LATERAL PREFERENCES AND VISUAL FIELD ASYMMETRIES: APPEARANCES MAY HAVE BEEN OVERSTATED

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It is a convention in tachistoscopic visual half field (VHF) studies to
the hand preference of the subjects. This is because most authors assume
preference has a substantial effect on the probability of finding the exp
VHF asymmetry. So, unless handedness is a factor of interest, it is a co
practice to see the phrase "all subjects were right-handed" in the method se
The assumption that left-handers return less consistent VHF asymmetries
right-handers is based on clinical studies, in which it was demonstrated tha
handed patients have less chances of language problems after injury of th
cerebral hemisphere (e.g., Bryden, Hécaen and DeAgostini, 1983; see als
findings with invasive tests; e.g., Loring et al., 1990).

However, the belief of considerable handedness effects on VHF asymm
in tachistoscopic laterality tasks has not yet been validated by a st
evaluation of the relevant literature. The only thorough review of hande
effects on behavioral laterality indices was confined to dichotic listening (Br
1988a). In that article, Bryden concluded that across studies 81% of the
handers showed the expected right-ear advantage for verbal stimuli, wh
this was only true for 64% of the left-handers. Assuming an 85% rate of c
classification, Bryden argued that these figures were in line with those
clinical studies. It is, however, not clear to what extent Bryden's review c
extrapolated to VHF studies, as it has repeatedly been shown that
superiorities in tachistoscopic tasks are not highly correlated with ear advan
in dichotic listening tasks (e.g., Dagenbach, 1986; Eling, 1983; Hellige,
and Taylor, 1988; Nestor and Safer, 1990; Wexler and King, 1990).

To get a better idea of the impact of hand preference on VHF asymme
all the issues of *Neuropsychologia* between 1980 and 1992 and *Cortex* bet
1985 and 1992[2] were reexamined to look for articles in which right-hande
left-handed subjects had been tested, even though the handedness effect
not the main aim of the study. This procedure was preferred to a search
Psychlit for articles that primarily investigated handedness effects, because
well known that the latter search leads to a biased estimate (journals h
preference not to publish articles in which the major null-hypothesis can n

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[1] The author is research associate of the Belgian National Fund for Scientific Research (NFWO).

[2] The reason why *Cortex* has been sampled from 1985 on, is because the library of the K.U. Leuv
then started to purchase the journal.

rejected). Eighteen experiments were located on the basis of the above inquiry, coming from 13 different articles. Most studies used the Edinburgh Inventory (Oldfield, 1971) to assess hand preference.

A problem with the analysis was that the results of VHF studies are rarely presented in a uniform way. For instance, only one study (Graves, 1983) reported the percentage of subjects with a RVF or LVF superiority, which is the common measure in dichotic listening tests (see Bryden, 1988a, above). Therefore, whenever possible, the VHF asymmetry was calculated on the basis of the dependent variable given in the article. This number was then rewritten as a positive number if presentation in the RVF led to superior performance, and as a negative number if presentation in the LVF led to superior performance. A distinction was made between studies that measured processes of the dominant and the non-dominant hemisphere, and between studies that made use of latency or accuracy data.

Table I lists the results of the analysis. As can be seen, hand preference did have the expected effect on VHF asymmetries: Fifteen of the eighteen experiments found a more pronounced VHF asymmetry in the expected direction for right-handers than for left-handers (chances that such a pattern can be found by chance, are less than .01 according to the binomial test). However, it is also clear that the effect, apart from its consistency, is far from impressive. Within studies handedness is rarely a significant factor, even though most experiments involved a fairly large number of subjects. Also the magnitude of the effect in terms of milliseconds or percentage accuracy is not overly pronounced. It might be argued that the latter is because the wrong dependent variable has been used, and that clearer results would have been obtained if the percentage of subjects with the expected VHF superiority had been counted, just as in dichotic listening studies (see above). Some evidence against this position, however, is provided by Graves (1983), who measured word recognition and reported 80% RVF superiority for right-handers against 77% for left-handers (see also Chiarello et al., 1984). So, it seems that the effect of handedness on VHF asymmetries is smaller than generally accepted by laterality researchers.

Several reasons may be invoked for the small effect of hand preference on VHF asymmetries. First, it could be argued that hand preference was not measured accurately (e.g., Bryden and Steenhuis, 1991). Three aspects are involved: (i) Questionnaires like the Edinburgh Inventory only assess one dimension of what seems to be a three-dimensional structure, (ii) direction and degree of hand preference are not separated, which decreases the predictability if only one is related to cerebral dominance, and (iii) it may be wondered whether hand performance rather than hand preference is the desired indicator of handedness. A second reason why hand preference only has a minor main effect on VHF asymmetries may be due to the possibility that handedness effects are attenuated by moderator variables, such as sex, familial sinistrality, and handwriting posture, although reviews (e.g., Bryden, 1988a; Bryden and Steenhuis, 1991) indicate that these variables in turn have a quite limited and often inconsistent impact on laterality indices. A third reason for the absence of pronounced handedness effects may be that VHF studies are not a good paradigm to assess laterality of cerebral functions. There is indeed some

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TABLE I

VHF Asymmetries for Right-handed (RH) and Left-handed (LH) Subjects, together with the p-value for the Difference between Both Groups

Source	Task	N_{subj}	$Asymm_{RH}$		$Asymm_{LH}$	p
Dominant hemisphere, latency (ms)						
Bradshaw et al., 1981	Lexical decision	48R/48L	26		18	n.s.
Shimizu and Endo, 1981	Word recognition (kana)	18R/18L	38		17	n.s.
Birkett, 1981	Letter matching (normal)	40R/40L	5		37	n.s.
Boles, 1989	Number reading (words)	22R/15L	21		13	n.s.
Brysbaert and d'Ydewalle, 1990b	Word naming	7R/7L	76		75	n.s.
Franzon and Hughdahl, 1986	Stroop interference (words)	30R/30L	5		−12	<.01
		total:	29		25	
Dominant hemisphere, accuracy (percentage correct)						
Piazza, 1980	Word recognition	32R/32L	6		4	n.s.
Graves, 1983	Word recognition	30R/30L	?	>	?	n.s.
Sheehan and Smith, 1986	CVC recognition	45R/22L	17		7	?
Kim and Levine, 1991a	Word recognition	31R/32L	2		3	n.s.
Nichols and Cooper, 1991	Line length discrimination	15R/7L	?	>	?	n.s.
		total:	8		5	
Non-dominant hemisphere, latency (ms)						
Bradshaw et al., 1981	Face discrimination	48R/48L	−18		−10	n.s.
Boles, 1989	Number reading (bargraph)	22R/15L	−23		−11	n.s.
Strauss and Goldsmith, 1987	Face expression	44R/7L	?	<	?	n.s.
		total:	−21		−11	
Non-dominant hemisphere, accuracy (percentage correct)						
Piazza, 1980	Face recognition	32R/32L	−2		1	<.01
Sheehan and Smith, 1986	Dot enumeration	45R/22L	−10		−4	?
Christman, 1989	Form perception	12R/12L	−1		−6	.06
Kim and Levine, 1991a	Face recognition	31R/32L	−4		0	<.05
		total:	−4		−2	

controversy in the literature to what extent VHF asymmetries are an indication of hemispheric specialization, and not caused by other factors such as attention allocation, reading habits, and the like (Bryden and Mondor, 1991; Efron, 1990; Hellige, Bloch and Taylor, 1988; Kim and Levine, 1991b), although at the moment Efron (1990) is the only one who defends the strong position that VHF asymmetries are completely unrelated to cerebral asymmetry. Finally, it may be argued that the low covariation between handedness and VHF superiority is due to the fact that both variables assess different aspects of laterality, which need not be related to each other. Evidence is growing (Allen, 1983; Boles, 1989, 1991, 1992; Bryden, 1986) that the deterministic triangle "right hand preference, left hemisphere language, and right hemisphere visuospatial abilities" is an erroneous simplification of reality. For instance, Bryden, Hécaen and DeAgostini (1983) reported that although language problems were more frequent after left hemisphere lesions and visuospatial problems more frequent after right hemisphere lesions, the occurrence of the two symptoms was statistically independent; that is, patients with language problems had the same probability of additionally experiencing visuospatial difficulties as patients without language problems. A similar lack of negative correlation between laterality indices related to language functions and laterality indices related to visuospatial functions was reported for dichotic listening (Bryden, 1986), and various VHF tasks (Boles, 1989, 1991, 1992). So, it seems that different cerebral functions are lateralized independently, which is in line with current computational models of the brain. Computational models emphasize that cognitive activities consists of different components which function quite autonomously (Allen, 1983; Fodor, 1983; Kosslyn, 1987). Applied to the covariation between handedness and VHF asymmetries, this suggests that handedness and visual laterality indices may be largely unrelated, because they measure independent subsystems. The same need not be true for hand preference and speech output, as both make use of adjacent motor areas. Interestingly, dichotic listening and hand preference may also be more likely to covary, because there is evidence that speech perception is mediated by the same articulatory motor programs as speech output (Liberman and Mattingly, 1985; Pisoni and Luce, 1986).

The rest of the article will be confined to the final explanation of the low correlation between hand preference and VHF superiorities, namely the idea that both dependent variables measure aspects of cognitive functioning that are lateralized separately. The explanation involves two prospects: (i) Other lateral preferences than handedness may be better predictors of VHF asymmetries, and (ii) the predictors need not be the same for all VHF tasks. These possibilities will be examined in two new tachistoscopic experiments that yield a right VHF superiority (Experiment 1: word naming) and a left VHF superiority (Experiment 2: symmetry detection). In both experiments the prediction power of hand preference will be evaluated against the prediction power of foot, eye, and ear preference (Coren, 1993; Porac and Coren, 1981). The last two preferences may have higher correlations with the lateralization of visual functions, because they are not primarily concerned with motor output. The status of foot preference is less clear: On the one hand, it may be a better index of motor laterality than hand preference because it is less susceptible to cultural pressure (Chapman, Chapman and Allen, 1987); on the other hand, surveys have shown that hand and foot preference are highly intercorrelated (Porac, Coren, Steiger et al., 1980), and that crossed preferences are present in only a small percentage of the population (5% according to Dargent-Paré, DeAgostini, Mesbah et al., 1992; 5.5% according to a study of our own with the questionnaire of the Appendix and based on 253 students).

The only tachistoscopic study we know of that investigated the influence of hand, foot, eye, and ear preference on VHF asymmetries, was done by Strauss and Goldsmith (1987). They measured reaction latencies for photographs of faces diplaying different expressions presented in LVF and RVF, and obtained a LVF superiority in 67% of their sample of 51 undergraduates. A multiple regression analysis involving handedness, footedness, eyedness and earedness as predictors, revealed that only eyedness explained a small ($R^2 = .15$) but significant amount of the variance in the visual laterality scores: Right-eyed subjects showed a more pronounced LVF superiority than left-eyed subjects. An analogous result was obtained in a subsequent dichotic listening experiment that had verbal phrases spoken in different tones-of-voice. Other behavioral studies that examined the relationship between lateral preferences and laterality indices were limited to dichotic listening (Searleman, 1980; Strauss, 1986; Bryden, 1988b). Searleman (1980) correlated measures of handedness, footedness, and eyedness with laterality indices of a verbal dichotic listening task and found footedness to be the best predictor. Strauss (1986) added earedness to Searleman's list of predictors and discovered that this explained most of the variance in a similar task. Finally, Bryden (1988b) reported sighting eye dominance to be a significant predictor of ear advantages in a dichotic listening task with verbal material. However, just like Searleman (1980) he did not include ear preference in his list of predictors.

Tentatively, it may be concluded that for dichotic listening and verbal stimulus material ear preference looks to be the best predictor. For non-verbal material (at least recognition of emotional expressions), Strauss and Goldsmith's (1987) study suggests that eye preference is the relevant factor. The fact that different predictors are obtained for different (classes of) tasks is in line with the computational idea expressed above. Purpose of the present manuscript is to find out whether the same pattern of results applies to tachistoscopic VHF tasks. The findings of Strauss and Goldsmith (1987, Experiment 1; see above) hint that at the least for non-verbal tasks this may be the case.

EXPERIMENT 1

The first experiment deals with word recognition. Subjects had to name five-letter words presented left or right of the fixation location. Subjects had been selected on the basis of their scores on a questionnaire, so that the percentage of left side preferences was considerably higher than in the population (see Table III).

Materials and Method

Subjects

Subjects were 71 undergraduate students from the University of Leuven. All were males. They had been screened to take part in a larger program that investigated the issue of interhemispheric transfer in the processing of foveal stimuli (Brysbaert, 1994). All subjects were naive with respect to the purpose of the experiment, had normal or corrected-to-normal vision, and were native Dutch speakers. Participation happened on a voluntary basis.

Questionnaire

The questionnaire used was a compound of the Edinburgh Inventory (Oldfield, 1971) for handedness and the Porac and Coren (1981) questionnaire for footedness, eyedness, and earedness (see the Appendix). Subjects had to indicate the direction and the degree of their preference for the various questions: They were asked to give a number between +1 and +3 to mark the degree of their right side preference, and a number between −1 and −3 for their left side preference. They were not allowed to use the neutral digit 0. A preliminary study on 253 students gave correlations between the different indices that were in line with those reported by Strauss (1986) and Strauss and Goldsmith (1987). Correlation was lowest between eye and ear preference ($r=.265$, $n=253$, $p<.01$) and highest between hand and foot preference ($r=.731$); the other correlations were coinciding and ranged from .416 to .482. No significant differences were found when correlations were calculated on the Porac and Coren (1981) measure (i.e., number of right responses minus number of left responses) or on the average value of the numbers given by the subjects.

Stimuli

Stimuli consisted of 200 five-letter words. Words of this length were chosen because previous research had indicated that they lead to more reliable data than words of a shorter length (Brysbaert and d'Ydewalle, 1990a). Nouns, verbs, adjectives, and functions words were mixed to get a sample of the total language corpus. All words were high frequency words (mean = 160/720,000, range 38-1,415; Uit den Boogaart, 1975). At the beginning of the experiment, the words had been randomly divided in two samples, one of which was presented in one VHF, the other in the second VHF. The distribution of words over VHFs was counterbalanced over series. Words were presented in lower case letters, had a length of 15.3 mm, and were presented with the nearest letter 15.3 mm left or right of the fixation location. Subjects were sitting at a normal reading distance between 40 and 60 cm (there were no head restraints). At a distance of 57 cm, stimulus magnitude of 10 mm coincides with a visual angle of 1 deg.

Procedure

Stimuli were presented with an IBM XT microcomputer connected to a Philips 12" monochrome monitor. The computer collected the responses by means of a voice trigger, with both stimulus and response timing performed to the nearest ms (Bovens and Brysbaert, 1990). Screen persistency was circumvented by displaying a mask immediately after the stimulus. This mask consisted of five ASCII codes 178 (▓) aligned horizontally.

The experiment contained four series, during which all words were presented two times in LVF and two times in RVF. Presentation of the same stimuli in LVF and RVF ensured that laterality indices were unaffected by the distribution of stimuli over VHFs (Brysbaert and d'Ydewalle, 1990a). Stimulus presentation was unilateral. Time line of a trial was: a random foreperiod between 1000 and 2000 ms, a warning sound for 150 ms, a delay of 750 ms, stimulus presentation for 160 ms, mask presentation until the subject reacted, and evaluation by the experimenter. The fixation mark (ASCII code 92, '__') remained visible throughout. Subjects were instructed to look at the fixation mark as soon as they heard the warning tone, and to report the presented words as rapidly and accurately as possible. If they did not recognize the word, they were asked to guess or to say 'no' if no sensible answer was possible. Within a series, stimuli appeared randomly in the left and the right visual field. This was achieved by randomization of the stimulus series before the session started (Brysbaert and d'Ydewalle, 1990a). Each subject and each series got a different randomization (for procedures, see Brysbaert, 1991). The experimenter had a printout of the 200 words. This allowed him to indicate on-line whether the subject's response was correct or not. He also indicated whether the voice onset time registration was good (this could be noticed by looking whether the mask disappeared before the subject responded or whether the mask remained present during the response; the former was an indication of noise on the system, the latter a sign that the system had failed to register the voice).

In order to ensure that the subjects really fixated the fixation mark, after a random number of trials (geometric distribution with expected value of 5, see Brysbaert, 1991), a random digit instead of a new stimulus was presented above the fixation mark for 60 ms, followed by a mask (ASCII 178). Subjects had to name the digit. If they made a mistake, they were warned by a tone. The experimenter told them that more than 10% of errors made the series invalid. It took the subjects on the average one series before the criterion of less than 10% was reached. Though there was no digit to be named on each trial, the strategy made the subjects very alert to look at the fixation mark on all trials. A series of 200 words and about 40 digits took more or less 30 minutes to complete. At the beginning of the experiment, subjects were told how to use the microphone and what stimuli would be presented. They were then given 10 example trials. After each series, subjects got feedback about the mean reaction time for the correct answers, the number of mistakes they had made, the number of data that had to be dropped because of unsatisfactory time measurement, and the number of digits they had missed. Pilot studies had shown that this was the best incentive to motivate them to perform as good as possible.

Results

Percentage of trials that had to be excluded because of deficient time measurement amounted to 2.5%. In addition, reaction times that after logarithmic transformation were shorter than the mean minus three times the standard deviation or longer than the mean plus three times the standard deviation were excluded as well. This percentage amounted to 2.3%. Trials with deficient time measurements were only excluded from the analyses involving latency data; they were not excluded from the analyses of accuracy data.

VHF asymmetries were measured with two indices (see also Table III for the raw data): The point-biserial correlation index for latency, and the lambda index for accuracy. The point-biserial correlation index was calculated with the following equation: $r_{pb}=((RT_L-RT_R)/s)*(P*Q)^{1/2}$, in which RT_L and RT_R stand for the mean reaction latencies in LVF and RVF, P and Q for the proportions of stimuli presented in LVF and RVF, and s for the standard deviation of all reaction latencies. The point-biserial correlation ranges from −1 to +1; a positive index indicates a RVF superiority, a negative index a LVF superiority. The lambda index of laterality was calculated with the equation: lambda = $\ln(R_+/R_-)-\ln(L_+/L_-)$, in which R_+ and L_+ stand for the number of correct responses in RVF and LVF, and R_- and L_- for the number of incorrect responses in RVF and LVF respectively. A positive lambda index, just like a positive point-biserial correlation index, indicates a RVF superiority, a negative lambda index represents a LVF superiority. The point-biserial correlation index and the lambda index of laterality were preferred to other indices, because they allow detailed analysis of individual data (Brysbaert and d'Ydewalle, 1990b).

TABLE II

Correlation between the Lateral Preferences and the VHF Asymmetries; Experiment 1 (Above the diagonal, preferences defined according to the Porac and Coren measure; below the diagonal, preferences based on the average value)

	Hand	Foot	Eye	Ear	L	r_{pb}
Hand	—	.728**	.652**	.722**	.191	.185
Foot	.747**	—	.526**	.666**	.108	.104
Eye	.654**	.569**	—	.612**	.016	.024
Ear	.714**	.704**	.620**	—	.300*	.250*
L	.207	.118	.018	.221	—	.671**
r_{pb}	.197	.134	.050	.239*	.671**	—

** N = 71, p<.01.
* N = 71, p<.05.

A t-test was calculated on the laterality indices to check whether the experiment measured the intended lateralized processing. For the lambda index of accuracy this was not really necessary, because the index was positive for all but one subject, and so was, of course, the t-value of the whole sample (mean lambda = 1.22, t = 19.53, d.f. = 70, p<.01). The point-biserial correlation index of latency was negative for eight subjects only and, therefore, pointed to a reliable overall RVF superiority as well (mean r_{pb} = .176, t = 12.08, d.f. = 70, p<.01). Test-retest reliability (calculated with the intraclass correlation of Shrout and Fleiss, 1979) amounted to IC = .796 for the lambda index, and to IC = .809 for the point-biserial correlation index.

Table II lists the correlations between the lateral preferences and the laterality indices of the word naming experiment. Above the diagonal are the correlations based on the Porac and Coren measure (number of right responses minus number of left responses); below the diagonal are the correlations based on the average values. The high correlations between the lateral preferences indicate that subjects to some extent had been selected according to the consistency of their lateral preferences (i.e., correlations in the order of .60 instead of .40 for the unselected sample; see method section). Table II also shows that there is only one lateral preference which has a small, but significant correlation with the laterality indices of the experiment. It is ear preference. The pattern is slightly clearer for the Porac and Coren measure than for the average value, which suggests that the degree of preference does not yield additional information apart from the direction. A multiple regression analysis confirmed this finding, but additionally pointed to the fact that eye preference tended to have a negative correlation with the laterality indices of the experiment (p<.10) if ear preference was partialled out. Table III lists the relevant data when subjects are classified on the basis of their lateral preferences (determined with the Porac and Coren measure). It allows the reader to calculate measures not discussed in the text. The appendix contains the correlations between the items of the questionnaire and the lateral indices of the experiment.

TABLE III

Distribution of the Subjects over the Different Preferences According to the Porac and Coren Index (number right responses minus number left responses, left≤0) and the Different Modalities (hand, foot, eye, ear), as well as the VHF Scores of Experiment 1, and the Number of Subjects with a LVF Superiority on the Basis of the Latency Data (N_{ls}).

		Accuracy			Latency			
I. pref.	N	LVF	RVF	L	LVF	RVF	r_{pb}	N_{ls}
LLLL	32	0.49	0.74	1.22	733	668	0.183	2
LLLR	2	0.42	0.83	1.99	775	708	0.253	0
LLRL	7	0.49	0.66	0.72	704	684	0.072	2
LLRR	3	0.52	0.78	1.31	551	505	0.214	0
LRLL	6	0.57	0.77	1.04	712	674	0.114	2
LRLR	1	0.54	0.69	0.67	671	648	0.083	0
LRRL	1	0.54	0.69	0.63	511	481	0.153	0
LRRR	1	0.63	0.89	1.54	723	602	0.265	0
RLLL	0							
RLLR	1	0.48	0.79	1.43	583	525	0.382	0
RLRL	1	0.20	0.44	1.18	1095	1068	0.020	0
RLRR	0							
RRLL	0							
RRLR	0							
RRRL	1	0.48	0.79	1.41	629	549	0.308	0
RRRR	15	0.42	0.72	1.42	823	744	0.206	2

Discussion

Experiment 1 assessed the covariation between lateral preferences and VHF asymmetries in a word naming task. In line with previous studies (Table I), handedness had a small and insignificant effect in the expected direction. As in Strauss (1986), ear preference was the only significant predictor of language lateralization; even then, it did not account for more than 9% of the variance. However, the fact that the significance was obtained both with dichotic listening (Strauss, 1986) and with tachistoscopic visual presentation (the present study), indicates that the effect is not modality specific. A slightly complicating factor was that eye preference correlated negatively with the laterality indices when earedness was partialled out. This pattern of results was present in Strauss (1986) as well, who obtained a (nonsignificant) negative correlation between eyedness and the dichotic listening index when ear preference was partialled out. It is not clear at the moment how to interpret this finding, but it suggests that Strauss (1986) and Searleman (1980) may have been wrong in their recommendation to use the overall sidedness as a predictor of laterality. It looks as if eye preference might have a separate status, at least for the prediction of language functions. In the next experiment, we will examine whether the same is true for a function subserved by the non-dominant cerebral hemisphere.

EXPERIMENT 2

Experiment 2 deals with the laterality of symmetry detection. In a series of studies, we have found that symmetry is best detected when the stimulus is

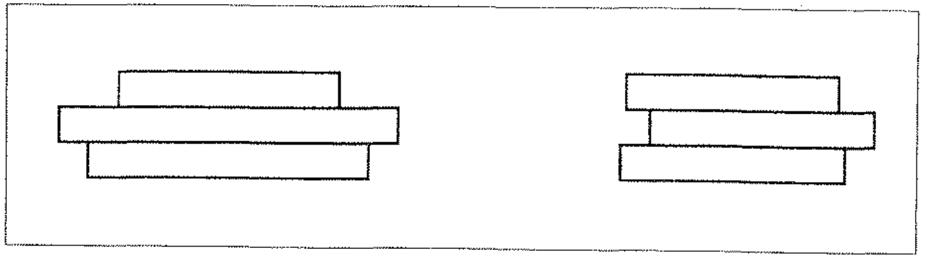

Fig. 1 – *Example of symmetric (left) and asymmetric (right) stimuli used in Experiment 2.*

presented in the LVF (right cerebral hemisphere), independent of the way in which the symmetry is violated for the asymmetric stimulus set. The study reported here consists of a condition in which responses of right and left-handers were compared.

Materials and Method

Subjects

Subjects were 102 undergraduate students of the University of Leuven. They were naive with respect to the purpose of the experiment, and had normal or corrected-to-normal vision. Participation happened as partial fulfilment of course requirements. Twenty-seven subjects were male, 75 female. Subjects had been selected so that the number of left side preferences was larger than in the population (see Table V).

Stimuli

Stimuli consisted of 100 random drawings made up of three horizontal rectangles. Half of the drawings were symmetric around the vertical meridian; half of the stimuli had one rectangle displaced to create asymmetry (see Figure 1). The height of the drawings was 17 mm, the width of the individual rectangles could vary between 14 and 50 mm. Figures were presented with the centre 53 mm left or right of the fixation location that consisted of two small vertical lines placed one above the other. Subjects were asked to fixate the gap between the two lines. Subjects were sitting at a distance between 40 and 60 cm from the screen (there were no head restraints).

Procedure

Stimuli were presented with an IBM AT microcomputer connected to a 12'' monochrome Laser monitor. The computer collected the responses by means of a response panel, with both stimulus and response timing performed to the nearest ms (see above). The experiment contained five series, with 100 stimuli each. Stimuli were generated on-line with the built-in random number generator. Stimulus presentation was unilateral. Time line of a trial was: a random foreperiod of 2000 ms, a warning signal involving a blinking of the fixation lines, a delay of 750 ms, stimulus presentation for 160 ms, and a response from the subject indicating whether the stimulus had been symmetric or not. The fixation lines remained visible throughout the whole trial. Subjects were instructed to look at the fixation mark as soon as it blinked, and to react as rapidly and accurately as possible. The reaction involved a bimanual button press with the indices or the middle fingers (counterbalanced across subjects). Bimanual reaction was chosen to circumvent stimulus-response compatibility. Reaction time of the fastest finger was used as dependent variable in the subsequent analyses. Subjects always had to press with the fingers of both hands; otherwise, the program waited for the missing response. Within a series, stimuli appeared randomly in the left and the right visual field. This was achieved by randomization of the stimulus series before the sessions started. Each subject and each series got a different randomization. After each session, the subjects got feedback about their reaction latency and accuracy. Before the start of the test trials, subjects received 20 practice trials, to give them some experience with the task and to ensure that they understood the instructions correctly.

TABLE IV

Correlation between the Lateral Preferences and the VHF Asymmetries; Experiment 2 (Above the diagonal, preferences defined according to the Porac and Coren measure; below the diagonal, preferences based on the average value)

	Hand	Foot	Eye	Ear	L	r_{pb}
Hand	—	.714**	.379**	.296**	.037	.002
Foot	.656**	—	.324**	.349**	−.023	.042
Eye	.433**	.335**	—	−.020	.082	.033
Ear	.344**	.443**	.015	—	−.081	−.024
L	.045	−.063	.071	−.038	—	.082
r_{pb}	.005	.066	.008	−.012	.082	—

** N = 102, $p<.01$.

TABLE V

Distribution of the Subjects over the Different Preferences according to the Porac and Coren Index (number right responses minus left responses, left ≤0) and the Different Modalities (hand, foot, eye, ear), as well as the VHF Scores of Experiment 2, the Number of Subjects with a RVF Superiority on the Basis of the Latency Data (N_{rs}), and the Number of the Male Subjects (N_m)

		Accuracy			Latency				
I. pref.	N	LVF	RVF	L	LVF	RVF	r_{pb}	N_{rs}	N_m
LLLL	11	0.88	0.88	−0.07	751	760	−0.035	6	3
LLLR	4	0.92	0.91	−0.17	724	735	−0.076	1	2
LLRL	2	0.82	0.83	0.07	744	743	−0.019	0	0
LLRR	0								
LRLL	0								
LRLR	2	0.90	0.83	−0.71	922	922	0.024	1	2
LRRL	1	0.88	0.88	0.08	614	658	−0.275	0	0
LRRR	1	0.89	0.88	−0.04	785	818	−0.182	0	0
RLLL	3	0.93	0.87	−0.93	783	795	−0.112	1	0
RLLR	3	0.90	0.88	−0.17	758	785	−0.142	0	1
RLRL	3	0.84	0.81	−0.28	728	737	−0.022	2	0
RLRR	4	0.86	0.87	0.01	788	787	−0.019	2	4
RRLL	5	0.90	0.89	−0.01	783	794	−0.094	1	2
RRLR	17	0.90	0.89	−0.15	769	772	−0.048	7	4
RRRL	23	0.88	0.88	−0.02	809	820	−0.037	8	6
RRRR	23	0.84	0.82	−0.17	895	917	−0.058	8	3

Results

Reaction times that after logarithmic transformation were shorter than the mean minus three times the standard deviation or longer than the mean plus three times the stardard deviation, were excluded from the analyses of the latency data. They amounted to 1.4% of the data. As in Experiment 1, VHF asymmetries were measured by means of the lambda index for accuracy and the point-biserial correlation index for latency (for the other data, see Table V). t-tests indicated that both measures yielded a small but significant LVF advantage (Lambda $= -0.13$, $t = 2.91$, d.f. $= 101$, $p < .01$; $r = -.054$, $t = -4.08$, d.f. $= 101$, $p < .01$). Fifty-six percent of the subjects showed the expected LVF superiority for the lambda index, 64% had a LVF superiority for the point-biserial correlation index. Both measures were largely independent, as can be seen in Table IV.

The covariation between the lateral preferences and the laterality indices of the experiment was calculated as in Experiment 1, and is summarized in Tables IV and V (see the Appendix for data on the individuals items of the questionnaire). None of the lateral preferences had a reliable effect on the laterality indices, not when calculated as the Porac and Coren measure or as the average value (Table IV), and not when the sex of the subjects was taken into account. To ensure that the lack of a significant correlation was not due to a low reliability of the laterality indices, the intraclass correlations for lambda and r_{pb} were calculated (Shrout and Fleiss, 1979). For the lambda index, the intraclass correlations amounted to IC $= .439$; for the r_{pb} index, it was IC $= .539$. This means that the correlations between the lambda index and the lateral preferences should be multiplied by $(1/0.439)^{1/2} = 1.5$ to account for the noise in the lambda data; for r_{pb}, the multiplication factor equals 1.4. Nowhere does this suffice to approach significance.

Discussion

Experiment 2 was included to investigate whether Strauss and Goldsmith's (1987) finding could be replicated, that right cerebral hemisphere tasks covary with eye preference. This turned out not to be the case, as can be seen in Tables IV and V. A symmetry detection task that returned a reliable LVF superiority, was not related to any of the four lateral preferences tested. All correlations were virtually zero, also when they were corrected for the unreliability of the VHF asymmetry index.

Two arguments may be invoked to explain why Strauss and Goldsmith's correlation between LVF superiority and eye preference was not repeated. First, it might be that the correlation of Strauss and Goldsmith was due to chance fluctuations, and, therefore, is not reproducible. This explanation, however, is seriously weakened by the fact that Strauss and Goldsmith's result was not based on a single experiment, but was found both with a tachistoscopic VHF task and with a dichotic listening task. The second interpretation is that Strauss and Goldsmith's outcome only applies to the lateralization of the perception of emotional expressions, and not to the perception of visuospatial relations. This agrees with Boles (1992), who reported null correlations between facial figural tasks and spatial tasks (positional and quantitative). A problem with the second explanation, however, is that as far as we know, no compelling reasons have been published that allow to justify why eye preference would be related to the perception of emotional expressions in the absence of a covariance with visuospatial processing.

GENERAL DISCUSSION

The present article examined the effect of lateral preferences, particularly hand preference, on VHF asymmetries in tachistoscopic tasks. This was done first by a review of a sample of the literature (Table I), and then by the presentation of two new empirical studies that investigated the issue (Table II and IV). The resulting picture indicated that hand preference does have an influence on VHF superiorities in the expected direction, but that the effect is smaller than generally accepted and that for some tasks other lateral preferences may be a better predictor. This has both theoretical and practical implications.

Theoretically, the observed low correlation between hand preference and VHF asymmetry could be due to (a combination of) two factors: measurement error, and/or a low correlation between the evaluated constructs. Unless the former factor refers to the fact that (i) the Edinburgh questionnaire is not a good assessment of hand preference, or (ii) that tachistoscopic VHF experiments are not a good index of laterality (see the Introduction), measurement error can hardly account for the data of the present experiments. Test-retest reliability of the questionnaire is known to be in the order of 90%-98% (Coren, 1993), and, due to the large number of observations, the reliability of the obtained VHF asymmetries was quite high (around .80 for Experiment 1, and .50 for Experiment 2). Therefore, the lack of a substantial covariance between hand preference and VHF superiority in Experiment 1 and 2 is unlikely to be due to insufficient testing.

Remains the alternative that the true correlation between handedness and laterality of several visual functions is limited in magnitude. As indicated by Cohen (1988, pp. 77-83, 531-535), the effect size of a correlation investigated in the behavioral sciences is rarely close to plus or minus one. Rather, a correlation in the order of $r = .50$ already indicates a large effect size. Most sizes are in the range of $r = .10$ to $r = .30$. At first sight, this looks disappointing. However, with respect to cerebral asymmetry, it may be the kind of covariation one would expect if laterality is based on probabilistic rather than deterministic grounds. Suppose that the brain is functionally organized into a collection of separate, in principle bilateral, processing systems. Although available in both cerebral hemispheres, some processing systems are forced to develop asymmetrically, because the activity they underlay requires the coordination of rapid sequences of operations over both halves of the body. One such system is the speech output control centre, which due to an innate bias (McManus and Bryden, 1993) has higher chances of growing dominant in the left brain half. The dominance of the speech output system on one side of the brain increases the a priori (genetic) *probability* that its input, the phonological output lexicon, is situated on the same side, if for nothing else than to decrease the transmission distance. For the same reason, the input of the phonological output lexicon, the auditory input lexicon and part of the semantic system, have *higher chances* to become dominant in the brain half where the phonological output lexicon is situated. This in turn increases the *probability* of a superior visual input lexicon on the side of the auditory input lexicon. In a similar way, the dominance of the speech output system on one side of the brain enhances the genetic *chances* that other processing systems involving fine motor programming are predominantly situated in that cerebral hemisphere (for an elaborated version of the above model of laterality, see Kosslyn, 1987, from whom several ideas have been borrowed).

Note that in the just depicted model everything turns around *a change in probability*: The dominance of a process component on one side of the brain affects the a priori chances that another component will become superior on the same side (or the opposite side; Corballis, 1989). Two extreme versions are (i) that the chances remain virtually unchanged, which leads to statistical independence of laterality of different functions, and (ii) that changes are enlarged up to 100%, which implies a deterministic view of lateralization. In-between, there is a whole range of possibilities, going from a slight change to a very pronounced modification, which possibly depends on the nature of the systems involved, and/or on other characteristics of the subject (e.g., the size of the corpus callsum). Important, however, is that the expected correlation between the asymmetry of two functions can be rather low, and will decrease when the "distance" between the functions increases. Suppose, for example, that the genetic distribution of the different components in the above model is altered, so that a correlation of $r = .60$ arises between two successive processing stages. Further assume independence of the different steps in the chain of intercorrelations. Then, the expected correlation between handedness and the visual input lexicon, will amount to $r = (.60)^4 = .13$; the correlation between handedness and the auditory input lexicon will be slightly larger and amount to $r = (.60)^3 = .22$.

The above reasoning may help to understand why the effect of hand preference on VHF asymmetries in tachistoscopic laterality tasks is so small. Given our findings and the results of power analysis (Cohen, 1988, p. 93), one may expect that we had about 30% chance of not finding a significant ($p < .05$) correlation between handedness and VHF superiority in both experiments, if the expected correlations were not larger than .20. The reasoning above also makes clear why the correlation between the ear preference of the subjects and their VHF superiority for word naming (Experiment 1) was larger than the one between handedness and VHF superiority, if one assumes that ear preference is more related to the auditory input lexicon than hand preference.

The practical implication of the low covariance between lateral preferences and VHF asymmetries is rather straightforward: The gain associated with subject selection on the basis of those preferences will be quite limited. This need not be bad, as long as subject selection does not involve major difficulties (e.g., when the subject sample is limited to right-handers). However, if the inclusion of lateral preferences as a selection criterion leads to a serious reduction of the population, the expected outcome is hardly worth the effort. For instance, the limitation of subjects to male left-handers is likely to result in major difficulties to find enough subjects, but not in a substantially higher probability to find persons with atypical VHF scores. The same is true for the inclusion of a substantial percentage of left-handers in order to increase the variability of VHF data (e.g., in correlational studies). When left-handed subjects are difficult to trace, the researcher may do just as well to include a few more right-handed persons in the sample. If, on the other hand, subject selection does not pose a great problem, the present findings (Experiment 1) and those of Strauss (1986) suggest that better prediction of lateralization of language functions is possible if ear preference is used as selection criterion rather than hand preference. Data by Strauss and Goldsmith (1987) indicated that for the laterality of emotional expressions, eye preference may be the best predictor. According to Experiment 2 of the present article, the same is not true for visuospatial processes (at least not for symmetry detection), where no lateral preference had a significant relationship with the VHF asymmetry.

Abstract

A review of a sample of the literature on differences in visual half field (VHF) asymmetries between left- and right-handed subjects, showed that hand preference only had a small influence on VHF superiorities. Across studies, the effect usually was in the expected direction, but within studies, it rarely reached significance. The finding was replicated in two new empirical studies, one with a task that yielded a right VHF superiority (word naming), and one with a task that returned a left VHF superiority (symmetry detection). A comparison with other lateral preferences (footedness, earedness, and eyedness) indicated that the VHF asymmetry of the word naming task was better predicted by ear preference than by hand preference; no such superiority was found for the symmetry detection task, where no lateral preference correlated significantly with the VHF asymmetry.

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Appendix

Items of the Questionnaire and Their Correlations with the Laterality Indices (lambda and point-biserial correlation) of Experiment 1 and 2

	Exp 1_L	Exp 1_{rpb}	Exp 2_L	Exp 2_{rpb}
Handedness				
1. writing	0.286	0.258	0.017	−0.007
2. drawing	0.228	0.239	0.017	−0.007
3. throwing	0.066	0.123	0.036	0.033
4. scissors	0.132	0.204	0.067	0.011
5. toothbrush	0.152	0.116	0.020	−0.008
6. knife (without fork)	0.118	−0.011	0.124	0.054
7. spoon	0.198	0.159	0.009	−0.051
8. broom (upper hand)	0.172	0.177	0.048	−0.044
9. striking match (match)	0.133	0.115	0.000	−0.006
10. opening box (lid)	0.096	0.153	−0.017	0.052
Footedness				
1. kick a ball	−0.084	0.016	−0.065	0.092
2. pick up a pebble	0.111	0.034	−0.076	0.034
3. step on a bug	0.134	0.091	−0.000	−0.051
4. step on a chair	0.215	0.223	0.053	0.067
Eyedness				
1. telescope	0.011	−0.005	0.134	0.031
2. look into a dark bottle	0.017	−0.044	0.088	−0.022
3. keyhole	0.016	−0.028	0.080	0.069
4. sight down a rifle	0.014	0.166	−0.007	0.043
Earedness				
1. conversation behind door	0.284	0.216	−0.074	−0.033
2. earphone	0.224	0.116	−0.009	0.047
3. heartbeat	0.321	0.285	−0.096	0.006
4. clock in a box	0.274	0.302	−0.098	−0.102