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AAMRL-TR-89-042



**THE BOUNDARIES OF
HEMISPHERIC PROCESSING IN
VISUAL PATTERN RECOGNITION**

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ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

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NOVEMBER 1989

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FOR THE COMMANDER



CHARLES BATES, JR.

Director, Human Engineering Division
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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AAMRL-TR-89-042			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Armstrong Aerospace Medical Research Laboratory		6b. OFFICE SYMBOL (If applicable) AAMRL/HED	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) Wright-Patterson AFB OH 45433-6573			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO. 62202F	PROJECT NO. 7184	TASK NO. 10
11. TITLE (Include Security Classification) The Boundaries of Hemispheric Processing in Visual Pattern Recognition					
12. PERSONAL AUTHOR(S) McNeese, Michael D.					
13a. TYPE OF REPORT Final		13b. TIME COVERED FROM JAN 87 TO NOV 89		14. DATE OF REPORT (Year, Month, Day) November 1989	15. PAGE COUNT 25
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) hemispheric asymmetry; visual recognition; learning and cognition; cerebral cortex; human performance		
FIELD	GROUP	SUB-GROUP			
05	08				
06	04				
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This paper discusses some of the positions, theories, and experiments which compose the adaptive hemispheric processing area. This discussion will necessarily address some of the basic questions of human learning and relate some of the assumptions that are critical for interpreting research findings. The paper will begin by looking at some theoretical perspectives, then look at some of the author's own research application in hemispheric processing within the area of face recognition and attentional processes. A neuro-cognitive systems model of results is proposed to interpret findings.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Michael D. McNeese			22b. TELEPHONE (Include Area Code) /(513) 255-8805		22c. OFFICE SYMBOL AAMRL/HED

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Preface

The research underlying this report was performed by the Harry G. Armstrong Aerospace Medical Research Laboratory, Human Engineering Division, Wright-Patterson AFB, Ohio in support of Work Unit 71841046, Strategic Information and Force Management. The research which led to this review was conducted with the expert support of Dr. Ron Katsuyama, a National Research Council Associateship appointment at AAMRL.

Also, the author gratefully acknowledges the support of other support personnel. Discussions with Dr. Sal Soraci, Research Assistant Professor of Psychology, Vanderbilt University, helped form the foundations for this review. The support of the following Systems Research Laboratory personnel was essential in conducting the research. Bill McGovern who served as experimenter; Curt Mayrand and Brian Porter for their adept programming skills and advice; and Greg Boethe who provided timely insights and oversaw the engineering/hardware development.

I would also like to thank Mr. Walt Summers, Lt. Col. William Marshak, and Mr. Don Monk, AAMRL/HE, for their support of this research.

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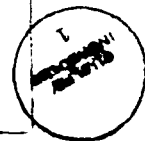


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INTRODUCTION

The problem which researchers need to address is how the brain's two hemispheres come to work together on a particular task. The question of how the hemispheres work conjunctively has often been ignored. Indeed many studies in the past as well as today are more interested in the decomposition of brain activities with the bias of trying to find specialization. As researchers try to theorize how the two brains are separated and integrated, there are some basic, philosophical questions which rise to the surface. This paper will attempt to highlight some of these issues as appropriate as they yield insights into many of the assumptions one must be prepared to make. As these assumptions vary, the corresponding theoretical perspectives change, as does the experimental design to test the theory. A look at some of the many models proposed for hemispheric processes should provide a feel for such different orientations of the phenomenon.

HEMISPHERIC MODELS OF PATTERN RECOGNITION

There are a number of comparisons among models of hemispheric asymmetry which can be made. Many models focus exclusively upon cerebral anatomical structures (e.g., Sergent, 1982; Kinsbourne, 1980); whereas others tend to focus on cognitive strategies (Ellis, 1983; Moscovitch, 1979). Still, other models take an attention-theoretical view to integrate many inconsistencies in the literature (Friedman & Polson, 1981).

Herein, is the first example of a basic philosophical issue. The cerebral position is akin to a nativist view as these researchers make the assumption that hemispheric processing (HP) can always be attributable to a neurophysiological/biological basis. The reason for asymmetry is built-in according to native biological principles of evolution that dictated the human to have two distinct hemispheres, each with a different capability. Note that primates such as rhesus and squirrel monkeys also demonstrate some of the cerebral asymmetries that humans do.

In contrast, those researchers which believe HP is just a reflection of cognitive strategies do not take the reductionist argument, but rather suggest that information processing, in accordance with task demands, acts to determine possible specialization. The cognitivists believe that HP is

independent of the hardwiring occurring in the cerebral structure. As will be shown, there are many varieties of approaches even within each of these camps.

One of the major problems, in understanding the HP area, is the researcher's strict adherence to only one view of HP as elaborated in the type of models presented above. This may leave one with a stunted view of the complexity of HP. The author's contention is that a general model of cerebral laterality must take a systems perspective which addresses both right and left hemisphere cooperation and interaction. Cooperation between hemispheres must involve cerebral, cognitive, and attentional orientations or it will be a weak model of the domain. In order to systematically address these broad components; cerebral functionality, cognitive strategies invoked by cognitive demands, and auditory-image modulations which create demands need to be viewed separately.

Cerebral Function

There have been many studies that act to associate a particular brain function with a given hemisphere (Sperry, 1974; Kimura, 1964; Gazzanaga, 1970). Typically, and often in a popularized overstated manner, these results posit that the left hemisphere was found to be involved with analytical, serial processing, whereas the right hemisphere was involved with spatial-wholistic processing (Bogen, 1969; Moscovitch, 1979; Patterson & Bradshaw, 1975).

The research involving hemispheric asymmetry with respect to face recognition has further elucidated the role of the right hemisphere in processing visuospatial stimuli. Studies involving normal adult subjects (e.g., Geffen, Bradshaw, & Wallace, 1971; Hilliard, 1973; Klein, Moscovitch, & Vigna, 1976) as well as patients with unilateral cortical lesions (Benton & Van Allen, 1968; Milner, 1968; Warrington & James, 1967) and commissurotomy patients (Levy, Trevarthen, & Sperry, 1972; Sperry, 1974) have shown that the right hemisphere is superior to the left hemisphere in face recognition tasks. This is demonstrated by greater speed and accuracy in the recognition of faces presented to left visual field.

These studies have provided the impetus for a voluminous amount of research that has led to different perspectives and models to address

hemispheric asymmetry. The research in this area presently has many confusing results. Reconciliation between different results is hard to obtain because of critical differences in parameters which are not always matched across studies. Also, there has been great variation in the extent to which studies have been replicated. Part of this inconsistency may be attributed to imprecise experimental designs, and part may be attributed to the wide degree of variance in individual differences in HP. Consequently, the field today is often considered a confusing mess. Yet, the fact remains that humans do have two interactive hemispheres, each with some specialties.

There is reason to believe that such cerebral specialization is authentic under prescribed conditions. However, cerebral function has often been discussed as an absolute, invariant truism. This is a criticism of much of the literature as many experimenters have this a priori nativist assumption.

This paper emphasizes the point that cerebral function is conditional and relative to operational performance characteristics. What is needed is an approach that focuses on *hemispheric cooperation*. In this sense, the aim is to look at functionality as a process that transpires between two brains wherein each brain has certain advantages and disadvantages to engage in certain actions, and each brain has a limited amount of resources which can be expended upon these actions. Hence, the neuro-cognitive systems model proposed is that functionality is an adaptive process which may shift from utilization of one hemisphere to the other given: the operational requirements of a task composite, the degree of relative specialization of the hemisphere initially presented the task, and the relative expenditure of resources for each hemisphere. A prime idea is that hemispheric shifting is necessary for the brain to adapt its function to the needs that are imposed upon it.

This posits that a researcher must complete a task analysis to properly understand what demands will be placed on the subject as well as to document the precise methodology used to implement and assess HP. McNeese (1983) suggests that exposure duration, stimulus luminance, task requirements, delay of target onset, mask qualities, stimulus familiarity, and the role of a central task all must be considered when interpreting HP research. Hiscock (1988) states that asymmetry is subject to influence of stimulus characteristics, familiarity, the number of dimensions on which

faces differ, the way they are defined (i.e., reaction times, errors, minimum exposure duration/performance level specified), and various age-related differences.

Cognitive Strategies

Inherent in the cooperation between hemispheres is the notion that certain cognitive strategies seem to be best performed by one hemisphere rather than the other. There may also be certain actions that each hemisphere performs equally well but by using different strategies. Please note that this does not preclude a hemisphere from using a certain strategy, but suggests that each hemisphere obtains advantages dependent on conditions. Currently, the assumption is that cognitive strategies may fall into two distinct types: A.) piecemeal- feature recognition (Sergent, 1982), and B.) configurational- constructive processing (Ellis, 1983). More specifically, piecemeal recognition is used when recognition can be based on a single feature, when there are familiar invariant patterns, and is identified by Klatzky (1986) as a picto-literal or linguistical strategy. Picto-literal refers to a representation that uses an analogue, depictive image as form; and has concrete, idiosyncratic details for content; and is encoded via visual perception and internal reperception processes.

In contrast, configurational strategies are based upon recognition via a synthesis of various features, prototype construction, and are identified by Klatzky (1986) as a visuo-conceptual strategy. Visual-conceptual refers to representations which are descriptive, conceptual, propositional in form; abstract and categorical in detail; and are processed via perception, categorization, and interpretation. Depending on various factors (e.g. cognitive demands), these types will either be equivalent or one type will produce a definite advantage. As mentioned, it is assumed that these strategies are indigenous to one hemisphere or the other, (i.e., piecemeal recognition occurs in the left and configuration occurs in the right hemisphere). Yet, this assumption must be one of the major factors that anticipates research which looks at cerebral function-cognitive strategy tradeoffs.

Embedded within the discussion of cognitive strategies is an old philosophical issue. It is that of the Plato-Aristotle debate. The rationalist

position suggests that face recognition would be known only by processes of the mind (i.e., the piecemeal-recognition and configurational-constructive strategies). On the other hand, the empirical position would suggest that faces only exist in the world and that a person recognizes them only by sensing them. At a global level we could evaluate face recognition on the basis of perceptual differentiation ala Gibsonian principles, wherein a person continues to pick up multiple examples of faces through familiarity and becomes expert at classifying different patterns.

A Gibsonian view of face recognition would not invite interpretation through hemispheric or cognitive explanations. The environment presents many people with various features of faces which become the means for identification. Categorical invariance across features act to form differentiation. In this case neither cerebral structure, nor cognitive strategies loom as significant to face recognition. However, the visuo-conceptual strategy has some commonalities in that the subject bases categorical/wholistic perception upon reiterative construction of faces via the decomposing-composing process. But the Gibson view posits that these processes come solely from the patterns that are noticed in the environment rather than being visuo-conceptual processes of the mind. The idea of familiarity is one which holds great interest for the author and one which recent studies have addressed.

There is another point which is worth considering when evaluating HP research through a Gibsonian lens. If the environment is the basis for a person differentiating a face, then one must make the assumption that faces are viewed in many different positions and are picked up by dynamic motion through space. This is a critical point to be made in the context of experimental studies which use tachistoscopic presentations. Most experiments which reveal specialization for one hemisphere over the other; present static, frontal photographs of faces (for brief periods of time) without the face ever being in a different position. This may represent a modest segment of the total environmental experience that people receive in dynamic settings. Hence, one of the critical deficiencies of HP lies in restrictions brought about by the experimental methods for assessing the phenomenon. As we will see, the author has conducted experimental research which attends to some, but not all of these criticisms raised by a Gibsonian approach.

As we will see in the next section on cognitive demands, the utilization of a particular strategy is effected by single versus dual task conditions as well as many other factors.

Cognitive Demands

The cognitive demands produced within single and dual task paradigms are a determining factor for requiring the use of piecemeal or the configurational strategies. The main idea is that a broad continuum of operational requirements can be created by precise control of these cognitive demands. This discussion of demands emphasizes the role of the stimulus material and what the subject does with it. In this respect, Gibsonian views become salient, but note that the focus here is to emphasize the interaction between the perceptual structure of the stimulus array and the person encoding this structure. Broadly, we may define some of these demands as *visuo-spatial image modulations*. Some examples of modulation are transformation across perspective, image inversion, image derivation, image half-life, and image exposure duration. Note that the precise control of these modulations can create demands that range from low-order to high-order cognitive requirements that precipitate needs for certain cognitive strategies (e.g., an inverted face requires piecemeal recognition).

Attention as a Cognitive Demand. Attentional resources are also a different type of cognitive demand in that any given task may require a certain amount of resources to be processed. Attention has been theorized as a single capacitance (Kahneman, 1973), an econometric commodity (Navon & Gopher, 1979), and as multiple resource pools (Wickens, 1984). Attention has also been addressed as a kind "fluency" which occurs when an expert automatizes a process, wherein it becomes so compiled that resources are not used to perform efficiently (see Anderson, 1983).

Of particular importance for this paper is the Friedman & Polson (1981) multiple resource framework; whereby each hemisphere is considered to be a separate, independent resource pool. Each hemisphere is viewed as quantitatively equivalent. Their predictions suggest that decrements abound if task composition overloads resources specific to one hemisphere. Under single task requirements, there would be more

options for transference to the opposite hemisphere for the most advantageous processing type. However, when dual task conditions are invoked, the processing resource factor figures robustly in the equation to determine the most effective cooperation between hemispheres. Thus, their type of theory moves toward using dual task arrangements, in order to show decrements in accordance with different types of task composition. Under conditions of dual-task paradigms it is assumed that (dependent on task composition) attentional resources will be expended in different amounts. The Friedman & Polson model does not allow interhemispheric transfer of resources. We will return to these dual task arrangements later as a way of looking at the proposed neuro-cognitive systems model.

It is important to consider attention as a cognitive demand that interacts with other image modulation demands to effect a certain pulse on operational requirements. This really sets up a foundation for a proposed experimental paradigm.

RECENT RESEARCH ON THE HEMISPHERIC RECOGNITION OF FACES

Recent research in face recognition has proposed the use of different processing mechanisms, each of which are utilized according to the demands of the task, the nature of the stimuli, or the temporal stage of processing (e.g. Ellis, 1983; Klatzky, 1986; and Rhoades, 1985). As such the research is in the information processing tradition. However, we will see that visual-spatial image modulations in the stimulus structure are major determinants of learning face recognition. The different subprocesses proposed in any of these models could conceivably involve left- or right-hemisphere (LH or RH) lateralization. Accordingly, the nature of lateral asymmetry in face recognition, obtained from different experiments, might result from the use of different types of processing mechanisms or differential attentional resource allocations. Hence, results that have previously appeared contradictory might be attributable to differences in procedural or stimulus differences which, in turn, elicit different processing strategies and/or different attentional demands.

As one can see, understanding HP is contingent upon the interaction of many complex factors. Cerebral structure, cognitive strategies, and cognitive demands all interplay to determine a particular outcome on any one experiment. Dependent on the investigator's assumptions that are manifested in the methodological design, different interpretations may arise. Before looking at a proposed model, the author feels that there are 2 areas of research within the single task paradigm which must be unraveled. They both deal with modulations in the stimulus.

Stimulus Familiarity and Transformations across Perspective

Due to the restriction in length of this paper, only two of the major image modulations are analyzed. The first is the important role of facial transformations across perspectives (i.e., a frontal face, a face rotated 45° to a 3/4 perspective, or a face rotated 90° to a side perspective). Studies at the Armstrong Aerospace Medical Research Lab (see Katsuyama & McNeese, 1987, 1989a; Katsuyama, McNeese, & Schertler, 1987; McNeese & Katsuyama, 1987) have examined differences between recognition based upon physical features and "structural" features (e.g., higher-order relations and perceptual invariants across perspectives). If subjects are presented a target face in a frontal viewing perspective and are given 4 frontal face

response choices, then direct feature-to-feature match could be the basis for recognition. However, if the subjects are presented a target face in a frontal viewing position, but are then given 4 faces which have been rotated to the 3/4 or side profile, then one could posit that the subject has done some kind of mental transformation to the frontal image stored in their mind, in order to facilitate recognition performance.

In addition to investigating the role of transformations across perspectives, the studies examined differences between recognition based upon stimulus familiarity. Procedures that require recognition of unfamiliar faces tend to generate greater left visual field/right hemisphere (LVF/RH) superiority, whereas, procedures involving familiar faces tend to produce RVF/LH superiority (e.g., Umiltà, Brizzolara, Tabossi, & Fairweather, 1978; Marzi & Berlucchi, 1977, Marzi, Tressoldi, Barry, & Tassinari, 1986). Satisfactory performance in conditions involving highly familiar stimuli could require minimal processing of only a single, salient feature. In contrast, recognition of unfamiliar might require a deeper level of processing in which several features might be evaluated. This distinction might be characterized in terms of Cohen's (1973) description of serial (or piecemeal) versus parallel (or configurational) processing. Accordingly, the LH would be expected to excel in the extraction of a single feature difference while the RH would excel in the synthesis of individual features.

There are two aspects of familiarity that must be delineated and they each make opposite predictions with respect to hemispheric advantage. The first might be termed invariant frequency. By this we mean that a given stimulus is exposed a certain number of times across all trials such that subjects develop familiarity with the invariant perceptual form. This is a developmental phenomenon which pursues the creation of prototypes based on repeated exposures.

In several studies, the role of stimulus familiarity was manipulated by means of repeated exposures during experimental trials. Reynolds and Jeeves (1978), Ross-Kossak and Turkewitz (1984,1986), Ross and Turkewitz (1982) utilized a small set of faces and demonstrated declines in initial LVF advantages followed by subsequent increases. These results could be interpreted in terms of processing strategies. Initial processing might involve evaluation of a configuration of features (perhaps similar to a gestalt) leading to a RH advantage. Subsequently, as familiarity accrues,

subjects engage in criterion shifting, responding according to a piecemeal mode of representation. Hence, due to the utilization of a single, distinctive feature, a LH advantage is demonstrated during this stage. With further familiarity, subjects shift to a strategy involving the synthesis of individual features into a prototype that results in a reemergence of the RH advantage. Findings such as these necessitate the use of a multi-process model of complex pattern recognition that involves both hemispheres.

When prototypes are used for recognition, as we have stated, there is support for right hemisphere advantages. What is difficult to determine is the time at which processing efficiency changes from feature recognition to prototype recognition. If this point was known precisely (rather than sampled after relative levels of frequency), then one might predict even more extreme levels of shift between right and left hemisphere adaptation.

Another aspect of familiarity reported in the literature (Marzi, Tressoldi, Barry, & Tassinari, 1986) revolves around variant exposures under different environmental contexts. Specifically, famous faces are examples of this type of familiarity. This type of familiarity has shown advantages for the left hemisphere.

The Katsuyama & McNeese studies were designed to assess whether a person uses transformation of mental images, or perceptual differentiation vis-a-vis familiarity of faces, or some combination. Let's take a close look at how these studies were methodologically conducted. The Katsuyama, McNeese, & Schertler (1987) methodology captures the interaction of stimulus familiarity, perspective change, and lateral asymmetry. Please note that we only used male, right handed subjects with 20/20 vision in all studies undertaken. This was done to reduce the variance associated with individual differences in HP.

Design. The independent variables of main concern in these studies are: 1.) Transformation Across Perspective (faces are presented in either as frontal, 3/4, or side views), 2.) Hemispheric Access (LH or RH), and Familiarity (relative exposure frequency per trial block). The dependent variables sampled were correct responses and reaction time. Note that these independent variables were manipulated in a variety of ways (i.e., within-subjects versus between-subjects) and sessions were repeated at specified times after the initial session and the results were generally

replicative.

Procedure. Subjects were presented with 288 match-to-sample trials; wherein, a target face either appeared to the left or the right of the central visual field. They were then presented with four response choices, one of which was the initial target face. The given response choices per trial were either presented in the frontal, 3/4, or side orientation. The trials were divided into 4 blocks of 72 trials. Faces could reappear as targets 6 times and choice items 16-19 times per 288 trials. Target faces were composed from different models photographed and then digitized and stored in a MacIntosh computer for access as required. These faces were presented for 133 msec. Subjects responded to stimulus presentation by pressing the appropriate key on their keypad, whereupon their choice and reaction time were recorded.

Results and Interpretation. Refer to Figure 1 for a general impression of results. Note the replication after subjects were brought back for another session 1 to 2 weeks later (entitled session 2 on the figure). Without detailing the very specific results, we may summarize by stating that there is a significant Hemisphere Accessed X Perspective X Familiarity interaction, $F(6,66) = 4.62, p < .001$. It is the nature of this interaction which we submit as evidence of hemispheric shifts between the left and right hemispheres as a function of the cognitive demands induced by the transformation across perspective.

An inspection of Figure 1 indicates that hemispheric advantages were greater on the 3/4 and side than on the frontal perspective trials. On the 3/4 and side perspective trials, an initial LH advantage was replaced by a RH advantage on Blocks 2 and 3. Subsequently, on Block 4 the hemispheric advantage was eliminated (for the 3/4 perspective trials) and replaced by LH advantage (for side perspective trials). It is interesting to look at the findings for the side view particularly. When faces are relatively unfamiliar, subjects utilize the left hemisphere; whereas, once familiarity begins to develop (in blocks 2 and 3) the right hemisphere is advantageous. Finally, after familiarity is developed (block 4) subjects revert back to left hemisphere usage for an advantage. The shift from RH to LH processing in Block 4 may suggest that this type of familiarity was experienced after the subjects experienced a face repeatedly in both target and response choice roles. Thus, familiarity might cause changes in knowledge representation,

whereupon certain strategies rely upon different representations under familiar and unfamiliar situations.

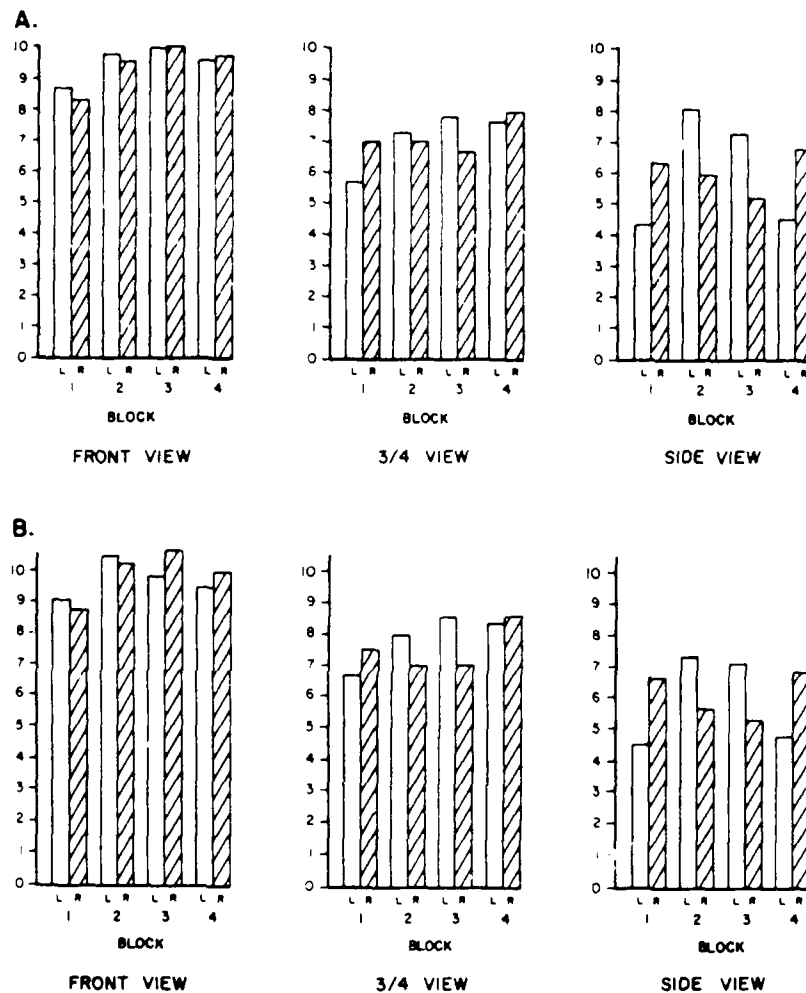


FIGURE 1. MEAN CORRECT RECOGNITION RESPONSES ON SESSION 1 (PANEL A) AND SESSION 2 (PANEL B) ACCORDING TO VISUAL FIELD (L=LEFT VISUAL FIELD; R=RIGHT VISUAL FIELD), TRIAL BLOCK, AND VIEWING PERSPECTIVE.

The study further manipulated familiarity by exposing half the subjects to a condition which contained only one set of faces, and another group of subjects to a condition which contained two sets of faces. Thereby, the first condition receives greater exposure to each face in the experiment than does the second condition, hence leading to greater familiarity with the faces in the first condition. Note that Figure 1 shows that the same hemispheric shifting patterns develop in either condition.

Differential Salience of Features.

One of the issues involving familiarity is the extent to which each face within the set of experimental stimuli might become familiarized differently based upon the saliency of specific features. This pertains to whether target-distractor disparity is relevant in understanding the effects of familiarity. Some faces may contain dominant, distinctive, or easily "picked-up" features (e.g., a large nose) which allows them to be familiarized with a much faster criterion. This could lead to greater reliance on a LH strategy for such face types. On the other hand, other faces may be less distinctive and may require additional processing before familiarity ensues. These face types may require much more involvement by the RH.

In order to assess the effects of such individual differences in the nature of the stimuli used, Multi-Dimensional Scaling (MDS) and Hierarchical Clustering Analysis approaches were utilized to see if the individual differences of stimulus items used might be predicated upon underlying dimensions. This is related back to looking at the demands inherent in the nature of stimuli used and may be entirely responsible for contradictory results that tend to occur in the laterality literature.

Because different faces may be paired randomly as target and choice (under certain restrictions), familiarity may be skewed in terms of its development across experimental trials. Any given trial might contain a predominance of highly distinctive, less distinctive or both face types. If such differences exist in the stimuli themselves, and they are not attended to during construction of trial types, then is it possible that laterality effects might be contingent -in part- to the luck of the draw?

Different experiments may show different laterality results due to subtle interactions between individual differences in the familiarization of stimuli and individual differences/subject across conditions. Results tend to indicate that different pairings facilitate different salience hierarchies, and thus differential sensitivity to familiarity development which determines the nature of laterality direction.

Results of recent research in stimulus familiarity and transformations across perspective suggest that visuo-spatial image modulations actively

determine the boundaries of HP. Results revealed that lateral asymmetry is not contingent upon the nature of the stimulus initially encoded. We believe that this rules out a strict Gibsonian view. Rather, the prior experience with stimulus items, in conjunction with, the required cognitive processing following initial exposure determine the type of strategies needed and the nature of HP obtained. These studies show the complexity of interpretation and necessity of consistency in experimental designs, just within a single task paradigm. In order to test the other type of cognitive demand, attentional processes, a dual task arrangement is required. Current studies are using such designs to assess a proposed neuro-cognitive model but results are still sketchy and not completely understood (see Katsuyama & McNeese, 1989b).

DISCUSSION

A critical review of HP in the context of single task performance has elicited a variety of issues and has suggested many of the boundaries of HP.

A more complex line of research considers the functions of the LH and RH as a cooperative hemispheric interaction. When considering both hemispheres interactively, an additional set of questions must be considered to ascertain boundary conditions. Some problems which must be considered are: Do images presented to the hemispheres transfer to the opposite hemispheres and is this time stabilized or variable? What are the effects of masking (after stimulus presentation) upon transfer time? Do errors reflect that the image is only partially transferred to the other hemisphere or something else? Is hemispheric criterion shifting due to a lack of attentional resources present in the hemisphere currently processing the task? Is interhemispheric transmission freely available or subject to constraints? How does memory representation interact with "what" gets transferred across channels? How does the idea of priming of cerebral space by concurrent activity support interhemispheric transmission? and Does the hemisphere which receives the input first process it immediately or transfer it to the opposite hemisphere for an advantage? One of the underlying issues in such questions is the extent to which learning accounts for HP. This begs the question as to whether HP is under biological, automatic, or conscious control and how the control is learned. The answers to these questions is a matter of conducting research which uses dual task paradigms.

Studies currently being analyzed by Katsuyama & McNeese (1989b) hope to examine the role of dual tasks systematically stratified across hemispheres. The combination of a verbal name recognition task with the transformation across perspective task can create different attention conditions. The Friedman & Polson (1981) model suggests that each hemisphere has a pool of resources which can be used to process a problem. When these pools are overloaded by concurrent dual task processing, certain deficits occur. The purpose of the dual task studies are to see if this model can be supported.

Verbal name recognition is best performed in the LH. When combined with a task which demands that the subject recognize a side perspective face (a task best performed by the RH) there should be no interference or

even an improvement on the task, as each hemisphere would have sufficient attentional resources to process both tasks. Note that this is a theoretical position in contrast to a single capacity viewpoint to attention (see Kahneman, 1973). In single capacity theories, attention is viewed as a single resource for consumption rather than being pools of separate resources. When the front perspective face is presented to the LH, concurrent with the verbal task, this should produce a bottleneck as there are not enough resources to address each task concurrently. This assumes that the front face will be processed by the LH and not transferred to the RH. However, if it is transferred then this still is manifested as a greater latency in reaction time. Thus, the bottleneck should be forthcoming. Results from these studies should determine the time-sharing abilities of hemispheres engaged in different processing tasks.

Another theory (Kinsbourne and Hicks, 1978) focuses on spreading cortical activation within a contiguous functional space. This theory suggests that when two or more activities concurrently occur in the same cerebral space, a priming effect is obtained. Thus, this theory predicts just the opposite of the Friedman & Polson view, given a dual task paradigm. The results of these dual paradigm studies are extremely complex to analyze. It is the author's hope that results will help to differentiate the role of attention across interhemispheric cooperation.

Briefly, a proposed *neuro-cognitive systems model* can be created to analyze the research findings. Realize that this model is only tentative and must be held captive to the dual task results. The model we propose makes transfer (of an impending image to the opposite hemisphere) a discretionary decision that is enabled through the appropriate use of attention switching (i.e., the subject will make a criterion shift to the other hemisphere if it has the capability to perform the cognitive demands requested and if there are enough attentional resources to support this capability). The decision whether to switch attention to the opposite hemisphere is made on the basis of cognitive demands inferred, as well as, the current state of resources at the activated and opposite hemisphere. The relative advantages in terms of response latencies are a function of attentional levels, capabilities present in a given hemisphere, and the time associated with making the transfer itself.

In essence, a meta-cognitive component has been conceptualized as a formal decision maker for allocating brain functionality between the hemispheres. The shifting that occurs between the LH and RH is evidence for the actions of meta-cognitive component. Using this approach, McNeese (1989) created a number of rules for transfer using an inductive artificial intelligence rule-based model. The rules can be seen as predictions to compare with actual performance.

There is one issue which remains. It is how the meta-cognitive component learned to be a fluent decision maker. Most of the attention switching occurs extremely fast and is often not subject to phenomenological access. This perhaps points to a nativist approach or even a social-biological interpretation. It is possible that this meta-cognitive component has survived over many years and is built-in to our human composure. Changes in the component may be at a neuronal level and are not available within human consciousness. Maybe connectionist approaches would serve as suitable models of this social-biological meta-component of HP. Yet, connectionist approaches develop without a homunculus directing the flow. A connectionist model would assume that back propagation would be necessary to equate desired level of performances with derived levels. This brings up the question of whether spreading activation across hemispheres supplies this necessary feedback without the luxury of a homunculus.

We are left with an unfinished, and often times unclear story with respect to HP. This paper has tried to find some of the boundaries of the phenomenon. However, a great deal more research is needed to make sense of this area. Specifically, the question of how HP is learned is usually not addressed. We believe that learning must be under the control of a meta-component which assesses the effects of attentional switching. But in extant performance this learning may very well be complied. In order to understand the beginning roles of the meta-component, performance must be assessed in a decompiled state. This can be accomplished, as we did with familiarity, by looking at processes which develop performance from an initial naive state to one which is more fluent. It is in this development that the role of the meta-component will be fleshed out. Future knowledge in this area will be a function of understanding how the complexities of HP come to be learned by individuals.

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