Lateralization for Reading Musical Chords: Disentangling Symbolic, Analytic, and Phonological Aspects of Reading

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It has been repeatedly shown that the left hemisphere (right visual field) is superior to the right hemisphere (LVF) in reading English, a bias possibly due to any or all of three confounded factors: (1) the symbolic nature of the coding system; (2) the analytic requirements of the decoding process; and (3) the phonological associations of the elements. Recent work on reading Japanese ideograms (Kanji) disentangles (1) from (2) and (3), but leaves the latter two confounded. We further disentangle (2) and (3) by examining visual field preference for reading musical chords, representatives of an analytic, nonphonological symbol system. The strong RVF advantage is interpreted as indicating that the left hemisphere is dominant for reading an analytic symbol system that is not phonologically based. We conclude that the left-hemisphere advantage traditionally found for reading phonological symbols is due to their analytic nature in addition to any effect due to their linguistic association.

The division of hemispheric asymmetries along the analytic/holistic dimension has become almost a platitude. However, there are surprisingly few reports which specify clearly what this dimension is and how it

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relates to hemisphere differences. Usually, language is considered to have analytic qualities and to be left hemisphere dominant, while visuospatial processing is considered holistic and right hemisphere dominant (Krashen, 1976). However, this simple dichotomy is questionable, especially when dealing with language competency, i.e., language knowledge as a system (Poeck & Huber, 1977), as opposed to language performance tied to the auditory/oral channel. There are both analytic and holistic aspects to such a complex system. Part of the difficulty is in specifying what is meant by the terms “analytic” and “holistic.” Perhaps as a result of this confusion, numerous authors merely allude to the “analytic nature” of language or of left hemisphere processing without sufficiently defining this characteristic.

One interpretation of the analytic/holistic distinction is that an analytic strategy involves serial or sequential processing, while a holistic one involves parallel processing. There are certainly major serial properties to language decoding, and left-hemisphere superiority on this task has been repeatedly demonstrated. However, as Cohen (1973) showed, the left hemisphere affiliation with serial processing may be present only with linguistic stimuli, e.g., left hemisphere judgments about letters seem to involve serial processing, while the right hemisphere shows a parallel processing style on the same task, but the strategy difference does not show up when the tasks involve judgments comparing unnameable objects (Cohen, 1973). Moreover, the right hemisphere is sometimes superior with serial data such as melodies (Milner, 1962). Thus, although linguistic processing may have a sequential component, we cannot characterize left-hemisphere processing as necessarily serial. The problem of the language confound is discussed further below. Another interpretation of the analytic/holistic distinction might be represented by the focal/diffuse distinction of Semmes (1968); this approach seems to account for similar data, while postulating a more general, nonlinguistic base (Allard, 1972).

In this paper, we prefer a more traditional definition of the distinction (Bever, Hurtig, & Handel, 1976; Neisser, 1967): In analytic processing, the material is broken down into meaningful elements in the decoding process; in holistic processing, there is no such breakdown because smaller elements would not have meaning at the appropriate level. For example, spoken words (analytic) are composed of syllables, which are composed of phonemes, all of which have significance at a linguistic level; environmental sounds (holistic) often do not have meaningful components, i.e., they have no separable parts which contribute to the listener’s identification of the whole. Similarly, written English words are composed of letters, while letters are composed of lines. The latter breakdown does not produce elements that have meaning at the linguistic level; therefore, letters may be decoded holistically, while words are decoded analytically. This distinction is not simply a terminological variant of the
serial/parallel processing distinction, since longer words do not necessarily take proportionately longer to read than short words (Neisser, 1967).

The role of hemispheric specialization in the analytic/holistic discussion (using our definition) is not totally clear, because the correlation between this dimension of processing (i.e., analytic/holistic) and hemispheric dominance has always been confounded with the language factor (e.g., Albert, 1972), as shown by Cohen (1973). This confound is especially true of lateralization work involving the visual modality, since the usual stimuli used (i.e., letters) are part of both an analytic symbol system and a speech-related phonological complex. There is considerable evidence that speech-related stimuli are processed asymmetrically, whether they are part of a language known by the subject or not (Kimura & Folb, 1968; Segalowitz & Chapman, 1978; Molfese, 1977). Any left-hemisphere superiority found with letters could thus be attributed to this phonological factor, although undoubtedly additional processing variables also underlie dominance effects (Segalowitz & Gruber, 1977).

Recently, several interesting studies with readers of Japanese, both normals and aphasics, have reported a lessened left-hemisphere dominance (or even a right-hemisphere dominance) for reading Japanese Kanji, a nonphonologically based (ideographic) writing system, compared to reading Japanese Kana, a phonologically based writing system (Hatta, 1977; Sasanuma, 1975; Yamadori, 1975). These studies show clearly that the right hemisphere is capable of decoding written symbolic information when it is expressed in a style appropriate to that hemisphere’s cognitive abilities, in this case, holistic symbols representing linguistic information in a nonphonological manner (see Table 1). Since both Kanji and Kana are symbol systems, this work has unconfounded the symbolic factor from

TABLE 1
A Breakdown of the Cognitive Aspects of Reading Each Type of Symbol System and the Associated Hemisphere Advantage Found (after the Arrows)*

<table>
<thead>
<tr>
<th>Coding characteristic</th>
<th>Analytic</th>
<th>Holistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonphonological</td>
<td>1 Musical chords → Left</td>
<td>3 Kanji → Right</td>
</tr>
<tr>
<td>Phonological</td>
<td>2 English. Kana → Left</td>
<td>4 Early writing systems Rebus writing some Chinese ideograms → ?</td>
</tr>
</tbody>
</table>

* The contrasts between 1 and 2, and 1 and 3 illustrate the main conclusion of this paper. Since all these systems are symbolic, this third dimension is not shown (see text); it is separated from the other two by holding it constant.
the phonological and analytic qualities found in studies in reading English, in which all three factors are confounded. However, in the Japanese studies, there still exists a link between these latter two factors: Phonologically based symbols are encoded analytically while nonphonologically based symbols (Kanji ideograms) are encoded holistically.

The purpose of the present study is to disentangle further these last two factors: In writing systems, usually the symbols are based on an analytic—phonological system (e.g., English, Japanese Kana) or on a holistic—phonological system (e.g., Chinese, Japanese Kanji). Is the difference in hemisphere advantage found in the Japanese studies due to the analytic/holistic distinction or to the phonological/nonphonological contrast? One way to separate these two factors is to use a symbol system that is analytic (i.e., in which there are meaningful components which must be interpreted independently) and that is not linked to a phonological, i.e., speech-related, system. Musical notation provides a good example of such a system: in particular, musical chords can be analyzed into nonphonological elements which belong to a well-learned (in musicians) symbol system. As with words, chords can be broken down into meaningful elements and the musician is in fact probably forced to do so in the absence of contextual clues. If the dominance is due to the analytic/holistic distinction, musical chords should be processed more accurately by the left hemisphere. If on the other hand, it is the nonphonological characteristic that is important, then the right hemisphere should dominate. Although a right-hemisphere superiority has been found in the auditory processing of musical chords (which has been assumed to be a holistic task) (Gordon, 1970), no one has examined any lateralization effect in the visual processing (reading) of musical chords. Such a study would sever the remaining confounding link mentioned above, since music symbols are an analytic, but nonphonological, system. A left-hemisphere superiority has been found for musicians reading single notes (Oscar-Berman, Blumstein & Deluca, 1976), however, the results could have been due to a verbal set (naming the note) or to the response measure (only right-hand responses) required by the paradigm. The present experiment eliminates the confound of response measure and task requirements.

METHOD

Subjects

The subjects were 20 right-handed females, mainly university students, with no left-handed immediate relatives. Handedness was determined by self-classification (writing and throwing) and the Edinburgh Handedness Inventory (Oldfield, 1971). All subjects were sufficiently skilled at playing a keyboard instrument that they had no difficulty in playing chords with
an octave range without looking at the keyboard, as was required by the study. Their median reported experience on keyboard instruments was 9 years. Most were either studying music or were active amateur musicians.

Procedure and Apparatus

Subjects viewed a tachistoscopic presentation of a randomized series of three-note chords presented one chord at a time. All chords were written with upward-pointing note stems. Adjacent notes on the test chords were separated by either intervals of a third, a fourth, or a fifth. Clef signs were not included with the stimuli; according to their experimental condition (left- or right-hand response), subjects were instructed that all stimuli were to be read as either bass or treble clef. The notes used in the chords included those in the octave from the space below the staff (F₂ or D₄) to the second line from the top of the staff (F₃ or D₅), inclusive (see Fig. 1). Each chord was presented the same number of times in each visual field, centered 4° from the central fixation point; the notes subtended a visual angle of 24'. There were a total of 54 stimuli. The subject was seated in front of a Gerbrands (Harvard Model T-3B-1) tachistoscope with a dummy keyboard positioned under the T-scope eyepiece such that the subject could look into the eyepiece and play on the keyboard. The 10 (white) keys which were used in the study (treble clef D to D, base clef F to F) were connected to an event recorder (Esterline Angus Event Graph) that registered which notes were depressed. The paper tape record of the subject's responses was kept for scoring after the experimental run. Each trial consisted of (a) the presentation of a central fixation point (a vertical bar with approximately the same surface area as one of the chords) on an otherwise blank staff, which subtended 1.6° of visual angle vertically and extended across the entire field, (b) the presentation of a chord in either the left or right visual field, and (c) the subject's response, i.e., the depression of the appropriate keys on the dummy keyboard. Subjects were instructed to return the hand to the same position following each trial, resting lightly over an inverted C-chord (right hand, E₄, G₄, C₅, or left hand G₂, C₃, E₃).

The duration of the stimulus presentation ((b) above) was determined for each subject during a practice period; the duration was set so that the

![Fig. 1. Two of the stimulus set of chords showing the bottom and top limits of the range used.](image-url)
subject could be expected to make errors on about one-half of the trials, based on her practice-trials performance. (There was, however, some improvement during the test session, so that errors usually dropped below that level by the end of the session.) The data of subjects whose stimulus duration setting was 200 msec or greater were not used because of the possibility of a shift in eye fixation.

Subjects were allowed to set their own response pace and to replay a response chord if they felt they had misplayed it initially. In such cases, the second chord was taken as the subjects' response.

Half of the subjects were instructed to respond with the right hand and half with the left hand, although as noted above, all subjects were right handed.

RESULTS

Errors were analyzed in two ways: The data from the chords presented in the two visual fields were compared with respect to (a) the total number of notes played incorrectly, and (2) the number of chords containing errors. As shown in Table 2, there were significantly fewer errors for right visual field (left-hemisphere) stimuli; similarly, the left hemisphere showed an advantage on the number of chords correct. There were no significant effects for hand used or for interactions between hand used and visual field of presentation.

Since intuitively some of the chords seemed to require more spatial

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand (H)</td>
<td>67.6</td>
<td>6.4</td>
<td>1</td>
<td>67.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Hand × Subjects</td>
<td>2185.9</td>
<td>432.5</td>
<td>18</td>
<td>121.4</td>
<td>24.0</td>
</tr>
<tr>
<td>Visual field (VF)</td>
<td>348.1</td>
<td>108.9</td>
<td>1</td>
<td>348.1</td>
<td>108.9</td>
</tr>
<tr>
<td>H × VF</td>
<td>3.6</td>
<td>6.4</td>
<td>1</td>
<td>3.6</td>
<td>6.4</td>
</tr>
<tr>
<td>H × VF × Subjects</td>
<td>444.3</td>
<td>83.7</td>
<td>18</td>
<td>24.68</td>
<td>4.65</td>
</tr>
</tbody>
</table>

Means of Total Number of Errors and Number of Wrong Chords

<table>
<thead>
<tr>
<th>RVF (left hemisphere)</th>
<th>LVF (right hemisphere)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left hand</td>
<td>24.8 12.9</td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>22.8 12.9</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>23.8 12.9</td>
<td>29.7 16.2</td>
</tr>
</tbody>
</table>

a The "total number of errors" data are in standard script, the "number of wrong chords" in italics.
Fig. 2. Examples of triads with two intervals of a third (E minor) vs. one of a third and a fourth (C major).

thinking than others, e.g., a triad of thirds seemed easier to classify than a triad with a third and a fourth (see Fig. 2), we examined the relationship between errors on different chord types and visual field. However, an analysis of variance on percentage errors for each type of chord by visual field showed no significant interaction between the relevant variables. This analysis was done twice, with and without an arcsin transformation (Winer, 1971). A similar analysis on average number of incorrect notes per chord type produced similar results.

DISCUSSION

Traditional approaches to the question of cerebral dominance for music relegate this ability to the right hemisphere (Milner, 1962). However, more complete reviews (Gates & Bradshaw, 1977) show how inaccurate such a simplistic viewpoint is. The cerebral dominance shown for music tasks appears to be largely dependent on the cognitive activity of the subject, rather than on the stimulus materials. For example, although the right hemisphere has been shown to dominate in a passive music task (Carmon, Levy, Gordon, & Portnoy, 1975), a study using a more analytic listening task showed a left-hemisphere advantage (Bever & Chiarello, 1974; Johnston, 1977). In the present study, we also find a strong left-hemisphere advantage for the task of reading musical chords, which is surprising at first glance since the coding system is basically spatial in nature.

We feel this left-hemisphere advantage is due to the analytic nature of the task. A left-hemisphere advantage is also shown for reading English, but this may be due to the analytic and/or the phonological aspect of the coding system; reading musical chords removes the confounding of these two factors, and as the present study shows, supports the analytic/left-hemisphere link (see Table 1). On the other hand, the phonological factor in reading may or may not differentiate hemispheric performance.

We know that the right hemisphere is adept and maybe even superior at decoding nonphonological, holistic symbols, as in Kanji (Hatta, 1977). Since both this latter study and our study involve nonphonological
stimuli, the critical difference between them is on analytic/holistic dimension. Of course, it may be that the nonphonological stimuli do not bias in favor of either hemisphere, while phonological coding does bias in favor of the left hemisphere. To test this, the final box in Table 1 should be completed. Early writing systems (e.g., Sumerian, Hittite (Gelb, 1963)), rebus writing, and some Chinese ideographic radicals are phonologically based and holistically represented. Although finding subjects capable of fluent judgments in the first two types would be rather difficult, a test for hemisphere advantage on reading this type of system would answer this last question of phonological coding and brain dominance. If the phonological factor counteracts the holistic factor and reduces the overall right-hemisphere lateralization effect, then we know that the phonological coding system favors a left-hemisphere advantage. An undiminished advantage for the right hemisphere (compared with subjects who do not recognize the symbols as having phonological referents) would indicate that only the analytic/holistic dimension is important in cerebral processing asymmetries, and that the phonological characteristic of the symbol system does not favor one hemisphere over the other.

We still need to determine which aspect of analytic processing produces the left-hemisphere advantage. Although a serial decoding strategy need not accompany all analytic processing, subjects in our study did occasionally report a conscious strategy of reading the notes serially. If this is a general practice, Cohen’s (1973) findings should be extended to include nonverbal, analytic symbol systems. Whether such a strategy is conscious or not, however, there may be automatic element-by-element analysis at some level of the decoding process, in spite of the fact that words and chords can be recognized as wholes. In reading Japanese Kanji, on the other hand, such a strategy would be meaningless.

In summary, by using a task involving the decoding of a nonphonological, analytic symbol system (i.e., the reading of musical chords), we have shown that the left-hemisphere advantage traditionally found for the reading of phonological symbols is due to their analytic nature in addition to a possible bias due to their linguistic association.

REFERENCES

1 It should be noted that we are dealing only with symbolic visual material and therefore our findings may not generalize to nonsymbolic visual stimuli.


REFERENCE NOTE