateralized than females, favoring the left field on tasks demanding manipulation or perception of spatial relationships (Hannay, 1976; Kimura, 1969; Lansdell, 1962, 1968; McGlone & Davidson, 1973). More recently, Levy and Reid (1978) found that females performed better on traditional left-field tasks. The researchers offer the theory that left-hemisphere functions are more bilateralized in females, producing incomplete specialization of the right hemisphere. In view of these considerations, an equal number of males and females were used in the present study.

Another factor considered was handedness. All subjects in the present study, except for one female, were right-handed, as determined by the method of

self-report. It is not clear from the literature that handedness is a reliable index of laterality tendencies. However, the general assumption seems to be that virtually all right-handers tend to be language dominant in the left hemisphere, although even with left-handers, there is a slight majority (56%) who also favor language processing in the left hemisphere (Levy, 1974).

Studies involving handedness show no consensus. McKeever and Van Deventer (1977) found that left-handers who were presumed to be right-brain dominant for language showed no impairment of spatial ability. Earlier, Bryden (1965) found that right-handers were more accurate in recognizing visual material presented to the right side, while left-handers failed to show any consistent differences. A study by Altman (Note 3) found that handedness was not a factor in field preferences of subjects performing a simple motor-dexterity task (finger tapping) and a verbal visual half-field task (Hines-Satz Controlled Fixation, Short-Term Memory Paradigm).

Hines and Satz (1971) presented digit pairs to left- and right-handers in both dichotic listening and visual half-field tests and found both groups yielded a right-field superiority at a variety of presentation rates. In a later study (Hines & Satz, 1974), the same researchers again found no differences in field asymmetry related to family history of left-handedness. However, right-handers had cross-modal correlations (auditory and visual) that were high, while left-handers showed no correlation at all. The researchers believe that this suggests a dissociation between auditory and visual laterality in left-handed people.

The factors of sex and handedness have been related in some studies. Oldfield (1971), in an assessment and analysis of handedness, found that more males than females showed a tendency to left-handedness over all degrees of left-handedness. According to Davis and Woda (1978), within a basically left-speech-dominant organization, males and right-handers emphasize the verbal, temporal structure of auditory information and the nonverbal spatial structure of visual information. Females and left-handers tend to reverse this emphasis.

Finally, since the design of the present study included contrasting good and poor music readers, similar designs of word-reading studies were considered. Moore and Weidner (1974) investigated bilateral word perception in aphasics with left-brain injury and normal control subjects. Aphasics preferred the left field, while normal subjects preferred the right. Yeni-Komshian, Isenberg, and Goldberg (1975) tested good and poor readers with dichotic listening and half-field viewing of both words and digits. Although poor readers had a much lower left-field score with numerals than good readers, the overall accuracy of poor readers was not lower than that of good readers. However, poor readers did perceive words less accurately. Yeni-Komshian et al. suggested

that degraded processing in the right hemisphere or poor transmission from right to left hemisphere may exist in poor readers. In contrast to these studies, McKeever and Huling (1970) found that both normal and poor readers recognized more words in the right field.

To summarize the purpose of the present study: it was designed to investigate whether musical chords of various sizes and types would elicit laterality effects in preclassified good and poor readers of advanced piano music; random dot patterns were used as control stimuli in a companion experiment (see Kimura, 1966). Because of ambiguous results and a lack of precedents in the literature, it was impossible to form specific hypotheses about laterality effects for the chord experiment. It was expected, however, that the dot experiment would show males to be superior to females across reading groups.

Part 1 of the study consisted of the preparation and administration of a preliminary criterion-music-reading test to divide subjects into good and poor groups. Part 2 consisted of the design and administration of the two main visual half-field experiments, one using musical chords and the other control experiment using random dot patterns. Because the literature indicated that tonal memory is a right-brain function, a test of auditory musical memory (Drake, 1957) was also given to further clarify the results. For this reason, it is described in the discussion section.

PART 1

Preliminary Criterion Test of Good and Poor Music Readers

Method

Subjects. The subjects were 26 volunteers who were either college music students with a keyboard major or professional keyboard musicians who had graduated from music schools and were now in some way earning their livings as musicians. Four were professional piano accompanists; seven others regularly accompanied in the course of their work or studies, but were not employed specifically for that skill. Eight were self-described "poor readers." Half were male and half were female. All were right-handed except for one female. The average age was 27.

Stimuli. Forty-five excerpts from the standard piano repertoire were selected and judged according to three ascending difficulty levels, 15 excerpts for each level. Three judges, including the author, performed this task. Five styles of music were represented: Bach, Mozart, Beethoven, Brahms, and Impressionistic (Ravel and Debussy). Excerpts averaged seven musical measures in length and represented all flat and sharp key signatures. The face or content validity of the test defines good music readers as those who make fewer tonal and rhythmic errors than other music readers while reading actual music at the piano.

Procedure. The subjects played the excerpts from Xeroxed music-sized sheets, and their performances were recorded on tape. The subjects were allowed up to 30 sec to study each excerpt before playing. Alternate selections were available at all levels for those who recognized or had studied particular excerpts. The three easiest excerpts in each style were used as warm-ups so that scoring was done only on the remaining 30 excerpts, six in each style.

Table 1
Medians, Means, Standard Deviations for Groups
on Criterion Music Reading Test

Group	Median	Mean	SD
Total	703.5	691.7	349.0
Good	382.0	407.8	154.9
Poor	829.0	975.7	235.7

Results

The subjects were scored on various categories of tonal and rhythmic errors. Scores ranged from a low of 139 errors to a high of 1,453 errors. A reliability estimate of the test using the Spearman-Brown split-halves method produced a coefficient of .98. The median of the scores was 703.5, and those scoring less than that were classified as good readers; those scoring more than the median were classified as poor readers. The good group consisted of eight females and five males; the poor group consisted of five females and eight males. Table 1 gives medians, means, and standard deviations for the groups.

PART 2

Experiment 1: Dots

Method

Subjects. The subjects were the 13 good and 13 poor readers determined by the criterion-music-reading test given in Part 1.

Stimuli and Apparatus. All stimuli were drawn in black ink on white paper, then cut out and pasted on the viewing field, which was a 3×5 space on a white card sized 9.5×7.25 in. Sixty-four right-left pairs of patterns consisting of from 3 to 10 randomly drawn dots were constructed, 8 for each of the 8 sizes. Each dot was roughly 3/8 in. in diameter. Patterns were of similar intensity, and right-left pairs were mirror images of each other. Patterns were centered on the cards 1 deg to the left or right of the center fixation on an imaginary intersection of two lines. The vertical axis bisected the closest dot to the center fixation, and the horizontal axis bisected the center of the pattern. Two random orders were devised for the 64 pairs so that a repeated-measures design could be used. Figure 1 shows examples of stimuli.

Stimuli were presented on a Scientific Prototype Model GB three-channel tachistoscope. Distance from eye to stimulus was 54 in. Luminance of the field was 11.3 ml, and the center of the field was marked off by a small (1/4-in. square) cross on the field card.

Procedure. Each subject was seated at the viewer of the tachistoscope with instructions to center eyes on the field cross and count the number of dots that would be flashed to either the right or left of the cross. The subjects were cautioned not to attend to either side but to focus on the center cross, since stimuli would appear in prearranged random order. For each trial, the experimenter said "ready" as a signal for the subject to center on the cross and then flashed the stimulus for 80 msec (see Kimura, 1966). The subjects responded verbally as to number of dots perceived and the experimenter recorded the answer. Ten practice trials were given first and then the 64 pairs (128 cards) were presented twice. A few minutes of rest were given between runs.

Scoring was done in two ways: (1) number of incorrect trials (any trial in which there was an inexact match to actual size of dot pattern) and (2) difference scores (for each trial, the difference between the actual size of pattern and the subject's answer). It was found that using incorrect trials alone was too gross a measurement, since it did not permit discrimination between those

whose trials were incorrect by many dots and those incorrect by only a few dots. Consequently, the more interesting effects were found with difference scores, and those scores are reported here.

Results

The analysis of variance was done on two between-groups factors of reading *group* (good, poor) and *sex*, and three within-groups factors of *field* (left, right), *run* (2 runs), and *chunking size* (3-10 dots). Table 2 presents the main and significant interaction effects. Only those effects with $p \leq .05$ were considered significant.

Two significant main effects, for field and run, show that all subjects were more accurate in the left field (means = 7.5 vs. 8.12) and in the first run (means = 7.12 vs. 8.52). Although the good group was generally more accurate, with the poor group falling even further behind in Run 2, the factor of group was not statistically significant (means = 6.43 vs. 9.23).

The significant effect for size denotes that, across groups and sexes, error increased as size of dot pattern increased. The significant interaction between size and sex qualifies this main effect. Figure 2 and Table 3 show that males were more accurate than females as pattern size increased. A trend analysis using orthog-

Figure 1. Examples of dot stimuli used in Experiment 1. Each set is a mirrored left-right pair.

Table 2
Main Effects and Significant Interactions
for Dot Laterality Experiment

Source	SS	df	MSe	F	p
Field	66.62	1		4.412	.047
Run	396.59	1		5.424	.029
Group	1,552.07	1		3.396	.079
Sex	811.56	1		1.776	.196
Size	10,039.52	7	1,434.21	34.175	.000
Size by Sex	943.37	7	134.76	3.211	.003

Figure 2. Size X sex interaction, Experiment 1, dots.

onal components showed that the difference in the linear trend of the two sets of scores accounted for 93% of the variance between sexes ($p = .001$).

Experiment 2: Chords

Method

Subjects. Subjects were the 13 good and 13 poor readers determined by the criterion-music-reading test given in Part 1.

Stimuli and Apparatus. Stimuli were drawn on cards in the same manner as for the dot experiment. Sixty-three right-left pairs of chords consisting of from 2 to 6 notes were constructed, 7 pairs for both 2- and 6-note chords, 14 pairs for both 3- and 5-note chords, and 21 pairs for 4-note chords. The differing number of pairs for some sizes denotes more than one chord array type for those sizes. Each notehead was roughly 3/8 in. in diameter. Chords varied in complexity, being made up of three types: (1) TP—traditional plain tonal chords that had no modifying accidentals (sharps or flats); (2) TA—traditional tonal chords that had from one to four modifying accidentals; and (3) AT—atonal, nontraditional chords consisting of intervals and accidental combinations usual in 20th century piano compositions. Chords were centered vertically and horizontally 1 deg to the right or left of center fixation. Examples of chord stimuli are shown in Figure 3. As with dots, the 63 chord pairs were given two different random orders for a repeated-measures design.

The apparatus was the same as that used for the dot experiment, with the addition of a small (four-octave) Wurlitzer electric piano placed directly below the viewer of the tachistoscope.

Procedure. The subjects were seated at the piano with the tachistoscope's viewer centered directly over the keyboard. An

assistant was responsible for changing cards and tripping the flash while the experimenter stood beside the piano with an answer sheet containing each chord in the order shown. Each subject was instructed to focus on the center cross, and then the assistant tripped the flash for 150 msec. (Presentation time was equal to the maximum latency time generally accepted for one eye movement, because pilot studies had shown shorter presentation times resulted in too many errors.) Each subject was instructed to play as many notes as possible in each trial and to keep fingers on the keys until the experimenter had recorded the response. This sequence for each trial took an average of 10 sec. Ten practice trials were given first and then the 63 pairs (126 cards) were presented twice, with a few minutes of rest between runs.

As with dots, scoring for chords was done on the number of wrong notes rather than on a grosser score of wrong trials only. The finer discrimination of taking a difference score was not possible, since the correct answer involved not only the number of notes but also the correct names of notes (playing the notes correctly on the keyboard). In addition, the scoring here represents an averaged score. Each score for each size and type of chord was divided by the number of trials possible for that size and type. This ratio scoring was necessary since the number of trials for each size and type was unequal, and comparisons of type within each size were of interest.

Results

The analysis of variance was done on two between-groups factors of reading *group* (good, poor) and *sex*, and four within-groups factors of *field* (left, right), *run* (2 runs), *chunking size* (2 to 6 notes), and *chord type* (3 types). Table 4 shows main and significant interaction effects. Only those effects with $p \leq .05$ were considered significant. All subjects favored the right field (means = 20.37 vs. 19.15), with the good group significantly more accurate (means = 16.88 vs. 22.65) over all types and sizes of chords. In addition, a practice effect was found, with both groups performing more accurately in Run 2 (means = 20.85 vs. 18.67). The significant main effects for chord size and chord type must be qualified by an interaction between the two factors. Figure 4 and Table 5 show the size-type interaction as a dip in note errors for four-note chords of the second type, TA.

DISCUSSION

The only similarity between the results of the two laterality experiments was that accuracy decreased overall as the size of chord or dot pattern increased. The more interesting conclusions of the study are drawn from the contrasting results found in the two experiments for the factors of *field*, *sex*, *group*, and *run*. Here, also, correlations of the musical memory

Table 3
Dots: Cell Means (Difference Scores) for Size, Sex, Size by Sex

Sex	Size								Mean
	3	4	5	6	7	8	9	10	
Male	1.93	4.97	5.58	7.18	6.54	7.87	9.47	10.90	6.81
Female	1.72	3.97	5.23	9.32	9.83	11.34	12.88	16.47	8.85
Mean	1.83	4.47	5.40	8.25	8.19	9.61	11.18	13.69

Figure 3. Examples of chord stimuli used in Experiment 2. Chords were identical for left and right fields.

Table 4
Main Effects and Significant Interactions
for Chord Laterality Experiment

Source	SS	df	MSe	F	p
Field	689.68	1		7.893	.010
Run	1,746.96	1		18.058	.000
Group	12,564.64	1		16.514	.001
Sex	27.69	1		0.036	.850
Size	75,502.42	4	18,875.61	171.788	.000
Type	7,546.68	2	3,773.34	45.446	.000
Type by Size	10,991.28	8	1,373.91	17.306	.000

test with the preliminary reading test and the tachistoscopic tests are discussed.

Field

Subjects, across sexes, favored the right field for chords and the left field for dots. Similar results have been found in other studies, cited earlier. One of these, by Oscar-Berman et al. (1976), employed a masking paradigm to measure iconic memory for single notes and obtained a left-field superiority. It is interesting to speculate whether or not the same results would occur if chords were used rather than single notes. Although more complicated kinesthetic judgments are needed for response to chords, as opposed to single notes, cognition might still be dependent on a type of memory, i.e., memory for the "feel" of each chord in the fingers. Might such a memory mechanism, like the iconic memory measured by Oscar-Berman et al. (1976) be attributable to the right hemisphere? Or would the more complicated spatial judgments needed for processing chords preclude or limit the use of such a memory mechanism? If the latter is so, then the sequential processing of the left hemisphere may be implicated. The present study provides some evidence

for this. All males, both good and poor readers, favored the left field on the dot task and were significantly more accurate than the females as the difficulty of the task increased. Yet, the same males favored the right field for recognition of chords, suggesting that the same processes were not dominant for both types of stimuli.

From the present study, it may be concluded that the right hemisphere is not dominant in the recognition of musical notation that is presented in discrete chunks (Experiment 2). The right hemisphere may, however, be more involved in the reading of continuous musical notation, as music is normally read for performance. Here, the factor of tonal memory is relevant, although how tonal memory is defined and measured seems most important. Defects in tonal memory have been linked to right-temporal-lobe impairment by many clinical researchers, some of whom were cited earlier. Many of these studies utilized the tonal memory test of the Seashore Measures of Musical Talents (Seashore, Lewis, & Sætevit, 1939). In this test, sets of three, four, and five tones are each compared with a second playing in which one of the tones is different. The judgments required are thus simple, requiring memory for small tonal groups taken out of melodic context. This lack of musical context is one criticism leveled at the test.

For this reason, the subjects in the present study were given a test of musical memory that tested auditory memory for whole melodic excerpts, the Drake Musical Memory Test (Drake, 1957). The test requires comparison of a melody with either a repeat or transformations of the melody, transformations that must

Figure 4. Type X size interaction, Experiment 2, chords.

Table 5
Chords: Cell Means (Averaged Note Errors)
Type, Size, Type by Size

Type	Size					Mean
	2	3	4	5	6	
TP	5.84	10.99	16.38	22.02	27.85	16.62
TA	8.63	20.06	15.35	26.61	32.89	20.70
AT	11.92	17.70	23.39	32.57	24.21	21.96
Mean	8.80	16.25	18.37	27.06	28.32	

be specified as to type (three types). The judgments are therefore more complicated and presented in a more musical context than that of the Seashore test. However, it has been reported that the test has "moderately high" relationships with the Seashore test (Lundin, 1964).

Taking this into account, the Drake Musical Memory Test was correlated with the Part 1 criterion test (sight-reading ability) and the Part 2 experimental tests (dots and chords). Table 6 shows that a small significant correlation of .397 ($p < .05$) was found between musical memory and the criterion-reading test. This correlation indicates that musical (tonal) memory, as defined by Drake, does have something to do with music reading, but not when that reading is done in discrete (tachistoscopic) chunks. However, it is not possible to dismiss the importance of such discrete chunking ability to music reading, since a correlation of .57 ($p < .01$) between the chord test (Experiment 2) and the criterion sight-reading test was also found. In fact, it would appear that for the sight-reading of these subjects, chunking ability is more important than tonal memory. And, if chunking ability for chords is attributed to the left hemisphere, as indicated by the results of Experiment 2, then the left hemisphere emerges as most important for music reading. This is true even if the factor of tonal memory can be linked to the right hemisphere, given the modest correlation of that factor with the sight-reading criterion test. Underscoring this conclusion are the hemispheric ambiguities already noted in nonclinical studies of melodic recognition.

Sex

Sex differences emerged only in the dot experiment, in which the males were superior to the females on larger sized patterns. This male superiority is confirmed in the literature, already cited, which indicates that males show more left-field dominance than females on tasks connected with spatial relationships.

The lack of sex differences in the chord experiment conflicts with some findings in the literature. Davis and Woda (1978), cited earlier, found that males and right-handers emphasized the nonverbal, spatial structure of visual information, and females and left-handers the verbal structure of visual information. In the present study, neither sex nor hand preference seemed to be factors in laterality preferences for

either of the two visual tasks. Both male and female subjects (all right-handed except for one female) seemed instead to base their field preferences on stimuli content (chords or dots). Thus, males showed no advantage over females in the chord task in which left-hemispheric dominance was indicated by all subjects' preference for the right field. However, males were superior to females in the dot task in which left-field preference across sexes implied right-hemispheric dominance.

An interesting speculation is that the use of recognition level as the dependent variable in the chord experiment may not have been a fine enough measure to tap right-brain involvement whereby sex differences might emerge. Males might show a left-field dominance for chord perception in another type of measure, e.g., one for iconic memory as used by Oscar-Berman et al. (1976).

Group

The good sight-readers were significantly superior to the poor sight-readers only in the chord experiment. This is not surprising, since the majority of the good sight-readers were female (8 vs. 5). Therefore, the good group would not be biased toward a right-hemisphere task like dot enumeration. Nevertheless, the lack of reading-group significance in the dot experiment suggests that poor music readers can perform nonmusical perceptual tasks almost as well as good readers. Yeni-Komshian et al. (1975) propose that poor word readers have some defect in right-brain processing. Given the poor music readers' performance on the dot task, the present study does not lead to this conclusion, for males performed better than females across groups. However, assuming the chord task tapped left-brain function, it may be that poor music readers are somehow deficient in left-brain processing.

Run

With chords, a practice effect occurred with better overall accuracy in Run 2, while with dots there was an overall decrement in accuracy in Run 2. This occurred across groups and sexes. Thus, with this group of musicians, only the more familiar musical stimuli responded to practice. This finding supports the previous suggestion that perceptual ability per se may not be a strong factor in music-reading skill dif-

Table 6
Correlations of Musical Memory Test with
Part 1 and Part 2 Tests

	Test Type		
	Criterion	Chord	Dot
Musical Memory	.397*	.173	.118
Criterion Test		.574**	.092
Chord Test			.002

Note—The chord test was given in Experiment 2; the dot test was given in Experiment 1. * $p < .05$. ** $p < .01$.

ferences. Apparently, it is in the perception of *musical* stimuli that better music readers excel.

Finally, an interesting interaction that occurred in the chord experiment across groups bears further comment. (Figure 4 shows this interaction between chord type and chord size.) It may be partially due to the fact that trained musicians analyze, study, and write more four-note chords than any other size chord in the course of their formal music study. However, it is puzzling as to why a more complex type (TA) with accidentals should be as easy to perceive as plain chords (TP) when both are of the same size. Further study would be interesting in order to rule out a chance occurrence with these particular subjects.

Summary of Conclusions

Given the theory of the contralateral relation of hemispheric activity to visual fields, some propositions about music-reading ability can be drawn from this study. When quick visual recognition of musical chords is concerned (as in Experiment 2), the language-dominant hemisphere seems to play an essential role for readers of all skill levels. However, the significantly poorer accuracy of the poor reading group in the chord experiment suggests that some impairment or non-development of the dominant hemisphere may exist in poor music readers.

As for the minor hemisphere, it does not seem to be directly involved in quick chord recognition, although it may be indicated, via auditory musical memory, in the reading of continuous musical phrases (as in the Part 1 criterion test). From the present study, there is some evidence that this is so, given the correlations of the auditory musical memory test with both the chord experiment and the criterion-reading test (see Table 6). However, the present study offers no evidence that good music readers are superior in use of the right hemisphere. The results of the dot enumeration experiment, in which right-hemisphere dominance was implied for all subjects, showed that good readers were not significantly superior to poor readers, although good readers were more accurate overall. It should be noted that the larger number of females in the good reading group may have biased this result.

In spite of the female majority in the good reading group, there is no evidence from this study to imply that females are better music readers than males. Sex differences do not seem to play a role in music-reading ability. There is evidence that males are better at perceiving spatial relations (as in dot enumeration), but this ability cannot be directly connected with music-reading ability.

Only one factor, practice, was shown by this study to have direct influence on music-reading skill. Both good and poor readers improved their accuracy with the Experiment 2 chords when the chords were run a second time. This practice effect did not occur with the dots of Experiment 1.

To conclude, good music readers in this study excelled only in perceiving music notation. They may have some intrinsic cognitive abilities, particularly in the left hemisphere, which account for their good reading skill. And, even though practice may improve the skills of both good and poor readers, it seems reasonable to assume that the intrinsic skills of the good reader would tend to maintain his advantage over the poor reader.

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