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Variations in Characteristic Perceptual Asymmetry: Modality Specific and Modality General Components

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The current study investigates sources of between-subjects variation in asymmetry scores on visual half-field and dichotic listening tasks. For each of these presentation modalities, subjects were given multiple laterality tasks. Results indicate that about 50% of the between-subjects variations in asymmetry scores in each modality is attributable to individual differences in perceptual asymmetries that are not stimulus-specific, referred to as "characteristic perceptual asymmetries" in this paper. In addition, the question of whether individual differences in characteristic perceptual asymmetries are modality specific, modality general, or both was investigated by entering subjects' asymmetry scores from visual half-field and dichotic listening tasks into a principal component analysis. The results of this analysis indicate that there are both modality specific and modality general influences on subjects' characteristic perceptual asymmetries.

INTRODUCTION

Asymmetry scores of normal right-handed subjects on standard laterality tasks (e.g., visual half-field presentation, dichotic listening) are ex-

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tremely variable in both magnitude and direction. In particular, only about 60–80% of normal right-handed subjects show the "expected" direction of perceptual asymmetry on individual laterality tasks (e.g., right visual field advantage for recognizing words). In contrast, clinical data indicate that patterns of hemispheric specialization are extremely consistent among right-handed subjects.

For example, sodium amytal tests carried out on patients with focal epilepsy typically show that at least 95% of right-handed subjects have productive language functions lateralized to the left hemisphere (e.g., Rasmussen & Milner, 1975). The discrepancy between clinical and normal laterality data may be attributable to more consistent left hemisphere lateralization of productive language functions, typically tested during sodium amytal testing, vs. receptive language functions, typically tested in laterality studies with normals (Strauss, Wada, & Kosaka, 1985). It is also possible that longstanding epilepsy in patients undergoing sodium amytal testing may have altered their patterns of hemispheric specialization. Despite these differences, however, it is generally acknowledged that normal right-handed subjects are not as variable in their patterns of hemispheric specialization as laterality test data indicate.

This wide variability in the asymmetry scores of normal right-handed subjects compared to clinical data has limited the use of individuals' asymmetry scores as measures of underlying hemispheric specialization. Typically, variations in asymmetry scores in normal subjects have been attributed to "random error in measurements" rather than reliable individual differences (Chiarello, Dronkers, & Hardyck, 1984; Colbourn, 1978; Satz, 1977; Schwartz & Kirsner, 1984; Teng, 1981). Most studies emphasize findings of group-typical asymmetries, giving little attention to individual variations in asymmetry patterns.

In contrast to the "random noise" explanation for individual variation in asymmetry scores, results of several studies indicate that a stable individual trait, referred to in this paper as "characteristic perceptual asymmetry," accounts for a significant proportion of the between-subjects variability in asymmetry scores. For example, Levy, Heller, Banich, and Burton (1983a) found a positive correlation between subjects' asymmetry scores on left and right hemisphere specialized tasks (asymmetry scores computed as $R - L$ for both tasks). Similarly, Levine, Banich, and Koch-Weser (1984) report that subjects' asymmetry scores on tasks that are nonlateralized for subjects as a group are positively correlated with their asymmetry scores for left and right hemisphere specialized tasks. Consistent with these findings, applying a principal component analysis (PCA) to subjects' asymmetry scores on five laterality tasks, Kim, Levine, and Kertesz (1990) report that about 50% of between-subjects variation in asymmetry scores is attributable to a component on which all tasks are weighted in one direction with similar magnitude. In addition, a metaanalysis of the correlations between subjects' asymmetry scores on left and right specialized tasks reported in the literature indicates a significant positive correlation between asymmetry scores on left and right hemisphere specialized tasks (Kim & Levine, 1991b).

The positive correlations between-subjects' asymmetry scores on a variety of laterality tasks suggest that each individual has a characteristic direction and degree of perceptual asymmetry that is not stimulus-specific (Levy et al., 1983a). These "characteristic perceptual asymmetries" may range continuously from strong leftward asymmetries to small or nearly equal asymmetries to strong rightward asymmetries. In contrast, underlying patterns of hemispheric specialization appear to be highly consistent among right-handed subjects. Levy et al. (1983a) have proposed that a subject's characteristic perceptual asymmetry is superimposed on underlying hemispheric specialization and that both of these factors are reflected in his/her asymmetry score on any given task. Thus, the mean asymmetry score for a group of subjects shifts depending on whether the task is left hemisphere specialized, right hemisphere specialized, or nonlateralized. However, individual subjects tend to maintain the same position relative to other subjects in the distribution of asymmetry scores on each of the laterality tasks.

There have been several proposals for the underlying factor(s) contributing to characteristic perceptual asymmetry. First, Levy et al. (1983a) propose that characteristic perceptual asymmetries reflect stable individual differences in the relative arousal levels of the left and right hemispheres. According to this hypothesis, a subject's asymmetry scores on laterality tasks may be shifted to the left or right, in favor of the side of space contralateral to the more aroused hemisphere. An alternative hypothesis suggested by Hellige, Bloch, and Taylor (1988; see also Sidtis, 1982) is that characteristic perceptual asymmetries are mediated by peripheral factors such as sensory pathway dominance rather than central factors such as hemispheric arousal asymmetries. According to this hypothesis, individuals may differ in the efficiency with which information is transmitted to the cortex from the left or right sensory fields.

Other explanations for positive correlations between subjects' asymmetry scores have been proposed. Hellige et al. (1988) raise the possibility that characteristic perceptual asymmetries may be mediated by individual variations in the efficiency with which information is transferred across the corpus callosum. However, this explanation would require that the efficiency of callosal transmission be asymmetric such that subjects with highly efficient transfer from the left to the right hemisphere have inefficient transfer from the right to the left hemisphere, and vice versa. Finally, Boles (1989; see also Spellacy & Blumstein, 1970) proposes that characteristic perceptual asymmetries are attributable to individual differences in hemispheric specialization itself. According to this hypothesis, individual subjects vary with respect to the strength of specialization of each hemisphere for the functions it subserves. For example, for some subjects, the left hemisphere may be strongly lateralized for functions such as word recognition whereas the right hemisphere is weakly lateralized for functions such as face recognition. In contrast, other subjects show the opposite pattern. However, such wide variations in patterns of hemispheric specialization among normal right-handed subjects appear to be inconsistent with clinical data (e.g., Rasmussen & Milner, 1975). In sum, the results of several studies indicate positive correlations among subjects' asymmetry scores on diverse laterality tasks, but the factors underlying these positive correlations remain at issue (for a review, see Kim & Levine, 1991b; Segalowitz, 1987).

The current study reports an experiment that aims to further elucidate the features of characteristic perceptual asymmetry in normal right-hand subjects. Three questions are addressed. First, we address the question of whether subjects' asymmetry scores on visual laterality tasks are affected by individual differences in characteristic perceptual asymmetry. Second, we address the question of whether subjects' asymmetry scores on auditory laterality tasks are affected by individual differences in characteristic perceptual asymmetry. Finally, the question of whether characteristic perceptual asymmetry is modality specific or modality general, or affected by both modality specific and modality general components, is addressed by performing a global analysis of subjects' asymmetry scores on auditory and visual laterality tasks. The last issue is relevant to the question of whether characteristic perceptual asymmetry is centrally or peripherally mediated. In particular, the finding of a modality general component of characteristic perceptual asymmetry would provide support for central mediation.

To date, there is no direct evidence as to whether characteristic perceptual asymmetry is modality specific or modality general or both. Existing studies have either been within a single modality (Kim et al., 1990; Levine et al., 1984; Levy et al., 1983a) or, if cross-modal, have only examined the relation between subjects' asymmetry scores on *verbal* visual and auditory tasks (Bryden, 1965, 1973; Dagenbach, 1986; Graves, 1983; Hellige et al., 1988; Hines, Fennell, Bowers, & Satz, 1980; Hines & Satz, 1974; Smith & Moscovitch, 1979; Wexler, 1990; Zurif & Bryden, 1969). These studies report that subjects' asymmetries on visual and auditory tasks that are verbal in nature are either weakly related or unrelated (for a review, Kim & Levine, 1992b; Segalowitz, 1986). Some studies have suggested that this result is attributable to a dissociation in hemispheric specialization for visual and auditory linguistic processes (Bryden, 1965, 1973; Smith & Moscovitch, 1979; Zurif & Bryden, 1969). Alternatively, a large proportion of between-subjects variability in verbal laterality tasks may reflect variations in characteristic perceptual asymmetry. According to this hypothesis, the weak-to-nonsignificant correlations between subjects' asymmetry scores on verbal visual and auditory laterality tasks would indicate that variations in characteristic perceptual asymmetries are largely modality specific. In the current study, we examine the relation of subjects' asymmetries across a broad range of linguistic and nonlinguistic tasks in order to further investigate the question of whether characteristic perceptual asymmetry is modality specific or modality general or both.

METHOD

Subjects

Sixteen male and sixteen female adult subjects were recruited from the University of Chicago community. All subjects were right-handed native speakers of English. Subjects had normal or corrected visual acuity in both eyes and no known hearing impairments, according to self-report. Each subject was individually administered three tachistoscopic laterality tasks and a free-vision laterality task. Following the visual tasks, they also were administered three dichotic listening tasks. Subjects were given a brief rest break between each task. The Edinburgh Handedness Inventory (Oldfield, 1971) was administered at the end of the session. The mean LQ (laterality quotient) of subjects on this test was 74 (SD = 21).

Visual Half-Field Tasks

Stimulus materials. Three different stimulus types were presented tachistoscopically: words, photographs of faces, and photographs of chairs. The word stimuli were four- and five-letter names of common objects. All words were typed in black capital letters and aligned vertically on white stimulus cards. Vertical alignment of the words was used because with horizontal alignment, the beginning vs. end of left and right visual field words fall at different retinal positions, possibly contributing to visual field asymmetries (Kirsner & Schwartz, 1986). The face stimuli were black and white front-view photographs of previously unfamiliar adult male and female faces with neutral expressions. The chair stimuli consisted of black and white front-view photographs of a variety of wooden, straight-back chairs. Each stimulus card consisted of two stimuli of the same type, one in the LVF and one in the RVF, symmetrically displaced from the midline. The medial edge of each member of a stimulus pair was located 1.5° from the center of fixation for words and faces, and 2° for chairs. Horizontal visual angle of the stimuli ranged from 0.5° for words to 3.5° for faces, and vertical visual angle of the stimuli ranged from 2.5° for words to 3.5° for faces. A fixation symbol (+, =, Δ, ∞, *, o) appeared at the center of each stimulus card.

For each stimulus type, the left–right location of the members of each stimulus pair was counterbalanced across subjects. Thus, for each stimulus type, two sets were generated. For example, for words, the word *chair* appeared to the left of fixation and the word *lemon* appeared to the right of fixation in Set 1 and vice versa in Set 2. Half of the subjects received Set 1 stimuli of each type (words, faces, chairs) and half received Set 2 stimuli of each type.

For faces and chairs, two choice arrays of 12 pictures (3 rows × 4 columns) were used. Subjects were presented with the appropriate array following each tachistoscopic face or chair trial. For faces, one array contained all female faces and the other all male faces. For chairs, an attempt was made to place items of similar brightness in the same array, i.e., lighter-toned chairs in one array, darker-toned chairs in the other. From each array of 12 pictures, eight pictures appeared on stimulus cards twice, two pictures appeared on stimulus cards once, and two pictures were never used. This was done in order to discourage a "process of elimination" strategy for trials shown late in the series.

Procedure. All stimulus types were bilaterally presented to binocular view in a Gerbrands two-channel tachistoscope (Model T-2B). Trials were blocked by stimulus type. The non-lateralized chair task (Kim et al., 1990; Levine et al., 1984) was administered first, followed by the word and face tasks. The order of presentation of the word and face tasks was counterbalanced across subjects.

For each task, subjects were presented with 12 practice trials immediately followed by 20 test trials in a fixed random order. The number of practice trials was relatively large in order to roughly locate the exposure duration at which individual subjects would perform at about 50% accuracy prior to the commencement of the test trials. The 50% performance level was chosen as maximal asymmetries may be obtained at this level. Based on pilot work, the starting exposure duration for the first practice trial was set at 60 msec for chairs, 80 msec for faces, and 180 msec for words. Exposure duration remained the same if a subject responded correctly to one item of a pair, was increased by 10 msec if both items were missed, and was decreased by 10 msec if both items were correct. However, exposure duration was never allowed to exceed 200 msec, considered to be the latency to initiate an eye movement (Pirozzolo & Rayner, 1980).

Subjects began each trial by viewing a preexposure field consisting of the outline of a small black rectangle at the center of the field. The stimulus card appeared simultaneous with the offset of the fixation field, 500 msec after the subject initiated a trial by depressing a telegraph key in front of himself/herself. On each trial, the subject's first task was to verbally identify the symbol which appeared at the center of each stimulus card and then to report the lateralized stimuli. Accurate report of the center symbol served as an index of central fixation. Trials on which the center symbol was reported incorrectly were excluded and administered again at the end of each block. For the word task, subjects verbally reported the stimuli. For the chair and face tasks, subjects responded by selecting two stimuli from the appropriate 12-item array, which the examiner presented following each trial.

Dichotic Listening Tasks

Stimulus materials. Three different dichotic stimulus tapes developed by Kimura (1961, 1964, 1967) were used: words, digits, and melodies. On all three tapes, dichotic pairs were constructed such that one member of the pair was presented to one ear at the same time the other member was presented to the other ear. On the word tape, a test trial consisted of four dichotic pairs of familiar monosyllabic words (e.g., rock–top, week–feel, tin–pill, sad–have) consecutively spoken by a female. On the digit tape, a test trial consisted of three dichotic pairs of digits consecutively spoken by a female (e.g., 3–6, 9–8, 5–0). On the melody tape, a test trial consisted of a dichotic pair of melodies. Each melody was a four seconds solo excerpt of a classical concerto. Following presentation of each dichotic melody trial, a series of four choice melodies were presented binaurally. Two of these binaural melodies were identical to the preceding dichotic pair.

Procedure. All stimulus types were played to subjects on a Panasonic cassette-tape player (Model RX-F9) with Realistic NOVA-10 headphones. The volume for both ears was set to a comfortable standard level, and this level was checked before each test session. Trials were blocked by stimulus type and the order of presentation of the three stimulus types was counterbalanced across subjects. The order of trials was fixed across subjects within each stimulus type. Before presentation of each stimulus type, subjects were presented with two or three practice trials of that type. For the word and digit tasks, subjects responded by verbally reporting as many words or digits as possible in a free-recall paradigm. For the melody task, subjects responded by verbally reporting which two of the four binaurally presented melodies were presented in the dichotic pair, after listening to all four choices (e.g., "the first and the third ones").

Immediately following presentation of each stimulus type, the tape was rewound and the stimulus series was re-presented with the subject wearing the headphones in the opposite

TABLE 1
DIVIDED VISUAL HALF-FIELD TASKS: MEAN LEFT VISUAL FIELD (LVF) AND RIGHT VISUAL FIELD (RVF) SCORES AND STANDARD DEVIATIONS (SD) ($N = 32$)

	LVF		RVF	
Tasks	M	SD	M	SD
Words	8.90	(4.03)	9.25	(4.10)
Chairs	9.78	(3.02)	9.96	(2.95)
Faces	11.34	(2.54)	6.46	(2.87)

orientation as on the first presentation. This was done in order to counterbalance any residual differences in audio channels. Half of the subjects began with one headphone orientation, the other half with the reverse orientation. Combining trials from the first and second presentation, there was a total of 20 word trials, 24 digit trials, and 24 melody trials. Accordingly, the maximum score for each ear was 80 for words (4×20), 72 for digits (3×24), and 24 for melodies (1×24).

Free-Vision Facebook Task

Stimulus materials and procedure. Subjects were administered Levy, Heller, Banich, and Burton's (1983b) chimeric facebook task. Neutral and smiling photographs of each of nine male posers were used to construct 36 pairs of chimeric faces. The two photographs of each poser were cut in half on the midsagittal axis and recombined to make two different chimeras, one with the smile produced by the left half of the poser's face and the neutral expression by the right half of the same poser's face and vice versa for the other chimera. Each of these chimeras was paired with its mirror image, once with the normal image at the top of the page and the mirror image at the bottom, and once with the positions reversed. This yielded a total of 36 pairs of chimeric faces, four pairs of stimuli for each of 9 posers. Each poser appeared once in each successive quarter of the test. The 36 chimeric face pairs were presented in a booklet with one pair per page. The subject's task on each item was to decide which of two mirror-imaged chimeras, the one with the smile to the subject's left or the one with the smile to the subject's right, looked happier. Subjects were allowed to view each item as long as they wanted to before making a decision, but generally responded within a few seconds. They were encouraged to make a decision if at all possible, but in the event that no decision was possible, were allowed to give a "can't decide" response.

RESULTS AND DISCUSSION

ANOVA of Divided Visual Half-Field Tasks

A preliminary analysis indicated that there was no effect of Set (left–right location of stimuli), thus, this factor was eliminated from subsequent analysis. An ANOVA was performed on the number of stimuli recognized correctly in each visual field on the visual half-field tasks. Stimulus Type (Words, Faces, Chairs) and Visual Field (LVF, RVF) were within-subjects variables and Sex of subjects was a between-subjects variable. Mean visual field scores and standard deviations for each stimulus type are shown in Table 1. The main effect of Visual Field was significant, reflecting an overall LVF advantage ($F(1, 30) = 5.52$, $p < .05$). However, this effect was modified by a significant visual field by stimulus type interaction ($F(2, 60) = 20.38, p < .0001$). No other main or interaction effects approached statistical significance in this analysis.

Tests of simple effects revealed a significant LVF advantage for recognizing faces ($F(1, 30) = 40.06, p < .0001$), and no significant visual field asymmetry for recognizing chairs or words ($F(1, 30) < 1$ in each case). The pattern of results for faces and chairs is consistent with previous reports (Kim et al., 1990; Levine et al., 1984). However, the absence of a RVF advantage for word recognition is inconsistent with previous reports of a significant RVF advantage for this same task as well as similar tasks (e.g., Kim et al., 1990; Levine et al., 1984; Levy et al., 1983a).

It is possible that the absence of a significant RVF advantage for word recognition is mediated by inclusion of relatively weak right handers in the present sample. However, inconsistent with this hypothesis, the mean asymmetry score of the 16 subjects with higher LQ scores on the Edinburgh Handedness Inventory was not significantly different from the mean asymmetry score of the 16 subjects with lower LQ scores ($F(1, 30) < 1$). Alternatively, the absence of a significant RVF asymmetry for words may be attributable to our sample including an over-representation of subjects with characteristic perceptual asymmetry in favor of the LVF or a subset of subjects showing particularly strong leftward characteristic perceptual asymmetries. Supporting this possibility is the finding that the mean visual field asymmetry of the current sample (computed as $R - L$) is displaced toward the LVF for both the word and face tasks, compared to that of our previous sample of 31 right handers (Kim et al., 1990; words, $t(61) = 1.68, p < .10$, two-tailed; faces, $t(61) = 1.25$, n.s.).

PCA of Divided Visual Half-Field Tasks

In order to address the question of whether subjects' asymmetry scores in visual modality is affected by individdual differences in characteristic perceptual asymmetry, the relation among subjects' asymmetry scores on the three tachistoscopic tasks were examined. For all three tasks (words, chairs, faces), asymmetry scores were computed using the formula, $R - L$, where R is the number of stimuli recognized correctly in the RVF and L is the number of stimuli recognized correctly in the LVF. All correlations between subjects' asymmetry scores on the three tasks were significantly positive (one-tailed tests), ranging from .307 to .362 (see Table 2a). These positive correlations are consistent with the hypothesis of stable individual differences in characteristic perceptual asymmetry that operate at least within the visual modality. The correlation between asymmetry scores and overall accuracy ($R + L$) was low for all three tasks (range: $-.023$ to .124), ruling out the possibility that the correlations between asymmetry scores on different tasks are mediated by variations in overall accuracy.

Individuals differences in characteristic perceptual asymmetry were fur-

TABLE 2

DIVIDED VISUAL HALF-FIELD TASKS: (A) CORRELATIONS AMONG ASYMMETRY SCORES AND (B) PRINCIPAL COMPONENTS OF ASYMMETRY SCORES

Tasks	(a) Correlations (N = 32) Words	Chairs	Faces
Words			
Chairs	.307*		
Faces	.362*	.340*	
	(b) Principal components		
Tasks	PC1	PC2	PC3
Words	.575	−.602	.552
Chairs	.562	.782	.267
Faces	.593	−.156	−.789
Eigenvalue	1.674	.695	.630
Proportion of total variance	55.8%	23.1%	21.0%

* $p < .05$, one-tailed.

ther examined by entering subjects' asymmetry scores into a principal component analysis (PCA).[1] The characteristic perceptual asymmetry hypothesis predicts that a component on which all laterality tasks are weighted in one direction will emerge. Consistent with this hypothesis, the first principal component was characterized by high and homogeneous loadings of all three tasks in one direction (see Table 2b). This charac-

[1] A PCA computes uncorrelated linear combinations of the original variables that account for the maximal variance in the sample (Johnson & Wichern, 1982). Although as many components as original variables are required in order to account for 100% of the variability in the sample, often much of the variability can be accounted for by a small number of components. Thus, a PCA attempts to replace a large number of correlated variables with a small number of uncorrelated components. This small number of uncorrelated components may provide greater understanding of what is measured by the original correlated variables. We restrict our discussion of principal components to those with an eigenvalue greater than unity, as principal components with eigenvalue less than unity may reflect random variations specific to a particular sample (cf. Bernstein, Garbin, & Teng, 1987).

In addition, all discussion of principal components will be based on the "unrotated" solution. It is well known that "rotation" of components allows infinite sets of mathematically equivalent ways to factor a matrix, a problem known as "factor indeterminacy." The problem of factor indeterminacy, though guarding against unwarranted "reification" of factors, can be counterbalanced by a priori theoretical considerations. In the present study, the hypothesis that individual differences in perceptual asymmetries are attributable to variations in characteristic perceptual asymmetry (Levy et al., 1983a) predicts a general factor on which all variables have high loadings in one direction. The present use of the unrotated PCA solution is in accordance with this prediction, as various "rotation" methods are specifically designed to eliminate the general factor structure. Further, the use of unrotated PCA solution avoids problems with various rotation methods and problems with post-hoc selection of a factor structure from various rotated solutions.

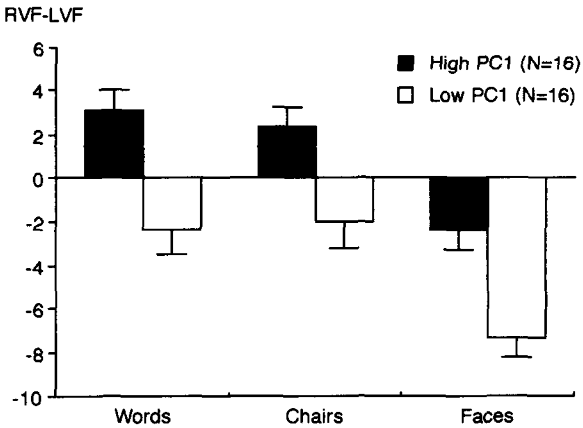

FIG. 1. Mean asymmetry scores (RVF − LVF) and standard errors of High and Low PC1 groups as defined by a median-split on the first principal component of asymmetry scores on the three divided visual half-field tasks.

teristic perceptual asymmetry component accounted for 55.8% of the total variance in the sample. A median-split of subjects based on their first component scores indicated that the asymmetry scores of subjects with high PC1 scores (N = 16) were displaced toward the right on all three tasks relative to subjects with low PC1 scores (N = 16; see Figure 1). Thus, high PC1 scores reflect characteristic perceptual asymmetry in favor of the RVF whereas low PC1 scores reflect characteristic perceptual asymmetry in favor of the LVF. The correlation between the first principal component and overall accuracy was low for all three tasks (range: −.012 to .068), ruling out the possibility that the first component reflects variations in overall accuracy.

In order to determine whether strong and weak right handers have different component structures, a separate PCA was performed for the 16 strongly right-handed subjects and the 16 weakly right-handed subjects according to their scores on the Edinburgh Handedness Inventory. For both groups, the first component was characterized by high and homogeneous loadings of all three tasks in one direction. In addition, the amount of variance accounted for by this component was similar between the two groups (strong right handers: 55.8%, weak right handers: 57.7%). Thus, the effects of characteristic perceptual asymmetry on laterality scores do not differ for strong and weak right handers. In fact, in another study (Kim et al., 1990), we found that effects of characteristic perceptual asymmetry on laterality scores do not differ for left-handed vs. right-handed subjects.

An additional PCA was performed on subjects' left and right visual field scores for each task rather than on their asymmetry scores. Table 3

TABLE 3
DIVIDED VISUAL HALF-FIELD TASKS: (A) CORRELATIONS AMONG VISUAL FIELD SCORES AND (B) PRINCIPAL COMPONENTS OF VISUAL FIELD SCORES

(a) Correlations ($N = 32$)

Task/VHF	Word LVF	Chair LVF	Face LVF	Word RVF	Chair RVF	Face RVF
Word LVF						
Chair LVF	.201					
Face LVF	310*	.395*				
Word RVF	.258	−.109	−.023			
Chair RVF	.086	−.213	−.079	.354*		
Face RVF	−.174	−.021	−.265	.194	.354*	

(b) Principal components

Task/VHF	PC1	PC2	PC3
Word LVF	−.247	.585	−.270
Chair LVF	−.446	.193	.654
Face LVF	−.491	.345	.112
Word RVF	.287	.558	−.188
Chair RVF	.445	.419	.051
Face RVF	.465	.114	.669
Eigenvalue	1.853	1.524	.977
Proportion of total variance	30.8%	25.4%	16.2%

* $p < .05$, one-tailed.

shows the correlations among LVF and RVF scores and the results of the PCA on these scores. Sources of between-subjects variability in visual field scores may include variations in the ability to perform well in addition to variations in characteristic perceptual asymmetry. Variations in the ability to perform well will mediate a positive correlation between LVF and RVF scores, as "high ability" subjects would perform well in both sensory fields whereas "low ability" subjects would perform poorly in both sensory fields. In contrast, variations in characteristic perceptual asymmetry will mediate a negative correlation between LVF and RVF scores, as subjects with characteristic perceptual asymmetries in favor of the RVF perform well on stimuli presented in the RVF but poorly on stimuli presented in the LVF. The reverse is true for subjects with characteristic perceptual asymmetries in favor of the LVF. Furthermore, variations in characteristic perceptual asymmetry may account for more variance in visual field scores than variations in the ability to perform well, at least when performance level across different subjects is held relatively constant through titration as was the case in the present divided visual field tasks. In fact, the first principal component of left and right visual field scores was characterized by loadings of all three LVF scores in one direction and all three RVF scores in the opposite direction. This characteristic perceptual asymmetry component accounted for 30.8% of the total variance. The second component was characterized by loading of all six left and right visual field scores in one direction. This "ability-to-perform-well" component accounted for 25.4% of the total variance.[2]

It may be suggested that characteristic perceptual asymmetry is due to some systematic bias introduced by the use of verbal report of a central symbol. While some studies report that report of a central symbol may activate the left hemisphere (e.g., Carter & Kinsbourne, 1979), other studies report that it has no effect on asymmetry scores (e.g., McKeever, Suberi, & Van Deventer, 1972). In our laboratory, we have consistently found LVF advantages for the recognition of visuospatial stimuli (e.g., faces) using central symbol report (Kim et al., 1990; Levine, Banich, & Koch-Weser, 1988). Thus, any possible left-hemisphere activation resulting from the use of this technique must be small. In addition, a recent study by Boles (1989) indicates that even when verbal report of a central symbol is not required, subjects' asymmetry scores on left and right hemisphere specialized tasks are positively correlated. Thus, characteristic perceptual asymmetry may not reflect a bias introduced by use of verbal report of a central symbol.

Finally, an ANOVA of the present data suggests that the present sample may include an over-representation of subjects with characteristic perceptual asymmetry in favor of the LVF, biasing the direction of the mean perceptual asymmetries to the LVF. However, an over-representation of subjects with characteristic perceptual asymmetry in favor of the LVF does not appear to affect the correlations between subjects' asymmetry scores or the PCA results. In particular, although the mean visual field asymmetry of the present sample is displaced toward the LVF compared to that of our previous sample (Kim et al., 1990), the correlation between asymmetry scores is consistently positive in both samples. Further, the PCA results are similar in the two studies, showing a first component on which all tasks load in the same direction.

ANOVA of Dichotic Listening Tasks

Each dichotic listening task was analyzed separately, as they involved different procedures. For each task, an ANOVA was performed with Ear (left, right) as a within-subjects variable and Sex of subjects as a between-

[2] It may be suggested that the "ability-to-perform-well" component reflects use of different exposure duration for individual subjects rather than diversities in subjects' ability to perform well. However, the correlations between exposure duration and visual field scores were negative rather than positive (range: −.369 to −.599), indicating that subjects with higher visual field scores were given shorter exposure duration than subjects with lower visual field scores. These negative correlations are consistent with the hypothesis that the ability-to-perform-well component reflects diversities in subjects' ability to perform well, which would have been greater if a fixed exposure duration was used for all subjects (Levy et al., 1983a).

TABLE 4
DICHOTIC LISTENING TASKS: MEAN LEFT EAR (LE) AND RIGHT EAR (RE) SCORES AND STANDARD DEVIATIONS (SD) FOR MALE (N = 16) AND FEMALE SUBJECTS (N = 16)

		LE		RE	
Tasks		M	SD	M	SD
Words	Male	14.81	(5.54)	21.56	(7.50)
	Female	11.93	(5.56)	26.50	(7.71)
Digits	Male	66.37	(6.69)	67.18	(7.32)
	Female	66.06	(6.73)	70.18	(2.25)
Melodies	Male	16.81	(2.42)	17.00	(2.16)
	Female	17.93	(2.69)	16.31	(2.46)

subjects variable. Mean ear scores and standard deviations for each task are shown in Table 4, separately for each Sex. Subjects as a group showed a significant right ear (RE) advantage for recognizing words ($F(1, 30) = 34.53$, $p < .0001$). The Sex by Ear interaction also was significant ($F(1, 30) = 4.64$, $p < .05$), reflecting a stronger RE advantage for females than males. Subjects as a group also showed a significant RE advantage for recognizing digits ($F(1, 30) = 8.03$, $p < .01$). For digits, the Sex by Ear interaction approached statistical significance ($F(1, 30) = 3.62$, $p < .07$), again reflecting a stronger RE advantage for females than males. On the melody task, subjects as a group showed a nonsignificant left ear (LE) advantage ($F(1, 30) = 2.01$, $p = .16$). The Sex by Ear interaction approached statistical significance ($F(1, 30) = 3.20$, $p < .09$), reflecting a left ear advantage for females ($F(1, 15) = 7.57$, $p < .05$) and no asymmetry for males ($F(1, 15) < 1$).

For all three dichotic listening tasks, the mean ear asymmetries were in the expected direction. However, the mean LE asymmetry for the melody task failed to reach statistical significance. The absence of a significant LE advantage for the melody task is in part attributable to males as a group showing no asymmetry. In addition, further analyses on the melody task indicated that subjects' ear asymmetry scores on the first and second presentations of this task were negatively correlated ($r(30) = -.413$, $p < .05$). In contrast, the same correlations were positive on the word ($r(30) = .371$, $p < .05$) and digit tasks ($r(30) = .562$, $p < .001$). Examination of subjects' responses on the melody task revealed a tendency to recognize the same member of each pair on the second presentation as on the first presentation (recall that the headphones were reversed on the second presentation so that melodies presented to the left ear on first presentation were presented to the right ear on second presentation and vice versa). This response pattern may be partly responsible for the present failure to find a significant LE advantage on the melody task. In fact, on the first presentation, subjects as a group tended toward a LE advantage ($F(1, 31) = 1.98$, $p = .16$), whereas there was no sign of asymmetry on the second presentation of the melody task ($F(1, 31) < 1$).

In average, the females in the present sample showed a larger ear advantage in the expected direction than the males for all three dichotic listening tasks. This finding suggests that females are more strongly "lateralized" than males. However, these sex differences were very weak and based on a small number of subjects ($N = 16$ for each Sex). In view of the fact that sex differences in asymmetries reported in literature are rather inconsistent and plagued by failures to replicate (Fairweather, 1982), it is not advisable to give significance to a weak sex difference in asymmetry from a small sample, at least until it can be demonstrated to be replicable. Therefore, we will not further discuss the present sex differences on the dichotic listening tasks.

PCA of Dichotic Listening Tasks

In order to address the question of whether subjects' asymmetry scores in the auditory modality are affected by individual differences in characteristic perceptual asymmetry, the relation among subjects' asymmetry scores on the three dichotic listening tasks were examined. For all three dichotic listening tasks, individual asymmetry scores were computed using the formula $(R - L)/(R + L)$, where R is the number of stimuli recognized correctly in the right ear and L is the number of stimuli recognized correctly in the left ear. This index was chosen in order to minimize effects of different accuracy levels among subjects on asymmetry scores. Unlike the visual field tasks, where performance level across different subjects is held relatively constant through titration, performance level is left to vary freely in the dichotic listening tasks.[3] Asymmetry scores of the melody task were computed on the basis of the first presentation only in order to avoid the contribution of the unexpected response pattern on the second presentation of this task to subjects' ear asymmetries (see above).[4] The correlation between asymmetry scores and overall accuracy was low for all three tasks, ranging from $-.198$ to $.172$.

The correlations between subjects' asymmetry scores on the three di-

[3] In order to investigate whether the present results are related to the choice of the particular asymmetry index, an additional PCA based on the asymmetry index, $R - L$, was performed. The results of this PCA were highly similar to the results of the PCA based on $(R - L)/(R + L)$. These similar results reflected the fact that the two asymmetry indexes, $R - L$ and $(R - L)/(R + L)$, were highly correlated ($r(30) > .97$ for each stimulus type).

[4] In a separate analysis, subjects' asymmetry scores of all three dichotic listening tasks were computed on the basis of the first presentation only. The result of a PCA based on these scores were highly similar to the results of the PCA reported in text.

TABLE 5
DICHOTIC LISTENING TASKS: (A) CORRELATIONS AMONG ASYMMETRY SCORES AND (B) PRINCIPAL COMPONENTS OF ASYMMETRY SCORES

Tasks	(a) Correlations ($N = 32$) Words	Digits	Melodies
Words			
Digits	.474**		
Melodies	.103	.278*	
Tasks	**(b) Principal components PC1**	**PC2**	**PC3**
Words	.607	−.490	.625
Digits	.675	−.096	−.731
Melodies	.418	.866	.272
Eigenvalue	1.600	.910	.489
Proportion of total variance	53.3%	30.3%	16.3%

* $p < .10$
** $p < .01$, one-tailed.

chotic listening tasks were similar to those for the visual half-field tasks in that all three correlations were positive (see Table 5a). The correlation between the word and digit tasks (.475) was higher than for either the correlation between the word and melody task (.278) or the correlation between the digit and melody task (.103). This may reflect the greater similarity between the word and digit tasks, which are verbal recall tasks, than between either of these and the melody task, a nonverbal recognition task. In any case, these positive correlations between asymmetry scores on the dichotic listening tasks are consistent with the hypothesis of stable individual differences in characteristic perceptual asymmetry within the auditory modality.

As for the visual half-field tasks, individual differences in characteristic perceptual asymmetries in the auditory modality were further examined by entering subjects' asymmetry scores into a PCA. Similar to the results of the PCA with the visual half-field tasks, the first principal component was characterized by loadings of all three dichotic listening tasks in the same direction (see Table 5b). Although the loadings were in the same direction, loadings for the word and digit tasks were higher than for the melody task. This characteristic perceptual asymmetry component accounted for 53.3% of the total variance in the sample. A median-split of subjects based on this component indicated that the asymmetry scores of subjects with high PC1 scores ($N = 16$) were displaced toward the right ear on all three dichotic listening tasks relative to subjects with low PC1 scores ($N = 16$; see Fig. 2). Thus, subjects with high PC1 scores have

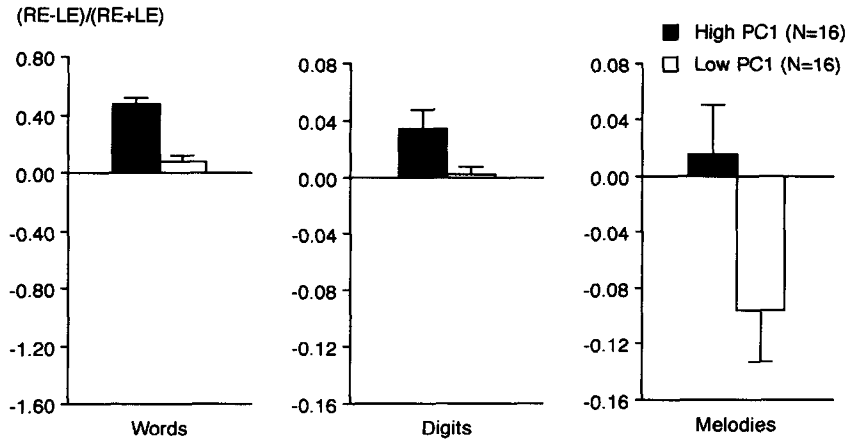

FIG. 2. Mean asymmetry scores ((RE − LE)/(RE + LE)) and standard errors of High and Low PC1 groups as defined by a median-split on the first principal component of asymmetry scores on the three dichotic listening tasks.

characteristic perceptual asymmetry in favor of right ear whereas subjects with low PC1 scores have characteristic perceptual asymmetry in favor of the left ear. The correlation between the first principal component and overall accuracy was low for all three tasks (range: −.076 to 040), indicating that the first component does not reflect variations in overall accuracy.

The overall accuracy on the dichotic word task was low (M = 23.3%) compared to the other two dichotic tasks (Digits M = 93.6%; Melody M = 70.8%). To a large degree, these differences are attributable to the fact that the probability of being correct by chance is high on the digit and melody tasks but practically zero on the word task. In any case, the low accuracy on the word task raises the question of whether the present results reflect the inclusion of subjects with relatively low accuracy on this task. In order to address this issue, separate PCAs were performed on the asymmetry scores of the 15 subjects with higher accuracy on the word task (accuracy range: 24.3 to 37.5%) and the 17 subjects with lower accuracy (accuracy range: 13.1 to 23.1%) (the high and low accuracy groups are unequal in size due to ties on median accuracy scores). As for the original PCA, the first principal component was characterized by loadings of all tasks in one direction for both high accuracy subjects (loading range: .264 to .758) as well as low accuracy subjects (loading range: .462 to .641). Thus, the original PCA result does not appear to reflect the inclusion of subjects with relatively low accuracy on the word task.

As for the tachistoscopic tasks, an additional PCA was performed on

TABLE 6

DICHOTIC LISTENING TASKS: (A) CORRELATIONS AMONG EAR SCORES AND (B) PRINCIPAL COMPONENTS OF EAR SCORES

(a) Correlations (N = 32)

Task/ear	Word LE	Digit LE	Melody LE	Word RE	Digit RE	Melody RE
Word LE						
Digit LE	.227					
Melody LE	.125	.258				
Word RE	−.261	.090	.231			
Digit RE	−.164	.656**	−.014	.314		
Melody RE	.108	−.025	−.139	.203	.075	

(b) Principal components

Task/ear	PC1	PC2	PC3
Word LE	−.034	−.692	.377
Digit LE	.602	−.367	.088
Melody LE	.265	−.318	−.515
Word RE	.403	.462	−.132
Digit RE	.628	.118	.137
Melody RE	.086	.236	.739
Eigenvalue	1.843	1.343	1.127
Proportion of total variance	30.7%	22.3%	18.7%

** $p < .01$, one-tailed.

subjects' left and right ear scores on each dichotic task rather than on their asymmetry scores. Table 6 shows the correlations among left and right ear scores and results of PCA on these scores. As for visual half-field scores on tachistoscopic tasks, between-subjects variability in left and right ear scores on dichotic listening tasks may reflect variations in the ability to perform well as well as variations in characteristic perceptual asymmetry. Furthermore, variations in the ability to perform well may account for more variance in ear scores than variations in characteristic perceptual asymmetry, at least when performance level is allowed to vary freely as in the present dichotic listening tasks. In fact, the first principal component was characterized by loadings of all left and right ear scores in the same direction except left ear scores on the word task. This ability-to-perform-well component accounted for 30.7% of the total variance. Both the left ear score on the word task and the right ear score on the melody task loaded weakly on the first component, possibly because of the relatively low performance of subjects on these stimuli. The second principal component was characterized by loadings of all three left ear scores in one direction and all three right ear scores in the other direction. This characteristic perceptual asymmetry component accounted for 22.3% of the total variance.

TABLE 7

DIVIDED VISUAL HALF-FIELD TASKS AND DICHOTIC LISTENING TASKS: (A) CROSS-MODAL CORRELATIONS AMONG ASYMMETRY SCORES (B) PRINCIPAL COMPONENTS OF ASYMMETRY SCORES

	(a) Correlations ($N = 32$)	Divided visual field tasks		
Tasks		Words	Chairs	Faces
Dichotic listening tasks	Words	−.185	−.265	−.156
	Digits	−.066	−.327*	−.010
	Melodies	−.035	−.305*	−.099
Tasks	(b) Principal components	PC1	PC2	PC3
Divided visual field tasks	Words	.357	.518	−.188
	Chairs	.513	.087	.232
	Faces	.358	.553	.074
Dichotic listening tasks	Words	−.434	.265	.555
	Digits	−.431	.518	.185
	Melodies	−.324	.277	−.749
Eigenvalue		2.143	1.259	.949
Proportion of total variance		35.7%	20.9%	15.8%

* $p < .10$, two-tailed.

Cross-Modal PCA

In order to address the question of whether characteristic perceptual asymmetry is modality specific, modality general, or both, correlations between subjects' asymmetry scores on the visual half-field and dichotic listening tasks were examined. These nine cross-modal correlations were consistently negative, but nonsignificant (see Table 7a). This is particularly striking in view of the finding that the within-modality correlations obtained on both the visual and auditory tasks were consistently positive (see Table 2a and 5a). As an example, Figure 3 illustrates the nonsignificant negative correlation between asymmetry scores on the word visual field task and the word dichotic listening task ($r = -.185$, n.s.). This nonsignificant correlation does not reflect a few subjects showing extreme dissociation between the two asymmetry scores, as no outlier is apparent. Note also that this cross-modal correlation, which is between two verbal tasks, is not significantly different from any of the other pairwise cross-modal correlations, e.g., that between faces vs. melodies (see Table 7a).

Cross-modal correlations were further investigated by correlating subjects' PC1 scores obtained from the PCA of asymmetry scores on the three visual half-field tasks (see Table 2b) with their PC1 scores from the PCA of asymmetry scores on the three dichotic listening tasks, the two components that reflect characteristic perceptual asymmetry (see Table

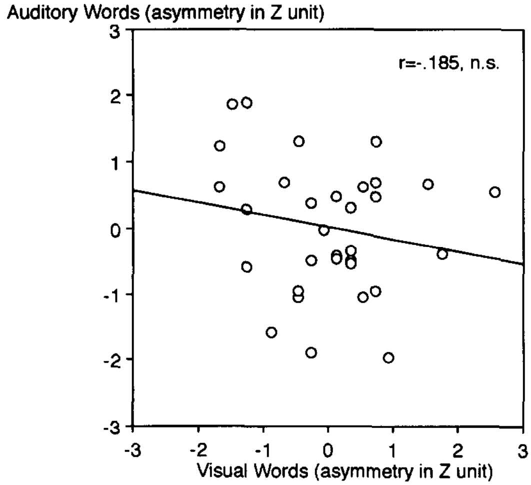

FIG. 3. Scatter plot between subjects' asymmetry scores (in Z score unit) on the divided visual half-field word task and the dichotic listening word task.

5b). In each modality, high PC1 scores reflect characteristic perceptual asymmetry in favor of the right side of presentation. The cross-modal correlation between the two PC1 scores was negative, but was not significant ($r(30) = -.288$, n.s.). The absence of a significant correlation between principal components that account for a large proportion of between-subjects variability in each modality suggests that the nonsignificant correlation is not simply due to random variations in asymmetry scores in each modality. Consistent with the absence of significant correlation, a canonical correlational analysis also revealed no significant relation between subjects' asymmetry scores on the visual half-field tasks and the dichotic listening tasks (Wilk's $\underline{\lambda} = .7866$, n.s.).

The absence of a significant correlation between subjects' characteristic perceptual asymmetries in the auditory and visual modalities is consistent with characteristic perceptual asymmetry being modality specific or to it being influenced both by modality specific and modality general factors. In an attempt to differentiate these possibilities, subjects' asymmetry scores on tachistoscopic and dichotic listening tasks were entered into an overall cross-modal PCA. The first principal component, which accounted for 35.7% of the total variance of asymmetry scores in the sample, was characterized by loadings of the visual half-field tasks in one direction and the dichotic listening tasks in the other direction (see Table 7b). This component lends support to there being a modality specific component of characteristic perceptual asymmetry. The correlation between this component and overall accuracy was low for all six tasks (range: $-.181$ to

.055), indicating that the component does not reflect variations in overall accuracy.

The second principal component, which accounted for 20.9% of the total variance of asymmetry scores in the sample, was characterized by loadings of asymmetry scores on both visual half-field and dichotic listening tasks in the same direction (see Table 7b). Although the loadings were all in the same direction, the loading of the chair task was low, .087, compared to loadings of the other tasks, which ranged from .265 to .553. The emergence of a component on which asymmetry scores on both visual half-field and dichotic listening tasks load in the same direction suggests that there also is a modality general component of characteristic perceptual asymmetry. As for the first principal component, the correlation between the second principal component and overall accuracy was low for all six tasks (range: −.175 to .070). Thus, the results of the cross-modal PCA are most consistent with there being independent modality specific and modality general components of characteristic perceptual asymmetry.[5]

Finally, we investigated the question of whether variations in the ability to perform well in one modality are related to variations in the ability to perform well in the other modality. This question was addressed by correlating subjects' PC2 scores obtained from the PCA of their left and right field scores on the three tachistoscopic tasks (see Table 3b) with their PC1 scores from the PCA of their left and right ear scores on the three dichotic listening tasks, the two components that reflect ability-to-perform-well (see Table 6b). In each modality, high PC scores reflected higher ability to perform well in that modality. The cross-modal correlation between the two PC scores was significantly positive ($r(30) = .328$, $p < .05$, one-tailed). This finding indicates that subjects who perform well on the tachistoscopic tasks also tend to perform well on the dichotic listening tasks and vice versa for subjects who perform poorly on the tachistoscopic tasks. Variations in the ability to perform well on tachistoscopic and dichotic listening tasks may be significantly related to individual differences in psychometric *g*, as prior studies found a significant relation between "mental speed" (e.g., inspection time, reaction time) and IQs (for a review, see Brand & Deary, 1982; Jensen, 1982).

[5] The same pattern of results is found when a principal factor analysis (PFA) is used rather than PCA (for a technical distinction between the two, see, e.g., Bernstein et al., 1987). A PFA of the present data was performed with the prior communality estimate for each variable set equal to its squared multiple correlation with all other variables. The results of this PFA showed that the first principal factor was characterized by loadings of the divided visual field tasks in the positive direction (loading range: .396 to .619) and by loadings of the dichotic listening tasks in the negative direction (loading range: −.356 to −.540). The second principal factor was characterized by loadings of both the divided visual field and the dichotic listening tasks in the positive direction (loading range: .104 to .394). These results of a PCA and a PFA show that at least for the present data set, a PCA and a PFA yield similar results.

Free-Vision Facebook Task

Individual subjects' asymmetry scores on the free-vision facebook task were computed using the formula $(R - L)/36$ (Levy et al., 1983b), where R is the number of items on which the face with the smile to the subject's right looked happier, and L is the number of items on which the face with the smile to the subject's left looked happier. Thus, a positive score indicated a bias toward deciding that the chimera with the smile on the right looked happier, and a negative score indicated a bias toward deciding that the chimera with the smile on the left looked happier. For subjects as a whole, the mean asymmetry score was $-.466$ (SD = .455), which significantly differed from zero (no asymmetry; $t(31) = 5.79$, $p < .0001$). The mean asymmetry score of our sample is more biased to the left than that of Levy et al.'s sample (1983b) ($t(141) = 1.83$, $p < .10$, two-tailed), consistent with the possibility of our sample including an over-representation of subjects with characteristic perceptual asymmetry in favor of the left side. As in Levy et al.'s study (1983b), there was no significant difference in the facebook asymmetry scores of males and females ($F(1, 30) = 1.24$, n.s.).

In order to determine whether individual differences in asymmetry on the facebook task reflect variations in characteristic perceptual asymmetry, subjects' asymmetry scores on this task were correlated with their asymmetry scores on the visual field and dichotic listening tasks. All correlations were nonsignificant, ranging from $-.074$ to .225. In addition, there was no significant correlation between subjects' asymmetry scores on the facebook task and any of the principal components obtained in the within-modal or cross-modal PCAs. Thus, at least for the present sample, individual differences in laterality on the free-vision task do not appear to be related to variations in characteristic perceptual asymmetry in either modality. However, in view of the previous studies reporting a significant correlation between asymmetry scores on the free-vision face task and tachistoscopic tasks (Kim et al., 1990; Kim & Levine, 1991b; Levy et al., 1983a), it is possible that the present finding of nonsignificant correlations reflects sampling variability.

GENERAL DISCUSSION

Consistent with previous findings, our results with visual half-field tasks indicate that individual differences in characteristic perceptual asymmetry account for about 50% of the variance in subjects' asymmetry scores in the visual modality. Similarly, our results with dichotic listening tasks indicate that individual differences in characteristic perceptual asymmetry account for about 50% of the variance in subjects' asymmetry scores in the auditory modality. The global analysis of subjects' asymmetry scores obtained on visual half-field and dichotic listening tasks supports the hypothesis that there are both modality specific and modality general components of characteristic perceptual asymmetry. There is some indication that the modality specific component accounts for more of the variance in subjects' asymmetry scores than the modality general component (35.7% vs. 20.9%).

The existence of a modality specific component of characteristic perceptual asymmetry is supported by opposite loading of visual and auditory asymmetry tasks on the first component of the global analysis. Some of the studies examining the correlations between subjects' asymmetry scores on *verbal* visual half-field and dichotic listening tasks (Bryden, 1973; Smith & Moscovitch, 1979; Wexler & King, 1990) also report negative correlations, although the majority of such studies report a nonsignificant positive correlation (for a review, see Kim & Levine, 1992b). Consistent with those studies reporting a negative correlation, Boles (1991) found a factor on which visual lexical tasks and dichotic lexical tasks are loaded in the opposite direction, in a factor-analytic study of multiple asymmetry scores in each modality. The present results indicate that the negative correlations between subjects' asymmetry scores on visual and auditory asymmetry tasks, reported in some previous studies (Boles, 1991, Bryden, 1973; Smith & Moscovitch, 1979; Wexler & King, 1990), are not limited to verbal tasks, but include a broad range of verbal and nonverbal tasks. It is possible that the negative correlation between asymmetry scores in the two modalities is attributable to stable individual differences in between-modality competition for limited hemispheric resources.

Our finding of modality specific and modality general components of characteristic perceptual asymmetry is relevant to the question of whether central (e.g., hemispheric arousal asymmetry) and/or peripheral factors (e.g., sensory pathway dominance) are involved in subjects' characteristic perceptual asymmetries. The modality specific component of characteristic perceptual asymmetry may be mediated by central and/or peripheral processes. However, the modality general component suggests that individual differences in central factors such as asymmetric hemispheric arousal play a role in mediating variations in characteristic perceptual asymmetry (Levy et al., 1983a).

The present study examined characteristic perceptual asymmetry under conditions of bilateral input for both visual and auditory modalities. Recent evidence indicates that individual differences in characteristic perceptual asymmetry are manifested more consistently when stimuli are presented bilaterally than when they are presented unilaterally (Kim & Levine, 1991b, 1992a). For example, subjects' asymmetry scores on bilaterally presented, left and right hemisphere specialized tasks are more positively correlated than their asymmetry scores on unilaterally presented, left and right hemisphere specialized tasks (Kim & Levine, 1991b). This higher sensitivity of bilateral than unilateral tasks to characteristic perceptual asymmetry is consistent with the view that characteristic perceptual asymmetry is at least partially mediated by central factors, as no difference in the sensitivity of unilateral vs. bilateral presentation to characteristic perceptual asymmetry would be expected if characteristic perceptual asymmetry is mediated by peripheral factors only (Kim & Levine, 1991b, 1992a).

The higher sensitivity of bilateral than unilateral tasks to characteristic perceptual asymmetry may be related to the varying demands of these two types of tasks make on subjects' processing resources (Kim & Levine, 1991b, 1992a). In particular, under bilateral presentation conditions, in which processing resources are relatively limited, there may be a tendency for subjects to differentially allocate resources to the hemisphere that is "characteristically" more aroused. This would exaggerate arousal differences between the hemispheres, with the result that bilateral presentation is more sensitive to characteristic perceptual asymmetry than unilateral presentation.

Consistent with the finding that characteristic perceptual asymmetry is more readily revealed by bilateral than unilateral stimulation, hemineglect following unilateral brain damage also is much more apparent under conditions of bilateral than unilateral stimulation (i.e., extinction to simultaneous stimulation) and, sometimes, is only apparent under conditions of bilateral stimulation (for a review, see Bender, 1952; Heilman & Watson, 1977). This parallel between characteristic perceptual asymmetry in normal subjects and hemineglect in brain-damaged patients may be attributable to perceptual asymmetries in both populations reflecting an imbalance in hemispheric arousal, albeit a normal, smaller imbalance in one case and a larger, pathological imbalance in the other. Similar to normal subjects, brain-damaged patients may allocate more processing resources to the more aroused, intact hemisphere under conditions of bilateral stimulation (Rapcsak, Watson, & Heilman, 1987; Riddoch & Humphreys, 1987). In normals, the degree and direction of hemispheric arousal asymmetry may be a trait of each individual, whereas in brain-damaged patients, the imbalance may be determined primarily by characteristics of the lesion such as side, location, and size. Nonetheless, to some extent, a patient's premorbid arousal asymmetry may be reflected in the magnitude/direction of hemineglect shown following brain damage (Kim & Levine, 1991b, 1992a). For example, following right hemisphere damage, neglect of the left side of space may be stronger among subjects with characteristic perceptual asymmetry in favor of the right side (assumed to reflect greater left hemisphere arousal) than among subjects with characteristic perceptual asymmetry in favor of the left side (assumed to reflect greater right hemisphere arousal). The reverse would be expected following left hemisphere damage (Kim & Levine, 1991b, 1992a).

Findings from hemineglect patients also are consistent with our finding of a strong modality specific component of characteristic perceptual asymmetry. According to several recent studies (De Renzi, Gentilini, & Pattacini, 1984; Schwartz, Marhock, & Kreinick, 1988; Sieroff & Michel, 1987), the number of patients with extinction in either the visual or auditory modality far exceeds the number of patients with extinction in both visual and auditory modalities. For example, De Renzi et al. (1984) report that only 5 of 43 patients (11.6%) with visual or auditory extinction show extinction in both modalities. Thus, consistent with the present finding that characteristic perceptual asymmetry in normal subjects is strongly influenced by modality specific factors, extinction in brain-damaged patients is typically modality specific.

In apparent constrast to our finding that characteristic perceptual asymmetry is more strongly influenced by modality specific than modality general components, Farah, Wong, Monheit, and Morrow (1989) recently suggested that the parietal lobe's attentional mechanism operates on a supramodal representation of space. Their findings show that patients with right parietal lobe damage are similarly impaired in their ability to attend to invalidly cued contralesional visual stimuli regardless of whether these stimuli are preceded by auditory or visual cues. Although these findings provide evidence that neglect of visual stimuli is similar whether cues are visual or auditory, they do not directly address the issue of whether spatial attention is supramodal or modality specific. The infrequent co-occurrence of extinction in the visual and auditory modalities, reported in the studies cited above, may be more relevant to this issue.

In summary, our results show that characteristic perceptual asymmetries influence subjects' asymmetry scores in both visual and auditory modalities, at least under conditions of bilateral input. Although the underlying mechanism(s) of characteristic perceptual asymmetry is unknown, it is clear that central factors are involved and that indiividual differences in this factor account for a significant proportion of the between-subjects variability in asymmetry scores. Moreover, the influence of characteristic perceptual asymmetry on laterality scores provides a potential explanation for the discrepancy in laterality findings between studies of normal subject and studies of unilaterally brain-damaged patients (Kim & Levine, 1991a). Finally, with respect to the question of whether characteristic perceptual asymmetries are modality specific or modality general, our results support a hybrid model, in which the modality specific component affects subjects' asymmetry scores somewhat more than the modality general component.

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