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Cet article tente de présenter brièvement les développements actuels sur la restauration fonctionnelle dans le système nerveux central. On constate que les processus retenus dès la fin du XIXème siècle pour rendre compte des phénomènes de restauration sont les mêmes que ceux actuellement invoqués, la grande différence étant que ces hypothèses sont soumises à expérience.

Les mécanismes intervenant dans le retour des fonctions après lésion de leurs substrats nerveux peuvent être regroupés en redondance (restitution) et réorganisation (substitution).

Les facteurs susceptibles de faciliter ou d'inhiber la restauration sont passés en revue soit qu'ils tiennent à l'individu (âge, sexe, espèce, expérience antérieure), soit à la lésion (nature, masse, type d'évolution), soit aux conditions post-lésionnelles (chimio-thérapie, rééducation).

La question de la restauration post-lésionnelle a été profondément renouvelée par la démonstration de l'existence de phénomènes de régénérescence axonale ou collatérale au niveau du système nerveux central. Si leur importance dans la récupération fonctionnelle peut être encore discutée, il semble cependant que ces régénérescences peuvent aboutir à assurer une certaine réorganisation particulièrement dans le cerveau immature où les régénérescences axonales sont surtout constatées. Deux autres processus doivent aussi être pris en compte, l'hypersensibilité de dénervation et la dérépression synaptique.

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LATERAL DIFFERENCES IN NORMAL MAN AND LATERALIZATION OF BRAIN FUNCTION *

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The historical development of work on lateral differences (LDs) is described and an evaluation is attempted of the present state of the study and of the conceptual and methodological problems which it encounters.

Contemporary work is mainly motivated by the notion that LDs reflect hemispheric specialization and thus provide a means of studying hemisphere function in easily available normal subjects. Work on LDs in visual recognition has first been conducted, however, within a completely different conceptual framework. Right visual field advantage (RVFA) for words and letters was first thought of as reflecting the left-to-right direction of latin writing which produces opportunity for differential perceptual learning in the two hemifields or, as was later considered, creates left-to-right scanning habits. On the contrary, right ear advantage (REA) in dichotic listening was, from its discovery by Kimura, shown to be linked to lateralization of speech control in the left hemisphere. The possibility that visual field effects could also be related to hemispheric specialization was then examined by looking for effects of handedness and for correlations between LDs and pathological data. After considerable initial resistance, the notion has become widely accepted.

While the early work tended to deal with broad categories of tasks or of stimulating materials, more analytical approaches have been developed and investigators have tried to specify the component operations which are responsible for observed LDs. It has been shown that a same task can give rise to different patterns of asymmetry according to the particular operating mode which is adopted. Chronometric methods have been used to isolate processing stages with different lateralizations, and specific hypotheses have been advanced concerning levels at which lateralization originates.

Regarding the mechanism of LDs, the most often considered interpretation is based on the notion of *direct access*, i.e. of an advantage associated with primary projection in the competent hemisphere. According to whether localization of the critical operations is strict or relative, one of

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two alternative versions of direct access, called respectively the *callosal relay* and *efficiency* models, apply. Other mechanisms based on *hemispheric activation* or *priming* and on *interference* between operations competing for hemispheric processing capacity have also been considered and presumably contribute, beside direct access, to observed LDs. There are also other sources for LDs than brain asymmetry, a fact which tends to be overlooked with the current focusing of interest on hemispheric interpretations. Even in cases where the role of hemispheric specialization has been established, other determinants can play amplifying or masking roles, as has been shown for auditory laterality effects.

Current attempts at providing simple dichotomous general characterizations of hemisphere function, such as the one in terms of holistic vs. analytic processing, are described. The opinion is offered that such attempts are premature and that they reflect an underestimation of the complexity of the problem. It is argued (1) that the present catalogue of registered LDs is both too narrow and too subject to selective biases to provide a basis for ambitious generalizations; (2) that a convincing account of lateralization would require an understanding of its evolutionary origin; (3) that it would also require a more advanced understanding of the various mechanisms, including interhemispheric interactions, intervening between hemisphere competence and performance.

Introduction

The arrangement of the sensory afferent pathways is such that the respective inputs to the cerebral hemispheres from a particular stimulus generally depend on the site at which the stimulating energy impinges on the sensory periphery. Thus, in vision, the partial decussation of fibres at the optical chiasma results in all inputs from one visual hemifield being directed to the contralateral occipital cortex. The case is more complicated for audition. Each ear is connected to Heschl's gyri of both hemispheres. However, contralateral connections contain a larger number of units than ipsilateral ones, so that the general principle of *functional decussation* still applies. A somewhat similar situation seems to hold for somesthetic inputs (Gazzaniga and Ledoux 1978).

One consequence of these anatomical circumstances is that one can affect the hemispheric projection of sensory information by manipulating the site of stimulation relative to the axis of symmetry. When lateral differences (LDs) are observed at the level of performance, they can teach us something about the distribution of functions between the hemispheres. This simple notion has in the last twenty years aroused considerable hopes in psychologists and neuropsychologists, and sparked an explosion of empirical research the results of which have been recently the object of very critical appraisals (Marshall 1981; Studdert-Kennedy 1981).

In the present paper, the historical development of these studies will be sketched, an attempt will be made at evaluating their present state, and some of the conceptual and methodological problems which they pose will be discussed. Given space limits, all pretension to produce anything like a review had to be given up from the start. The presentation is selective. It is of course influenced by the theoretical preferences of the author, but a serious effort has been made not to let these preferences distort the picture which is being given of the evidence regarding the topics that have been included.

Right visual field advantage for words and letters

The interest for LDs started in experimental psychology largely independently of any concern for the asymmetrical organization of the human brain, a problem which at the time was the exclusive province of clinical neurologists. As far as the contemporary movement is concerned [1] it began with a startling finding made by Mishkin and Forgays in Hebb's laboratory at McGill and published by them in 1952. The aim of the study was to show that stimulus equivalence, Gestalt psychologists' "transposability", could be established by experience, as Hebb's neuropsychological theory of pattern recognition implied. The particular equivalence which was chosen was that between letters presented in different retinal locations. When reading a language written from left to right, the segment of text of direct interest after that at the fixation point is situated to the right, creating better conditions for the development of relevant identification circuits in the parts of the visual system connected with the right visual field (RVF) than in those connected with the left visual field (LVF). The authors presented English words in a tachistoscope in different unpredictable locations relative to the point at which the subject had been asked to fixate, and obtained as predicted a right visual field advantage (RVFA), i.e. a larger proportion of correct identifications in the RVF than in the LVF.

There were, however, alternative possible explanations of RVFA, which were discarded through further experiments. One group of explanations was dealt with in a single experiment. These were: (1) variations of acuity across the retinas; (2) variations in the clarity of

[1] As usual, pioneers had forerunners. Zaidel (1982) attracts attention to the somewhat forgotten work of Franz (e.g. Franz and Davis 1933).

patterns; (3) an attentional bias toward the RVF, and (4) "dominance" of the left cerebral cortex "for vision" (sic). These four interpretations all predicted the same constant effect whatever the presented material. To the contrary, the perceptual learning interpretation predicted that for letters in a writing system which, like Hebrew or Arabic, goes from right to left, LVFA would be obtained. Bilingual subjects were shown English and Yiddish words left and right of fixation, and displayed the predicted LVFA for Yiddish words together with the normal RVFA for English ones. Another possibility, that the beginning of words is more informative than their end, was discarded through an experiment where subjects had to identify words with either the first or the second half blurred.

One potentially important aspect of the results was that the LVFA obtained for Yiddish words was clearly smaller than the RVFA obtained for English ones. This difference might have suggested a multi-factor determination of field advantages, but the authors preferred to attribute it to different degrees of experience of the subjects with English and Yiddish text, thus sticking to an interpretation solely in terms of perceptual learning. As a consequence, the possibility of a relationship between visual field effects and hemispheric specialization was no more considered for several years.

In 1957, Heron, another student of Hebb, proposed a completely different interpretation of Mishkin and Forgays' findings, one that these authors had not considered. Heron presented rows of letters either on one side only of the fixation point, or simultaneously on both sides. He obtained RVFA with unilateral presentations and LVFA with bilateral ones. Both results, he argued, could be accommodated by the hypothesis that the presented material is processed in an order consonant with reading habits, thus in a left-to-right one for English script and in a right-to-left one for Yiddish or Hebrew script. The first items to be processed had a better chance to appear in overt report, a prediction implicitly based on the notion of a fading trace of the visual presentation, which George Sperling was going to elaborate with great success in the following years. The whole mechanism, which Neisser (1967) called the "directional scanning hypothesis", elegantly accounted for RVFA with unilateral presentations of English letters and words and LVFA with unilateral presentations of Yiddish words and with bilateral presentations of English material. The fact, which soon became known, that field effects were stronger for words or letter strings than e.g. for geometric shapes or pictures of common objects (Terrace 1959; Bryden 1960) was attributed to the fact that the former materials evoked scanning habits more strongly.

Right ear advantage for speech in dichotic listening

In 1961, Kimura, then at the Montreal neurological Institute, reported that in Broadbent's (1954) dichotic listening test, where the subject who wore earphones heard three successive digits in one ear and simultaneously three other digits in the other ear, and was asked to report as many digits as he could in any order, recall was better in right-handed subjects for the digits presented to the right ear. This was called *right ear advangtage* (REA). Kimura also tested patients in whom the sodium amytal test had shown that the control of speech rested in the right hemisphere, and these displayed a *left ear advantage* (LEA). A clear correlation was thus demonstrated between ear asymmetry and lateralization of brain function.

Kimura (1967) later noted that in monaural tests, where the digits are delivered to one ear at a time, no asymmetry is apparent. She proposed that REA results from the combination of two factors: specialization of the left hemisphere for linguistic functions and stronger connection of each ear to the contralateral than to the ipsilateral hemisphere, leading to prepotency of contralateral inputs in case of discordance. Then, Milner et al. (1986) and Sparks and Geschwind (1968) separately showed that, in split-brain patients, REA gives way to complete suppression of left ear inputs, and this was interpreted by the latter authors as meaning that intra-hemispheric inhibition of discordant ipsilateral inputs is complete and that whatever performance is obtained in normal subjects on left ear inputs is based on information relayed through the commissures.

Kimura's procedure in her original study was far from optimal and the results could be related to factors such as the subject's decision to attend to one ear or to the other or to memory limitations as well as to a perceptual mechanism. Better tests, with only two items delivered on each trial (with synthetic speech, for instance, this is sufficiently difficult to avoid ceiling effects) and instructions prescribing order of report (Bryden 1962) or requiring the report of the input to one ear only on each trial (e.g. Haggard and Parkinson 1971; Morais and

Bertelson 1975) have, however, since largely confirmed the existence of a perceptual advantage favoring speech delivered to the right ear. The necessity of dichotic competition has on the other hand not been confirmed, for REA can be obtained with monaural presentations provided a more sensitive index of performance, such as reaction time, is used (Springer 1973; Morais and Darwin 1974).

Further support for the hemispheric specialization interpretation of ear differences was brought when it was shown that the opposite pattern of ear advantage, LEA, could be obtained in right-handers with tasks involving other types of material: melodies (Kimura 1964), environmental sounds (Curry 1967), or directing attention to other aspects of the material: judgments of emotional tone (Haggard and Parkinson 1971), recognition of intonation pattern (Blumstein and Cooper 1974). The dichotic situation thus appeared to produce something akin to that favorite neuropsychological pattern of proof, double dissociation.

The reinterpretation of visual field effects

In her 1961 paper, Kimura suggested that RVFA for words and letters could also be related to LH dominance for linguistic processing. In fact, the impression made by her discovery of REA played a major role in persuading students of visual field effects to consider more seriously the possibility of an interpretation in terms of cerebral lateralization of function. Another powerful factor was, of course, the work on commissurotomy patients which created a strong interest for hemispheric differences (Sperry 1968; Gazzaniga 1970). Three main lines of evidence were used to back the suggestion.

(*a*) One consisted of comparisons of hemifield differences in right- and left-handed subjects. Bryden (1964) e.g. reanalyzed the results of his earlier tachistoscopic experiments, and found that a higher proportion of right-handers than of left-handers displayed RVFA. This result, he noted, was consonant with the information provided by the newly introduced sodium amytal test, which had just confirmed that, as the data from aphasia research had long since suggested, LH control of speech is less frequent in left-handers than in right-handers. He also observed, and later confirmed, that the effect of handedness was much more pronounced for single letters than for letter strings, and this suggested that performance on the first type of material was less influenced by order of processing. Orbach (1967) examined the combined effects of handedness and of direction of writing in an experiment where both left-handed and right-handed bilingual Israelian subjects were asked to identify both English and Hebrew words presented left and right of fixation. He found that both factors were effective, a result which thus strongly supported a multifactor conception of lateral differences.

It is somewhat ironical that the first successful argument for the hemispheric reinterpretation of visual field effects was a relation to handedness. Later work has in fact shown that the link between brain lateralization, handedness and behavioral asymmetries is, to say the least, a complicated one. Although RVFA and REA seem to be reduced in left-handed subjects, or at least in familial ones (Zurif and Bryden 1969; but see Briggs and Nebes 1976, for negative results) they do not correlate between themselves (Bryden 1965). There have also been recent suggestions of a relation of REA to handedness not mediated by hemispheric lateralization (Bryden 1978; Warrington and Pratt 1981) a point to which we shall return later.

(*b*) A somewhat less satisfactory line consisted of criticizing the evidence for other determinants, thus trying to establish the hemispheric specialization interpretation by default. The strategy was of course based on the implicit postulate that a single factor was operating. In a series of papers, McKeever and his coworkers argued that the LVFA obtained by Heron and many other investigators (e.g. Bryden and Rainey 1963) with bilaterally presented material, and which was one of the main factual bases of the directional scanning notion was actually due to inadequate control of several factors, of which the main one was gaze fixation. (They disregarded the equally important argument based on the inversion of the field advantage with right-to-left written material.) Using a "central task technique" where a small digit was displayed at the fixation point at the same time as the lateralized material, and had to be reported before that material, they repeatedly found strong RVFA for bilaterally presented words – stronger in fact than for unilaterally presented ones (McKeever and Huling 1970, 1971). Critics have pointed out that the central task not only constrained fixation but could also bias scanning strategies in a way conducive to RVFA (White 1973; Kaufer et al. 1975; Bryden 1978). A controversy ensued, which helped making the complexity of the bilateral paradigm explicit, the contenders eventually agreeing at least on the multifactorial character of the phenomena (White 1973; McKeever 1974).

(*c*) A third line of evidence was that tasks for which work with unilaterally lesioned or commissurotomy patients suggested differential hemispheric involvement produced the corresponding hemifield effect. The studies available for this kind of argumentation are by far the more numerous. It must be noted immediately, however, that the majority were not designed to test the hemispheric interpretation of lateral differences, but rather took it for granted, and considered laterality effects as tools for the investigation of hemispheric functions. Nevertheless, the fact that convergences were obtained contributed to strengthen the confidence in the hemispheric interpretation.

The suggestions which were originally put to the test were of a rather general character. The main one was that RVFA was not to be obtained for all materials, or all tasks, but that other, tentatively labelled "non-verbal", would give LVFA. The importance accorded to this question should be related to the situation in the late '60s, when the substitution of the notion of hemispheric specialization, i.e. of two hemispheres with different capacities, to the older one of a dominant LH, was still a matter of controversy: actually it was only the split-brain data that finally imposed the notion of specific RH competences.

Kimura (1967, 1969) found LVFA for dot localization and for dot enumeration, together with RVFA for embedded letter recognition. She failed on the other hand to obtain any field advantage for the recognition of meaningless shapes, which had previously been shown to be more difficult for RH than LH patients (but with a different method of presentation). The LVFA suggested by clinical data was obtained for line slope recognition (Fontenot and Benton 1971), random dots stereograms identification (Durnford and Kimura 1971), difficult color discrimination (Davidoff 1976; Hannay 1979), human face recognition (Hilliard 1973; Rizzolatti et al. 1971; Geffen et al. 1971).

These LVFAs were generally smaller than the RVFAs found for words or letters, and also they often proved more difficult to replicate. Dot localization, for instance, has produced as many negative as positive results, and even RVFA (see Davidoff 1981a for an extensive review). The effect obtained with random dots stereograms has been shown to depend on the size of the dots (Pitblado 1979). One reason which has often been advanced for the smaller size and lower reliability of RH superiorities is the fact that perceptual recognition is often followed by verbal labelling, or naming, at which the LH is better.

RVFA has generally been found for the identification of pictures of familiar objects or of geometric shapes and this result has generally been attributed to the fact that naming is unavoidable with such materials. One must of course be cautious not to accept that kind of interpretation without supporting evidence. Otherwise, all cases where no lateral difference is observed could be registered as evidence for RH superiority masked by LH superiority for subsequent naming. But there are cases such as line slope identification and face recognition for which the possibility that naming, among other factors (Umiltà et al. 1978), can mask LVFA has been convincingly established (Berlucchi 1974). All in all, these two types of tasks seem to have produced LVFA more reliably than any other.

The material which is probably most noticeable for producing erratic patterns of laterality is meaningless shape identification. Although LVFA has been reported more frequently than the other patterns, RVFA and no field advantage, especially when the response measure has been reaction time, all have occurred depending on factors such as complexity, difficulty of the recognition task and others so far insufficiently identified. The lability of the effects obtained with meaningless shapes has actually made them a choice material for exploring the influence of attentional and strategic variables on perceptual asymmetries (Hellige and Cox 1976).

The case of random shapes illustrates one difficulty of the correlational approach. Greater susceptibility to RH than to LH damage has been reported for particular tasks, such as perceptual closure in the Street Completion Test (De Renzi and Spinnler 1966) or in Mooney's Test (Newcombe 1969) or segregation of embedded figures (Kimura 1964). But different pictures have been obtained with other tasks. For random shape recognition, Bisiach and his associates has observed a strong tendency for greater susceptibility to LH damage, although an effect of RH damage has appeared in some conditions also (Bisiach and Faglioni 1974; Bisiach et al. 1979). One should thus be cautious not to draw conclusions for shape perception in general. It is tempting to speculate that the often expressed notion of RH superiority for shape perception was derived from the general principle of RH specialization for all visual or all perceptual functions rather than from specific clinical data. It would seem that the tentative generalizations of early neuropsychology have sometimes been taken much more seriously than they were meant to be, especially by psychologists. This is one of the problems of cross-disciplinary collaboration: specialists on both sides of the boundary can overestimate the knowledge available on the other side. In the present case, one consequence is that much research presented as testing for correlations between lesion and LDs data has in fact been conducted in a confirmatory mode, leading probably to a tendency to publish positive results selectively.

Lateral differences as a tool for the study of cognitive organization

From the '70s on, work on LDs has been mainly motivated by its potential use in advancing our understanding of the division of cognitive functions between hemispheric sub-systems. Once the initial resistance to the hemispheric interpretation had been surmounted, many cognitive psychologists were attracted by the conceptual power of neuropsychological dissociations as a basis for a classification of mental operations. Experimenting with easily available intact subject on the other hand made it possible to examine suggestions provided by clinical or experimental neuropsychology with all the advantages of efficient contemporary experimental paradigms.

The early findings of Kimura, Bryden, etc. were generally described in terms of specialization of the hemispheres for dealing with particular types of material: the LH dealt with verbal material, the RH with others types, sometimes specified by default as "non-verbal". As we have noted in a previous section, the preoccupation at the time was not so much to detail the functions of the RH, as simply to show that it had some. Soon however, investigators began to ask which particular operations performed on a given type of material were responsible for the observed asymmetries.

The first important effort to analyze a domain of cognitive organization on the basis of LDs was the program of research inaugurated at the Haskins Laboratories in the late '60s to examine which particular aspects of speech were responsible for producing REA. The dichotic studies reported until then had generally been carried out with words as stimuli, mostly digit names. The Haskins workers used meaningless segments such as CV (consonant-vowel) or CVC syllables. Their work was developed within the conception of a speech processor, responsible for extracting from the information provided by earlier processes of auditory analysis the phonetic contrasts necessary for phonological interpretation, and which, unlike the bilateral auditory processes, would be based in the LH (Liberman et al. 1967; Liberman 1974). Shankweiler and Studdert-Kennedy (1967) found that discrimination of CV syllables differing by the stop consonant gave REA but not the recognition of steady state vowels. Later work showed that vowels could yield REA under particular conditions, e.g. shorter duration (Darwin 1971), lower signal-noise ratio (Godfrey 1974) or unpredictable variations in voice parameters (Haggard 1971). Other phones, like fricatives and liquids were found to occupy an intermediate position between stop consonants and vowels (Darwin 1971). The fact that REA was stronger for some phones was interpreted as meaning that only the more "encoded" ones, i.e. those whose acoustic realization is most variable as a function of context, engaged the speech processor, while less encoded ones like the vowels could be identified by the non-lateralized auditory processors (Liberman et al. 1967) but later Studdert-Kennedy and Shankweiler (1970) argued for a completely different interpretation in terms of differential sensitivity of the different speech sounds to degradation during callosal transfer. The evolution of the program, which has been thoroughly reviewed by Morais (1977) led to consider the possibility that beside phonetic processing, some aspects of auditory analysis could also be lateralized in the LH (Studdert-Kennedy 1975).

A point which the more analytically oriented work has gradually brought into focus is that the units about which the question of lateralization can most profitably be asked are cognitive operations, not categories of stimulating material or of tasks. Numerous studies have shown e.g. that the same material can give rise to different patterns of laterality, depending on the type of processing it is subjected to. In 1971, Haggard and Parkinson showed that subjects who were asked to judge the emotional tone of dichotically presented sentences did better on those presented to the *left* ear. In the same vein, Bartholomeus (1974) presented subjects dichotically with different melodies, sung using different words (letter names) by different singers. LEA was obtained when the task was to recognize the melody, REA when it was to recognize the letter names, and no ear advantage for recognition of the voice.

In the preceding example, different patterns of laterality were obtained by having the subjects extract different types of information from the material. But sometimes the same information can be extracted by different cognitive strategies or operating modes. The role of such factors is a matter of growing concern in contemporary cognitive psychology (Underwood 1978). A good example of the influence of strategies on patterns of laterality is a result reported by Bever and Chiarello (1974). These authors found that, whereas subjects without musical training displayed the usual LEA for melodies, trained musicians on the contrary displayed a REA. Apparently, musical training makes available modes of processing music which depend more on LH-based operations. The work on music perception has provided other examples of the dependence of laterality patterns on strategy. Thus Peretz and Morais (1980) in this laboratory, presented melodies dichotically to musically naïve subjects, and found no overall advantage for either ear. When, however, they partitioned the subjects on the basis of introspective reports of the method they had used to carry out the task, it appeared that subjects who reported concentrating on local details of the melodies showed REA while those who reported no such strategy showed a LEA.

The dependence of performance asymmetries on operating modes has important implications for the interpretation of individual differences or of changes of individual laterality patterns with time. Changes in asymmetries with age have often been used as cues to the development of brain lateralization (see Witelson 1978, for a review). In these studies, there has often been a tendency to forget that observed changes with ages can reflect change in operating modes as well as changes in lateralization (Bertelson 1978). The same applies e.g. to sex differences (McGlone 1980).

In cases where several operating modes are available to the subjects, the problem for the investigator is of course not simply to register their existence but also to discover the conditions under which each will be resorted to. Contemporary chronometric analysis has provided methods for attaining that sort of goal. One method consists of manipulating the classification of stimuli or "S-R mapping", the subject is asked to perform. Morais (1976) had subjects give choice reactions to monaurally presented CV syllables. In one condition, one response was given to either of two syllables and the other response to either of two other syllables, and a significant REA was found. In the other condition one response was given to only one syllable and the other response to any of the remaining three syllables, and no ear advantage was observed. Morais interpreted this result as due to the fact that with the 1–3 partition the task can be accomplished by a comparison of the presented syllable with a "pre-phonetic" representation of the target, a comparison which could be accomplished without engaging the LH speech processor.

Another method is the one used by Posner (1969) in his studies of character classification. The subject is asked to compare two simultaneously or successively presented letters, and give one key-pressing response if they are the same, and another response if they are different. Now, "same" can mean either two identical characters, like A-A or a-a, or alternatively two physically different characters like A-a which are however representations of the same graphemic category, or, if you prefer, have the same name. Posner found, and that result has been amply replicated, that "name matches" take longer than "physical matches". He has interpreted the finding as showing that name matches require one operation, the obtainment of the name of the characters, which is not needed for the decision of sameness in the case of physical matches. Two studies published in the same year have shown that the two kinds of matches produce different hemifield effects (Cohen 1972; Geffen et al. 1972): right-handed subjects gave a RVFA for name matches and a LVFA for physical matches.

The method can be applied to other types of material than alphabetic characters. It has for instance been used with pictures of human faces (Moscovitch et al. 1976; Bertelson et al. 1979). In our experiment, the subject first saw a photograph of a face in central position, then one to one side and had to indicate by moving a lever whether the two photographs represented the same person. In one condition ("facial identity condition") the two photographs of the same person presented on "same" trials showed that person from different angles (face and 3/4 profile). In the other condition ("physical identity condition"), they were identical pictures. A significant LVFA was obtained for the facial identity condition, none in the other condition. In a later, as yet unpublished experiment, we have found that matching faces differing in expression produces a stronger LVFA than matching faces differing, as in the first study, in orientation. Moscovitch et al. found that comparisons of pictures presented simultaneously and unpredictably in either the left or RVF produced a LVFA when "same" pairs were made up of a photograph and a caricature of the same person, and no field advantage when they consisted of two identical photographs or two identical cartoons. What these convergent results seem to imply is that to compare different pictures of the same person, it is necessary to extract some specific properties invariant over changes in orientation, expression or mode of representation, and that this extraction depends critically on some RH processes, whereas to decide that two pictures are identical or not, general procedures equally represented in both hemispheres are sufficient. Moscovitch et al. also showed that physical matches could give rise to LVFA when they involved two pictures presented at a sufficient time interval or, as in Rizzolati et al. 's (1971) experiment, a memorized face and a presented picture. They proposed that RH processing is necessary to produce a representation of sufficient duration.

A notion which is implicit in much of the preceding presentation is that mental activities are analyzable into successive stages, each taking a finite time. This notion has in fact played a central role in contemporary cognitive psychology. Methods for identifying stages have been developed (Sternberg 1969). Analysis into stages has generally been conducted within the conception of a hierarchy of cognitive operations, where operations at each level use as inputs the outputs from several lower level operations (Neisser 1967). As it proceeds from lower to higher levels, the sensory evidence is recoded into representations of increasing abstractness, which have also been assumed to have increasing durability (Craik and Lockhart 1972). In recent years, the insistance of early formulations on a bottom–up succession of operations has been criticized and more general 'heterarchical" models have been developed (Rumelhart 1977) which allow for both bottom–up and top–down successions. These notions have important implications for laterality research.

The original Haskins notion of non-lateralized auditory analysis followed by LH-lateralized phonetic processing – or RH-lateralized specialized processing for the extraction of other features, musical, intonational, etc. – belonged already to a processing stages approach. The approach has been generalized by Moscovitch (1979). Starting from data such as those on matching pictures of faces at the physical and physiognomic level which we have been discussing, and quoting also clinical data showing that asymmetries in the effects of lateralized lesions are rarely observed for low-level features such as color, luminance, contour, loudness, pitch or pressure, he proposed that the early stages of stimulus processing are bilaterally equipotential in all modalities and that asymmetries arise at later stages, concerned with the extraction of higher level patterns. On the other hand, when the task requires that the processing be carried out beyond that stage, lateral differences originating there will still affect performance, by a process of "transmitted lateralization".

Since the successive stages for many types of input have not been identified in detail, the proposal is still essentially programmatic. It needs a lot of elaboration in several places. But even if still schematic, it offers an attractive conceptual framework for further explorations.

The notion that early stages are not lateralized meets with some difficulties. Moscovitch himself notes that LVFA has sometimes been found for the extraction of apparently low-level features, and Davidoff (1982 a, b) shows that those cases are too numerous to be considered as noise. Results which are also difficult to integrate are those by Cohen (1972), Geffen et al. (1972), Hellige (1976) and some others, showing LVFA for the matching of identical letters. Other studies reviewed by Moscovitch (1979; 393) have shown no field advantage for the same task, and of course the equally negative results obtained for the matching of identical pictures of faces (Moscovitch et al. 1976; Bertelson et al. 1979) is also relevant. Within Moscovitch's position, the cases of LVFA can be accommodated by the notion that under some particular conditions, it becomes more efficient to obtain low-level information from higher level codes, a phenomenon illustrated for instance in the word superiority effect for letter recognition (Reicher 1969) and in the shape superiority effect for line slope recognition (Weisstein and Harris 1974).

The alternative to the notion of non-lateralization of early processing stages would be to suppose RH involvement. Davidoff (1982 b) e.g. appears to favor relative RH superiority. And of course a similar idea was implicit in the early characterizations of RH functions by the "non-verbal" label, which as many authors have noted (e.g. Corballis and Morgan 1978), makes sense only under the evolutionary hypothesis that the RH is competent for all those functions that were inhibited in the LH as a result of the development of the speech-related functions. Under an assumption of RH basis for all early processing operations, all cases where no overall RH advantage emerges would have to be accounted for by masking of the initial RH superiority, presumably due to some form of verbalization. This is not a plausible view. Verbalization could not account e.g. for the fact that the LVFA obtained for physiognomic matches of pictures disappears for physical matches: there is no reason why physical matches would induce more naming.

One obvious implication of the stage analysis, and which is independent of the issue of lateralization of the early stages, is that many tasks must evoke processing stages of opposite lateralizations. The several cases where naming a material changed the pattern of laterality from left to right perceptual field advantage imply just that kind of situation. A similar situation must exist for visual letter recognition: the result of Bryden and Allard (1976) that the direction of field advantage depends on typeface, implies that some typefaces, apparently the less distinctive ones, produce a strong LVFA for the perceptual stage, which is not compensated by the RVFA associated to the later linguistic interpretation operations, while for other letters, the opposite situation exists. In a situation where blind readers scanned rows of Braille characters for a given target, we have just found that the speeds reached with each hand were differentially affected by target/background discriminability, in the direction of greater left hand superiority for the less discriminable targets (Mousty et al. 1982).

The mechanism of behavioral asymmetries

In most of the studies examined so far, the relation between LDs and hemispheric division of function has been treated as an empirical finding which permitted to use lateral differences as cues to approach other problems. In comparison, there have been relatively few studies aimed at analyzing the mechanism of lateral differences. This lack of concern for mechanism is surely responsible for some of the confusion which reigns in the field.

(*a*) Kimura first, and after her the majority of investigators, linked lateral differences to the fact that data from some part of the sensory periphery are projected directly in the competent hemisphere, and those from other parts not. This notion has been called the *direct access* one. As became progressively clear, there are two different ways in which differences in primary hemispheric projection can affect later processing, which depend on how one conceives of hemispheric specialization. If the critical operations can only be carried out in one hemisphere, i.e. if there is *strict localization*, then data projected to the non-specialized hemisphere can only be processed after commissural transfer. Lateral advantage shall then result from delay or, more probably, from information loss due to such transfer. This mechanism for lateral differences has been called the *callosal relay model*. On the other hand, if processing compatible with task demands can be accomplished in both hemispheres, albeit more efficiently in one, i.e. if there is *relative localization*, callosal transfer is no more a necessity (although it can still occur) and differences in performance can directly reflect the unequal competences of the hemispheres. This model has been called the *efficiency model*. As is immediately apparent, the efficiency model can easily be rephrased to suit cases where a same result can be achieved through different operating modes, with different patterns of lateralization.

One way to discriminate between the two mechanisms is to compare the patterns of laterality observed in split-brain subjects with those of intact subjects. If the task of interest depends on strictly localized capacities, split-brain subjects will give zero performance for inputs directed to the uncompetent hemisphere. This is exactly the result obtained with dichotic listening (Milner et al. 1968; Sparks and Geschwind 1968; Tweedy et al. 1980), and it confirms that phonetic processing is the monopoly of the LH. Lexical access on the other hand, would be an example of operation involving relative localization (Zaidel 1976, 1982).

An approach that requires access to a little-available population is of course not a widely practicable one. Moscovitch (1973) has shown that the question can in principle be approached with intact subjects only, through chronometric methods. The principle is to measure RTs for responses given to lateralized inputs with effectors controlled from each hemisphere, e.g. lexical decisions (deciding whether a string of letters constitutes a word) expressed with the fingers of either the left or the right hand to strings presented in the left or RVF. Under strict localization, the delay resulting from the transmission of sensory information across the commissures will be involved whenever the letters are presented in the LVF, and the delay resulting from transmission of response order whenever the response must be given with the left hand. The effects of side of presentation and responding hand will thus add linearly in determining overall RT. Under relative localization, the RVF-right hand combination will still produce the shorter RTs, but now LVF-right hand, which will involve both perceptual processing in the minor RH and interhemispheric transmission of response orders will give rise to longer RTs than either of the left hand responses. A crossed visual-field by responding hand interaction is thus predicted.

Moscovitch quoted several studies which, for linguistic tasks showed additivity of responding hand and side of presentation effects. More recently, Day (1977) has provided data which strongly support the same conclusion for lexical access in the case of abstract words (his exp. 1 was in fact the example of the preceding paragraph). For choice RT to faces, Moscovitch et al. (1976) in their exp. 2, have obtained results in striking concordance with the predictions for the efficiency model: the shortest RT corresponds to the LVF-left hand combination and the longest one to the RVF-left hand combination.

The approach however is complicated by the factor of "signal-response compatibility": for a given side of presentation, responses given with the corresponding hand tend, all other things equal, to be faster than those given with the other hand. Moscovitch et al.'s (1976) exp. 1, where no overall field advantage is obtained for matching identical pictures of faces shows a clear pure compatibility effect. This complication might explain why the method has not been used more systematically, even by Moscovitch himself (but see Zaidel 1982). Another reason might be that the principle applies essentially to one-stage tasks. With the possibility that most tasks involve a number of stages, some successive, some simultaneous, each of which can be strictly or relatively lateralized on one or the other side, or also not lateralized, predictions become rather complicated. It becomes in fact surprising that simple patterns of results have ever been obtained.

(*b*) The direct access interpretations considered in the preceding section are based on *structural*, fixed properties of the afferent pathways. There have been some attempts at accounting for behavioral asymmetries by the operation of more dynamic control processes. It has been proposed, e.g. that the apparent incapacity of the RH of aphasic patients to understand language is not a reflection of lack of the necessary machinery, but rather the result of active inhibition exerted by the LH (Geschwind 1969). This model, which Moscovitch (1973) has called the *functional localization* model would explain why, in split-brain patients, where the inhibitory influences are no longer transmitted, the RH has been shown to be capable of non-negligible linguistic performances (Gazzaniga 1970; Zaidel 1976).

In a series of papers, Kinsbourne (1970, 1973, 1975) has proposed explanations of lateral differences which dispense with the direct access notion. The core of Kinsbourne's position is the idea of a variable balance of activation between the hemispheres, controlled by a form of mutual inhibition. Variations in that balance create a correlation between two categories of functions carried out by each hemisphere: the symmetrical functions of dealing with afferent and efferent messages concerning the contralateral periphery, and lateralized specialized functions. Engaging in linguistic activities will shift the balance of activation in favor of the LH and bias attention to the right half of space. Kinsbourne first backed his notion by experiments where the detection of gaps in tachistoscopically presented lines was shifted towards RFVA when the subject was engaged in a verbal memory task and towards LVFA when he had to retain melodies. Another line of evidence was provided by gaze aversion studies, in which subjects were asked questions, and tended to shift their gaze to the right when the questions had verbal content and to the left when the content was spatial in nature (Kinsbourne 1972).

Two questions must be asked concerning Kinsbourne's conception: (a) does the hypothesized mechanism actually occur? And, if yes, (b) can it provide a sufficient explanation of known lateral differences?

Although the gap detection phenomenon itself has not proved reliable (Gardner and Branski 1976; Boles 1979) effects of lateralized activities on perceptual lateral differences have been demonstrated. Morais and Landercy (1977) using choice reaction time to dichotically presented CV syllables found that the pattern of ear differences shifted toward REA when the subject was retaining sentences and LEA when he was retaining melodies. The effect however was obtained only when the critical variation on which the choice of the response had to be based was the identity of the (stop) consonant, not when it was the identity of the vowel. In a series of experiments, Hellige and his associates have used a situation where the subject had to identify Attneave-type random shapes presented tachistoscopically left or right of fixation, while at the same time rehearsing variable numbers of words. They found e.g. (Hellige and Cox 1976) that a medium memory load (2 or 4 words) shifted the pattern of laterality towards RVFA.

A larger load (6 words), however shifted the advantage back in the direction of the LVF. These results are consistent with the somewhat more sophisticated notion that the introduction of a secondary lateralized task can either favor, through activation, operations carried out in the same hemisphere, or, at higher load levels, hamper them by competing for available capacity. Further experiments have confirmed the reality of intrahemispheric competition (Hellige et al. 1979), and shown that it can result in overflow to the less competent hemisphere, more specifically that loading the LH with a word rehearsing task shifted the pattern of performance on letter recognition from RVFA to LVFA. There are signs that hemispheric capacity limitations may become a major focus of interest in the coming years. Moscovitch and Klein (1980) have shown recently that intertask competition is stronger for tasks with a common hemispheric basis, which provides explicit support for the notion implicitly accepted by most students of lateralization that intrahemispheric interactions are more important than interhemispheric ones.

Most tests of Kinsbourne's conception have been in the tradition of the gap detection studies, i.e. they have looked for effects of engagement in lateralized processing on the lateral distribution of attention. The opposite possibility, that attending to one side could affect the effectiveness of cognitive processes in a way consistent with their lateralization, has to the best of my knowledge not been considered before an unpublished experiment carried out in this laboratory by Morais and Pinchart [2]. These investigators presented their subjects with dichotic trains of clicks of varying intensity, and on each trial had them monitor those coming to one particular ear, together with giving choice RT responses to binaurally presented CV syllables. RT was significantly shorter when the subject was attending to the right.

Let us now turn to the second question: can hemispheric activation provide a sufficient explanation of known asymmetries? The notion is that it is activation created by previous trials that will bias attention to the corresponding side. It is clear that this contextual determination will only produce consistent side advantage when successive trials create activation in the same hemisphere. Several authors have shown that in fact lateral differences in opposite directions can still be obtained when the relevant stimuli are presented in irregular order. Thus Geffen et al. (1972) have obtained LVFA for physical matches and RVFA for name matches in Posner's character classification task with random presentation of stimuli requiring the different types of comparisons. Similarly, Berlucchi et al. (1974) had subjects give choice

[2] Since writing this paragraph, my attention has been drawn (by J.B. Hellige) to some work by Kinsbourne (1975: Exps. 4 and 5, pp. 86–87) where the direction in which the head had to be turned prior to giving a learned verbal response to a letter had detectable effects on RT (which however changed with practice).

reactions to letters and to faces presented in random order and obtained LVFA for the faces and RVFA for the letters.

It would thus seem that lateralized activation can indeed influence the pattern of laterality, but cannot account for the whole of the observed effects, so that one cannot dispense with the notion of direct access. Rather than run controversies concerning the respective advantages of structural and attentional explanations, the task for the investigator is to understand how the two kinds of factors interact in the causation of performance.

The importance of Kinsbourne's contribution is that it has forced us to realize that the mechanism of lateral differences can be much more complicated than was originally imagined. Regarding facilitation effects, there are obviously other possibilities than the effect, on which Kinsbourne concentrated, of activation on the lateral distribution of attention. It is possible, as Klein et al. (1976) mentioned, that activation of one hemisphere facilitates all operations carried out in that hemisphere. Such effects can be more or less specific. The rather specific priming phenomena which have received much attention recently (e.g. Posner and Snyder 1975) could obviously produce overall effects much similar to hemispheric activation.

(*c*) Lateralization of brain function is not the only possible source of behavioral asymmetry. Another is handedness, which can surely not be considered as a mere consequence of hemispheric specialization. A third one is the order of succession of symbols in writing systems, which in the majority of them is along the horizontal axis, i.e. from left to right or from right to left. Habits developed in writing and in reading can undoubtedly influence many performances. A fourth group of factors is constituted by the cultural rules concerning hand usage or occupation of right vs. left positions by people playing particular roles.

As we have seen, the role of reading habits in the causation of visual field effects was a topic of major concern in the '60s. But with the focusing of attention on hemispheric mechanisms, a tendency has developed to forget the possibility of other determinants. Bryden (1978) in a very thoughtful paper has expressed the opinion that we have become too accepting of hemispheric explanations. One consequence of that state of affairs is that a danger exists that any observed behavioral asymmetry be casually attributed to hemispheric specialization without further analysis.

One good example is lateral asymmetry in Ladefoged and Broadbent's (1960) click localization task, where the subject is asked to estimate the position in a string of speech where an extraneous sound such as a click or a cough has been superimposed. The task has been used by psycholinguistists in studies purported to analyze the role of syntax in speech perception. Fodor and Bever (1965) in the study where they inaugurated that line of research, ran the task dichotically and observed that the click was estimated to occur earlier when it was delivered to the left ear and the speech to the right ear than with the opposite arrangement. In an often quoted paper, Bever (1971) had childeren of different ages perform the same task, and used the results to argue about the development of language lateralization. The present author ran the task with both Hebrew and French sentences in bilingual subjects and obtained mirror-image patterns of laterality in the two languages: larger preposition of the click delivered to the left ear with French sentences, and to the right ear with Hebrew sentences (Bertelson 1972). It would thus seem that the phenomenon has little to do with cerebral lateralization. It probably rather reflects an influence, in literate people, of orthographic representation during listening to speech.

(*d*) In cases such as hemifield or dichotic effects in perceptual identification, the role of hemispheric specialization cannot be reasonably doubted any more. It is nevertheless dangerous to lose sight of the fact that other factors can play amplifying or masking roles, and consequently affect the relative sizes of lateral differences observed in different situations.

One such factor is the spatial distribution of attention. Kinsbourne's notion of a bias through hemispheric activation does not exhaust the ways through which attention can be controlled. Obviously, beside automatic effects like the one considered by Kinsbourne, attention can also be controlled through voluntary decision. When e.g. the dichotic test is carried out with instructions to report both inputs, the subject's choice to attend selectively to one or the other side can effect the ear advantage which is obtained. Bryden (1978) has discussed the problems of controlling voluntary attention in lateral differences work very thoroughly.

Another important possibility discussed by Bryden in the same paper is that handedness could affect lateral differences, possibly via the lateral distribution of attention, independently of its association with brain lateralization. He shows e.g. that in Kimura's (1961) original data, an independent effect of handedness on ear advantage can be observed in each lateralization of language group. A result going in the same direction has recently been reported by Warrington and Pratt (1981). These authors found that left-handed depressed patients, in whom observations made during unilateral electroshock therapy (ECT) indicated LH speech control, nevertheless tended to display LEA in dichotic listening. Given the somewhat conflictual state of the evidence regarding ear advantages in left-handed subjects, it may be premature to draw strong conclusions from that particular finding, but the notion of a direct influence of handedness on at least some lateral differences is worth pursuing.

These ideas relate rather nicely to some earlier work on the mechanism of auditory laterality effects. Some years ago, José Morais and the present author noted that the dichotic paradigm confounds two possible contributors to REA: the fact that the data reaching the right ear are more efficiently transmitted to the LH and the fact that they appear localized in the right part of space. They showed (Morais and Bertelson 1973, 1975) that a *right side advantage* for speech recognition can be demonstrated in the *diotic* situation, where the different stimuli are delivered over loudspeakers occupying different azimuthal positions relative to the listener, and also in a *stereophonic* situation where the stimuli are both delivered over two earphones, but with time phase differences creating an impression of lateralization to the left for one stimulus and to the right for the other one. The latter condition was critical, for the effect observed here cannot be attributed to higher intensity of one stimulus in the right ear. In another study, Morais (1974–75) showed that right side advantage can be eliminated (but not created, however) by misleading the listener about the actual separation of the two sources of stimulation. In a similar vein, Goldstein and Lackner (1974) found that the pattern of laterality obtained in the dichotic situation is modified when the subject wears prisms which displace the visual field laterally.

We suggested that REA might be a special aspect of the more general right side advantage. This notion however met with difficulties of its own. We had the opportunity to test patients who, presumably as a result of damage to the commissures, showed left ear extinction in the dichotic test (Bertelson et al. 1977). Contrary to our prediction, they did not show left side suppression neither in the diotic nor in the stereophonic situations, only a rather large right side advantage The same result has been obtained by Tweedy et al. (1980) with split-brain patients. Finally, Darwin et al. (1978) using an elegant "split formant" technique which makes it possible to deliver the phonetic information critical for the identification of a CV syllable to one ear while giving the impression that the sound comes from the opposite side, showed that, in that condition, ear of entry is more important than apparent position.

This somewhat complicated picture would suggest that auditory asymmetries involve at least two mechanisms, one based on direct access – the traditional Kimura-Geschwind notion – and the other on constraints on the spatial distribution of attention. The latter effect would be more important in the diotic situation than in the dichotic one. It is possible that the attentional component has a direct relation to handedness. In a so far unpublished experiment, Hublet has found as a matter of fact that left-handers display a left side advantage in the diotic situation, a result which must be put in parallel with the fact that left-handers have been found to have reduced REA in the dichotic situation, but rarely LEA.

The quest for "the nature of hemispheric specialization"

As has been suggested already, the early characterizations of hemisphere functions by terms such as "verbal–non-verbal", "verbal–visuospatial" or "verbal–perceptual" were not meant to establish taxonomies of cognitive operations. They were provisional generalizations, based on the few tasks for which hemispheric differences had been documented. It is of course easy to show that they do no longer offer sufficient accounts of all the asymmetries that have now been described. Linguistic functions do not constitute the homogeneous block they were once assumed to be. Work with split-brain patients has shown that if the RH is incapable of speech production nor of phonetic analysis (Levy and Trevarthen 1977), it is capable of some speech understanding and surely of lexical access (Gazzaniga 1970; Zaidel 1976, 1982). Right perceptual field advantages have been found for non-linguistic tasks: identification of rhythmic patterns (Natale 1977) of short time intervals (Vroon et al. 1977), of Morse sequences (Papçun et al. 1974) and of melodies in some subjects (Bever and Chiarello 1974). We have seen also that some non-verbal tasks, such as meaningless shape identification do not systematically produce LVFA. Finally, the work of Kimura, showing that concurrent speaking interferes with the programming of sequential fingers and arms movements, suggests that the LH is implicated in the latter (Lomas and Kimura 1976).

Such considerations have led several authors to look for some better, more inclusive, overall characterizations generally also in dichotomic terms. The usual strategy consists of scrutinizing the catalogue of registered hemispheric superiorities for some unitary principle. A review of these attempts has recently been published by Bradshaw and Nettleton (1981) in *Behavioral and Brain Sciences*, a journal which applies the "Open peer commentary" principle, i.e. where each article is followed by commentaries written by other specialists of the field. Much of what follows is based on the paper by Bradshaw and Nettleton and the commentaries it provoked.

The characterization which appears for the time being to command most attention, and for which Bradshaw and Nettleton display evident sympathy, is one which describes the operation of the LH as "analytic" and that of the RH as "holistic" or "Gestalt". The distinction has e.g. been used by Sperry and his coworkers in their analyses of split-brain performance (Levy-Agresti and Sperry 1968). One of its apparent attractions is that it seems to encompass as special cases other distinctions that have been proposed such as digital/analogue (Bateson and Jackson 1964), focal/diffuse (Semmes 1968), propositional/appositional (Bogen 1969), serial/parallel (Cohen 1973). It also evokes popular distinctions such as logical/intuitive or abstract/concrete.

The analytic/holistic distinction is however a vague one. Like most terms borrowed from everyday language, it carries a number of different meanings. This is not a reason to prohibit such importations, but the danger exists that terms of that kind be taken more seriously than they deserve, leading to unwarranted generalizations from some of their meanings to the others. It has been suggested above that this has happened in the case of the verbal–visual distinction. If one tries to translate the analytic/holistic dichotomy into more operational terms, which would allow testable predictions, one finds that it is compatible with several not necessarily equivalent translations such as focal attention vs. pre-attentive segmentation of the sensory field, attention to local detail rather than to overall configuration, serial classification vs. parallel testing of several features (or template matching), attention to high frequency vs. low frequency Fourier components. Hence, as several commentators of the Bradshaw and Nettleton paper pointed out, many apparent explanatory successes of the analytic/holistic dichotomy are actually post-hoc. Marshall took the example of the task consisting of choosing among several circles the one of which a particular arc is a part, and which work with split-brain patients has shown to be better accomplished by the isolated RH (Nebes 1974). Bradshaw and Nettleton describe the task as involving "the ability to form a complete Gestalt (e.g. a circle) from incomplete information (e.g. arcs of a circle)". And Marshall comments: "Had the data gone the other way, we can be sure that the task would have been described as implicating the ability to decompose circles into their constituent arcs (an analytic operation)...".

It is not difficult to find results which would make difficulties for rather obvious translations. The Reicher (1969) effect, i.e. the fact that a letter is recognized more efficiently when it is presented in the context of a word than in isolation, even when the possible effect of redundancy is controlled for, would appear to be an example of the use of higher order configurational properties, and hence would qualify as a case of holistic processing. The effect is nevertheless stronger in the RVF (Krueger 1975). Another example is provided by one of our unpublished studies which showed that an illusion similar to the Ponzo illusion, where the apparent lengths of two lines are affected by the orientation of converging background lines, an effect which would seem to imply configurational processing, is not stronger in the LVF than in the RVF.

Of course, one could, as Morais (1981) proposes, undertake to test systematically for hemispheric correlation the different operational translations of the fundamental dichotomy. As he suggests, the notion of holistic or configural processing, in the sense defined by Garner (1974) and by his associates (Pomerantz et al. 1977) of processing at the level of emergent pattern properties not available in the component elements, would be a good candidate. The studies of Cohen (1973) where she explored possible hemispheric correlations of the serial/parallel distinction belonged to the same vein, and were certainly worthwhile, even if they eventually led to negative results. It appears however that such analytical approaches are fundamentally alien to the strategy of searching for "the one good label", to the extent that the distinctions on which they focus are necessarily local ones, which cannot apply across all materials, tasks and operations as the original distinction is supposed to. The problem, in other words, is that in the present state of the field you cannot have generality and predictive power at the same time.

None of the other global characterizations examined by Bradshaw and Nettleton (another one is in terms of temporal vs. spatial patterning) fares much better than the analytical/holistic or the despised verbal/non-verbal distinctions. As several of the commentators (Cohen, Marshall, McKeever, Bertelson) did, one should ask whether trying to characterize hemispheric differences by one pair of adjectives is a worthwhile enterprise. It would rather seem that engaging in a pursuit of "the " good label implies an underestimation of the complexity of the problems involved in understanding hemispheric specialization. There are three essential points to consider here.

(1) The existing catalogue of LDs does not constitute a satisfactory data base for generalizations. The number of published studies, it is true, is considerable, but they have concentrated on particular tasks for which either pathological data, previous studies with normal subjects or current generalization from either of these sources predicted LDs. This concentration does not reflect some lack of imagination on the part of the investigators, for there were often sound reasons for sticking to particular situations: if one wanted to know e.g. if alternating at random stimuli giving rise to LDs in opposite directions would produce smaller differences, it was a natural choice to use words and faces. But from our present viewpoint, one must realize that relatively few studies were conducted with the purpose of exploring new tasks for possible LDs. One result is that there are domains of cognitive activity for which little information exists about hemispheric effects. For instance, in spite of the recurrent notion that the RH is better at dealing with space relations, there have been very few studies of visual field effects in phenomena such as size and shape constancies and the allied illusions and distortions, which are the main focus of the attention of students of space perception.

Another problem with the present catalogue is that it contains a larger than usual amount of contradictions, examples of which have been described. One reason might be the complexity of the mechanisms, which involve more parameters than experimenters generally control. Another might be low standards of experimentation on the part of some investigators. But a probably very influential factor is selective publication. Authors, editors and referees all have generally some ideas about what "good results" are. As a result, data which are striking and at the same time lend themselves to clear interpretations have a chance to be published soon, while those that are difficult to integrate within prevalent generalizations are likely to have to wait at least until the author has succeeded in producing a convincing rationale – be it a revolutionary one. That kind of selection process is probably unavoidable in any empirical discipline and it explains why some striking findings later prove difficult to replicate. The process however is likely to be amplified in a field of study like LDs where (a) the techniques and skills necessary to run an experiment are easily available, and (b) some results and some generalizations are rather widely known. The effect of these circumstances is that beside professional investigators, an unspecified number of people active in other fields will introduce lateralized presentations in studies carried out for other main purposes, and publish the results if they happen to be "interesting".

The conclusion regarding the first point is that if one wants really to develop a typology of hemispheric competences, work more descriptively oriented and less exposed to data selection than the one described in the present literature must be carried out. On the other hand, it does not seem that an effort focused on the description of present competences would by itself make lateralization understandable. This leads us to our two other points.

(2) In their commentaries, both Studdert-Kennedy (1981) and the present author argued that a meaningful answer to the question of "the nature of hemispheric specialization" could only be one in evolutionary terms. It would consist of identifying the advantages which resulted from lateralization of brain functions and favored evolution away from symmetrical organization. Several possibilities have been cited. One is control of articulatory movements, another coordination of the two hands. Levy (1974) has argued on the basis of paleontological data (the site of fractures on the skulls of baboons killed by early men) that the latter function may be prior to the emergence of speech. A discussion of the issue would fall out of the limits of the present paper. The argument was quoted as an example of what is relevant to understanding lateralization. It must also be noted that an evolutionary account of lateralization would probably not result in indicating a single function. The history of evolution is replete with examples of changes that occurred under one environmental pressure and then produced side effects which

guided further evolution. Brain asymmetry most likely has played a role in the evolution of a number of capacities beyond speech and hand coordination.

(3) Finally, understanding lateralization would also involve understanding the whole mechanism linking hemispheric capacities to cognitive performance. We would want to know not only what each hemisphere can do better than the other one, but also how operations carried out on one side are coordinated with those carried out on the other side, how they are integrated into a coherent activity. The studies purporting to analyze performance into processing stages, to investigate differences in processing modes, to discover different types of interactions between stages such as priming or interference, address the question directly. So, even if their present achievements are still remote from giving a complete picture of cognitive activity, they go in the right direction. Further progress will depend on general progress in cognitive psychology, and of course in the other cognitive sciences and in neuroscience. In the opinion of the present writer, it is essential not to isolate the study of lateralization from this wider framework, and one of the main dangers of excessive concentration on the characterization problem is that it tends to isolate lateralization research, for instance by creating concepts of its own.

Concluding remarks

Diversity of approaches, of strategies, of conception of research objectives are normal features of any field of inquiry, and work on LDs is no exception. This diversity has been apparent in the preceding examination, and has been put in relation to the different backgrounds of the different groups of investigators. In this last section, the main conclusions which are scattered throughout the text will be put together.

(1) Although some of the early work on LDs was guided by other interests, e.g. for possible effects of reading habits on general cognitive skills, it is clear that the vast majority of the studies reported in the last 20 years have been motivated by the notion that LDs reflect the different cognitive capacities of the hemispheres. As far as visual field effects and dichotic effects are concerned, this basic assumption is probably correct, provided it is admitted that other factors are also involved. LDs offer thus an opportunity to study the manifestations of

hemispheric specialization in intact subjects, and thus to supplement the information provided by work on the effects of brain lesions and by measurements of physiological indexes of cerebral activity. These are important objectives and they justify the interest which the method has attracted.

(2) Work on LDs has in recent years attracted much criticism from neurologists, neuropsychologists and psychologists alike. Some of these criticisms are probably not really specific and represent the sort of negative reaction which a topic often arouses when it becomes very popular. On the other hand, it is true that part of the published work can be criticized at the levels of conceptual elaboration and often also of experimental methodology.

(3) There has been a tendency to proclaim unrealistic ambitions for LDs work. Several authors have tried to provide simple characterizations of hemispheric differences, generally in dichotomic terms. These attempts reveal gross underestimations of the complexity of the problems implied in understanding lateralization of brain function. Such understanding in our view will only be attained gradually, through a process involving, beside much more work focused on hemispheric differences, through brain lesions, LDs and physiological methods, progress in the biology of language and other cognitive functions and in the analysis of cognitive mechanisms. Unrealistic claims are surely responsible for some of the current unfavorable reactions, for if present achievements are measured by such high standards, they can only be seen as disappointing.

(4) In spite of the large number of studies which are reported in the literature, our factual information on LDs is still very incomplete, and there are vast domains of cognitive activity for which practically no information exists. Work has tended, often for good reasons, to concentrate on particular situations. On the other hand, a considerable amount of selective publication is probably going on, as suggested by the frequent failures to replicate previous findings. Premature dichotomic generalizations have probably played a role here too. So, contrary to an often encountered opinion, there is room for more work exploring new domains for possible LDs, carried out in a critical frame of mind.

(5) Too little attention has in general been devoted to the mechanism of LDs. There has been a tendency to forget that to draw inferences from LDs to hemisphere function it is necessary to take account of all

the processes that mediate performance, and that some of them may be remotely related only, or not related at all, to brain asymmetry. The tendency has had unfortunate consequences especially when variations in LDs, such as sex differences or age differences, have been uncritically attributed to differences in degree of lateralization.

(6) The approach which has appeared as the more promising one is represented by studies designed to locate the sources of LDs as part of an analysis of cognitive performance into component operations. Conceptual and methodological developments in general cognitive psychology and psycholinguistics have provided a foundation for that sort of enterprise. Significant questions have been asked and some of them have received tentative answers: relation of LDs to processing modes, role of factors such as direct access, hemispheric activation, priming, interference, voluntary attention, involuntary biases etc. in determining asymmetries. The exploitation of these possibilities has only begun. Progress can be expected, provided laterality research is conducted as an integral part of the study of human cognition.

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On examine l'histoire des travaux sur les différences latérales (DLs) et on tente une évaluation de leur situation actuelle et des problèmes conceptuels et méthodologiques qu'ils posent.

Le travail contemporain est motivé principalement par la notion que les DLs reflètent la latéralisation des fonctions cérébrales et offrent donc le moyen d'étudier les fonctions des hémisphères chez les sujets normaux. La recherche sur les DLs dans la reconnaissance visuelle a d'abord été menée, toutefois, dans un cadre conceptuel complètement différent. L'avantage du champ visuel droit pour la reconnaissance des mots et des lettres a d'abord été considéré comme résultant de l'ordonnancement de gauche à droite de l'écriture latine qui crée des occasions d'apprentissage perceptif différentes dans les deux hémichamps, ou, comme il a été considéré plus tard, crée des habitudes de balayage de gauche à droite. Par contre, l'avantage de l'oreille droite dans l'écoute dichotique a été, dès sa découverte par Kimura, mis en relation avec la latéralisation du contrôle de la parole dans l'hémisphère gauche. La possibilité que les effets d'hémichamps soient également en relation avec la spécialisation hémisphérique a été considérée alors sur la base des effets de la dominance manuelle et des corrélations entre DLs et données de la pathologie. Après une résistance initiale considérable, la notion a fini par être largement admise.

Tandis que les premiers travaux étaient conçus en termes de catégories larges de tâches ou de matériel stimulant, des approches plus analytiques ont été développées ensuite, et les chercheurs