VISUAL FIELD DIFFERENCES IN SEQUENTIAL LETTER CLASSIFICATION TASKS

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ABSTRACT

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A review of the literature on visual field asymmetries indicated that although the constructs of strategy, processing, and attention had been invoked to account for results there was little objective evidence to support these views. The Posner letter classification tasks provide a methodology which enables such constructs to be tested empirically, and accordingly were employed in this research.

Sequential double letter classifications were used because they provide a stable visual match advantage (Kroll, 1975), permitting an evaluation of retention interval effects without the complications of code change. Despite such stability on cognitive dependent variables, visual field effects differed between 9 sec (Experiment I) and those of less than one second (Experiment III).

A change in coding bias was induced by the use of irregular time structure (Experiments IV, V, VII) although overall visual field differences were comparable to those obtained when coding was stable (Experiments III and VI). Four of the relevant studies indicated a right field advantage for cross-case (name) matches, and non asymmetric identity or visual match judgements.

Single letter stimuli showed a left field advantage for identity matches, and a right field effect for cross-case classifications.

The overall pattern of results indicated that visual field differences arose from the time of test stimulus presentation onwards. These findings were incompatible with models of visual field differences which have been advanced hitherto. An integration of strategy, attention and processing hypotheses was advanced and suggestions made for further research.

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CONTENTS

Page

List of Tables

CHAPTER 1

1.1. Introduction

Interest in the relationship between brain and behaviour is as old as civilisation. The earliest written clinical description of a brain lesion resulting in aphasia - the loss of the ability to speak without paralysis of speech organs - is contained in the Ebers papyrus dating from around 3,000 BC (Cadwallader et al, 1971). The Hippocratic writings contain some detailed discussions of the 'sacred disease' of epilepsy, and also describe the occurrence of hemiplegia following a contralateral brain insult.

Galen, writing in 200 AD, was also inclined to think that brain and behaviour were related in some manner, but he stressed the role of the brain ventricles as containers of the 'vital spirit'. The ventricular theory had its roots in Aristotelian speculation, and despite the lack of corroborative evidence, it became the dominant 'doctrine' until the end of the seventeenth century (see Magoun, 1958). Even in the eighteenth century, observations were made, which with the benefit of hindsight offer strong support for localisation of function in the brain, but these were glossed over in a search for the 'cerebral organ', the seat of the Cartesian 'soul' or 'mind'. (see Gibson, 1962; 1969).

In surveying these early theories and speculations, one is struck first of all by the persistence of a dominant set of ideas, such as the Ventricular theory, and secondly, by the way in which such views affected the type of information which was considered relevant or irrelevant. Even in more modern times controversies over global vs local function have been strongly coloured by assumptions about the type of evidence and the aspects of function which are of importance.

Have we been liberated from the influence of doctrinal ideas in recent years? The answer is 'No'. Although the development of techniques, and methodology has allowed certain theoretical positions to be put to the acid test of empirical evaluation, the framework within which research is conducted still defines the areas of function which are appropriate for investigation and the relevance, of any subset, of the potential universe of data (see e.g. Kuhn, 1970).

Emancipation from 'metaphysical' or pre-theoretical assumptions may not be particularly desirable (or, in fact, possible). Research into how human beings act, is necessarily coloured by moral views on what man is, and his relationship to the world of which he is a part. It would be naive to suppose that because neuropsychological research deals with neurological variables that it is somehow more 'objective' than other fields of psychology (or, for that matter, any more 'objective' and neutral than other social sciences).

In the writer's opinion, little can be gained by a retreat into agnosticism, but much can be gained by the utilisation of a particular framework for analysis, and the maintenance of a healthy scepticism with regard to its ultimate 'superiority' over other points of view.

The following sections will explore some of the meta-theoretical positions which have been employed in research into neuropsychology. The purpose of this review is to place the framework of analysis employed in this thesis into perspective, and to assist in clarifying the assumptions adopted for this research.

1.2.

Kuhn (1970) has argued that the development of scientific knowledge can be described in terms of revolutionary changes in the framework of theory and assumption which determine the course of 'normal' research. This framework need not be explicit, but is accepted by the majority of workers in a particular area, at a common point in time. The term given by Kuhn to this 'framework' is 'paradigm'.

There has been considerable debate over the dynamics of Kuhn's system. For example, it is clear that the a-posteriori basis of his analysis does not necessarily give it predictive strength, in one sense of the term, it is itself a 'paradigm'. A second point of controversy has been Kuhn's classification of disciplines as 'scientific' or 'pre-scientific'. Originally (1962) he argued that achievement of a modal paradigm was a prerequisite for scientific maturity, but later modified his views (1970) to allow scientific status for areas in which more than one paradigm could be identified. This point has been discussed by several psychologists sensitive about the status of psychology (Joynson, 1970; Shotter, 1975), but it seems a sterile debate. The classification of disciplines appears to resemble a polythetic taxonomic system when 'no single feature is either essential for group membership or is sufficient to make (anything) a member of that group', rather than a monothetic system where the possession of a single set of features (a single paradigm) is both necessary and sufficient for group membership (Sockal & Sneath, 1963, p 13, 14).

For the purposes of this chapter, I shall be employing the term 'paradigm' as a generic concept to describe the framework of theory and assumption which has influenced a particular research strategy. In this restricted definition I do not intend to imply any predictive or sociological concommitants. Neither do I wish to suggest that a clearly defined paradigm has any classificatory implications, in as much as defining a particular approach as more-or-less 'scientific' than another.

When investigating the relationship between brain and behaviour four of the major assumptions are:

(1) The way in which the brain is organised.

(2) The way in which behaviour is classified.

(3) Which aspects of the behavioural domain are significant.

(4) How brain and behaviour relate to each other.

I shall deal with each of these assumptions in turn.

(1) The way in which the brain is organised.

The concepts of brain function employed by any particular position are, at least partially, dependent on the development of research and theory in the ancillary disciplines of anatomy and physiology. For example, before the discovery that brain tissue was composed of nerve cells and fibres, it was quite reasonable to assume, as Gall and

Spurzheim did, that the brain was composed of discrete organs. Analagously, before the development of theoretical concepts such as 'inhibition' (Brown Séquard, 1878) and 'neurone theory' (Waldeyer, 1891) static or mechanical models of function were quite appropriate.

Gregory (1961) argued that much neuropsychological research was misguided, since, without prior knowledge of how the brain was organised, inferences of function were likely to be in error. He cited the example of a T.V. - if a component was removed the 'pathology' observed did not necessarily relate to the function of that component. In the extreme case, a loud whining noise might be attributed to the loss of a whine-inhibitor. Weiskrantz (1968) has replied to this argument, and suggests that it is quite in order to make 'reasonable guesses' as to how the brain is organised, and to conduct research on this basis. Evolutionary theory suggests that there may be many subsystems functioning in parallel in the brain, and hence it is unlikely to be a serial processor like a T.V.

(2) The way in which behaviour is classified.

This depends on the units of analysis which are theoretically relevant within a particular paradigm. A particular position defines units, and suggests how they relate to each other in the larger behavioural domain. Thus for an associationist position, the basic units of analysis are sensations and ideas - brain lesions may interrupt the process by which these units become associated or may obliterate 'centres' where ideas are located, thus resulting in 'amnesia' (e.g. Wernicke, 1874; Charcot, 1883). In a 'functionatist' paradigm the basic units are adaptive behaviours which are considered at a macro-descriptive level and inter-relate as a function of biological demands (Luria, 1966). A further level of analysis is possible within this paradigm where functions are structionally analysed. This has given rise to a variety of positions ranging from 'faculty' (Gall & Spurzheim 1810-1819) to psycholinguistic (e.g. Vygotsky, 1963; Hécaen, 1972).

(3) Which aspects of the behavioural domain are significant.

A major emphasis in this research area has been on the platonic 'intellect' rather than on 'the will' or the 'passions'. Automatic vs Intentional behaviour was discussed by Jackson (1874) who regarded the left hemisphere "as the side of the so-called will", at least as far as verbal behaviour was concerned.

In more recent times there has been an increase in interest in the 'emotional' correlates of brain function (e.g. Dimond, 1975; Benton & Blumer, 1975) but, thus far, difficulties inherent in the assessment of 'emotion' have precluded any fine-grained analysis of the neurological systems involved in man.

(4) How brain and behaviour relate to each other.

There are two prototypical philosophical viewpoints on this question, dualism and monism. Dualist paradigms involve the assumption that physical and mental realms are distinct systems in their own right, thus the physical realm is composed of physical entities acting according to physical laws, the mental realm is compôsed of immaterial mental entities acting according to laws which may or may not be analagous to those applicable to the physical realm. There are a variety of ways in which the mental and physical can be related; they can operate in parallel, or in interaction, they may be causally related so that a physical event causes a mental event, or they can be 'identical' such that the occurrence of a mental event is both necessary and sufficient for the occurrence of a physical process (see Globus & Maxwell, 1976, for a selection of such conceptualisations). The alternative to dualism, monism, does not distinguish 'mental' and 'physical' in these terms. There is no special spiritual thing called 'mind', and hence there is no problem in relating mind to body. Certain aspects of these viewpoints will be dealt with in greater depth below.

1.3. Metatheoretical Assumptions

Three major 'metatheoretical' positions in psychology have been identified by White (1967). These positions represent 'ideal types' and will be summarised below. It should be realised that this classification is a conceptual scheme, rather than a true representation of an absolute 'position' typified by any particular psychological theory - some theories, or 'schools of thought' are better examples than others. Likewise, some aspects of neuropsychological research are better illustrations than others, and I shall describe these in the context of my discussion of a particular 'metatheory'.

The first two positions to be considered are essentially dualist. The first, physical theory was the major conceptual influence on Associationist and Gestalt positions. It has been an important influence from the mid-nineteenth century onwards in attempts to 'map' psychological processes and events onto neurological substrata. The second is the political theory of mind which has influenced views of brain organisation, and is reflected in discussions of hemisphere 'dominance' and 'inhibition. The final example, functional theory, differs from the previous two standpoints in that it has 'monist' implications for the age-old 'mind-body' problem. This metatheory is represented in the earliest attempts to localise function, and, in one form or another, is representative of some contemporary approaches (e.g. Luria, 1973).

(i) Physical Theory

This 'metatheory' owes much to Cartesian dualism, and the theories of the eighteenth century associationist philosophers. It distinguishes between the separate realms of 'physical and mental', and draws an analogy between 'mental things' and 'physical things'. The physical world is divisible into parts, functioning according to physical laws, and by analogy it proposes that the mental world is populated with mental things which function according to laws which may, or may not, have their parallel in the physical domain.

According to empiricist philosophy 'mind' could be divided into basic elements - sensations and 'ideas'. These elements, it was argued, combined together in complex thought according to laws similar to those which had been found useful in the physical sciences. Thus Hume borrowed from Newton's theory and regarded 'association' to be analogous to gravitation, and J.S. Mill used contemporary advances in chemistry to devise his 'Mental Chemistry'. Gestalt Psychology was a product of philosophical critiques of associationism (e.g. by Brentano; 1874), but can be subsumed within the same metatheoretical position since it too regarded mental events as 'entities' or 'processes', although combining according to the laws of 'field theory' borrowed from physics rather than chemistry or mechanics.

The influence of the associationist school was of considerable importance in the development of psychology and hence of neuropsychology. In the nineteenth century, advances in physiological and anatomical knowledge (e.g. Meynert's 'fibre tracts') suggested a plausible neurological basis for 'association'.

These ideas were synthesised in an elegant and highly influential model of language functioning by Wernicke (1874). Before presenting Wernicke's views, some background details are necessary: In 1861 Broca had exhibited the brain of a patient (Leborgue - known as 'Tan') who had lost the ability to speak, although without muscular paralysis, some twenty-one years previously. On post-mortem he was found to have a massive left hemisphere (predominantly frontal) lesion, as hypothesised by Broca's colleague Auburtin. Several other instances of this type of impairment had been observed in the years between 1861 and 1874, all cases had lost the 'faculty for articulate language', whilst maintaining comprehension (see e.g. Jackson, 1874). Wernicke observed a patient who was able to speak, but had a deficit in comprehending speech. On post-mortem it was demonstrated that the patient's lesion was in a different site - the left temporal lobe. The site of the lesion (left temporal gyrus) was close to the termination of the auditory nerve. Wernicke suggested that the damage had destroyed the centre for 'auditory images of words', resulting in a specific form of amnesia. He further argued that the frontal convolutions were responsible for the storage of the 'articulatory images of words', and that in normal functioning these two areas were associated by fibre tracts. Although Wernicke was initially quite cautious in his specific localisation of 'centres' - regarding "the whole of the convolutions around the sylvan fissure" as a speech area he subsequently delineated precise storage areas (this was partially a product of his adoption of Meynert's model of recovery of function - see Freud, 1891). This precise localisation was not strictly warranted by the data (see e.g. Hecaen & Albert, 1978).

Predictive power was reduced in an important modification proposed by Charcot. He argued that there were four fundamental 'elements' in language; the auditory image, the visual image and two forms of articulatory image. There could be 'amnesia' for any or all of these and "therefore it follows that the various groups of memories have their seal in various localised regions of the brain" (1887). He additionally suggested that, as a product of experience, different individuals may use one or more of these 'ideas' as the central coordinating centre for language, thus the form of deficit and its implications for overall functioning could not be easily predicted from the lesion site alone.

The critical aspect of Wernicke's model had been its predictive power. He was able to postulate syndromes which had not been documented - the disconnexion syndromes. Wernicke's scheme was followed by a number of similar models each postulating 'centres' by inference from deficit. This form of theorising became somewhat undisciplined and, although many of their ideas were interesting, the 'Diagram Makers' fell into disrepute.

Research was conducted within the tradition of Gestalt psychology following the decline in popularity of the extreme localisationist views (see Marie, 1906). The Gestalt theory suggested that a fundamental aspect of function was the ability to form 'Gestalten' which were isomorphic to an electrophysiological field in the cerebral cortex. Different pathological syndromes were described as a product of physiological and behavioural adaptation to the disruption caused by lesions. Perhaps one of the best known exponents of this view was Head (1926) who discussed intellectual impairment from a Gestalt perspective whilst maintaining a localisationist approach in performing clinical diagnosis.

I do not intend to add to the literature on the global-local debate here. Reviews sympathetic to the global position are provided by Head (1926), Riese (1950; 1959). Lashley's influential work has been neatly summarised by Zangwill (1963). Interest in the 'associationist' position has recently been reawakened by the American neurologist, Norman Geschwind, who reviews studies in this tradition (1973).

Although the early analogies of chemistry and physics have largely been superseded in contemporary psychology, the older associationist perspective has persisted in certain influential neurological research programmes. Sperry and his co-workers, (see Sperry et al, 1969, for a summary of early work, also Gazzaniga, 1970; Dimond, 1972; 1978) have provided substansive support for a major disconnexion syndrome, the 'split brain' (for critical reviews see e.g. Beaumont, 1979; Whittaker, 1977). Investigation into these callosal section subjects showed dramatic dissociations between the hemispheres, and resulted in a tremendous upsurge in research on this topic. The bias of this research has been considerably influenced by its neurological antecedents, and emphasis has focussed on the location of processing systems rather than upon the psychological aspects of processing.

Whilst there have been some benefits from this neurological-diagnostic approach to brain function this emphasis has undervalued the potential contribution from contemporary psychological theorising. Research has tended to stress the "where" of function rather than the "how" under the assumption that the subject has very little control over either. As those familiar with psychological research into 'normal' subjects (i.e. neurologically intact people) will realise, neither assumption is necessarily tenable (see e.g. Marshall, 1973).

The 'physical theory' has been a major source of ideas for psychology in general. However, it is important to note that there are objections to this theory on philosophical grounds and I shall consider some of those put forward by

White (1968). White points out that the physical theory involves two main assumptions (a) that the terms used to describe the mental world refer to distinct 'entities' or 'processes' and (b) that the relationship between such 'elements' can be specified by analogy with the physical domain. He takes issue with the first of these assumptions on analytical linguistic grounds and suggests that terms used to describe mental events do not <u>necessarily</u> refer to a distinct process or entity. The assumption that this is the case is based "on an undue concentration on common nouns". Although such nouns may refer to specific things, there are numerous examples of global concepts - such as justice. For example, two such terms; 'time' and 'gravity' were initially construed as the products of an occult 'force' or 'process', but (although useful at one stage in the development of physics) subsequently became replaced by more adequate formulations. Ryle has produced a detailed analysis of the concepts used in describing mental occurrences (see Ryle, 1951). He suggests that many terms used in psychology are instances of 'polymorphous' concepts - under one set of conditions a particular activity, e.g. looking, can be an instance of the polymorph 'attention' but under other circumstances it need not be. Attention could be used to describe a variety of activities.

This analysis does not <u>a-priori</u> rule out a single psychological (and/or physiological) process which may be either necessary and sufficient for the occurrence of e.g. attention. However, it serves as a warning against an assumption that this is necessarily the case.

(ii) Political Theory

The political theory of mind was put forward in its most articulate form by Plato. He considered mind and body as separate entities, and suggested that the organisation of mind would reflect a political system. More speculatively he suggested that the characteristic of a particular political system would be reflected in the mental attributes of the individuals 'contained' in the system. Thus a country/ state which was typified as having a 'rational' political system would contain 'rational' individuals.

His ideal model of mind was a hierarchic organisation based on the democratic system, with higher elements controlling lower. He also divided mind into three components, the will, the intellect and the passions, assigning to each a different location in the body, because he considered it implausible for a particular structure to perform different and possibly conflicting functions at the same time.

A form of 'political theory' was intrinsic to several early models of psychological function based on evolutionary (Lamarkian) principles. Two such models: those of Laycock (1860) and Spencer (1855) were a major influence on J.H. Jackson (although certain aspects of his theorising were also a product of Bain (1873) - an associationist). Jackson was a psychophysical parallelist and distinguished between psychological and physiological realms of discourse. Jackson conceptualised the nervous system as a hierarchical organisation, having three levels - reflex, automatic, and voluntary. Location of function was related to the complexity of a particular activity. Highly complex functions - such as language - required the concerted action of several levels. Following Bain, he regarded thought as "the movements corresponding" to a particular psychological function, such movements were represented in their highest or most abstract form in the cerebral cortex, but he was adamant (1874), that thought was neither solely 'internal speech' nor the movements related to 'visual' ('retino-ocular') function.

In his discussion of cerebral asymmetry in the human brain Jackson anticipated many of the more modern views on 'cerebral dominance'. In 1874 he suggested that there was a bilateral representation of language and 'retino-ocular function'. One side of the brain was 'automatic' in its mode of image revival, whereas the other was dominant, employing both automatic and voluntary modes. The left hemisphere was the 'leading hemisphere' for verbal abilities but the right led for the "retino-ocular" (or in contemporary terms, visuo-spatial skills). Jackson's dyadic system was superseded by a monolithic major-minor concept of inter-hemisphere dominance relationships. In these more egalitarian times there has been a shift back towards dyadic (Dimond, 1972), and even pluralist models (Cohen, 1978).

Contemporary views on the optimal organisation of function between and within the cerebral hemispheres owe much to the 'political' viewpoint (see Marshall, 1973, for a summary of two proposals). According to other models, the hemisphere dominant for a particular task exerts an inhibitory influence on the 'minor' hemisphere in order to reduce processing interference (see e.g. Gazzaniga, 1974; Jones, 1966; Moscovitch, 1972; 1976; Kinsbourne, 1970; 1973;

1975; Nebes, 1978). There is evidence from human neuropathology which suggests that a focal lesion can on occasion result in greater cognitive impairment than hemispherectomy (see e.g. Kinsbourne, 1978) and animal studies support both neural (Berlucchi, 1966) and structural (Sprague and Meikil, 1965) inhibition, but it is an open question whether 'optimisation' is achieved under normal circumstances in this manner.

The 'political theory' has been criticised for the assumption that political systems are necessarily analagous to individual functioning. There are several obvious examples - e.g. a political structure can be 'successful' and 'efficient' on some criteria, whereas the individual in that system need not be. The analogy between neurological systems and the political realm faces certain difficulties - not least being the judgement that a particular mode of organisation is somehow 'better' than another (see e.g. Marshall, 1974). It is, perhaps, no accident that laissez-faire 'dominance' models have achieved their greatest levels of development in late nineteenth century English and contemporary American theorising where this principle is evident in the prevailing politico-economic ethos.

(iii) Functional Theory

The functional perspective owes more to analogies drawn from biology and systems analysis than to those based on politics and the natural sciences. Its major emphasis has been on the adaptive nature of action. Discussion has dealt with problems such as how a single set of actions may subserve a variety of ends, or a single goal may be achieved by a variety of actions.

The earliest discussion of this perspective is provided by Aristotle. He argued that an object was defined in answering the question "What is it?". An adequate reply would provide a statement of the functions, powers, and abilities of a particular object. The 'psyche' was defined as the organised set of functions, powers and abilities of <u>any</u> object, rather than as an immaterial spirit or mind. According to this definition, thoughts, memories, and ideas are not processed located in the 'mind', but rather functional attributes of the human psyche.

This theoretical position is essentially monist since the term 'psyche' refers to a conceptual abstraction, rather than to a particular 'essence' or entity. It emphasises the context in which a specific action occurs rather than causal processes operating within the organism.

An identical action may serve different functions according to the environment, or context of action. To use an example from White (1968) playing the piano may be done in order to give a lesson, for practice, personal enjoyment or to annoy the neighbour. Philosophical discussions in the functionalist tradition stress this aspect of behaviour (e.g. Ryle, 1949). Psychological functionalists have tended to emphasise the situation where the same definable function may be performed by different actions, e.g. one could annoy the neighbours by playing the piano, ignoring them, and a variety of other techniques best left to the imagination. Biologically (or ecologically) oriented models have been concerned with adaptation to the physical and social environment. Such an emphasis is evident in the Gibsonian approach to perception (e.g. Gibson, 1966).

A crude form of biological functionalism was utilised by the phrenologists Gall & Spurzheim. They established that the brain was crucially involved in experience and behaviour:- "several grains of opium in the brain's ventricles are sufficient to show that, in this life, will and thought are inseparable from their physical foundations" (1810). Subsequently they attempted to account for differences in 'abilities' between people, and between species, in terms of the size of critical areas of the brain. Their emphasis was on differences in the capacity for biological adaptation.

This project required (a) the isolation of significant abilities and (b) the correlation of structural differences with (a). In fulfilling the first part of their programme Gall regarded himself as a 'slave of nature' and rejected the <u>a-priori</u> classification of the 'faculty' philosophers. However, it seems reasonable to infer that in practice he was not adverse to using a framework to guide his own speculations since his lists of functions, or faculties bear a strong resemblance to those of Reid and Stewart. (Thompson, 1967) Gall collected evidence from animal species, as well as from people and suggested that functions were performed by 'cerebral organs'. The level of development of these organs reflected the development of the 'faculty' in question. Gall and Spurzheim made the assumption that the shape of the skull was determined by the shape of the brain - hence 'the system of bumps' or phrenology could give a measure of the way the cerebral organs were developed.

Phrenology fell into disrepute fairly quickly (see Brown, 1970) but was a wrong step in the right direction as far as the development of neuropsychology was concerned. Gall and Spurzheim had luckily located the language function at the front of the brain, and subsequently Gall's student Bouilland produced neuropathological case material in support of this thesis. At one stage he even offered cash to anyone who could produce an instance of language pathology without anterior damage. His son-in-law Auburtin argued a similar case - without financial incentive, and an acquaintance, Broca, came up with supporting evidence.

Although Gall & Spurzheim started with a 'functional' type of orientation their concept of 'faculties' was more in line with a physicalist model, and their levels of analysis and description became somewhat muddled (see Brown, 1970). In contemporary neuroanatomy, a more rigorous form of 'phrenology' has emerged. Geschwind (1975; 1978) has given clear discussions of anatomical asymmetries in the human brain, and speculates that linguistic capability may be due to systems located in the planum temporale of the left hemisphere.

Luria (1973) has elaborated the idea of 'functional systems' in contemporary neuropsychology. He distinguishes between two forms of 'function'. At one level he argues we can ask what is the function of e.g. a neuron, and can be answered in electro-chemical terms. On a more 'molar' level we can refer to the function of e.g. digestion, and examine the functional system involved. He defines a functional system as a variable set of structures performing an invariant functional task.

This conceptualisation is similar to psychological functionalism described above. At an abstract level, resemblances can be seen between Luria's neuropsychological framework and the personality-cum-social-psychological theory of McDougal, cited by White as an example of psychological functionalism. McDougal (e.g. 1923) proposed that a set of invariant needs were served by variable means in social interaction. Luria suggests that there are definable functional categories of cognitive performance which are subserved by a variable set of systems in the brain.

McDougal's major concern was with the delineation of 'needs', that is, in identifying salient functional categories. This emphasis led to an unwieldy, and grandiose itemisation of a large range of attributes which were of little use in explaining social behaviour. Luria adopted an extant conceptual structure (Russian psycholinguistics) to define functionally significant components of behaviour. He concentrated on the determination of neurological loci of functional systems, and on investigations of their interaction. Luria's model has more predictive value than McDougal's and may be useful in neurological diagnosis, however it is fundamentally static with respect to the development of psychological theory. There are sound cultural and practical reasons for Luria's particular bias, but such a rigid approach runs the risk of over emphasising congruent data, and of ignoring evidence which fails to fit neatly into the framework of a specific psychological theory.

Functional positions have been criticised by White (1968) for their limitation to a descriptive level of explanation. Whilst this may be the case for several theories (such as McDougal's) it is less clearly applicable to Luria's model which, by emphasising the interactive aspects of systems and functions achieves some 'predictive' utility. In areas other than psychology functional schemes have been successful. Systems analysis is one example of a functional approach which may be both predictive, and useful in dealing with complex organisations. Any specific systems analytic scheme may be modified on the basis of empirical data derived from 'modelling' the system or from observing its operation, under various constraints. Since the adequacy of systems analysis lies, frequently, in its ability to predict the operation of an organisation, a level of explanation may be achieved which has somewhat greater power than description. The problems with functional approaches to psychological questions, therefore, do not lie in the constraints they impose on explanatory power, rather, the difficulty resides in the types of theory which have been advanced, and the constructs which have been used to classify behaviour, and cognitive skills.

To summarise the points made in this section:

Three metatheoretical positions were discussed.

(a) the political theory which emphasises the hierarchical organisation of mental phenomena, and is evident in discussions of hemisphere dominance interactions.

(b) the physical theory which regards mental processes as 'entities' which may be reduced to fundamental 'elements' and inter-related according to discoverable laws.

(c) the functional theory which emphasises the interactive nature of action: two orientations were cited, the philosophical in which the paradigm case is invariant action and variable function, and the psychological which is concerned with variable actions subserving invariant functions.

These 'metatheories' are abstract ideal types rather than representations of specific positions currently held in psychology. They should not be considered as competitors in the free market of intellectual advance, but rather as programs for research and theory which highlight different problem areas.

CHAPTER 2

2.1. Introduction

The previous chapter outlined a range of views of brain-behaviour relationships. The major part of this chapter will be concerned with the background to the research methodology employed in this thesis. Section 2.2. will consist of a brief introduction to the sources of evidence employed in neuropsychology, and sections 2.3. onwards will deal with one particular source, visual asymmetries, since this was the approach utilised in the research reported herein.

Since at least the mid-nineteenth century it has become apparent that the human cerebral hemispheres are asymmetric in their function. The nature, and extent of this difference, and its adaptive significance is still a matter of open debate. In subsequent sections of this chapter I shall review some of the more important contemporary currents of thought on hemisphere asymmetry, but for the present, we may adopt the description by Hecaen & Albert (1978) that...

> "the left hemisphere is responsible essentially for verbal functions and abstracting ability, the right hemisphere for nonverbal perceptual and spatial functions" (p.410)

This 'summary statement' is a convenient precis of many important research findings, but like any other generalisation, it is subject to certain qualifications and restrictions.

Perhaps the most important modification which needs to be stated at this stage, is that this classification is limited to right-handed people. Many left-handers appear to have a more diffuse (Beaumont, 1974) or 'bilateral' (Zangwill, 1960; Milner et al, 1966) organisation of (at least some) systems. The remainder of this chapter will be concerned mainly with evidence from studies of right-handed groups.

2.2. Sources of Evidence

One of the most attractive features of research into human neuropsychology has been the availability of a wide range of techniques suitable for investigating functional lateralisation in both neuropathological and neurologically 'intact' subject groups.

(a) Clinical Studies

Unilateral brain damage offers much valuable information on the organisation of function in the human brain. Reviews are plentiful (see e.g. Benton, 1972; Dimond, 1972; 1980; Gazzaniga, 1970; Joynt & Goldstein, 1975; Kinsbourne, 1971; Schmitt & Worden, 1974; Walsh, 1978; Hecaen & Albert, 1978). A persistent problem in attempts to localise function has been in the determination of site, and extent of damage. Thus, the degree of pathology may co-vary with lesion laterality, disruptions to left hemisphere language systems being brought to the notice of physicians at an earlier stage than impairments in e.g. visual processing (e.g. Arrigoni & De Renzi, 1964; Benton, 1965; Costa & Vaughan, 1962; Wolff, 1962). Midline (and posterior-anterior) shift may occur when large haematomas or neoplasms are involved, and may co-vary with lesion site within a hemisphere, greater degrees of e.g. midline shift occurring in superior and frontal aspects of the hemispheres due to mechanical constraints within the skull. Technological advances such as computerised axial tomography (the 'EMI-scan') should make it possible to obtain broadly comparable groups in terms of the effects of midline shift, oedema, and raised intra-cranial pressure for contemporary research projects. Other variables, such as aetiology, and the correlation between lesion site and lesion type may be less easy to control in practice, although theoretically feasible.

A number of investigations concerned with hemisphere asymmetries have been based on the temporary, or permanent 'loss' of one cerebrum. Evidence for the organisation and potential reorganisation of function within a single hemisphere has been obtained with hemidecorticate patients (see Dimond, 1972; Smith & Sugar, 1975; Gott, 1973; Walsh, 1978). A temporary isolation of the hemispheres has been claimed for the techniques of sodium amytal ablation (e.g. Milner et al, 1962; Wada, 1949; Waltregny et al, 1972) and ECT (e.g. Pratt et al, 1971). However, the precise anatomic locus of these treatments may be unclear and because of their 'radical' nature use has generally been restricted to pathological subject groups whose pattern of functional asymmetry may not be similar to any 'normal' population.

Section of the neo-cortical commissures for the relief of intractible transcortical epilepsy (Van Wagenen & Herron, 1940; Bogen & Vogel, 1960) has provided further information on hemisphere specialisation (see e.g. Gazzaniga, 1967; 1970;

Sperry _et al_, 1969; Gazzaniga and Le Doux, 1978; Dimond, 1972). Partial section of the commissures has also been studied (see e.g. Dimond _et al_, 1977; Gazzaniga & Freedman, 1973; Gazzaniga, 1974; Risse _et al_, 1978).

Studies by Akelaitis & Smith on the Van Wagenen series of patients did not indicate any remarkable effects of the operation (see Akelaitis, 1943, and references). However, following a series of studies on animals with neo-cortical commissure section and/or chiasm section, Myers & Sperry (1958) developed procedures for limiting input to one side of the brain. By requiring subjects to fixate a central point when stimuli were presented to right and left visual fields an analogy of chiasm section was achieved. Using this procedure a clear disconnection syndrome was obtained.

Several recent reviews have recommended caution in extrapolation from 'split brain' patients, since all epileptic subjects have degrees of brain pathology, and severe cases with long standing lesions may have atypical brain organisation (Oxbury, 1975; Gazzaniga, 1977; Whittaker & Ojeman, 1977; Beaumont, 1979). Gazzaniga (1977) points out that the extreme pattern of 'disconnection shown by these subjects may be a by-product of the operation, representing an adaptive compromise between systems in the two hemispheres.

(b) Non-Invasive Techniques

In this sub-section I shall be giving a (necessarily brief) consideration of some of the techniques which have been utilised in the study of (predominantly) neurologically intact subject groups. The types of study which have been conducted may be classified according to the modality of stimulus presentation and the type of dependent variables utilised (e.g. reaction time, accuracy, or electrophysiological indices).

i) Dependent Variables:

Electrophysiological Indices

Perhaps the most 'direct' measures of functional organisation have been derived from electrophysiological procedures such as EEG monitoring which have frequently been employed in clinical diagnosis. The advent of sophisticated analysis techniques has enabled use to be made of EEG suppression within the alpha frequency band (e.g. Donchin, 1977), averaged evoked potentials (e.g. Davis & Wada, 1976) and contingent negative variation (e.g. Butler & Glass, 1974) as indices of lateralised system involvement in neurologically intact subject groups.

The results from this comparatively new area of research appear to have a lot of promise, but there remain many problems in interpreting the functional significance of electrophysiological changes and numerous controversies over appropriate methodology (e.g. Näätänen, 1975; Ledlow, Swanson & Kinsbourne, 1978).

Reaction Time and Accuracy

Response latency has been extensively employed as a dependent variable in studies of hemisphere asymmetry. When stimuli are presented so that the physical location of the material is likely to give input priority to one hemisphere, then the latency in response to materials can give an index of the efficiency with which each side of the brain deals with the task.

More extravagant claims have been made for the type of information that response latency can yield. Poffenburger (1912) suggested that the difference between ipsilateral and contralateral response to an imperative stimulus could yield a measure of interhemispheric transfer time (IHTT). Filbey & Gazzaniga (1969) contrasted the effects of manual, and vocal R.T. to stimuli presented to right and left visual fields (see below). With verbal R.T. they obtained a right visual field advantage and calculated an IHTT of 30 ms. Attempts to replicate this study have been unsuccessful in many cases (see e.g. Kleinman et al, 1978). Swanson et al, (1978) have recently reviewed the area and conclude that there is no evidence for an 'IHTT', since estimates vary with task complexity, stimulus-response mappings, and stimulus eccentricity. Some recent work has suggested that for simple R.T. a right hemisphere advantage may be shown (e.g. Howes & Boller, 1975; Anzola et al, 1977) and that the effects of spatial compatability may be most marked in choice reaction time when right-handed (left hemisphere?) advantage may be shown (Anzola et al, 1977).

Response latencies have also been employed in the study of interference, or overlapping in processing demands. The rationale being that occupying processing space in one hemisphere may interfere with response output, if the two systems overlap at same level of processing. McFarland & Ashton (1975; 1977; 1978) have demonstrated that both the nature of the tasks (verbal or visuo-spatial) and the difficulty in making a response; are involved in determining the extent of 'interference' as shown by lateral R.T.'s. Their evidence for interference was greatest for verbal task - difficult right-handed output conditions. Several studies (including those reported in this thesis) have used R.T. as an index of cognitive processing in the two cerebral hemispheres. For example, Cohen (1973b) attempted to determine whether memory search was serial or parallel in the two hemispheres (see below).

Ollman (1977) has criticised the standard procedure of attempting to maintain a constant level of accuracy, whilst allowing R.T. to vary as a function of task demands. He demonstrates that this model is dependent on one of a number of mathematical descriptions of the R.T. process - the fast guess model - for which there is only limited support. The usual procedure of emphasising high levels of accuracy may enhance speed-accuracy tradeoff, or allow it to vary without control over different tasks, rather than eliminate it.

Taking all of these considerations into account it seems to be most sensible to employ R.T. as a measure of 'efficiency' in conjunction with indices of accuracy. There is no justification for combining the two, into a single 'Z' score for example, since there is no a-priori means of determining how they are related in absolute terms. The use of response latency may increase the 'sensitivity' of measures of hemisphere asymmetry, and has the advantage of reducing confounding due to individual differences in the typical 'accuracy' study. Since latency may interact with a number of spatial variables (Fitts,1966) subject groups should be adequately counterbalanced for response laterality so that the significance of such interactions can be determined within the context of a particular experimental task.

ii) Independent Variables:

Research into visual and auditory asymmetries[1] in normal subject groups has been the subject of much controversy. As Bryden (1978) has pointed out, there has been an overwhelming tendency to ascribe ear, or visual field advantages to hemisphere asymmetry in cognitive function, and to ignore or at least to play down, other possible determinants of such differences.

To anticipate the arguments which will be presented at a later stage in this thesis, the precise locus of such asymmetries, in the complex chain of events from stimulus presentation, to response output is not necessarily crucial. What is important, is to determine whether different patterns of lateral advantage can be shown to relate to particular aspects of cognitive function: the use of hemisphere asymmetry as an explanatory construct then allows the researcher to suggest alternative procedures for subsequent investigation of dissociations which may have been observed.

Both auditory and visual studies of asymmetry are based on procedures developed within 'pure' experimental psychology. Therefore, they provide a suitable starting point for the investigation of interactions between cognitive function and visual field or auditory lateral advantages.

[1] (For the sake of brevity I have omitted discussion of tactile input, see e.g. Fontenot & Benton, 1971; Witelson, 1974)

Auditory Asymmetries

Dichotic listening involves the presentation of two competing auditory messages, one to each ear, (see Broadbent, 1958), an index of asymmetry being obtained from differences in recall or recognition between right and left ear stimuli. Verbal material generally produces a right ear advantage, whereas non-verbal stimuli frequently yield a left ear advantage (but see Papcum et al, 1974, and the discussion by Berlin & McNeil, 1976). The basis of this effect is not clearly understood, although Kimura (1961; 1964; 1967) has given clinical validation with unilateral temporal lobectomy, and sodium amytal tested chronic epileptic groups. She suggests that competition results in occulusion of the ipsilateral auditory pathways and that asymmetry is determined by the reception of input on each side of the brain. With 'sensitive' dependent variables, such as R.T., asymmetries have been shown with monaural input (Kallman, 1977; 1978; Bever et al, 1976) hence suggesting that Kimura's interpretation may not be entirely adequate. Alternative views include; attentional bias (Morais & Bertelson, 1975), output bias (Friedes, 1977), competition for processing space (Elias et al, 1977) and an interaction between output processes and memory decay (Schuloff & Goodglass, 1969). More recently, Darwin & Howell (1978) have developed an elaborate model of the interaction of such variables in monaural stimulation.

Visual Asymmetries

Asymmetries in the visual modality have been investigated extensively. Although there are several different methodological approaches, and there is active debate on interhemisphere interactions, a single structural model has provided the framework for neuropsychological research on this topic.

The geniculo-striate system is organised such that input to one half of visual space is received by contralateral primary visual cortex. Thus, it is suggested that advantages in input produce an overall receptive advantage for one side of the brain. Kimura's (e.g. 1961) 'physicalist' model suggests that subsequent asymmetries are the product of functional differences between the cerebral hemispheres. Information may be dealt with less efficiently by the inappropriate processing systems or re-routed to systems in the hemisphere specialised for a particular task. Kinsbourne's (e.g. 1970) 'political' model places greater emphasis on the role of topographical biases in attention, (resulting from asymmetric hemisphere activation levels) as a potential modifier of input advantages.

The fundamental neurological model almost certainly oversimplifies the complex interactions between stimulus location and processing laterality in the neurologically intact brain. For example, it is now widely accepted that two visual systems with different functional attributes are involved in perception (Trevarthen, 1968; 1970). The properties of the mid-brain circuits may be more 'perceptually' sophisticated than was previously supposed (e.g. Weiskrantz _et al_, 1974), and the receptive fields of units within these circuits may be large, and 'bilateral' with respect to visual space. Even in cerebral cortex, areas anterior to the occipital lobes receive bilateral input (see Cowey, 1978), contributed by cortico-cortical and thalamo-cortical interconnections. The relative latencies of ipsilateral and contralateral stimulation have been estimated for single callosal units by Bremmer (1958) at 3 msec. Ledlow et al (1978) attempted a similar measure employing electrophysiological techniques siting single electrodes on each side of the scalp at positions somewhere between the occipital and parietal reference points (Jasper, 1958). They obtained estimates of 15 msec. These studies are uninformative with regard to 'transfer-time' at the more neuropsychologically interesting sites in the brain (e.g. parietal and temporal cortex) where evidence for bilateral representation is conclusive (e.g. Cowey, 1978).

Although the physiological underpinnings of the neuropsychological model of visual field effects are, at least, a little shaky, it has, nevertheless, stimulated a huge body of research, which has produced a number of intriguing results. These will be considered in the following pages, because visual asymmetries were chosen as the topic of this research project.

At the present time, it seems more appropriate to consider the mode of interaction between hemisphere function and visual laterality as an open question. Given the complexity of this problem, the 'structural model' has worked remarkably well, and thus it will be taken as a reference point for developing the arguments of this thesis.

Many visual studies of hemisphere function in normal people have adopted the structural framework outlined above.

There are four main techniques which have been employed:

(1) Contact lens studies

Participants in this type of experiment wear lenses which occlude one half of visual space. The technique allows the assessment of visual field asymmetries in the performance of quite complex tasks (see e.g. Dimond *et al*, 1976).

(2) Free field 'salience' studies

In this procedure stimuli which are normally asymmetric are presented to observers under a variety of conditions in free vision. Thus, a composite picture of two halves of the human face may be compared to see which one is more 'like' the original (e.g. Campbell, 1977; Gilbert & Bakan, 1973) or mirror reversal may be used (e.g. Levy, 1977). These studies whilst interesting are open to a number of interpretations other than cerebral asymmetry of function. In normal vision material is rarely 'lateralised' to one visual field, and the results which these investigations have produced may be a *correlate* of some aspect of cerebral asymmetry, or handedness, rather than being directly related to hemisphere function.

(3) Split field studies

This technique was extensively used by Dimond and his co-workers (see Dimond & Beaumont, 1974 for a description of techniques and apparatus). Materials have been separately presented to nasal and temporal hemiretinae, and comparisons drawn between 'two hemisphere' and 'single hemisphere' presentation conditions. A variety of monitoring procedures have been used to ensure central fixation, and a wide range of exposure durations employed. Stimuli have been 'channeled' exclusively to one visual hemifield to investigate asymmetries on vigilance (Dimond & Beaumont, 1973) and fatigue effects (Dimond & Beaumont, 1972).

(4) Tachistoscopic presentation

In this type of procedure, stimuli are presented for very brief durations in an attempt to confine input to particular retinal areas. To this end, exposure durations have generally been shorter than the latency of saccadic eye movements (approximately 178 ms (Rayner, 1978)). Subjects are required to fixate a central point and stimuli are presented to both visual fields (bilaterally) or to a single visual field (unilaterally) on each experimental trial.

This research tehcnique has been extremely popular (see the reviews by e g. Moscovitch, 1979; Harcum, 1978; White, 1972; 1973); It was chosen for the present research project.

2.3.

In the preceding section, the rationale underlying the use of lateralised tachistoscopic presentation as a procedure for investigating cerebral asymmetry was briefly outlined. To recapitulate: the general model suggests that stimulation of one visual hemifield results in a receptive advantage for the contralateral cerebral hemisphere. Functional asymmetries between the hemispheres may then interact with input variables, resulting in asymmetries on the criterion task or tasks.

As stated, this model oversimplifies many of the theoretical issues which have been raised in discussion of lateral asymmetries, however it serves as a useful initial approximation within which the general methodology may be dealt with. This section will be concerned, primarily, with methodological considerations, theoretical aspects will be discussed in some detail in 2.4. below.

Methodology

If it is hypothesised that some component of the overall variance in the dependent variable of a lateralised tachistoscopic task is due to the effects of cerebral asymmetry, it may be necessary to support this view by demonstrating that other possible sources of variance are uncorrelated with lateral advantages (i.e. that they are 'random' and may be dealt with by univariate statistical procedures). The difficulties raised by such confounding tend to be somewhat different for the various approaches to research which have been adopted.

1. The 'main effect' approach.

This research strategy is characterised by the search for a main effect of visual field on the criterion task. Problems due to confounding are quite difficult to analyse within a 'main effect' study. Elimination of one source of correlated error variance by the use of methodological refinements (e.g. fixation control) may result in the required 'purity' of the hemisphere x task interaction, but the possibility of introducing further sources of variability by the use of such procedures can rarely be eliminated.

2. The interaction approach.

This research strategy has much in common with the 'double dissociation' approach in clinical neuropsychology (see Teuber, 1955; 1959; Kinsbourne, 1971; Shallice, 1980, *in press* and Weiskrantz, 1968, for discussion). Essentially, this technique requires that an interaction be shown between visual field of presentation and two sets of tasks or task demands. In terms of correlated error variance, evidence for an interaction may indicate that there is support for a hemisphere asymmetry hypothesis, however, it could also indicate that the two 'tasks' interacted with error variance in different ways. For example, current evidence (Hammond, 1979) suggests that serial position curves for displays spanning the visual fields may be considerably different, depending upon the materials employed (non-verbal shapes or letter shapes). Thus an interaction between visual field and e.g. shape recognition and letter recognition, could be due to the manner in which the information was 'scanned' (see below), to hemisphere differences, or to an interaction between these two. The most parsimonious solution to this problem, namely, of requiring different cognitive operations to be applied to identical materials (e.g. Ledlow *et al*, 1978) begs several important questions but provides some degree of additional control.

From the brief summary presented above, it is clear that both the 'main-effect' and 'interaction' technique are open to distortion from correlated 'noise'. To anticipate the arguments which will be presented subsequently, such 'distortion' only becomes crucial when the lateral visual field stimulation procedure is utilised solely for the purposes of diagnosing left and right hemisphere involvement. However, since the vast majority of published studies on lateral asymmetries have either given some consideration to the validity of this diagnostic technique, or at least assumed its validity, some discussion is required of the more prominent sources of correlated error which may arise.

When verbal materials have been utilised in tachistoscopic presentation (e.g. words, or letter strings) the typical pattern of results has been for a left field advantage when the stimuli span the visual fields and a right field advantage when the display is parsed into two groups (bilateral presentation), or is presented to either the right or left of fixation (unilateral presentation). The findings from studies employing 'non-verbal' materials have been somewhat less consistent, although a good proportion of the published work indicates a left field advantage for such stimuli in unilateral trials. This pattern of results tends to support a hemisphere asymmetry interpretation of visual field effects but a range of alternative viewpoints have been put forward.

(a) Fixation bias

If subjects systematically bias fixation to the right or left of a central point, then 'main effect' studies or 'interaction' studies which utilise a blocked-trials design may be open to distortion (but see Geffen _et al_, 1972). Stimuli presented to the 'biased' visual field would be received with higher degrees of acuity than those presented to the 'neglected' side.

Some degree of control over strategic fixation bias may be achieved by random stimulation of the right or left visual field in unilateral trials (e.g. Hellige et al, 1979) or by cueing order of report at time of stimulus presentation in bilateral trials (e.g. Ellis & Young, 1980). McKeever and his co-workers have developed a procedure for controlling fixation under bilateral stimulation which allows order of report to be varied independently. Subjects are required to identify target digits presented at fixation prior to making a response to the bilaterally presented stimulus display (see e.g. McKeever & Gill, 1972). This technique may, however, produce artefact from floor effects (Schaller & Dziadoz, 1975) or introduce attentional and scanning biases (see Kershner et al, 1977).

A variety of other procedures have been employed in order to control fixation: they include video monitoring (e.g. Geffen et al, 1973). Electro-oculographic monitoring (e.g. Dimond & Beaumont, 1971a; 1972) maintenance of the Haidigers brush illusion (e.g. Dimond et al, 1972) and direct observation (e.g. Dimond, 1971). These procedures are, however, somewhat limited in sensitivity over the range of visual angles employed in lateralised presentation (typically between 2° and 6°). Furthermore, all but the 'Haidigers brush' technique depend upon the assumption that accurate fixation may be achieved for 'baseline' estimates. Recent work at Nottingham University (Beggs, pers. comm.; 1980) indicates that subjects conscious awareness of 'fixation' does not necessarily map into spatial coordinates in a 1:1 manner - his research shows a normal distribution of fixation accuracy with a standard deviation of over 1°.

Under instructions to fixate eye-movements may be restricted to 5' of arc (Alpern, 1971) and if asked, subjects attempt to cooperate (Geffen et al, 1973). Thus random stimulation of the visual fields, appropriate stimulus eccentricities, and sufficiently short exposures, are probably sufficient to ensure that, in the statistical sense, stimuli are predominantly lateralised to a single visual field for both right and left sided presentation.

(b) Acuity or sighting dominance.

White (1969) in reviewing tachistoscopic studies argued that acuity dominance may be important in binocular viewing conditions. Crovitz (1961) found a higher incidence of left acuity dominant people than right dominant, the incidence of left dominance being twice as high in individuals whose monocular sighting preference was for their left eye. If the crossed optic pathways are superior to the uncrossed (as suggested by Osaka, 1978; Sampson, 1969) then a disproportionately higher incidence of 'left' acuity dominant subjects could contribute towards a left visual field advantage. Curcio et al (1974) questioned the assumption that acuity as assessed in standard optical procedures was related to acuity in tachistoscopic tasks. When acuity was measured tachistoscopically, they found no relationship between acuity dominance and word recognition. Unfortunately this study cannot be accepted as conclusive evidence against the role of differential acuity since no right field advantage was found for their verbal material, despite the case of the digit report technique which generally yields a massive effect. It is not clear what role acuity and sighting dominance play under binocular stimulus presentations. Different ability groups may differ in their sighting preference (Kershner & Jeng, 1972; Crossland, 1939) which may confound some between group comparisons. However, for groups drawn from the typical 'student' population, this confounding may not be of much importance, since one may assume approximately comparable levels of 'ability' within the samples studied. Additionally, the higher incidence of left dominant subjects found by Crovitz (1961) fails to account for the high incidence of right field advantages in tachistoscopic studies, and hence it may be of little importance when reasonably large, clear, stimulus materials are used.

(c) Muscular tone

Bryden (1978) has argued that other 'peripheral' factors may affect lateral asymmetries. He suggests that muscular tonus may be of importance, and hence comparison between right and left handedness groups may be less informative about hemisphere asymmetries than was once thought. There is insufficient evidence on this point to determine its importance.

(d) Directional bias

There has been a considerable amount of research dealing with the problem of spatial serial position functions in tachistoscopic tasks. Reviews are available in Harcum (1978) and White (1976). Heron (1957) argued that the left field advantage obtained in trials where stimuli spanned the visual fields could be accounted for by a 'post exposural trace' scan which proceeded from left to right in accordance with reading habits. The same process, he argued, could account for the right field advantage with unilateral stimulation since scanning towards the right, was a more familiar task, than was a scan towards the left.

The left field advantage obtained with stimuli spanning the visual fields was found to be critically dependent upon the use of an unconstrained 'whole report' paradigm: when subjects were probed for recognition or recall of particular items, or when recall was requested in right to left or left to right sequences, several studies failed to replicate the overall left field advantage obtained with spontaneous recall (e.g. Merickle, Lowe & Coltheart, 1971). Merickle *et al*, 1971) noted that under conditions of backward masking the initial and terminal items of the display set were recalled with greater accuracy than were stimuli in the centre of the display. They argued that subjects employed an 'ends first' strategy in processing tachistoscopic stimuli, and that this mode of processing was characteristic of normal word reading. Bradshaw *et al* (1977) replicated this pattern with lateralised presentations, and suggest that the *central* letters of words are crucial in visual field asymmetries.

A peripheral-central order of processing priority has received support from studies of lateral masking. This technique contrasts the efficacy of stimulus recognition when the critical item is flanked by a redundant or 'noise' element (e.g. Bouma, 1973; Bradshaw *et al*, 1977). Under these conditions reports of the target element is most efficient when it is peripheral to the 'noise' stimulus, a finding which White (1976) suggests is congruent with the operation of a general peripheral-central processing order (rather than as an invariable 'ends first' analysis). His experiments contrasted stimulus location with display structure, and provided evidence in support of this view.

White, however, goes on to argue that left to right analysis may be of importance in translation from a visual code into 'auditory verbal' short-term memory. Similar perspectives have been offered by Schwantes (1977; 1978), MacKavey et al (1975) and Harcum (1978) who suggest that left to right bias operates in encoding from iconic into subsequent limited capacity memory systems.

Both White (1976) and Harcum (1978) have independently argued for a multi-stage conceptualisation of 'scanning' processes. White suggests that peripheral-central analyses may be a characteristic sequence of attentional focusing on the contents of a pre-categorical 'iconic' store. Harcum's model allows for aspects of the display configuration to 'attract' focal attention (e.g. Kahneman, 1973) and thus override pre-attentive processing biases. Crovitz & Schiffman (1965) and Hirata & Bryden (1976) have shown that introducing a gap into a 'bilateral' array diminishes the left field advantage, an effect which Harcum's model can deal with adequately.

Both White (1976) and Harcum (1978) describe left to right analysis of such information as an optional strategy (White) or 'control process' (Harcum). That is, it is not a mode of analysis which is invariably adopted for all types of material, but may be the easiest technique for subjects to apply when dealing with tachistoscopic tasks. This conceptual flexibility is required by observations that non-alphanumeric materials may produce different serial position functions to those shown by e.g. letter stimuli (see e.g. Harcum, 1978; Hammond, 1980).

Given this degree of 'uncertainty' with regard to subjects strategies, it is difficult to determine in advance, whether a particular task will evoke a 'left-right' processing mode. Evaluation must necessarily be made on the basis of the evidence from any particular experiment.

It has been argued that the fixation-digit report technique referred to above is especially prone to left-right scanning effects (e.g. White, 1972; Orenstein, 1976; Orenstein & Meigham, 1976). McKeever (1974; 1976) has countered these objections and suggests that scanning alone cannot account for the large right field advantage which are typically observed with this procedure. This is supported by MacKavey <u>et al</u> (1975) who contrasted experiments in which the digit was reported with those in which it was present but not recalled. They obtained comparable right field advantages under both sets of conditions. Similar effects were shown for horizontally and vertically aligned stimulus pairs suggesting that a sequential left to right 'scan' from fixation outwards could not account for their massive and reliable right field effects.

Fudin (1976) and Fudin & Masterson (1976) have argued that hemisphere asymmetries interact with scanning biases at the locus of memory retrieval. They suggest that subvocal rehearsal is a necessary component of many tachistoscopic tasks, and since the left hemisphere is best for organising this control process, a right field advantage is obtained.

It might be suggested that MacKavey et al's data was compatible with Harcum's 'pre-attentional' scanning mechanism. Since their stimulus materials were not evenly spaced across the visual field. Fudin's account, whilst interesting, remains almost indistinguishable from the rehearsal models put forward by White (1976) and Harcum (1978).

The problem of directional bias is a complex one which needs to be considered in both the design, and evaluation of experiments devised to investigate cerebral asymmetry.

The summary presented above leads to the conclusion that two sources of 'correlated noise', fixation eccentricity, and directional bias in display processing may confound the inference that a given set of results is due to hemisphere asymmetry. The problem of fixation bias may be minimised within an interaction design, if the variables defining the interaction are applied in mixed list presentation conditions. The involvement of directional analysis needs to be evaluated empirically for any given experiment, and taken into account when interpreting results.

Although the evidence from visual field studies may be 'noisy' there is converging data from research into the effects of unilateral brain damage which supports the contention that hemisphere differences may contribute towards the asymmetries which have been observed. To cite one recent example: Hellige & Webster (1979) have noted a left field advantage for degraded letter stimuli which corresponds to the deficit shown by right hemisphere lesioned patients in identifying 'fragmented letters' (Warrington & James, 1967). In the final analysis, it is convergent evidence such as this which can provide convergent 'validation' for the interaction between visual field asymmetries and cerebral function. The causal mechanisms are likely to be complex, but this should not be a deterrent to research.

Regardless of the structural determinants of visual field effects, however, they remain an intriguing problem. Their interest is enhanced by their pattern of interaction with 'cognitive' or functionally defined variables (such as Hellige and Webster, see above). The possibility remains open, therefore, that they may be utilised as a source of evidence for the identification of salient components of behaviour in a defined cognitive skill. The hypothesis that such effects may be the product of differential involvement of asymmetrically organised neurological systems may subsequently be investigated utilising other forms of research methodology.

Research into the interaction between cognitive processing and visual field effects has, almost without exception, been conducted within the framework of a hemisphere differences approach (but see Harcum, 1978). The following section will examine the general metatheoretical models adopted by research workers in this area as an aid to analysis and interpretation.

2.4. Theoretical Perspectives

In the preceding chapter, three broad orientations towards psychological research and theorising were discussed.

The physical, political and functional 'metatheories'.
Much of the theorising in the area of human hemisphere asymmetries can be categorised under one or another of these positions, although, as is the case in much contemporary psychology, there are a variety of 'mixed' models. In this section I shall give some consideration to the more influential viewpoints, citing them as exemptions of the metatheoretical orientations described above.

1. Physical Theory

The physical metatheory was characterised as an emphasis on the search for elementary mental processes and for laws predicting their interaction. Associationist models of brain function (e.g. Geschwind, 1973; Wernicke, 1874) were cited as exemplars of this perspective. The work on split brain patients utilised the interaction between a major neurological disconnection, and appropriate methodology (unilateral stimulation) in demonstrating the capabilities of functionally isolated right and left hemispheres. Much of the discussion of this evidence has, however, focused upon the attributes of the disconnected hemispheres, reaching its apogee in (e.g. Sperry's) argument that commissural section produces two minds each with its own mode of thought and consciousness (see e.g. Sperry *et al*, 1969, also Beaumont, 1979 for philosophical and empirical objections to this view).

Kimura's (1966; 1969) model of visual field asymmetry owes much to the influence of 'split-brain' research. As Hellige *et al* (1979) point out this model makes two key assumptions (i) that the hemispheres differ in their information-processing attributes and (ii) that input to the visual field contralateral to a specific hemisphere provides a receptive advantage in cognitive processing for that side of the brain. If (i) is treated as an assumption rather than as an empirical problem, then there is a danger that only confirmatory evidence will be reported, or that discrepant results will be interpreted as a product of processing differences described in paradigmatic accounts of hemisphere function (for example see Umiltà et al, 1974; Hannay et al, 1976; Fontenot, 1973; Dee & Hannay, 1973; Hellige, 1976; Bryden & Allard, 1976). Assumption (ii) entails an application of disconnection theory to normal function. This runs the risk of considering the hemispheres as 'mass action' machines under unilateral stimulation conditions. In addition, its adoption has resulted in a neurological diagnostic approach to research into 'normal' asymmetry, and perhaps more usefully, in a concern with rigorous methodology, which permits a degree of comparability between the various studies which have been reported.

The remainder of this section will deal with some illustrative examples of the use of 'physicalist' frameworks in research into visual field asymmetries. Where relevant, evidence from clinical studies will also be cited.

The 'two minds' hypothesis has been applied in discussion of hemisphere function in normal subjects (e.g. Ornstein, 1972), and in a somewhat less extreme form in consideration of information processing modes specific to each side of the brain. The latter views suggest that there may be a fundamental difference in cognitive style between the hemispheres and thus that different laws of processing interaction may be applicable. The most frequently discussed hypotheses have suggested either a serial-parallel processing distinction (e.g. Cohen, 1973a), or Analytic-Gestalt processing (e.g. Umiltà et al, 1978, and see e.g. Hellige et al, 1979 for discussion).

These proposals are, and have been amenable to empirical evaluation. The serial-parallel hypothesis has been studied in the context of memory search rates (see e.g. Sternberg, 1975). Cohen (1973a) obtained different linear trends over different sizes of memory set for right and left visual fields. Although she obtained evidence for serial analysis with right visual field presentation, with latency to decisions showing a linear increase with increments in set size, her left field effects were ambiguous. These indicated a decrease in latency as the size of the memory set was increased rather than constancy over varied set sizes as predicted by the parallel search model. Seamon (1974) and Seamon & Gazzaniga (1973) investigated the effects of rehearsal strategy on search latencies. They obtained parallel search functions with relational imagery instructions and noted that this pattern was pronounced with left visual field stimulation. Metzger & Antes (1977) replicated the visual field x rehearsal strategy interaction, but noted that it was confined to conditions in which the probe stimulus was a picture. Rothstein & Atkinson (1975) were also unable to replicate the strategy x processing 'style' interaction with word stimuli. It is now recognised that the distinction between search rates which operationally define 'serial' and 'parallel' modes of processing may be misleading,(e.g. Sternberg, 1975) raising problems for attempts to test the hemisphere specialisation hypothesis in a suitably precise manner.

The Analytic-Gestalt (wholistic) hypothesis has proven less amenable to empirical test than the related serial/parallel model. It has frequently been invoked descriptively to account for asymmetries in the perception of 'non-verbal' material, such as Vanderplass & Garvin (1959) shapes (e.g. Hellige _et al_, 1979) or facial stimuli (e.g. Umiltà _et al_, 1978). For shape stimuli, a left field advantage has been obtained by a number of workers when shapes are in the 6-12 point range (Hellige & Cox, 1976; Hellige, 1978; Dee & Hannary, 1973; Dee & Fontenot, 1975; and Hatta, 1976; 1979). Hellige (1976; 1978) suggested that there may be a weak or non-existent asymmetry for more complex forms because these were more likely to be dealt with 'analytically'. In support of this hypothesis Hellige (1976) obtained insignificant effects with complex materials, however Fontenot (1973) and Hellige _et al_ (1979) found left field advantages. Fontenot (1973) further suggested that low complexity stimuli may be "more verbal" since his study indicated weak asymmetries with these stimuli.

Analytic-Gestalt processing distinctions may be amenable to operational definition. Hellige _et al_ (1979) argue that overall latency to make 'same' and 'different' judgements may provide an index of these processing modes. They drew comparisons between two experiments, and argued that under appropriate conditions the left hemisphere could function in a 'Gestalt' mode. Unfortunately, it is unclear whether this pattern of latencies was due to processing differences, or to a task complexity effect since there were marked differences in the conditions of these experiments (match to a single item in memory vs. simultaneous presentation for same-different judgements). Fairweather et al (in prep.) employed a more refined measure of 'analytic' processing with 'same-different' judgement tasks utilising schematic faces as stimuli. They varied the number of 'different' features, and employed relative latency to judgements of these stimuli to index analytic processing. They concluded that the analytic-Gestalt distinction was not particularly useful in predicting visual field asymmetries.

The proposition that right and left hemisphere may differ in their 'cognitive style' is an interesting one, but thus far, the evidence in favour of this view is not convincing. There are problems, especially when the 'visual field asymmetry' literature is considered, in determining whether a particular set of results indicates a general property of hemisphere function, or whether it is a property of hemisphere function specific to particular task demands. On the latter view, for example, it could be argued that e.g. the left hemisphere possessed serial processing systems, without entailing any general conclusion about the conditions under which such systems operated. With visual field stimulation techniques, it is very tempting to consider each side of the brain as a 'mass action' machine yet the anatomical locus or loci of the interaction between task demands and visual field asymmetries is undefined. Such a global view of function has no support in the clinical literature where e.g. antero-posterior differences have been extensively documented (e.g. Hécaen & Albert, 1978).

A potentially important contribution of research in the 'physicalist' tradition has been a concern with the way that materials are processed, rather than with ostensive stimulus classification as 'verbal' or non-verbal. The significance of this emphasis is illustrated in considering the problem of strategy.

Marshall (1973) has argued that different patterns of hemisphere asymmetry may either be due to 'real' difference in cerebral organisation, or to different strategies adopted by subjects, or subject groups when performing 'strange' experimental tasks. Thus females, for example, might be inclined to adopt a verbal strategy when dealing with 'non-verbal' material whereas males might emphasise the non-verbal approach. Different patterns of asymmetry found under these circumstances could either be due to strategy, or to the way in which the brain was 'wired up'. It should be realised that this problem is not limited to situations in which group differences are observed, but applies even to conditions where all subjects show similar anatomically defined dissociations. The task might require 'non-verbal' systems in one group of subjects and 'verbal' systems in another but because of structural differences between the groups a common pattern of e.g. hemisphere asymmetry might be shown.

To rephrase Marshall's (1973) problem we can ask:

(a) Is a given result the product of functionally identical systems?

(b) Is it the consequence of different functional systems achieving a common end result?

It may not be necessary to distinguish between (a) and (b). If the category of performance is grossly defined e.g. 'non-verbal' or 'verbal', within the limits of a particular task, subject groups either differ in their laterality patterns - or not. Although potentially useful, such gross definitions may not, however, be the most informative - if for example subjects show one pattern of laterality on study (i) and a different pattern of study (ii), when the materials employed are similar in their 'verbal' or 'non-verbal' properties (as defined ostensively by the experimenter) the problems of interpretation are considerable. The real difficulty in this context arises from the use of descriptive classifications which do not have any clear theoretical foundation, and thus preclude an assessment of the efficacy, and consistency of the constraints imposed on performance by task demands.

The importance of a theoretical model of task performance in dealing with 'strategy' effects is underlined by Cohen's (1979) comment that: "it is arguable that redistributing the component stages of processing across the hemisphere (given that they perform the different component stages at different levels of efficiency) is equivalent to a change of strategy" (p. 314). Without some delineation of the "component stages of processing" involved in task performance, this argument becomes tautologous since strategy is (presumably) defined by hemisphere asymmetry, and hemisphere asymmetry defines the type of strategy involved.

There is little point in attempting to infer 'process' or 'strategy' solely on the basis of observed visual field asymmetries. Although "it would be much simpler if laterality patterns could be taken as straightforward indications of processing difference as (physicalist) models suggest" (Hellige _et al_, 1979) the current state of knowledge in this area does not permit any such inference. The logical solution to this problem lies in the investigation of lateral asymmetries in 'processing', as defined by specific theoretical accounts of cognitive performance rather than in attempting to infer 'process' directly from structure.

There are a range of well validated procedures for examining dissociable sub-components of function, which have been developed independently of 'visual field' research. The use of such procedures, and the application of appropriate theoretical models of task performance opens much wider possibilities for studying 'strategy' effects, and for investigating how, and more crucially _whether_ they interact with patterns of lateral asymmetry.

On first consideration, 'strategy' appears to be an intractible problem, highlighting as it does, the flexibility and complexity of human performance. Although our knowledge of this area is still somewhat primitive, there are outlines of theory available: For example, Posner (1978) suggests that strategic control of memory processing operates after early input coding, and at the level of decision and response mechanisms. Similar ideas were evident in the concept of 'control processes' put forward by Atkinson & Shiffrin (1968), but Posner's model is somewhat more powerful, because it permits both direct empirical test and convergent validation.

Although the complexity of the 'strategy' issue was emphasised by Marshall in 1973, there has been no serious attempt to address this problem directly. However, recent research has shown some concern with the potential contribution of 'mainstream' cognitive psychology in dealing with asymmetries in task performance.

The theories and models of information-processing provide a framework within which more precise attempts to define visual field asymmetries may be conducted. The clearest statements of this approach are provided by Cohen (1978; 1979) and Moscovitch (1979), who provide comprehensive reviews of this area. Cohen hypothesised that hemisphere asymmetries may vary according to the stage of processing involved. For example, she argued (Cohen, 1976) that iconic memory was divisible into visual and verbal subcomponents. Left field advantages were obtained on an index of visual persistence and right field advantage on a measure of verbal coding. Moscovitch (1979) questioned the assumptions underlying Cohen's mathematical analysis, and argues that her results were inconclusive. Cohen's work may also be criticised because she failed to replicate the partial-report superiority which operationally defines iconic memory (e.g. Sperling, 1963) thus calling into question the processing stage at which any visual field effects occurred.

Moscovitch's review (1979) posed the question: "At what stage in information processing do hemisphere asymmetries occur?" He argued in somewhat circular terms that "hemispheric asymmetries emerge only at the level of a central processor that integrates information from the peripheral channels and represents it in terms of configurational, relational, or categorical properties that reflect the mode of operation peculiar to the processors in each hemisphere" (p. 388). He reported experiments contrasting 'peripheral' and 'central' masking, (see Turvey, 1973), which showed a right field advantage under central masking conditions, and no visual field effects when peripheral masking was used (but <u>contra</u> Hellige & Webster, 1979).

This result is challenged by other studies employing masking stimuli. McKeever and Suberi (1974) investigated metacontrast functions for single letters in right and left visual fields. Their results were complex, indicating a maximum of metacontrast effects with 30 msec SOA's in the left visual field, and with 20 msec intervals in the right. They argued that this indicated longer processing times for left field stimuli, since visual field asymmetries were prolonged and parallel for the first 90 msec of SOA. However, the only statistically reliable points on their metacontrast functions occurred at 20 and 30 msec so their claim for 'temporal displacement' should be restricted to very early stages of processing. Although McKeever & Suberi interpreted their data in terms of more rapid processing in the right visual field, and are cited by Moscovitch in support of his arguments, other results are ambiguous and could reasonably be interpreted as indicating a left field superiority for early visual processing.

This interpretation was offered by Hellige & Webster (1979) who investigated forward and backward masking functions in the lateral visual fields. They obtained a left field advantage for short SOA's, and insignificant field effects as the interval was prolonged. They suggest that this reflects lateral asymmetries when mask and stimulus are 'integrated' during peripheral masking (e.g. Warrington & James, 1967).

Moscovitch (1979), McKeever & Suberi (1974) and Hellige & Webster (1979) all replicated the masking functions reported in e.g. Turvey (1973) however, as yet, it is impossible to achieve a satisfactory model which could account for all three sets of results.

Brief exposure durations may produce left field advantages (Gibson _et al_, 1972) and visual persistence may be larger in the left visual field (Erwin & Nebes, 1976) suggesting that right hemisphere function is implicated in early visual processing. However, the relationship between these manipulations and specific stages of processing is unclear. Turvey (1978) for example, argues that persistence, masking, and partial report measures do not necessarily index the operation of a common 'iconic' memory system. Moscovitch suggests that right hemisphere based inferential processes may be implicated by brief exposure durations, but does not explain why such processes should be absent during masked presentations.

The occurrence of discrepant results in studies of visual field asymmetries in early visual processing may indicate that there are a number of systems involved which are differentially implicated by particular types of task, or types of material. The use of an operationally defined process (such as that provided by masking functions) should enable rigorous research to be conducted on this topic. Furthermore, this approach may enable visual field asymmetries to be utilised as a research technique for the study of processing. This does not necessarily entail that such differences may be inferred from visual field dissociations, but rather, that laterality of presentation may be considered as an independent variable for investigating and fractionating (Shallice, 1979) components of cognitive function. Subsequently, it may be hypothesised that hemisphere asymmetry is implicated by a particular pattern of results, but it would not be strictly necessary to employ neuropsychological techniques, for attempting to provide convergent evidence for any psychological 'dissociations' which were obtained. This approach has the potential to provide a more satisfactory account of similarities and differences between the hemispheres, and to make contributions towards psychological knowledge.

Although there have been deficiencies in the 'physicalist' approach, it has however enabled a somewhat more sophisticated conceptualisation of hemisphere function than was permitted by a purely descriptive 'language-visuospatial' dichotomy. For example, a considerable body of research now suggests that the right hemisphere can demonstrate some 'language' capacities under the appropriate conditions (see Searlman, 1977). Zaidel (1977a; 1977b; 1978) has obtained evidence of right hemisphere vocabulary in two commissurotomy and one hemispherectomy patient which was consistent with the level of 'an average aphasic' although not comparable to any particular aphasic syndrome. Syntactic ability was limited (Zaidel , 1977a) and phonological processing minimal (Zaidel , 1977a). However, with similar patient groups Levy & her co-workers (Levy et al, 1971; Levy & Trevarthen, 1977) have found no evidence for phonological analysis or generative capacity.

On the basis of tasks which emphasised phonological processing Moscovitch (1972; 1976) argued that the right hemisphere in normal people was not involved in language (see below, Chapter 3). However, a number of comparatively recent investigations have suggested that its performance on some classes of words may be better than others. Ellis & Shepherd (1974), Hines (1976; 1977), Day (1977) and Orenstein & Meighan (1976) found that abstract words showed the typical RVF advantage whereas concrete words were recognised more easily in the LVF than abstract, thus suggesting that the right hemisphere had some capacity for analysing this material. Marcel & Patterson (1978) have argued that the critical variable was the imageability of words rather than their concreteness. Saffran et al (1980) attempted to replicate the abstract-concrete dissociation but were unable to do so and they argue that much of the research in this area has been marred by poor statistical analysis and extrapolation from unanalysed patterns of data. More recent work, (Young et al, 1980), suggests that an abstract-concrete interaction may be obtained under conditions of bilateral exposure, when stimuli are cued for order or report at time of presentation. This effect may, however, be restricted to a small subset of concrete words (Ellis pers. comm. 1980, in prep.) which are not obviously distinguishable, along an abstract-concrete imageability dimension, from those which produce right field advantages.

At the present time, it is not possible to draw any firm conclusions on the existence of, or nature of, right hemisphere language systems (see Coltheart, 1980 for further discussion).

Summary

Research within the 'physical' perspective has made a valuable methodological contribution by placing emphasis on processing constraints as determinants of visual field differences rather than on ostensive definitions of stimuli as more-or-less verbal or non-verbal, thus enabling comparisons to be drawn between different experiments, and different materials. The use of replicable phenomena, drawn from experimental (cognitive) psychology has enabled 'processing' to be defined independently of hemisphere asymmetry, and has also raised the possibility of applying extant theoretical formulations to describe hemisphere function and interaction (e.g. Cohen, 1978; Moscovitch, 1979).

It would be premature to attempt a full evaluation of the contribution of research within the 'physicalist' orientation. Some advances in understanding of the variables which influence visual field asymmetry have been suggested in the detailed review made by Moscovitch (1979). However, it would be fair to comment that although a wide range of interesting questions have been raised few conclusive answers are available (e.g. Cohen, 1978).

Further consideration of selected aspects of the 'physicalist' approach will be given in the following chapter where the application of information processing frameworks to studies of visual field asymmetry will be dealt with in greater detail.

2. Political Theory

There are two currents of thought on hemisphere function which owe much to a political orientation, these are the 'organisation' theories which have attempted to relate a particular pattern of lateral asymmetry to levels of ability in 'verbal' or 'visuo-spatial' tasks; and dominance models which are concerned with the conditions under which one hemisphere will 'inhibit' or 'dominate' the other.

Two of the main theories of functional organisation were discussed by Marshall (1973). The 'Levy-Sperry' hypothesis (see e.g. Levy & Sperry, 1968) which argued that a bilateral representation of language in left-handers would have a detrimental effect on visuo-spatial performance. The 'Buffery-Gray' hypothesis (Buffery & Gray, 1972) suggested that females were more strongly lateralised for both language, and visuo-spatial abilities, which led to superior linguistic and inferior visuo-spatial performance. The evidence for 'deficit' in left-handed subjects is far from conclusive. In college students, Briggs et al (1976) obtained lower full-scale WAIS for left and mixed handers, but in larger studies of children (Hardyk et al, 1976), young adults (Heim & Watts, 1976), and the populations of English villages (Newcombe et al, 1975) no 'deficit' was observed on a range of IQ scales. Peterson & Lansky (1977) noted a greater proportion of left-handed architectural students performed consistently and completed their courses, but the numbers in this sample were minute (12 left-handers). There has been much research on this topic, for reviews see e.g. Hardyk & Retinovitch (1977) Beaumont (1974).

The current status of 'sex differences' research is difficult to evaluate in summary form. An extensive review of the literature up to 1975 is provided in Fairweather (1976). He suggested that many of the studies on this topic had been marred by poor design and methodology. More recent studies may also be criticised on these grounds, but a consensus that females may utilise bilateral systems in the performance of 'verbal' tasks is emerging (e.g. Bradshaw et al, 1977; Bradshaw & Gates, 1978; McGlone, 1977). Bradshaw & Gates (1978) argue from a range of insignificant, and limited, effects that females have 'lexical' (semantic and phonological input systems) in the right hemisphere. The generality of their findings may be questioned since (a) strong criterion biases to 'Yes' judgements were obtained, which were not analysed by sex, although their data suggests that females responded more slowly and made somewhat fewer errors and (b) because phonologically homophonic non-words were judged more accurately, and more rapidly than equated non-homophones (e.g. experiment 2), a result which is somewhat atypical (e.g. Spoehr & Smith, 1975) suggesting that criterion effects may have affected crucial 'different' judgements in specific ways (as Bradshaw & Gates point out). Furthermore, this pattern of results tends to indicate that phonological processing was irrelevant to their task demands, and that judgements were based on visual evidence. This raises the interesting possibility that visual input 'logogens' (Morton & Patterson, 1980) or 'word form' systems (Shallice & Warrington, 1980, in press) were differently organised in males and females. However, since both groups showed a decline in right field performance with contralateral stimulus repetitions, it is unclear whether this particular interpretation is warranted.

McGlone (1977) has argued, on the basis of data from brain-injured subjects, that females have bilateral organisation of receptive, and productive language skills. In a a group of 92 patients, males were significantly more likely to show signs of aphasia than were females. Although her groups were equated on aetiology (vascular versus neoplastic) her evidence for severity, and localisation of lesion is totally inconclusive: 32% of EMI-scans were 'normal' and where 'abnormal' were 'not categorised by lobe' (p. 786), thus the imprecise index of EEG focus was chosen in preference to operation notes, or 'hard' radiological evidence. Although EEG may be helpful in localisation "it should be borne in mind also, that, while positive findings in the EEG are of diagnostic significance, in most cases negative findings do not rule out the presence of even major pathology" (Walsh, 1978, p.78). It is, therefore, impossible to determine, whether the extent of the patients' lesions covaried with sex, or whether there was any interaction between lesion site and the sex difference which McGlone reports.

The 'sex differences' argument has been invoked to 'explain' female superiority in some verbal tasks (see above) but there is no conclusive evidence to support a causal relationship of this type. The possibility that differences in cerebral asymmetry may be found between males and females requires further study: the present evidence is suggestive, but by no means 'conclusive'.

Marshall criticised the research in this area because inadequate consideration had been given to the structure of tasks, or the strategies which subjects adopted. The 'strategy' argument was assessed in the previous section where it was suggested that there was considerable difficulty in defining strategy unambiguously. Task structure, or the relationship of the task to other biologically and theoretically relevant parameters is an important consideration in determining whether a particular pattern of asymmetry is limited to a particular set of operations.

The determination of 'optimal' organisation has relied on correlational, studies or, more frequently by reference to studies on different subjects showing a particular pattern of 'deficit'. The assessment of such 'optima' is culturally bound, since evaluation has generally been made in the context of IQ scores, which cover only a limited sample of 'adaptive' behaviour. At the present time it would probably be wisest to adopt a conservative approach and attempt to determine when and how different patterns of lateral organisation are manifest, rather than to make the value laden judgement that one is somehow 'better' than another.

Another manifestation of the 'political' viewpoint is shown in the variety of 'dominance' models which have been proposed to account for the manner in which the hemispheres interact in normal behaviour (see Dimond, 1972; Dimond & Beaumont, 1974; Gazzaniga, 1974). One such model which has provoked a large amount of research is Kinsbourne's (e.g. 1970; 1973; 1974; 1975; 1978) attentional bias hypothesis.

Kinsbourne's ideas are derived from a Pavlovian model of the inter-relationship between attention and inhibition. He suggests that 'activation' of one hemisphere by a particular task will bias attention towards the contralateral half of space. This bias may be accompanied by changes in the orientation of receptor mechanisms, or a facilitation for orientation towards the contralateral half of space.

These ideas were introduced as a corrective to the 'anatomical' or 'access' model, and were an attempt to account for the failure of many tasks, of an ostensibly non-verbal nature, to produce strong and replicable left field advantages in visual studies. According to Kinsbourne (1972) subjects may engage in non-correlated verbal thought activities whilst performing such tasks, and hence bias their attention towards the right visual field. This 'theory' does not directly contradict the Kimura model, but distinguishes between pre-stimulus orientation biases and 'post-stimulus' effects, and hence represents a development resting on somewhat similar assumptions.

One of the main difficulties with Kinsbourne's view is in determining when 'activation' is likely to occur. In a series of studies Kinsbourne (1973) found that concurrent verbal activity enhanced the perception of gaps in the right visual field. Geffen _et al_ (1973) found that with more complex task material (digits), interference rather than facilitation was shown, and Gardner & Branski (1976) found that concurrent shadowing actually reduced sensitivity in gap detection for right field presentations. Hellige & Cox (1976) studied the effects of different memory loads on visual field differences in the recognition of 12 point shapes, and words. Their evidence suggested that for loadings of 2-4 nouns right field performance was improved, but with 6, it was depressed. Unfortunately, a strict 'activation' interpretation is not warranted by their 'low load' data since the memory lists and exposure durations were between subjects variables and the material may well have been dealt with differently according to the level of demand. Furthermore, the effects of 2-4 nouns on verbal recognition apparently enhanced the left field in a more dramatic manner than the right, although performance was not at 'ceiling' level in any single condition. Hellige & Cox invoked a 'callosal transfer' explanation for their data, but this does not fully account for the pattern of results.

In a more recent series of experiments Hellige _et al_ (1979) extended the dual task methodology in an attempt to define the processing level at which attentional effects occurred. They did not replicate the findings of Hellige & Cox (1976) in 'pure lists' of simultaneous form comparisons (experiment 2), but obtained similar effects when 'heavier demands on visuo-spatial memory' were made by requiring subjects to match form stimuli to a single item held in memory. The 'weight' of these demands was undefined by Hellige et al, and since subjects performed this task more efficiently and were given ample opportunity to code the memory items it is arguable, that smaller loads and/or verbal mediation were involved. Hellige et al (1979) concluded that attentional effects occurred only at higher levels of stimulus coding, and, furthermore, that the left hemisphere acted as a limited capacity information channel. Both their methodology, and inferences have been discussed in detail by Cohen (1979) who concludes that this topic requires further investigation.

Some work has been conducted on asymmetries in lateral eye-movements whilst subjects perform verbal and spatial problem solving (see e.g. Kinsbourne, 1972: Gur et al, 1975; Hiscock,1977;Erlichman & Weinberger,1978). Kinsbourne's evidence tended to support a dissociation between direction of gaze and the type of problems which were being solved, but Gur found that 'anxiety' affected the extent and duration of such movements. Hiscock performed an experiment controlling for 'anxiety' and position of interviewer, his study showed lateral movements in the predicted direction only for a small subset of questions. Spatial problem solving frequently led to no measurable lateral deflections. In agreement with Hiscock (1977) it is only possible to conclude that the 'eye-movement' hypothesis may be too simple to account for all the effects.

There is some evidence to suggest that a verbal warning signal may result in a faster right hand R.T. than left (Bowers & Heilman, 1976). No asymmetries were observed for a nonverbal warning signal, but it is unclear whether this represents an asymmetry in activation, or reflects the 'codability' of the signals. Cohen (1975) has noted that cueing for stimulus type may be more beneficial for right visual field presentations under some conditions, which may suggest an inequality of this form (see also Klein et al, 1976).

A number of experiments have studied the effects of mixing nonverbal and verbal stimuli in a random manner for presentation to the right or left visual field (Rizzolatti et al, 1971; Dee & Hannay, 1973; Hellige, 1978) these studies obtained a right field advantage for verbal stimuli and a left field advantage for nonverbal stimuli; an overall left field advantage; and an overall right field advantage respectively. It is not clear what Kinsbourne's model predicts under these circumstances, since unilateral activation could be disadvantageous for equiprobable mixed list stimuli (see also the discussion on Posner matches in the following chapter).

The usefulness of Kinsbourne's model is limited by the global definition of 'attention' which he employs. Many cognitive theories of 'attention' now recognise it as a complex, multi-component phenomenon (e.g. Posner & Boies, 1971; Posner, 1975; 1978; Pribram & McGuinness, 1975) rather than the simple Pavlovian activation-inhibition dimension discussed by Kinsbourne although activation-inhibition effects are envisaged under certain task constraints (see also Shallice, 1972; Moscovitch, 1979; Posner, 1978).

An additional problem in evaluating this theory has been the difficulty in specifying effects as due to attention or the product of coding shifts (Hellige, 1978; Cohen, 1979). As was the case in studies considered under the 'Physical Theory', many experimental designs have failed to index or restrict the manner in which stimuli are dealt with, relying solely on an ostensive definition of 'verbal' or 'nonverbal', rather than attempting to relate the tasks to any extant body of theory, or to define 'process' independently of lateral advantage.

3. Functional Theory

The functional viewpoint has probably received its fullest expression in speculation on the biological bases of hemisphere asymmetries (see Harnad *et al*, 1976; Dimond & Blizzard, 1977). Attempts to account for the adaptive significance of the unequal representations of function in the human (and infra-human) brain are, however, hampered by difficulties in specifying the precise manner in which the functional organisation of the brain is arranged both within and between species. Whilst a visuo-spatial/verbal dichotomy summarises much of the available data (for the human species) it lacks the level of precision necessary for the determination of evolutionary and adaptive implications (see above). Until a more detailed analysis is available an adequate evaluation of the biological-functional perspective is not possible. With regard to human social and biological adaptation a study of individuals impaired at a particular locus, or in a particular functional aspect of performance could prove valuable, but this avenue of research has not, as yet, been systematically explored.

There has been no application of 'functional' metatheory to visual field asymmetry in normal subjects, although the borderlines between 'physical' and 'functional' models have become somewhat blurred in research into clinical subject groups. Morton & Patterson (1980), for example, argue that neuropsychological evidence may be invaluable in identifying significant components of cognitive function. They emphasise functional deficit, rather than localisation as the major contribution of research into acquired disorders of reading, although their cognitive model is essentially 'physicalist' in its assumptions (see Morton, 1970; confusingly termed "A Functional Model for Memory").

A problem raised by such research lies in the possibility that brain-damaged patients may either (a) utilise the remaining components of the 'normal' (normative) system in performance or (b) may employ totally different systems from those used by intact subjects (a question raised by the 'right hemisphere' reading hypotheses (e.g. Coltheart, 1980; Saffran _et al_, 1980)). This difficulty reduces to an 'artificiality' argument, such as that employed by Neisser (1976) in discussing the poor 'ecological validity' of laboratory research into cognitive function.

Neisser's view may, in turn, be regarded as an _a-priori_ critique of the generality of sub-systems, or models of systemic organisation to conditions removed from the laboratory. 'Generality' is, however, amenable to empirical test within the domain of laboratory investigation (convergent validation), thus a particular functional deficit in a brain-damaged subject may suggest the existence of a particular sub-component in e.g. memory or reading, whose generality may be evaluated by the use of suitable research techniques employing 'normal' subjects, in a more familiar nomothetic investigation programme. If convergent validation is obtained then the focus of interest could return to the patient, whose capacity for 'normal' function, under a static set of independent variables or constraints, could be evaluated.

The approach to be developed in this thesis owes much to physicalist models of hemisphere x visual field interaction, but I intend to treat this framework as a working hypothesis rather than as an established set of facts. My main emphasis will be upon visual field presentation as a procedure for examining cognitive performance. I would justify this bias by suggesting that there <u>may</u> be something more than 'random noise' involved in the apparent instability of visual field effects (see e.g. this section). Interesting patterns of interaction have been obtained, and it is possible that failure to emphasise the psychology in neuropsychology, has resulted in the 'loss' of information about sub-components of performance which may have been differentially implicated by studies which 'fail to replicate' other work.

This orientation requires a detailed consideration of a somewhat limited set of tasks, primarily developed within mainstream cognitive research programmes. Those chosen for this research were variants of the Posner (e.g. 1978) letter classification procedure, for which an extensive body of theory, and associated research has been established. The aspects of performance indexed by this task are interesting in terms of general theory, their ability to differentiate task components such as coding, attention and strategy, and, importantly, because such components of performance have been variously employed in explaining visual field effects. The following chapter will be concerned with a brief introduction to this area.

Summary

This chapter has given an overview of contemporary research into neuropsychology. Emphasis was given to visual field asymmetries where potential sources of artefact were discussed. The final section considered theoretical accounts of visual field differences as ? instances instances of physical, and political metatheories. The more recent emphasis on a 'functional' approach to clinical neuropsychology was discussed, and the hybrid commitments of this research programme outlined.

CHAPTER 3

This chapter will fall into two principal sections. The first provides an introduction to Posner's theoretical model, the second examines attempts to investigate visual field asymmetry effects which have employed aspects of Posner's theory, and methodology.

3.1. Posner's Model

(a) Isolable subsystems

Posner argues that stimulus input results in the activation of a number of 'psychological pathways', or isolable memory systems (e.g. Posner & Rogers, 1978). Such activation is likely to be in parallel, although the rate of change within any single pathway may differ from others. Thus activation of a visual representation of the stimulus form may occur more rapidly than that of the pathway concerned with its phonetic or 'name' transform.

This pattern is illustrated by the letter classification task: Subjects are required to make a speeded classification of pairs of letter stimuli according to rules defined by the experimenter. In the example cited above, a comparison between physical identity (PI) judgements (e.g. AA) is contrasted with name identity (NI) classification (e.g. Aa). When letter pairs are presented simultaneously, PI judgements are performed more rapidly than NI (Posner & Mitchel, 1967).

A range of converging experiments have indicated that the systems mediating NI and PI judgements are isolable, in that classification latencies to either type of arrays may be differentially affected by particular operations. For example, PI judgements are relatively impaired by the addition of visual 'noise' to the array (Corcoran & Besner, 1975) whereas item frequency facilitates NI judgements more than PI (Pachella & Miller, 1976).

When a delay is interpolated between the presentation of members of the classification set, single letter items show a gradual decline in the relative advantage of physical to name matches (Posner & Keele, 1967; Posner *et al*, 1969). This finding was initially described as a 'loss' or decay of visual information (Posner *et al*, 1969), subsequently: as evidence for sequential abstraction of higher level codes (Posner, 1969), as evidence for visual generation of the opposite case transformation (Boies, 1971; Posner, 1972) and currently, as an interaction between levels of passive pathway activation, and attentional control (Posner, 1978). The position adopted by Posner (1978) admits the plausibility of all the preceding interpretations, and emphasises that they need not necessarily be considered as strict alternatives which provide 'the' answer to the problem of alteration in relative latencies during a sequential classification task.

As will become evident in the following section research into visual field differences in the letter classification task has, without exception, focused upon the isolable processing systems indexed by PI and NI classifications. There has been little discussion of, and no operationalisation of, attentional components of task performance, although Moscovitch (1979) suggests that such considerations may be of relevance.

Posner argues that 'attention' may be considered as involving three separate sub-components: alertness, selectivity, and set (Posner, 1975; Posner & Boies, 1971; Posner _et al_, 1973; Posner & Snyder, 1975a; 1975b). In Posner (1978) 'selectivity' has been re-labelled 'conscious attention', a term which captures the phenomenal implications of the construct in somewhat more vivid terms.

(b) Alertness

By the term 'alertness' the constructs of 'phasic' and 'tonic' levels of arousal are implied. Posner's work has focused on the former because, perhaps, of its relative simplicty in operationalisation in speeded (reaction time) tasks. Presentation of a warning signal prior to the imperative signal may facilitate response latency provided that sufficient 'warning time' is provided. The locus of such facilitation could be at initial stimulus analysis, because the subject is better prepared for stimulus presentation, or it may be a result of facilitation in response output. Posner & Boies (1971) argue that the benefits of 'alerting' are entirely due to facilitation of decision and response mechanisms and that 'encoding' takes a constant length of time. Posner (1975) extends this argument to account for the different speed-accuracy tradeoff functions obtained with brief, and prolonged stimulus exposures. He suggests that alertness may increase accuracy with tachistoscopic presentations because decision mechanisms are able to operate on a higher quality of information. When stimulus displays are available for longer periods of time, rapidity of output may be disadvantageous because responses may be initiated prior to the optimal 'build-up' of information in the sensory-memory system.

(c) Selectivity

This term relates to the operation of central processes which are involved subsequent to automatic encoding. Posner suggests that selectivity (conscious attention) may be employed in order to facilitate particular input pathways, and to inhibit others. This suggestion has been operationalised by the use of econometric analyses of judgement latencies following pre-classification priming stimuli (Posner & Snyder, 1975a; 1975b). The concept of 'selectivity' may be applied in considering the operation of 'strategy' effects, where endogenously controlled 'attentional processes' may be involved. Under conditions where subjects are 'committed' to a particular mode of processing, neutral warning signals may operate as 'primes', and thus bring into play the inhibitory and facilitatory processes of selectivity.

(d) Set

Set has been employed to discuss the spatial-topographical distribution of attention. Posner _et al_ (1978) have provided evidence for the independence of spatial attention from receptor (eye) orientation. This construct most closely approximates to Kinsbourne's (e.g. 1978) account of spatial-attention interactions between the cerebral hemispheres. However, Posner's model is insufficiently developed to provide clear predictions with regard to the interplay of arousal, selectivity, and 'set', (which are treated as a unitary construct by Kinsbourne).

(e) Anomalies

Although single letter stimuli show a straightforward decline in PI advantage (section (a) above) over comparatively short retention intervals, (approximately 2 seconds) multi-letter arrays are anomalous.

Two letter combinations presented for sequential classification judgements show a persistence of the PI advantage for up to 12 seconds (Kroll & Parks, 1978) which occurs even in the presence of overt verbal rehearsal of letter names (Parks & Kroll, 1975). This finding has been interpreted as due to the difficulties in performing visual-generation operations on two letter stimuli, rather than on the dissociation of overt naming from name-matching. The Parks & Kroll interpretation of 'visual generation' implies a feed-forward loop from memory storage of physical attributes of stimuli which 'primes' or 'activates' name-level transformations in visual input pathways. Posner (1978) accepts this possibility, but emphasises the automaticity of multiple levels of representation following stimulus presentation, an account which appears to preclude 'difficulty' arguments (although his position on this point is by no means a clear one see e.g. Posner (1978) pp. 55-56).

Parks & Kroll's account becomes more problematic when the evidence from multi-letter arrays is considered (i.e. those comprised of three or more items). Such materials may show a smaller PI advantage than single letters following brief retention intervals (e.g. Posner & Taylor, 1969). This indicates that the processes involved in the persistent PI advantage for double letter stimuli are not necessarily a consequence of 'default due to difficulty' since visual generation mechanisms should be even more impaired when the magic number two is exceeded.

The double letter task therefore poses several intriguing questions, and requires further explanation. As a technique for the investigation of visual field differences, it has the attraction of providing an operational definition of visual memory unconfounded by alterations in code over time. 'Irrelevant' rehearsal processes may be studied in conjunction with 'visual memory' persistence enabling a direct comparison of the 'physicalist' and 'political' accounts of hemisphere function. Furthermore, simply because materials are shown to the lateral visual fields, there is no reason to avoid exploration of the problems posed in existing accounts of performance with double letter stimuli - in fact, the dynamics of lateral asymmetries may be informative with respect to sub-components of the processing systems which are involved.

This rather ambitious strategy was adopted in the present research programme. However, prior to discussing these studies, it is necessary to give some consideration to related work on this topic.

3.2. Introduction

The Posner letter classification task has been utilised in several investigations of lateral asymmetries. There are a number of reasons for its popularity, the principle ones being:

(i) The proposed codes involved in classification correspond to the postulated visuo-spatial and verbal processing modes of the hemispheres.

(ii) An operational definition of performance can be obtained in terms of the relative reaction times (R.T.'s) to various classifications.

(iii) If mixed trials are used an interaction between trial type and visual field can be interpreted as a reflection of a functional dissociation rather than as a consequence of 'perceptual' biases e.g. non-central fixation, acuity differences or ocular dominance.

(iv) The same stimuli can be presented under varying conditions of task demand thus avoiding the ambiguity inherent in studies which confound stimulus domain with task requirements. Interactions observed in such investigations could be due to hemisphere differences, differential familiarity, task difficulty and/or statistical artefact from 'ceiling' or 'floor' effects.

* * * *

There are fifteen published studies (including Ph.D theses) which have used simultaneous presentations of letters for classification. Four investigations to be considered in a later section have been concerned with mnemonic aspects of the task (Moscovitch, 1973; Wilkins & Stewart, 1974; Kroll & Madden, 1979; Kirsner, 1979). The studies of simultaneous trials are presented in summary form in Tables (i) and (ii).

This may assist in giving context to the complex (and often confusing!) data which has been produced. Writers such as Ledlow _et al_ (1978) and Hellige (1976) would seem to suggest that there is a 'prototypical pattern' in these findings, but if such an overall pattern exists it appears to be a product of experimenter-paradigm interaction rather than a function of the evidence. For simplicty of exposition the studies are shown in chronological order, effects are expressed as right visual field advantages (RVFA) left visual field advantages (LVFA), and insignificant effects (n.s.). Only absolute R.T. differences are shown. The single study which has employed a derived index of PI advantage (Cohen, 1972) is therefore presented as 'non-significant' (although she did find that there were hemispheric asymmetries on this score) since my own analysis of her raw data shows no differences in absolute R.T. or significant interaction. Table (i) shows findings for 'same' judgements, Table (ii) for 'different'.

Consideration of Table (i) suggests that the 'prototypical pattern' of a LVFA for PI, and RVFA for NI is only obtained in three of the eight relevant studies. An RVFA for NI pairs emerges on a small number of pure NI sequences but seems quite consistent (with the exception of Cohen's (1972) study mentioned above) for mixed presentations. The relationship between PI and LVFA does not appear to be very strong and may vary with response demands (Green, 1977).

'Different' classifications show no consistent pattern of visual field asymmetry, and there is no support for the postulate that the hemispheres are differently specialised

TABLE (i)

Visual field asymmetries in simultaneous classification tasks

Study	NI (A-a)	PI (A-A)	Response	Exposure
1. 'Pure Trials.				
Egeth & Epstein (1972)	-	n.s. RVFA	go-no-go	150 ms
Davis & Schmit (1973)	RVFA	LVFA	CRT (uniman)	150 ms
Geffen et al (1973	RVFA	LVFA	CRT (biman)	150 ms
Lefton & Haber (1974)	LVFA	n.s.	go-no-go PI	30 ms
Swanson & Ledlow (1974)	n.s.	-	CRT (2 hand) NI	-
Hellige (1975)	LVFA	-		
Hellige (1976)	LVFA decreasing to RVFA or n.s.	-	CRT (2 hand)	30 ms 100 ms
Green (1977)	RVFA	LVFA	r.hand go-no-go	100 ms
		n.s.	l.hand go-no-go	100 ms
		RVFA	CRT (2 hand)	100 ms
Ledlow et al (1978)	RVFA	n.s.	go-no-go	40 ms
Hellige et al (1979)	n.s.	RVFA		150 ms
2. 'Mixed' Trials.				
Gazzaniga (1970)	RVFA	n.s.	No information	No information
Ledlow et al (1972)	RVFA	n.s.	go-no-go	150 ms
Geffen et al (1972)	RVFA	LVFA	CRT bimanual	150 ms
Cohen (1972)	n.s.	n.s.	CRT unimanual	< 10 ms
Ledlow et al (1978)	RVFA	n.s.	go-no-go	40 ms

RVFA = Right visual field advantage
LVFA = Left visual field advantage

N.B. Posner et al (1967) note that pure PI blocks yield faster R.T.'s than mixed PI classifioations.

Table (ii)

Different Classifications

Study	PI	NI
1. Pure Trials		
Egeth & Epstein (1972	LVFA	
Geffen *et al* (1973)	LVFA	RVFA
Davis & Schmit (1973)	RVFA	n.s.
Lefton & Haber (1974)	n.s.	n.s.
Hellige (1975	-	n.s.
Hellige (1976)	-	n.s.
2. Mixed Trials	Both	
Geffen *et al* (1973)	RVFA	
Cohen (1973)	n.s.	
Green (1977)	RVFA	

for the judgement of 'sameness' and 'difference' (Egeth, 1971; Egeth & Epstein, 1972). Three studies (Lefton & Haber, 1974; Hellige, 1975; 1976) report an increasing response bias towards 'different' for peripheral trials when these are compared with centre field trials in the same experiment. Inspection of means for the other relevant studies suggests that different classifications are not markedly slower than NI judgements for peripheral presentations. Response biases as marked as those noted by Hellige and Lefton & Haber are not found in other studies.

With respect to laterality, the varied results for 'different' classification are not especially problematic for attempts to establish functional dissociations between the hemispheres since the processes entailed by 'different' judgements may vary widely with the specific set of letter combinations employed (see e.g. Posner, 1978 for discussion). Additionally if a response bias towards 'different' is operating under some conditions of letter presentation there is a higher probability of different classifications being made when evidence is weak, thus introducing 'noise' into the data.

Moscovitch (1976) compared the effects of visual and auditory confusability in audio-visual matching (not presented above because the methodology employed is not directly comparable with visual classifications). He found that RVF trials were more disruped by auditory confusers and the LVF by visual.

* * * * *

The earliest study concerned with visual field differences in simultaneous classifications was that of Egeth & Epstein (1972). They used a right-handed go-no-go response, half their subjects responding to 'same' pairs and the other half to 'different'. Contra-hypothesi they obtained an insignificant trend towards a right field advantage for same judgements and a significant left field bias for different classifications in pure PI trials. This, they suggested was due to the display structure (quite widely separated letter pairs) inducing a verbal strategy in 'same' responders and a visual strategy in the 'different' group. This interpretation hardly says anything 'new' about hemispheric function, and there is no <u>a-priori</u> reason why subject groups should respond to task demands in this manner. Furthermore, the task can be criticised on their failure to counterbalance for response output (i.e. by assigning equal numbers of subjects to response laterality conditions), their pattern of results could be accommodated within a processing 'interference' explanation (e.g. Green, 1977) as well as by a mutual facilitation of processing and response output since all subjects used their preferred hands to indicate decisions.

Lefton & Haber (1974) attempted to replicate Egeth & Epstein's findings in a more adequately designed task. Their exposure durations were much briefer and subject numbers greater. They compared the effects of go-no-go and CRT on PI classifications and additionally looked at stimulus spacing factors in a CRT task. In this series of experiments no visual field effects emerged for 'different' judgements although they noted a strong response bias towards 'different' with increasing retinal eccentricity (experiments 1a and b). A complete replication of Egeth & Epstein's study (widely spaced stimuli, go-no-go output) was not conducted, and the possibility of some interaction between these factors cannot be ruled out.

Lefton & Haber obtained a significant LVF advantage for NI stimuli in their experiment III. Hellige (1975) also observed a left field effect, but pilot work indicated that this bias was eliminated, and reversed with practice.

This observation was more fully explored by Hellige (1976). He presented two experiments which indicated that RVF presentations benefited more from practice than did LVF. His first experiment used 90 trial blocks of 30 ms exposures of either letter stimuli or Vanderplas & Garvin (1959) shapes:

stimulus type was a between subjects factor. The 'shape' stimuli did not yield visual field asymmetries at any level of practice - Hellige argues that this was possibly due to the wide range of stimulus complexity levels utilised in the study (see discussion above, Chapter 2). NI matches only gave an RVF advantage on trial blocks 3, 4 and 5. A more recent study (Hellige et al, 1979) showed a roughly similar pattern of 'practice' effects, but interpretation is complicated by the use of concurrent tasks in this investigation.

In order to account for these effects Hellige proposed that there were two stages in the acquisition of NI classification skills. Initially perceptual aspects of the task were more difficult and led to the use of right hemisphere systems. Subsequently, the verbal component of processing was relatively more demanding, resulting in a bias towards left hemisphere processing.

Hellige's second experiment was devised in order to explore the effects of a consistent level of perceptual difficulty on NI classifications. This was achieved by superimposing a vertical bar grid over the letter pairs in NI classification. A control group of subjects received pure NI trials. The results for the group receiving degraded stimuli showed a strong LVF advantage which increased with practice, the 'control' NI presentation conditions yielded an initial LVF advantage which declined to insignificance over 270 trials. Hellige does not seem to be able to explain either of these observations adequately in his two level conceptualisation of skill development and hemisphere 'dominance'.

The addition of visual 'noise' to classification pairs is a plausible procedure for increasing the perceptual complexity of the 'Posner' task. Corcoran & Besner (1975) have provided evidence for such effects, they demonstrated that PI judgement latencies were impaired relative to NI when a random-dot mask was presented superimposed over the letter stimuli. However, Hellige's data does not support his 'skill development' model, because there is no reason to expect perceptual <u>difficulties</u> to increase as practice was extended, yet an increased left field advantage was obtained.

It is unfortunate that a PI condition was not used in Hellige's study since the relative latencies to NI and PI stimuli might have been more informative than visual field differences <u>alone</u> as an index of the processing demands imposed by the classification task. It seems quite likely that extended practice with stimuli degraded by low frequency masks may result in the employment of inferential processes (Forster, 1979) based upon partial information about stimulus characteristics. If this were the case, then it is possible that PI and NI latencies would converge with extended practice under 'degradation' conditions comparable to Hellige's. This experiment has yet to be performed, but it would possibly throw some light upon his increased left field bias, since there is reliable evidence from clinical studies that such visual-categorical processes depend upon right hemisphere systems (e.g. Warrington & James, 1968).

Although Hellige's 'difficulty' hypothesis is provocative, it is stated too vaguely to allow a satisfactory, predictive model of the types of processing implicated by general terms such as 'visual complexity'. There are a number of studies in the literature which suggest that certain aspects of visual processing of letter and word stimuli may show a left field advantage.

Brooks (1973) reported a LVF advantage for cursive handwriting and Bryden & Allard (1977) have reported similar findings for script-like' type fonts. Bradshaw _et al_ (1976) and Taylor (1976) have demonstrated that mirror-reversed single letters and digits may give a LVF advantage. However, the applicability of a 'difficulty' hypothesis to studies of simultaneous classifications other than those of Hellige (1975), Hellige (1976)(experiment 1), and Lefton & Haber (1974) is questionable. For example, Geffen _et al_ (1972) employed one condition which was very similar to Hellige's pure NI task. For half their subjects this was given following 18 practice trials and consisted of 118 classification judgements. For the remaining subjects the NI condition followed a similar, brief, practice session, and 118 trials of pure PI judgements. This study gave a significant RVF advantage for both same and different NI judgements. Both the number of subjects used, and the magnitude of the asymmetries observed, suggest that Geffen _et al_'s effect was not simply due to extensive practice for one subject group. In contrast with the Geffen _et al_ (1972) study, Cohen (1973) gave her subjects considerable practice prior to presentation of mixed NI and PI stimuli yet she did not find an overall RVF advantage for NI pairs (as erroneously claimed by Hellige). The relative importance of practice effects, and their potential interaction with the visual and verbal 'complexity' of stimuli is difficult to determine at present. The visual field by level of practice interaction noted by Hellige does not appear to be entirely stable - even with comparable stimulus materials and subject groups. Some criterion of 'visual difficulty' is necessary before such a variable is invoked as an explanation for differing visual field advantages. Such changes may be a product of a serial development of skills, but they may also reflect qualitative alterations in subjects approach to the task, adaptation to lateralised presentation conditions (Ward & Ross, 1977) or interactions with response bias (Egeth & Epstein, 1972). With regard to the latter consideration, it is interesting to note that Hellige (1978), Hellige et al (1979) and Lefton & Haber (1974) - the only published examples of LVF advantage in simultaneous NI judgements - obtained strong response biases towards 'different' (considerably more marked than in any of the other investigations reported in this section). Such biases may have been of importance in determining the pattern of results which were obtained.

Ledlow and her co-workers have performed a number of experiments with pure NI trials in tests of Kinsbourne's attentional hypothesis (Swanson & Ledlow, 1974; Ledlow, 1976, summarised as Ledlow et al, 1978). Swanson & Ledlow (1974) used 150 ms exposures of the letters A and E in name match pairs and found no significant field effects for same judgements. Response output was go-no-go and they explained their findings as the result of combined effects of stimulus directed orientational biases and delegation of response output to the hemisphere contralateral to the direction of stimulation. This explanation could apprently be applied to any task in which insignificant results were obtained! Ledlow (1976) using a larger stimulus set and shorter exposure (40 ms) reported that with pure NI trials a small but significant RVF advantage was obtained. This effect was smaller than that observed when mixed PI and NI presentations were given.

Geffen _et al_ (1973) compared mixed and blocked trials in a single experimental design but found no interaction between conditions. Cohen (1973) used mixed trials only and near threshold exposure durations and showed a smaller PI advantage for RVF presentations. She argued that the index of advantage (NI-PI (R.T.)) was more likely to provide information on cognitive differences between the hemispheres than absolute R.T. which could reflect peripheral factors such as ocular, acuity, or manual dominance. Her argument is slightly strengthened by her failure to obtain any reliable pattern of results with a left-handed group of subjects. Unfortunately she failed to counterbalance adequately for response output all subjects responding with their preferred hands for CRT. Geffen _et al_ (1973) used a bimanual R.T. which may ignore rather than overcome response laterality x stimulus interaction since the R.T. clock was stopped by the first button pressed. Green (1977) has recently suggested that there may be an interaction between output demands and hemisphere processing in tasks of this type. In a go-no-go experiment she obtained an LVF advantage for blocked PI matches with right-handed output, for CRT classifications an overall RVF advantage was obtained in both PI and NI blocks.

Davis & Schmit (1974) used PI and NI classifications as a between subjects factor, and counterbalanced for uni-manual CRT. No interactions were reported which support the stimulus processing by response output thesis, their results closely resembled those of Geffen et al (1973). An LVF advantage was obtained for the PI group, and RVF advantage for the NI. Gazzaniga (1970) alludes to an unpublished experiment comparing PI and NI matches. No procedural details are provided, but he claims a significant right field advantage for NI and no significant asymmetries for PI matches.

A recent report of a task analagous to those discussed in this section has been made by Martin (1978). He required decisions to be made on the basis of verbal (letters terminating in the phoneme 'ee') or visual (letters containing a curved line) features. Unfortunately his study can be faulted on several crucial points, and his failure to obtain asymmetries may be due to any, or all of these. His method is unclear, describing both a central fixation point, and two lateral ones, for stimuli "typed so that they were 3° eccentric". To complicate interpretation still further visual R.T.'s are described as faster than verbal in the body of the report, but tabulated results suggest the opposite effect! He obtained a 'significant' interaction between sex of subject and yes-no judgements on the basis of a post-hoc analysis (the overall ANOVA showed no interactions with these factors). Since only

12 subjects were employed in this study generalisation does not seem to be warranted!

As suggested in the introduction to this section, the results from simultaneous classification tasks are complex and a unified explanation for the findings does not seem to be possible. A wide range of exposure durations has been used ranging from near threshold (Cohen, 1973) to the limits of saccadic latency. Response output has been go-no-go, uni-manual CRT, bimanual CRT and two-handed CRT in different investigations. Green (1977) suggests that the response output demands of tasks may obscure, or even enhance laterality patterns depending on whether facilitation or interference in processing is involved. Since 'interference' or 'facilitation' was defined post-hoc, and the various laterality patterns shown in Table (i) above do not seem to be closely related to output demands, Green's thesis does not seem to offer a satisfactory scheme for integrating results.

As Ledlow _et al_ (1978) point out, the most consistent finding has been of a right field advantage with NI pairs. Table (i) above suggests that this effect is most clearly demonstrated under mixed NI and PI presentation conditions. Ledlow _et al_ (1978) suggest that the attentional demands of stimulus processing may vary with classification-type uncertainty. Comparable suggestions were made by Posner _et al_ (1969), and have been largely substantiated by Pachella & Miller (1976) who noted that stimulus frequency (intrinsic to the blocked trial design) selectively facilitated NI judgements. It is not clear how such strategic (or attentional) 'bias' might affect visual field asymmetries. It is possible that it operates in conjunction with compensatory fixation strategies, or processing changes. Unfortunately no study of which the writer is aware has examined the 'strategic-bias' hypothesis in any satisfactory way. So the question remains an open one. Uncertainty regarding the laterality of the stimulus pair may also be important in obtaining any visual field differences. Geffen et al (1973) compared blocked and random visual field stimulations and obtained RVF advantage for NI and LVF advantage for PI pairs, but no interaction between conditions. Since response output demands were very different (go-no-go) in the Ledlow et al (1978) study and bimanual CRT in the Geffen et al (1973) investigation it is quite possible that this factor is of importance.

In order to determine the validity of inferences that the cerebral hemispheres are differentially involved in certain aspects of the Posner task it is necessary to incorporate different levels of classification within a single experimental design. Replication of the PI advantage (i.e. the more rapid classification of PI stimuli) would then allow a clear comparison to be drawn between the 'standard' central presentation conditions (on which the categorisation of 'visual' and 'verbal' levels of emphasis rests) and the conditions employed in a particular 'visual field' study.

It has already been noted that the Lefton & Haber (1974), Hellige (1976) and Hellige et al (1979) studies showed strong response bias effects under pure-block presentation conditions. This finding may have affected the stability (or replicability) of their tasks, but more seriously, their omission of a

PI judgement condition (with comparable output demands) prevents a determination of the relevance of their findings for the dissociation of lateralised systems involved in 'name-match' judgements. This problem arises because the category of performance required by name match judgements is not solely defined by the stimulus materials employed but is an operational definition of performance relative to other conditions (e.g. physical matches). Expressed in other terms: although the stimulus materials required name-identity judgements, we have no way of determining whether the specific task demands or subject strategies were comparable to other studies utilising similar stimuli.

The use of mixed trial blocks would appear to be recommended for studies of hemisphere specialisation. If there were differential involvement of lateralised systems in PI and NI classification pure blocks of a particular classification type might result in compensatory or facilitatory fixation strategies or attentional biases (see Kinsbourne, 1975).

Summary:

When mixed trial blocks have been employed, the data from simultaneous classification tasks suggests that NI judgements may be mediated more efficiently by systems which are lateralised in the left hemisphere. The single exception to this finding in the available investigations, was that of Cohen (1973) who utilised exposure durations of less than ten milliseconds. If very brief exposures are employed then the manner in which stimuli are analysed may be affected (see

Posner, 1978), and this aspect of Cohen's method may have added 'noise' to her data. The results of pure block presentations have been considerably more variable - showing the full range of field differences and insignificant results - for both classification types. The relative instability of effects under these conditions - (although often confounded by methodological flaws see above) - is possibly due to the greater latitude for strategic and attentional options.

PI judgements do not show as consistent a pattern of visual field advantage as NI judgements. Four of the occasions on which PI asymmetry has been assessed led to the 'prototypical' LVF advantage on one, a RVF advantage was reliably demonstrated (Green, 1977), but in the remaining cases no significant field biases were shown.

Although the simultaneous presentation of PI and NI stimuli appears to offer a powerful technique for the assessment of functional dissociations, the potential offered by an analysis of the sequential matching task is considerably greater. Stimulus materials can be maintained at a consistent level of familiarity and complexity whilst task demands are varied. The decline in PI advantage noted by Posner and his colleagues provides an operational definition of code bias which can be studied in relation to dissociations in the systems involved. An important advantage of the sequential presentation method is that it should allow a determination of the aspects of performance which require the involvement of dissociable systems - i.e. whether any asymmetries which may be observed relate to stimulus analysis and retrieval from memory, or whether they reflect the latency of 'memory code' development.

There are four studies in the literature which have explored the consequences of this type of sequential stimulus presentation. The first to be discussed (Moscovitch, 1974) used an auditory memory stimulus (S_1) and a visual match (S_2). The second, Wilkins & Stewart (1974) employed a procedure more closely related to Posner's work on sequential matching, using visual S_1 and S_2. The third, Kirsner (1979) failed to replicate the Wilkins & Stewart results. Kroll & Madden (1978) have recently reported a study employing materials which prolong the persistence of the PI advantage (double letter stimuli - see above) and also employed visual presentations.

Moscovitch used a two-second ISI in his first experiment and obtained significant effects of visual confusion for left-handed CRT's in different judgements, this group of subjects showed a greater degree of interference with LVF presentation. A second study used simultaneous presentations of auditory and visual stimuli, and showed an effect of confusion type (auditory or visual) which interacted with visual field of presentation. RVF presentations were significantly impaired for auditory confusers, left with visual. He argues from this finding that the right hemisphere "failed to exhibit linguistic skills", a rather tenuous argument since the inference of deficit relies on superior performance! His division of 'linguistic' skills resembles in some respects the Hellige (1976) thesis, and both appear to be oversimplifications of a multiply determined process.

Moscovitch's final experiment utilised delayed (2 sec.) matches of stimuli on the basis of terminal phoneme identity. No effects were found for 'different' judgements, and the only reliable effect (inferred from his series of ANOVA's) was a RVF advantage for phonemic matches. Unfortunately he confounded stimulus sets with judgements, only members of the positive set were presented as both sample and test items, the negative set were only shown visually. Hence it is impossible to determine whether subjects decisions were made on the basis of phonemically based traces or on the distinctive features of the visual stimulus. On one-twelfth of the trials first and second stimuli were identical, and in this condition a slight LVF advantage was obtained. He argues that this finding reflects a visual generation process in the right hemisphere. The visual generation hypothesis in this context is not without its problems. Posner _et al_ (1969) found minor differences between PI matches visually presented, and auditory visual matching with zero ISI's. Despite their complex arguments for the process (based on a subset of the stimuli and probability levels of greater than .05) the findings do not conclusively demonstrate that visual generation occurs. Visual generation, however defined, implies a temporal dimension and hence the failure to demonstrate temporal concommitants leaves the effect open to a variety of interpretations.

Moscovitch additionally argues that the right hemisphere in neurologically intact subjects exhibits no linguistic ability. This argument is based on a narrow definition of 'linguistic' - operationally the susceptibility of the LVF to visual confusions, and the RVF to acoustic in experiment II, and the superiority of the RVF in the terminal-phoneme classifications of experiment III. ('Visual generation' of letter stimuli is defined as non-linguistic). Moscovitch suggests that any capacity for language in the right hemisphere (even if performance were less efficient than the left) would appear as an interaction between responding hand and visual field, and that this would occur because of the differential benefits of access from lateralised processing systems to motor output! He suggests that a main effect of visual field which does not interact with responding hand conditions demonstrates that a single hemisphere is involved in the task. An interaction between hand of response and visual field was obtained in his first experiment which was significant only for visually confusing letter pairs, suggesting bi-hemispheric involvement.

Moscovitch's model of 'efficiency' in the absolute sense is defined by temporal efficiency in relative terms. The right hemisphere might be equally competent, but have a slower rate of performance than the left. Moscovitch suggests that if the right hemisphere is considerably slower than the left then it has little involvement in language function under normal conditions. This thesis does not seem to be open to empirical evaluation and constitutes one assumption from an infinite domain. The demonstration of ability may be restricted to the skills tapped by any single experimental task, and hence by the individual researcher's operational definition of 'linguistic'. Some would argue that the right hemisphere susceptibility to visually confusing stimuli constituted evidence for visuo-linguistic skills, since in order for such confusions to occur, there must be information, which is rapidly accessed, on the relationship between the sound of the letter and its form!

A final consideration concerns Moscovitch's model of the relationship between input processing and response output. He assumes that unilateral conditions will be facilitatory in nature but there is evidence to the contrary (see Green, 1976, and review therein). Additionally there are possibilities of interactions with stimulus-response compatability which may confound differences (see Colbourn, 1974). Swanson et al (1978) review the literature available on R.T. studies which have attempted to measure 'transfer time', and their arguments are relevant for considering any study which claims R.T. to be any more than a somewhat crude dependent variable, all an R.T. measure can 'tell' is the relative efficiency with which a task is performed.

Moscovitch (1976) does not attempt to link his findings with the cognitive literature on this task (e.g. Posner et al, 1967) only noting that visual confusion effects were maintained over 2 sec. ISI, whereas auditory confusion was greatest with simultaneous presentations. Since this data comes from two separate experiments, and no statistical comparisons were made, no conclusions can be drawn. (Although, it might be noted that this pattern conflicts with other evidence for 'confusability' in 'Posner' tasks (see Posner, 1978)).

Wilkins & Stewart (1974) provide a more direct link between the areas of cognitive psychology and hemispheric asymmetry research. They employed mixed lists, first and second (test) stimuli were presented for 100 ms separated by retention intervals of 990 or 50 ms randomly varied between trials (Wilkins, pers. comm., 1976). S_1 was always shown at fixation, S_2 in the lateral fields at 3°, response was two-handed CRT.

In their analysis of accuracy data, they obtained a significant interaction between ISI and visual field shown in Table (iii). This finding is widely accepted as demonstrating that "a preliminary non-verbal code is available in the right hemisphere until superseded by a verbal code in the left hemisphere" (p. 905).

Table (iii)

Adapted from Wilkins & Stewart (1974)

	Proportion Correct		
		ISI	
	50	(msec)	990
RVF	.902		.988
LVF	.953		.895

Since the Posner letter matching task yields an operational definition of memory code in terms of the PI advantage, a logical prediction is for an interaction between code type, hemisphere of presentation, and ISI. This was not found. Wilkins & Stewart report that post-hoc sign tests suggested PI matches were initially more accurate for LVF presentations but at 990 ms an RVF advantage was obtained. NI pairs were initially non-asymmetric but also yielded an RVF advantage at 990 ms.

Despite reservations on the nature of the post-hoc analysis, these findings can be accepted as indicative of differential involvement of the hemisphere at the ISI's utilised by Wilkins & Stewart. Unfortunately, the precise nature of this involvement is difficult to ascertain on the basis of pair-wise comparisons - it would be interesting to know, for example, whether changing patterns of field difference were related to alterations in the PI 'advantage' within and between hemispheres.

The main effect of stimulus classifications was significant as was its interaction with ISI and response laterality assignment. The means for this interaction are presented in Table (iv) below.

Table (iv)

Adapted from Wilkins & Stewart (1974)

Proportion Correct

	ISI (msec) 50		ISI (msec) 990	
	RH	LH	RH	LH
PI	.953	.961	.955	.961
NI	.867	.930	.953	.906
PI-NI	.086	.031	.002	.055

(RH = Right Hand)
(LH = Left Hand)

Consideration of the PI-NI accuracy scores (which gives an index of the PI advantage) shows that the typical PI decline was only obtained in right hand-same conditions a reversed (possibly non-significant) effect occurred in the left hand-same group. The source of the changing laterality pattern with time is therefore unclear since only one group of subjects showed evidence for a 'preliminary non-verbal code'.

The R.T. analysis gave an interaction between responding hand and classification type. The right hand-same subjects again produced a fairly normal pattern in response latency but as can be seen from the means presented in Table (v) the left hand-same group show an equally powerful reverse-Posner effect!

Table (v)

Adapted from Wilkins & Stewart (1974)

Classification Type	Reaction Times (msec)	
	RH	LH
PI	710.2	730.0
NI	744.0	695.0
PI Advantage	-33.8	+35.0

N.B. PI Advantage = NI - PI
(RH = Right Hand)
(LH = Left Hand)

Again, inference of a relationship between memory code and hemisphere of presentation does not seem to be warranted.

'Different' responses were analysed separately. There was a main effect of case similarity suggesting that "letter size might occasionally have been used as a short-cut to the production of different reponses" (p. 908). The latency data additionally gave a 3-way interaction between responding hand, visual field and ISI. The left hand-same subjects showed a LVF advantage of 40 ms at the short interval and a RVF advantage at the long of 23 ms. The right hand-same group showed RVF advantages of 20 ms and 8.5 ms respectively. It is not clear what importance should be attached to these findings. In the preceding consideration of the simultaneous classification tasks it was noted that 'different' classifications appear to give less consistent visual field asymmetries than 'same' judgements.

The data on 'different' classification however offer little support to Kinsbourne's model (see discussion above). The group which showed a strong bias to 'name' matches gave a LVF advantage for different judgements at the shortest interval, when the evidence for 'same' judgements presented above indicated a bias towards verbal coding. The right hand-same group of subjects showed a <u>declining</u> RVF bias as ISI's were increased, when they were apparently shifting from a visually based to a verbal processing mode.

The results of Wilkins & Stewart do not provide unequivocal support for either an information processing model of hemisphere asymmetries, (such as that of Cohen, 1976) or an attentional bias model (e.g. Kinsbourne, 1976). For an information processing interpretation to be adequate an interaction is required between visual field of presentation, and code type. Wilkins & Stewart only obtained an interaction between interstimulus interval and visual field of S_2 presentations, which did not seem to relate to the subjects PI or NI bias in any straightforward manner (see the discussion of response assignment interaction above). An attentional model would predict <u>either</u> an overall RVFA (pre-stimulus effect), or one which increased with the development of a verbal form of processing. Although the ISI x visual field interaction which was found for all subjects does appear to support this model, once again a breakdown of the forms of bias within subject groups does not offer any support for the thesis.

Kirsner (1979) reports an attempted replication of Wilkins & Stewart's experiment. He obtained insignificant visual field effects at very brief ISI's, which changed to reliable right field advantages as the retention interval was prolonged (to 50 ms). He argued that this pattern of results was congruent with an 'attentional bias' hypothesis (after Kinsbourne e.g. 1978). Unfortunately Kirsner employed exposure durations of 200 msec which may have permitted ocular scanning towards the stimulus (see chapter 2 above). Furthermore, he employed a blocked ISI procedure so it is unclear whether time structure effects were differently involved in the Wilkins & Stewart and Kirsner investigations (see Hamilton & Hockey, 1974).

Kroll & Madden report two experiments investigating visual field difference in sequential matching of double letter stimuli. They argue that their data indicates that 'high' and 'low' verbal subjects have different patterns of functional lateralisation. In their first experiment a post-hoc separation of subjects into low and high verbal ability groups (determined by the subjects verbal scholastic ability tests -VSAT) indicated that 'high verbals' (scoring 500 or more on the VSAT battery) had a significant left field advantage for NI judgements. The 'low verbal ability' group (scoring 495 or less on VSAT) did not show this pattern, their performance on NI judgements was somewhat more efficient when stimuli were presented to the right visual field. This experiment additionally examined the role of ISI using two unpredictable intervals for each subject. Half the subjects matched stimuli after ISI's of .5 seconds or 2 seconds, and the remainder following ISI's of 1 or four seconds.

An overall RVF advantage was found for both 'high' and 'low' verbal ability groups at 500 ms. No data was presented on relative matching latencies at the other intervals.

Judgements of the rationale for separating subjects into 'high' and 'low' VSAT subgroups was derived from a study by Kroll & Parks (1978) in which they reported that the magnitude of the 'Posner effect' (the size of the PI advantage) was inversely related to subjects VSAT scores. This finding suggested that a common dimension of verbal facility might be involved in both measures. Unfortunately the correlation between VSAT and the 'Posner effect' in the Kroll & Madden study was insignificant, hence rendering any inference of a causal relationship between the laterality of NI processing and verbal ability somewhat tenuous. "If we assume that, when both (S_1) and (S_2) are shown to the centre, high verbals have each hemisphere processing the information in its most efficient manner, and further assume that subjects can respond on the basis of the first comparison completed, we would predict that high verbals would show a smaller Posner effect than low verbals" (Kroll & Madden, op. cit. p. 388). Given similar magnitudes of "Posner effect" in the two groups there is no basis on which to categorise a particular pattern of hemisphere asymmetry as more, or less, efficient than another as the Posner effect did not correlate significantly with VSAT scores in Kroll & Madden's experiment 1, it does not appear to be a reliable index of verbal ability under the conditions which they utilised. Thus the difference between the groups, whilst apparently related to VSAT scores, were based on a task which was uncorrelated with VSAT, and the data, therefore, present intractible problems in interpretation.

Kroll & Madden report a second experiment in which sequential matches of pairs of letters, or Gibson figures were employed after fixed ISI's of 1 second. The data from the Gibson figures group was seriously confounded by speed/ accuracy trade-off and hence was difficult to interpret. Since the data from the 'letters' subgroup is more relevant to the current discussion and less confounded by speed/ accuracy effects only those findings will be considered here.

The subjects in this experiment were initially selected on college entrance VSAT scores but a high 'drop out' rate amongst the low VSAT subjects resulted in groups of twenty-three subjects with VSAT's of 510 or greater and sixteen with quotients of 490 or lower. Following this participation in the experiment, subjects were given a ninety minute battery of 'verbal' tests whose validity rests on the following criteria - they were "constructed on the basis of questions in a manual sold to prepare students for taking the SAT". Unfortunately, the VSAT scores did not predict field differences adequately in the second experiment so subjects were re-classified according to their subtest scores on the aforementioned battery. "Since the vocabulary scores seem to be the best predictors of the effects of interest subject .... were separated into high and low vocabulary groups". This division apparently resulted in several high VSAT subjects being re-classified into the low ability group. In this experiment field differences were negligible, with a group by visual field interaction restricted to conditions when letter and figure stimuli were combined in a single statistical comparison within LVF presentation conditions.

Vocabulary scores correlated with the size of the PI effect ($r = .233$) and high vocabulary subjects showed a smaller difference between their NI and PI judgements than did the low vocabulary subgroup. This difference between groups seems to be entirely attributable to slower PI judgements in the 'high vocabulary' group. NI classifications were performed equally rapidly by both sets of subjects (interpolation on Kroll & Madden's Fig. 4 yields a mean difference in NI judgements of approximately 3 ms between groups on NI and a difference of 55 ms in PI classifications) in this experiment, VSAT scores were slightly related to the magnitude of the PI advantage (r = -.260).

Kroll & Madden's findings do not appear to have any relevance for dissociating functional lateralisation patterns between groups. The "Posner effect" is, apparently, an unreliable index of 'verbal ability' as measured on VSAT, although it may relate to Kroll & Madden's (unpublished) vocabulary scale. However, it should be noted that an index of NI-PI latency may not simply reflect verbal facility but could indicate that, when verbal efficiency was equivalent, a particular subject, or subject group showed <u>impairment</u> in PI judgements. Without a comparison across ISI's it is impossible to determine whether such 'slowing' of PI classifications is the product of increasing emphasis on name, or formal features of the stimulus, or of an inverse relationship between visual match 'ability' and vocabulary scores! The manner in which these effects might relate to 'bilateral' representation of language is open to speculation.

The most crucial problem with Kroll & Madden's study lies in the paradox that when the "Posner effect" correlated with their criteria for distinguishing groups there were no significant field effects, or interaction between visual field, and group for NI stimuli. When the Posner effect was unrelated to this criterion a match x field x group interaction <u>may</u> have been shown. Thus, under conditions where the task apparently 'tapped' some aspect of verbal ability, the groups were equivalent, and the hemisphere effects insignificant, when skills other than 'verbal ability', (as assessed on VSAT) were involved, the groups differed!

The precise significance of these findings is obscure. In the preceding paragraph it was stated that a match x field x group interaction _may_ have been shown: It should be noted that even this finding needs to be treated cautiously since (a) assignment to groups was entirely post-hoc, (b) the statistical analyses were based on pair-wise comparisons between difference scores on subsets of the data, and (c) stimulus exposure durations were at the limits of acceptability (150 ms).

The only finding in the Kroll & Madden study which was uncontaminated by their post-hoc ascription of subjects to 'ability' groups was that of an overall RVF advantage at the 500 msec ISI in experiment 1. It is not clear whether this finding relates to the right field advantage obtained by Wilkins & Stewart after 990 msec with single letter classifications.

Summary

The studies reviewed in this section do not point towards any clear set of conclusions. Despite the potential power of the classification task, as a means of investigating visual field asymmetries in relationship to attentional and processing demands, the published research on this topic suffers from various logical and methodological flaws. Wilkins & Stewart's study provided no evidence for a code x hemifield interaction, although it suggests that the dependent variable of ISI may be of importance. Kirsner's investigation employed exposure durations which may have allowed ocular scanning to interact with 'attentional' or strategic bias, and finally Kroll & Madden's report is marred by conceptual and statistical difficulties.

The experiments to be reported in this thesis attempted to study the sequential classification task in greater detail than the research reviewed in this chapter. It was hoped that operationally defined coding effects might shed some light upon the basis of lateral asymmetries. Furthermore, it was hoped that lateral asymmetries would provide a useful procedure for investigating the cognitive system(s) involved in such classification tasks.

Although sequential double-letter judgements (e.g. Kroll & Madden, 1978) are somewhat atypical in producing a stable PI component, they were considered as a useful starting point for investigating code effects independently. Single letter, and multi-item arrays confound effects of retention interval with code change, thus it may be difficult to 'partial out' attentional effects (as e.g. identified by Kinsbourne) from those which might be due to e.g. inter-hemisphere transfer or asymmetries in rates of access to particular types of memory code.

CHAPTER 4

Method & Statistical Analyses

This chapter will be concerned with the methodology employed in the experiments reported in this thesis. With minor modifications, the apparatus and materials utilised remained constant throughout. Exceptions are noted in the relevant 'method' section of each experiment.

1. General Method

The experiments were controlled and the data recorded by Digital PDP Lab8E computer. Stimuli were presented on a 'free standing' VR14 screen, 17 cm x 25 cm, peripheral to the computer. Responses were registered by pressing one of two buttons .5 cm in diameter, 5 cm apart, and sited on an 11 cm x 8.5 cm x 5 cm metal box. The labels 'yes' and 'no' were written above the buttons with a felt-tip pen. Pressing one of the buttons interrupted a programmable clock, and responses were recorded to the nearest 10 msec. The buttons were linked to two separate digital input channels so that decision type could be recorded.

Stimulus displays were constructed using the graphics facility of UW/cig, (a development of 'Focal'). The stimuli were made up from the letters ABDGHJLPRT and their lower-case equivalents, formed within a 14 x 10 dot matrix. Each letter was composed of approximately 20 points (see Appendix 2). The letters appeared as horizontally aligned pairs in three positions on the display screen, in the middle, and to either right or left visual field. At a viewing distance of 50 cm each letter pair subtended a horizontal visual angle of 4.3°.

In the 'middle' position the letter pair was horizontally centred on the screen, in the left and right visual field positions the innermost edge of the letter pair subtended 4.26° from the centre of the screen. The letters appeared as green stimuli on a dark background.

Each letter pair was made up from one upper and one lower case stimulus. The relative position of upper and lower case letters was counterbalanced within the conditions described above, so that an upper-case letter appeared equally often in the first and second positions within a letter pair. The letters were combined so as to avoid high acoustic similarity groupings (e.g. Bd), duplication of letter names (e.g. Aa), or meaningful combinations (e.g. At). The 'meaningful' status of the stimuli was subjectively assessed by the experimenter.

Two pairs of letters were shown on each experimental trial. The first pair (S_1) was in the middle position on the display screen, the second (S_2) was shown for 100 msec in either right or left visual field. Visual field of presentation was randomised for S_2 using the pseudo-random number generator of UW/cig. A fixation cross was used in all experimental sequences (.85° x .85°). This was made up from a horizontal and a vertical line plotted on the screen.

Four types of S_1 - S_2 combinations were used. 10 different stimulus combinations were employed for each of the categories of S_1 presentations detailed in Table 4.1 below. S_2 stimuli were derived from S_1 as shown in the table. 'Different' S_2 letters were chosen from the stimulus list, visual and auditory confusion with S_1 was avoided (e.g. d $\rightarrow$ t or d $\rightarrow$ b).

Table 4.1.

Stimulus Combination Types

Combination	S_1	S_2
Physical identity (PI)	Ap	Ap
Name identity (NI)	Ap	aP
Different-change left letter (D_L)	Ap	Rp
Different-change right letter (D_R)	Ap	Ar

The order of presentation of the stimulus combination types was randomised using the UW/cig random number facility. Each type of combination was shown 20 times with 10 presentations of S_2 in each visual field. Factorial combination yielded a 10 (S_1 stimuli) x 2 (visual field) x 4 (combination type) - 80 trial experimental list.

Statistical Analysis

(i) Preliminary

The PDP8 was programmed to give a print-out of each Ss accuracy and response latency. Response times and decisions made were printed for each trial in the experimental series. Total accuracy, mean and standard deviation of correct responses and response latency was tabulated by conditions (NI, PI, Different) for each visual field.

A rough estimate of Ss consistency in maintaining fixation was provided by the standard deviations for R.T. in each visual field. It was assumed that if Ss were adopting a 'guessing' strategy with regard to stimulus location, then this would lead to some very short, and some very long R.T.'s. Since a correct guess would give a very short response latency whereas incorrect judgements would inflate latency. Subjects showing large standard deviations were questioned on their approach to the task. If the standard deviation was due to a single long response, then provided Ss did not admit to anticipating the stimuli this response was scored as an error. If, on the other hand, a number of short and long R.T.'s were observed, Ss were questioned in more detail, in order to determine whether this was a function of practice with the task, of attempts to anticipate stimuli, or 'peripheral' factors (such as e.g. blinking). If the effect appeared to be due to practice then the data was accepted for further analysis. Evidence of anticipation, or of physical difficulties led to rejection of the data, and replacement of the subject.

All subjects were asked "how they had remembered" the stimuli, and a record made of the particular strategy which was reported.

(ii) Statistical Analysis

The data from response latency and accuracy was subjected to a series of ANOVA's on the University CYBER computer. The design in each case was repeated measures factorial. Programs for analysis were kindly provided by R. Gillett of the psychology department.

Preliminary analysis of accuracy data indicated a high correlation between mean and variance thus accuracy scores were converted to proportions and transformed to $2(\arcsin\sqrt{x})$ (Winer, 1971) in order to stabilise variances. Mean R.T. was used in all latency analyses.

Procedure

Subjects were tested individually. The E gave instructions orally, using a sketch of potential stimulus configuration to assist in describing the task. On arrival at the laboratory S was asked to sit in front of the VR14. The experiment was described as "part of a study on how people remember letters". On each trial of the experiment two consecutive letter pairs would be shown, each pair comprising one capital letter and one 'small' or 'lower-case' letter.

A sketch of stimulus combinations, similar to that presented for Table 4.1. was shown. Subjects were informed that their task was to decide whether the letters in the second set of each trial had the same names as those in the first set. It was emphasised that the names of the letter stimuli were crucial rather than their physical characteristics.

S was handed the box containing the response buttons and instructed to hold it in both hands with thumbs resting on the buttons. Decisions about the classification of the stimuli were to be indicated as rapidly, and as accurately as possible by pressing the button labelled 'Yes' to indicate 'same' and 'No' to indicate 'different'.[1] Subjects held the response apparatus on their lap, out of their field of view. For half the subjects in each experiment 'Yes' decisions were

[1] the labels 'Yes' and 'No' were chosen rather than 'same' and 'different' because Ss in some pilot runs of these experiments apparently found it easier to make a 'Yes' rather than a 'same' judgement to physically dissimilar (NI) stimuli.

made using the right thumb, and 'No' by the left, for the remainder this lateral mapping of decisions was reversed.

S was told that the first pair of letters in a sequence would be shown in the centre of the screen, and that after an interval the second pair would appear on either the right or left of the screen. The side on which these letters appeared had been determined randomly by the computer. In order to maximise their performance it was necessary to keep looking towards the centre of the screen throughout the experiment. A cross would be shown on each trial to guide fixation and S should focus on the area where the two lines intersected. E stressed the importance of this procedure, and informed S that one of the aims of the experiment was an investigation of 'peripheral vision' so cooperation would be appreciated.

Questions on the task were answered. S was then asked to look at the screen and the letter stimuli were shown individually while E named them aloud. Exposure duration of these materials was variable (approximately 2 sec. each). S was then given an opportunity to review the stimuli before undertaking a series of practice trials. Practice trials were drawn at random from the experimental set, a different series and ordering being generated for each subject. Ss were told they had "done quite well" after practice was completed and reminded about the importance of fixation, speed and accuracy. Viewing distance was constrained in all experiments but the precise procedure differed. Specific details are provided in the reports which follow.

On completion of the experiment Ss were questioned on strategy in performing the task, and a short debriefing given.

CHAPTER 5

Experiment I

The first experiment was conducted as an exploration of lateral asymmetries for letter stimuli where evidence for a strong visual memory (PI) component in coding was available. The technique was adapted from that reported by Parks & Kroll (1975) who had shown that sequential presentation of double letter arrays resulted in the persistence of a PI advantage for ISI of at least 9 seconds. (More recently Kroll & Parks have demonstrated comparable PI persistence for over 12 seconds with these stimuli (Kroll & Parks, 1978).

Parks & Kroll discussed the implications of this finding for the 'decay' hypothesis of PI decline with single letters (e.g. Posner & Keele, 1967; Posner & Taylor, 1969; Posner *et al*, 1969; Posner, 1969). This hypothesis had suggested that visual memory was a transient, unstable code, which was necessarily replaced by a more durable verbal trace as the retention interval was prolonged. Parks & Kroll, however, demonstrated that the PI match superiority with double letter stimuli occurred even under conditions of paced, overt, verbal rehearsal suggesting that both verbal, and visual codes could co-exist, and that under appropriate conditions visual coding (indexed by PI match superiority), could be prolonged and stable.

As was discussed in Chapter 3, Parks & Kroll, and subsequently, Kroll & Parks (1978) argued that the atypical 'visual memory' effects obtained with double letter stimuli were due to difficulties in generating alternate case transforms in the visual memory system. Some support for this perspective was provided by showing comparable patterns of classification latency when nominal and physical matches between unfamiliar type faces were required.

Recently Kroll & Madden (1978) have reported an investigation of visual field differences for sequential classification of double letter stimuli. This study was considered in some detail in Chapter 3, but deserves further discussion in this chapter. Kroll & Madden report two experiments utilising double letter stimuli. The first was concerned with retention intervals from 500 msec to 4 seconds, and the second study employed a single, 1 second ISI. Their subjects showed a clear right field advantage in PI classifications in the first experiment, which does not appear to have been reliably replicated in the second. NI judgements produced a right field advantage for all subjects at 500 msec intervals (Experiment I). At intervals greater than 500 msec their first experiment showed a left field advantage in NI classifications for 'high-verbal' subjects, and a right field advantage for a 'low-verbal' ability group. Once more, there were problems with replication their second study. Since Kroll & Madden did not discuss ISI effects in their experiment 1, it is unclear whether these replication problems reflect differences in processing at the various intervals which were considered. Further evaluation of letter classification effects in their study 2 is complicated by the use of dubious statistical procedures, and failure to discuss or present analyses of the results of the letter classification task independently of a 'nonsense shape' classification condition.

The right field advantage in PI judgements was not discussed in much detail by Kroll & Madden yet this pattern of 'processing laterality' is of considerable theoretical interest. On the Parks & Kroll (1975) account, persistence of the PI advantage should reflect early (visual?) processing which may be lateralised to the right hemisphere (Cohen, 1978) or non-asymmetric (Moscovitch, 1979). An alternative interpretation, cast in terms of Kinsbourne's 'attentional' model (e.g. Kinsbourne & Hicks, 1978) might be applicable to this set of results, and (albeit post-hoc), might provide a functional, rather than structural, account of the group differences which Kroll & Madden obtained following longer retention intervals. This possibility will be given further consideration below.

Initially, however, it is necessary to consider why a left field, or non-asymmetric effect would be expected by 'processing', rather than 'attentional', models of hemifield asymmetries.

Parks & Kroll's (1975) data suggested that complex unfamiliar type faces were similar in their functional attributes to double letter stimuli, yet tachistoscopic recognition of 'script-like' or unusual type faces may produce a left field advantage (Bryden & Allard, 1976). If both double letter and unfamiliar type face effects reflect the involvement of pre-categorical visual memory traces, or equivalently, (in the present context) a 'visual' representation uncontaminated by visual generation, then it is possible that a left-field advantage would be predicted by a visual complexity (Hellige, 1976) or a process-based model of visual field asymmetries (e.g. Cohen, 1979). Alternative accounts might emphasise the difference between tachistoscopic recognition (whole report) and sequential matching (short-term memory) demands, and point to the 'perceptual' basis of the Bryden & Allard (1976) result (see e.g. Umiltà *et al*, 1980, *in press*). The latter interpretation would possibly indicate two dissociable components in the double letter matching task, the first based on perceptual analysis in the right hemisphere, and the second, on a *left* hemisphere visual memory system. It would be reasonable to expect a time-course in lateral asymmetries with double letter PI judgements if this was the case, yet Kroll & Madden did not report any analyses temporal effects on PI classification in their experiment suggesting that this pattern was not obtained.

These problems will be addressed in this and subsequent experiments. The first was concerned with an exploration of visual field asymmetries in a sequential double-letter classification task with comparatively long retention intervals (9 seconds). An ISI of this duration should be sufficiently long to permit verbal rehearsal, and would permit independent replication of Parks & Kroll's (1975) findings.

The predictions which might be made by the various theoretical accounts of visual field asymmetry are not strictly amenable to hypothesise deductive formulation at this stage. Nevertheless, three basic possibilities were considered when commencing research.

(1) Persistence in the PI advantage may reflect visual memory uncontaminated by access to categorical systems mediating 'visual generation'. On the account offered by Cohen (1975), this type of processing would be expected to relate to right hemisphere systems, and to produce a left visual field advantage. Moscovitch's (1979) review suggests that pre-categorical processing is bilaterally organised and, if this were the case, no visual field asymmetries would be expected in PI classifications. The 'classical' right field bias would be expected for NI judgements.

(2) The PI advantage may not be 'pre-categorical' but could reflect the operation of specialised left hemisphere processing systems concerned with letter retention and analysis. That is, there may be two component processes involved in this effect; initial perceptual analysis may be dependent upon right hemisphere systems (Bryden & Allard, 1976) but subsequent retention may be dependent upon left hemisphere processors. This interpretation would be able to account for Wilkins & Stewart's (1974) results where a time course in lateral asymmetries was found which bore little relationship to 'code' biases. It would suggest that the primary determinant of visual field effects was not 'coding' per-se, but a temporal gradient in 'engram' development. On the evidence provided by Wilkins & Stewart (1974), Kirsner (1979) and Kroll & Madden (1978) a right field advantage for PI matches would be anticipated, following 9 second retention intervals. This hypothesis cannot account for Kroll & Madden's 'NI' dissociation between groups, unless their

interpretation of structural differences is taken as valid, and as has been pointed out, there are good reasons for treating their account with caution.

In summary, the two 'process-based' or physicalist hypotheses which have been outlined above suggest (1) that code bias is a predictor of visual field effects and (2) that code bias, as defined by the PI-NI latency pattern is less relevant for hemisphere asymmetry than is the time course of memory trace development.

(3) The final hypothesis to be considered derives from an attentional-dominance framework (Kinsbourne, 1978; Kinsbourne & Hicks, 1978). This would predict that concurrent rehearsal of stimulus names would result in a right field bias for PI stimuli, but might interfere with NI judgements because of the overlap (or perhaps identity, Posner, 1978) between NI and naming processes. Post-hoc, this hypothesis could account for the failure to replicate in Kroll & Madden's study 2 by suggesting that ISI differences were crucial in producing interference with NI, and facilitation of PI, classifications with right field stimulation. Kroll & Madden's first experiment included ISI's of between 500 msec and 4 seconds and showed group x visual field effects only after 500 msec. Initially both NI and PI judgements showed a right field advantage. Their attempted replication employed a single 1 second ISI which may have been too brief to allow rehearsal effects to differentially interact with classification types.

In their first experiment, high-verbal subjects may have produced a left field effect in NI judgements because of interference arising from greater levels of overlap between NI and language systems, or because a single system was relatively more 'loaded' by rapid rehearsal processes at the relevant ISI's. If this account is valid, then use of longer retention intervals should not materially affect the pattern of results reported in Kroll & Madden's experiment 1, and could possibly result in a clearer left field bias for NI stimuli in an undifferentiated group of subjects.

Since this experiment utilised a single retention interval, only hypotheses 1 and 3 are strictly relevant to this study: The first hypothesis suggests a hemifield by classification interaction with either a left field advantage in PI judgements, or no significant asymmetries, and NI classifications should evidence a right field bias. The third hypothesis suggests the opposite pattern of results with right field advantages being more reliable for PI than for NI classifications.

Method

The general method outlined above was followed with the following features specific to this experiment.

Visual Materials:

Two random number lists were prepared using the randomisation function of UW/cig on the PDP8. These random number lists were used to construct stimulus lists, which determined the order of trial presentation.

On each trial the following sequence of events occurred: S_1 was presented in the centre of the VR14 for three seconds, there was a five second interval during which the screen remained blank, following this a fixation cross appeared in the centre of the screen for 1 second. Immediately on fixation offset S_2 was shown in either the RVF or LVF for 100 milliseconds.

The _S_s all viewed the screen from a distance of 50 cm, distance was controlled by the use of a viewing mask attached to the front of the VR14.

The mask excluded all external light sources, apart from a small (3" x 3") 'window' in the upper side of the mask which allowed some light to be reflected into the interior. This was necessary in order to prevent the formation of bright after-images which pilot work had suggested were a problem.

Subjects:

8 male and 8 female volunteer subjects (_S_s) took part in the experiment. All were right-handed for writing as assessed by verbal self report. The _S_s were all undergraduate students from various departments of the University, their average age was approximately 20 years.

Design:

The experiment was a repeated measures design. The following factors were controlled as between subject factors:-

(1) Sex of _S_

(2) Random list (1 or 2)

(3) Hand x Decision

Each S was given ten practice trials before the experimental series was shown. The inter-trial interval was 3 seconds during the experiment, but variable during practice.

The experimental trials were divided into 8 ten-trial blocks. Ss had the option of a rest pause after any ten trials, all Ss were given a break of between 3 and 5 minutes half-way through the experiment.

The experiment was conducted in the room housing the computer and tele-type. Signals indicating the termination of a ten-trial block consisted of output from the tele-type 3 seconds after the response to the final trial in each block had been given. S was instructed to tell E that a break was required when the tele-type was heard. If no break was requested, E began the next block of trials by restarting the program with tele-type input.

Results:

1. Qualitative

No subject required a rest interval other than that given after the fourth block of trials. All reported that they had not used an anticipatory strategy in dealing with stimuli presented to the RVF and LVF. Several indicated that such attempts had been made during practice, but that this strategy had been rejected when it was realised that this made the task more difficult.

When asked how the letters had been remembered, ten Ss reported that they had named the letters and rehearsed them sub-vocally during the retention interval. The other six Ss were unable to describe any clear, or consistent strategy and just stated that they "had remembered the letters". On prompting they agreed that this involved naming the stimuli.

2. Quantitative

Full tables of ANOVA results are presented in Appendix 1. The statistical analysis followed the general procedure outlined above. The data from response latency and accuracy was submitted to 3-way ANOVAs. The between Ss factor was response laterality, within Ss were visual field of S_2, and classification type (PI, NI, Different).

Accuracy

Preliminary testing indicated Arcsine transformation was necessary. Only one main effect reached significance at $\alpha = .05$, and that was the effect of visual field ($F_{1, 14} = 7.4$, $p < .05$) the mean proportion correct in RVF was .85 in LVF .8. The main effect of classification, and its interaction with visual fields was just short of acceptable levels of significance. (The main effect $F_{2, 28} = 3.13$, $p < .1$, and the interaction $F_{2, 28} = 3.03$, $p < .1$). Since the latter effect was predicted by two of the views outlined in the introduction, it is presented below as Table 5.1.

Table 5.1.

Proportion Correct

		Classification		
		NI	PI	Different
Visual field	RVF	.77	.9	.88
	LVF	.78	.84	.8

Response Latency

Preliminary inspection of the data suggested that there was some degree of inequality in all variances. However, F_{max} = 7.9 which is below the critical level at which distortion may be a serious problem. Thus the data was analysed without employing any transformed scale of measurement.

In this analysis only the classification factor was significant: $F2, 28 = 8.62$ ($p < .01$) subsequent Scheffe comparison indicated that PI judgements were significantly faster than either NI or Different.

Table 5.2.

Response Latency

	Classification		
	PI	NI	Different
Latency (msec)	859	973	1028

The main effect of visual field approached significance ($F1, 14 = 3.71$, $p < .1$), and means mirrored those obtained in the accuracy analysis with latencies to right visual field presentations at 944.7 msec, being 23.3 msec faster than those on the left. There was no evidence for an interaction between classification and visual field in the latency analysis $F2, 28 = 1.3$, $p > .25$.

Exploratory correlational analyses were attempted in order to determine whether the magnitude of the PI advantage bore any systematic relationship to lateral differences in classification. No co-efficient even approach significance, (all r's < .1) even when within domain (speed, accuracy) and across domain data was analysed. In view of the small number of subjects, and the complexity of the NI classification data this result is not particularly surprising.

Discussion

The visual field effects noted in this experiment were quite similar to those reported by Kroll & Madden for their subjects (if these are considered as a single sample for the purposes of comparison). There was a significant right field effect for PI classifications in both experiments and the interaction between classification and visual field was indicative of minimal asymmetries in NI and different classifications.

Although the interaction effect noted in this experiment fell short of conventional levels of significance, acceptance may be justified on the basis of Kroll & Madden's findings. However, they do not report appropriate statistics for any direct comparisons to be drawn, although the similarities in both sets of data are striking.

It might be argued that attentuation of visual field effects for NI judgements was due to artefact arising from 'difficulty' levels: If PI judgements were easier, as the latency data suggests, then NI classifications may have produced a noisier sub-set of data which was less likely to produce visual field differences. Task difficulty could result in increased variance in NI judgements, or more seriously, produce speed-accuracy trade-off which might be obscured by the use of separate analyses, of speed and latency data.

The variance objection may be countered by noting that F_{max} was insignificant for the latency data, and, following ArcSine transformation, was insignificant for accuracy measures also (F_{max} = 3.9). Thus it seems unlikely that this pattern of results was merely a by-product of violating ANOVA assumptions.

Since experimental sensitivity is inherently limited by the use of two dependent variables (unless ANACOVA procedures are applicable) individual laterality patterns in speed and accuracy were examined in order to determine whether minor trade-off effects had affected NI judgements. Although the group means for both speed and accuracy suggested that such a pattern was unlikely, it would be possible for the type of analysis conducted on this data to obscure any trade-off between speed and accuracy which was correlated with task complexity.

4 subjects showed opposite patterns of asymmetry in speed and accuracy for NI judgements. Of these subjects; three were more accurate with left field presentations, and one with right field. The latency differences were small enough to be considered as random error yielding a mean of 10 msec and standard deviation of 6. (To place these discrepancies into perspective, post-hoc testing of VHF differences in NI latency yields a t, df 30 = 1.4, $p > .1$ (1-tailed) with differences between means of 21 msec). The subject showing a right field advantage in accuracy was the

only individual to produce a latency difference which approached the difference between sample means (21 msec) the remaining three might plausibly be considered to show an overall left field bias since their latency differences between the visual fields were 8 msec or less.

These considerations suggest that there is some justification for accepting the visual field x classification interaction as valid, since it cannot be attributed to artefact and since highly similar results have been obtained by other researchers utilising these materials.

Since the 'individual differences' perspective has not been satisfactorily validated with the double letter task, no attempt was made to distinguish ability levels etc. as a function of visual field. An exploratory correlational analysis of the magnitude of PI advantage as a function of field bias for NI and PI judgements was performed, but although these results were insignificant (both r's $<.1$) the limited size of the sample does not permit any conclusions to be drawn with regard to this 'finding'.

Of the hypotheses outlined in the introduction to this experiment, the 'attentional' model appears to offer the most adequate account of this pattern of PI asymmetries. The predictions of the 'classical' processing models (Cohen, 1979; Moscovitch, 1979) are not substantiated by this data.

The hypothesis which was put forward suggested that PI judgements should either show a left field advantage or minimal asymmetries, yet a substantial proportion of the variance~~s~~ in the overall right field advantage was contributed by these classifications. Even if the arguments for acceptance of the visual field x classification interaction which were presented above, are rejected, the data still indicates that PI classifications manifest a reliable right field effect. Thus, there is no evidence for 'bilateral' or right hemisphere processing of these materials.

The suggestion of limited field effects shown with NI stimuli could, in principle, be dealt with by any model permitting structural interference between rehearsal and NI classifications. However, it might be argued that these results were not just 'insignificant' but the product of combining data across individuals with different functional organisation for NI classifications. That is, that a simple 'mechanistic' interpretation in terms of left hemisphere 'interference' would not be appropriate for a group of subjects evidencing the full range of left, right, and no visual field advantages.

There are two arguments which may be put forward against this interpretation: One statistical, and the other based on psychological criteria. On statistical grounds it is quite plausible to consider the varying patterns of visual field differences as the product of random error variance, in the absence of any sound a-priori basis for differentiating between groups of subject. Psychological considerations open the possibility that these varying effects were, perhaps, related to verbal activity, and different levels of 'interference' in individual subjects resulting in the patterms of asymmetry which were shown.

Both arguments are plausible in considering the present set of results. Kroll & Madden's data (as was pointed out in the introduction) is more easily accounted for within an 'interference' than within a structural differences model, since their field effects in NI classifications appeared to bear some correspondence to ISI duration. Neither this experiment, nor the Kroll & Madden study systematically controlled verbal activity during the retention interval, thus no conclusions on the utility of this interpretation may be drawn at the present stage.

The following chapter describes an experiment devised in order to investigate this aspect of task performance in greater detail.

Summary

This experiment obtained a right field advantage for the classifications of double letter stimuli which appeared to be somewhat more pronounced for PI judgements than for NI. This finding conflicts with a straightforward attribution of 'short-term visual memory' to the right hemisphere. The data was more congruent with an attentional model (e.g. Kinsbourne & Hicks, 1978) although the possibility of specialised left hemisphere-visual memory systems cannot be eliminated by this set of results.

CHAPTER 6

Experiment II

This experiment was designed in order to evaluate the role of attentional biasing on the sequential double-letter matching task. Experiment I showed a strong right field advantage in PI classifications and minimal asymmetries in NI judgements which could be interpreted within Kinsbourne's model of attention and interference interactions in the topological organisation of attention. This perspective (e.g. Kinsbourne & Hicks, 1978) would suggest that maintenance of the stimulus materials in memory had activated the left hemisphere, but that there was functional interference between left-hemisphere based short-term memory control systems and NI classification. Activation would benefit PI classifications, but interference would reduce the efficacy of NI judgements presented to the right visual field.

Kinsbourne & Hicks (1978) argue that behavioural interference effects may provide clues towards the structural organisation of language and spatial functions in the brain. Tasks which are mutually interfering may conflict because they draw upon a common pool of neural resources. Demanding tasks which do not produce interference effects may rely upon systems which are well separated in the brain (e.g. may be located in different cerebral hemispheres).

Kroll (1975) and Posner (1978) provide reviews of interference effects in sequential letter classification tasks. For example: Parks *et al* (1972) noted that when subjects were required to perform verbal shadowing in the interval between successive presentations of single letter classification stimuli, this resulted in selective impairment in NI classifications, and a concommitant prolongation of the PI advantage for intervals considerably longer than the 'usual' two seconds (see Chapter 3). Kroll & Parks (1978) have since demonstrated similar effects on NI judgements in double letter classification, shadowing had no influence upon PI efficiency.

These effects are somewhat more complex than they appear upon initial consideration: The double letter task shows a persistence in the PI advantage in the presence of overt verbal rehearsal, thus it is unlikely that concurrent shadowing merely blocks 'naming' systems. Articulatory suppression (see e.g. Baddeley, 1976) which may interfere with output phonology (Besner, 1980) does not affect NI judgements in single letter sequential classification (Ellis, 1980) suggesting that the shadowing data is either indicative of interference between NI and input phonological systems, or may reflect the effects of performance-resource limitations (i.e. is a by-product of task difficulty (Norman & Bobrow, 1975)).

The precise basis of the 'interference' between shadowing and NI judgements is not crucial when considering the utility of this particular methodology for investigating visual field effects. Since PI classifications are unaffected by concurrent verbal activity (e.g. Kroll & Parks (1978)) they should continue to show a right field advantage under shadowing conditions, if 'activation' alone determined their asymmetries in Experiment I.

The evidence on concurrent task performance in lateralised tachistoscopic performance is complex and, often, contradictory. Hellige *et al* (1979) provide an up-to-date review of the area, and Cohen (1979) has discussed their conclusions in some depth. Hellige *et al* (1979) suggest that the left hemisphere operates as a limited capacity processor, since verbal memory loads depressed right field performance, whereas non-verbal memory loads had no significant effects upon 'verbal' or non-verbal tasks. Hellige *et al* (1979) give some discussion to the effects of strategy in coding the tachistoscopically presented material under these conditions, but suggest that these effects were minimal. It was pointed out in Chapter 2 above that Hellige *et al*'s discussion of 'strategy' is marred by failure to control, or even to provide any independent index of 'strategic' variables, either in concurrent task demands or on the criterion visual field effects. There is no clear evidence on the way that their materials were processed under concurrent task conditions. For example, the conditions devised by Hellige *et al* in order to provide greater loads on 'spatial' memory involved prolonged presentation of a single random shape memory stimulus. Such conditions are at least as likely to provide opportunities for verbal recoding as for visual processing and a simplistic 'dual trace' model (visual-right hemisphere verbal-left hemisphere) could account for the non-specific deterioration in performance which they obtained. Furthermore, Cohen (1979) points out that Hellige and his co-workers made no attempt to equate levels of resource demand in 'verbal' and 'non-verbal' tasks, thus casting their conclusions vis the laterality of limited resources into some doubt.

To put this debate into perspective, it is necessary to give some consideration to other work which has addressed the activation-interference issue utilising dual task methodology with lateralised tachistoscopic presentation.

Kinsbourne (1973; 1975) employed concurrent verbal shadowing and has shown a right field advantage for initially 'non lateralised' simple stimuli, and argued that this reflected attentional bias due to 'activation' of the left hemisphere. Gardner & Branski (1976) employed very similar stimuli and shadowing tasks, but were unable to replicate Kinsbourne's findings. They suggested that shadowing had interfered with left hemisphere processing. Geffen _et al_ (1973) also employed a dual task procedure, requiring _S_s to perform a digit discrimination presented visually, whilst concurrently monitoring dichotic digits or music. The verbal dichotic task selectively impaired right field judgements, but it is unclear whether resource demands were equivalent for 'music' and 'digit' tasks. Geffen _et al_ also confounded material similarity between conditions; raising the possibility of 'structural' interference (Kahneman, 1973) in their 'verbal' task.

Hellige & Cox (1976) systematically varied the complexity of a verbal subsidiary task in order to assess the roles of attention and interference. Subjects either retained 0, 2, 4 or 6 nouns in memory whilst performing a random-shape recognition, or verbal recall task presented to RVF and LVF. Intermediate memory loads (2 or 4 items) improved RVF performance in shape discrimination, and both RVF and LVF in word recognition. High levels of interference reinstated a LVF advantage for the shapes, and impaired both fields for the verbal stimuli. There are two difficulties with this study: The first concerns strategy and coding effects and the second relates to the level of cognitive 'interference' produced by the subsidiary task. The latter objection also applies to the Geffen et al (1973b) study cited above.

The clearest evidence for a shift in visual field advantage as a function of concurrent task requirements, in the Hellige & Cox (1976) study was given by the random-shape stimuli, yet these materials have yielded a wide range of visual field differences in various laboratories (see Chapter 2). This suggests that subjects may deal with these stimuli in a number of different ways, but as there is no way in which 'processing' has been assessed independently of visual field asymmetry with these materials a 'coding shift' explanation is quite feasible as an account of Hellige & Cox's findings.

Both Hellige & Cox, and Geffen et al confounded the similarity of their subsidiary tasks with the requirements of their 'verbal' conditions. It is not possible to determine whether the RVF deficits observed were the product of interference with the general level of left hemisphere function, the blocking of one highly specific system, a change in the way that Ss dealt with the tachistoscopic task, or a consequence of increased resource demands during 'structural' interference.

The letter classification task may provide one procedure for evaluating the effects of attentional bias and interference during concurrent task performance. Since PI matches are relatively unaffected by verbal activity during presentation, or retention intervals, then overall performance on these stimuli should be at a comparable level when subjects are required to perform shadowing, or when they are free to rehearse (as in Experiment I above). If performance on these judgements is equivalent under both free (rehearsal) and concurrent shadowing conditions, there are sound theoretical reasons for considering that PI coding is equivalent i.e. that any change in visual field laterality (in direction or magnitude) reflects activation-interference effects, rather than strategy changes.

Cohen's (1979) (highly) 'arguable' point that laterality shifts are equivalent to changes in strategy could, of course, be applied to any 'changes' which were obtained under these conditions. However, for the purposes of the present experiment the more usual functional definition of code will be adopted as an index of 'strategy'. This may be justified by reference to the numerous studies devised in order to determine the isolability of NI and PI codes (see Posner, 1979) which have fruitfully applied this very assumption.

Kinsbourne & Hicks' (1978) analysis of the relationship between behaviourally defined interference effects and those arising from within-hemisphere interactions suggests that if PI coding is unaffected by the shadowing task, a right visual field superiority should be maintained. If, however, the effects observed in Experiment I reflected the operation of left hemisphere visual coding, it is possible that capacity limitations (Hellige _et al_, 1979) would result in diminution of visual field effects for these materials.

The major points made in this introduction may be summarised: (1) The results of Experiment I suggested an activation-interference effect which produced a right field advantage in PI classifications. (2) Behavioural evidence indicates that concurrent verbal activity does not affect PI judgements, but selectively impairs NI classification. (3) The sequential letter matching task operationally defines specific code biases which may have the potential to distinguish strategy from attentional-topological biases. (4) Kinsbourne's model makes comparatively clear predictions on the effects of concurrent task performance where 'coding' and attentional/interference effects are dissociable, i.e. the use of concurrent shadowing during sequential letter classification should enhance the PI advantage for right visual field presentations. (5) Previous work on this topic has failed to control for between task similarities, strategic biases, or levels of resource demand.

It was decided to employ concurrent shadowing with the materials, and retention intervals that had been utilised in experiment 1 in order to determine whether the predictions made on the 'attentional' model would be supported.

The types of coding indexed by the letter classification task are likely to provide a measure of processing shifts under dual task conditions. On an 'overload' hypothesis, it would be predicted that _all_ match types presented to the left hemisphere would be affected; on an interference, or coding shift hypothesis, it would be predicted that NI classifications would be selectively impaired, when presented to the right visual field.

Method

The method used in this experiment was similar to that employed in the previous study. Exceptions are described below.

Auditory Materials

A tape recording of two prose passages was prepared by E. The material was taken from Lorenz "King Solomon's Ring", selected because of its lack of proper names (a factor which had disrupted performance in a pilot study), and for a relatively high information content. The material was intended to be sufficiently complex to demand Ss attention, whilst being of sufficient interest to reduce boredom. The passages were approximately 15 minutes long. Words were read at the rate of 100 per minute, without stress on particular items and at a constant pitch (as judged by E). The tape was prepared in the department's sound-proof laboratory, and was presented to Ss via earphones from a Heathkit tape-recorder with integral amplifier, at 3.5" per second with individually determined levels of balance and volume.

Visual Materials

The same letter combinations and interstimulus intervals were employed as in Experiment 1. New lists were prepared as before, using the pseudo-random number generator of UW/cig.

Subjects

Eight male and ten female volunteers took part in the experiment. All were right-handed for writing, and had no left-handed first degree relatives as determined by self report.

Procedure

The shadowing task was described to Ss. They were asked to attempt to repeat as much as possible of the passage recorded on the tape as it was being presented. Volume and balance were determined for each S at comfortable levels, in each case the sound of the teletype could be distinguished above the level of the passage so that rest periods could be taken when required. Ss were given practice until shadowing was reasonably fluent, this was terminated after approximately five minutes.

S was then instructed on the letter matching task. Ten trials of classification were given without auditory input followed by ten trials under dual task conditions. S was instructed to try to maintain a constant flow of verbal output throughout the experiment, and to regard both tasks as equally important.

Results & Discussion

One of the female subjects had difficulty with the shadowing task and did not complete the experiment. Another female reported that she had tried to predict the visual field of the second stimulus. Her data confirmed this: and was dropped from the overall analysis. All other participants reported that they had maintained fixation throughout the experimental trials.

The majority of the Ss found the dual task tiring and difficult. A fairly constant stream of verbal output was achieved by most of the Ss, but there were occasional breaks, which did not appear to follow any consistent pattern. Several Ss reported that they had become "tired of talking" and during the five-minute rest interval needed to have a glass of water. It seems likely that the 'breaks' which did occur were related to fatigue rather than to material specific problems. Several Ss took advantage of the opportunity for additional rest-breaks at various stages of task performance. No S had more than 2 rest intervals, including the compulsory rest period half-way through the experiment.

Quantitative

Accuracy data was transformed to ArcSin to stabilise variance. This analysis yielded one significant effect, of classification, ($F2, 28 = 17.7$, $p < .001$) all other F ratios were less than two. Preliminary evaluation of the variances in latency yielded an F_{max} of 19.0 which suggests that ANOVA assumptions are likely to be violated ($p < .01$). Inspection of the data indicated that elimination of 'different' classification latencies would result in a more homogenous set: The F_{max} statistic on this subset of the data yields F_{max} 8.7 = 9.8 which is more satisfactory (critical F_{max} at $\alpha = 0.5 = 10.5$). It was determined to perform ANOVA on the untransformed 'same' latencies so as to facilitate comparison with the results of experiment 1 rather than to adopt an ad-hoc scale of measurement. The results of this analysis also indicated that there were significant differences between NI and PI judgements ($F1, 14 = 11, p < .01$). Classification accuracy and latency are presented in Table 6.1.

'Different' judgement latencies were more variable in the group of subjects indicating this response with their left hands (SD RVF = 512, SD LVF = 302) than in those responding with their right (SD RVF = 165, SD LVF = 126) within group comparisons yielded no significant visual field asymmetries the means on different judgements for each group, by visual field, are tabulated in Table 6.2. These figures suggest some spatial response compatability effects, but this is not supported by ANOVA on this data (untransformed) which would probably be biased towards false positive results.

The basis of these effects of variability are obscure, and not readily interpretable within any model of which the author is aware. They do not, however, detract from the findings on 'same' judgements, which from a theoretical point of view are the more crucial in this experiment.

Although the results of this experiment showed a large PI advantage, there was no visual field asymmetry on any measure. Thus there is no support for any hypothesis suggesting that shadowing acted as an activator of left hemisphere-right visual field performance. An 'interference' account appears to be more plausible on the basis of the data presented thus far.

In order to examine these findings in greater detail it is necessary to compare results with those obtained in experiment 1. Despite the difficulties subjects experienced in performing the shadowing task F_{max} comparisons for the accuracy data, and for the 'same' responses were non-significant. The highest value was F_{max} 11.4 for latency which, although high, is insignificant ($p > .05$).

Accuracy

The only effect to reach significance in this analysis was the interaction between experiment and visual field ($F1, 28 = 5.477$, $p < .05$). The interaction between experiment, visual field and classification fell just short of acceptability ($F2, 56 = 3.1$, $p \leq .06$; $F2, 56 = 3.15$). The means for this interaction are shown in Table 6.3. This suggests a tendency for PI performance to become non-lateralised, and a shift in 'different' classifications from right, to left field advantage.

In order to determine the basis of this suggested interaction further analysis was conducted on simple effects for 'same' responses only but there was no indication of a differential effect of shadowing on visual field asymmetry for PI judgements ($F1, 7 = 1$), suggesting that any potentially significant variance component in the interaction was due to a 'shift' in 'different' classifications towards a left field advantage. In view of the large variance in R.T.'s on different judgements in experiment 2, it is not clear that this apparent 'switch' is in any sense a reliable one.

Pairwise comparisons of overall NI, PI, and 'different' judgements indicate a significant difference in NI judgements between experiments ($U = 69$, $p < .01$ 1-tailed), and no reliable effect of shadowing on other classifications (all p's $> .1$). Thus any effect of concurrent verbal activity on classification performance was limited to NI judgements.

Latency

Analysis of the latency data yielded one reliable effect, that of classification ($F1, 28 = 21.6$, $p < .001$). No other values approached significance.

Discussion of Experiments I and II

In summary: there was reliable evidence for visual field asymmetries when subjects were free to engage in rehearsal, which was attenuated under concurrent shadowing conditions. This atten uation does not appear to be the product of low experimental sensitivity, since the effects were shown in combined analysis of both experiments I and II as a significant loss of visual field asymmetries in Experiment II.

Consideration of the (somewhat unreliable) interaction between visual field, classification, and experiment suggests that 'different' classifications were largely responsible for the attentuation which was observed, and since the types of strategy which may be applied to such classifications is not clear from this study, it is quite possible that a shift in the way that these stimuli tended to be processed could account for the suggested shift in laterality patterns.

General Discussion

Despite evidence for a differential effect of shadowing upon NI classifications, there was no indication of an interference-enhancement interaction between visual field, classification type, and concurrent task in this experiment. Rather, the evidence tends to support a general capacity limitation effect from shadowing which is principally confined to right visual field performance.

Kinsbourne & Hicks'(1978) model would suggest that highly specific interference effects, such as those shown between NI judgements, and concurrent shadowing would result in selective effects on the laterality of NI classifications, shadowing would be expected to interfere with left hemisphere performance of those judgements, but to facilitate right field presentation of PI classifications. This prediction was not supported.

Problems arise, however, in interpreting the specificity of shadowing effects. Although Posner (1978), Kroll (1975) and Kroll & Parks (1978) suggest that mutual interference between shadowing and NI classification (a) provides convergent validation for the isolability of NI and PI functional systems and (b) indicates that NI judgements reflect phonemic processing there are alternative explanations.

The most important consideration is derived from the work of Norman & Bobrow (1975), on resource limited and data limited processes. Essentially, Norman & Bobrow point out that restriction in processing resources (as for example when arising from dual task demands) is more likely to affect the more complex task of a two task set. The function describing performance-resource relationships is assumed to be monotonic and incremental to asymptote, but the rate at which functions accelerate, may be shown to differ as a product of task complexity. In the present case of shadowing a non-specific limitation in resource availability could result in apparent decrement in the more complex NI classification task which need not be indicative of differences in the systems mediating NI and PI judgements, and need not suggest similarities in systems mediating naming-rehearsal and 'name matches'.

To return to the implications of the present findings for the 'attentional' model of visual field effects: The data indicate that shadowing does not activate left hemisphere-right visual field biases, and possibly interferes with left hemisphere processing. However, it leaves open the possibility that rehearsal may produce activation effects because some crucial threshold for activation/interference has not been crossed.

These considerations highlight the problems inherent in dual task methodology as an approach to visual field differences. Whilst the attentuation of an established visual field difference may be taken as evidence for specific forms of interference, the exacerbation of visual field effects, in the absence of evidence for strategy changes may not have much to say about 'attentional' interactions. Such effects may merely reflect performance-resource limitation with the initially 'impaired' visual field becoming more impaired as general levels of resource are constrained. A simple model of this form could quite easily account for the majority of 'activation' effects which have been reported in the visual field asymmetry literature, without the need to adopt complex structural-anatomical or lateralised 'capacity' restriction accounts (e.g. Hellige et al, 1979).

Dual task studies are not the most straightforward techniques for evaluating laterality effects. In order for a definitive enquiry it would be necessary to stabilise processing strategies on left, right, and non-lateralised tasks, of equated difficulty, and to combine these factorially with a range of subsidiary tasks having a common difficulty/complexity metric. The problems posed in the development of such an enquiry are formidable, and hence were not pursued in this project.

In conclusion: The results of experiments I and II indicate that sequential double letter matches may produce a right field advantage when subjects have sufficient time for rehearsal, and that this effect is only slightly attenuated by the interference from concurrent verbal shadowing. There was no support for a model attributing the processing of PI judgements to the right hemisphere, rather, left hemisphere function was suggested by the results of experiment I and a degree of bilateral mediation by those of experiment II even though performance on PI judgements was equivalent in the two investigations.

TABLE 6.1

Results of Experiment II

	Accuracy and Response Latency	
	Accuracy	R.T.
NI	.68	1250
PI	.868	915
Different	.82	1030

TABLE 6.2

Results of Experiment II

	Different Judgements - Mean and (S.D.)	
	RVF	LVF
Right Hand = Different	912 (165)	1017.5 (126)
Left Hand = Different	1206 (512)	990 (302)

TABLE 6.3

Proportion Correct - Experiments I and II

	I (Free Rehearsal)		II (Shadowing)	
Classification	RVF	LVF	RVF	LVF
PI	.9	.84	.862	.875
NI	.77	.77	.63	.618
Different	.88	.8	.79	.85

CHAPTER 7

Experiment III

The results of the first two experiments did not support a model mapping the systems mediating PI classification to the right hemisphere. There appeared, instead, to be some flexibility since despite comparable levels of performance a right field advantage, and no asymmetry were observed.

In chapter 3, it was pointed out that Wilkins & Stewart's (1974) findings were also incompatible with this particular 'right hemisphere' hypothesis since although temporal alteration in visual field asymmetry were noted, with left field superiority in PI stimuli changing to an overall right field advantage, this occurred in the presence of name-level biases in half their subjects. A clarification of the basis of the hemifield x ISI interaction appears to be required.

It might be argued, for example, that their classification asymmetries reflected the development of memory codes which were not indexed by the relative advantage of PI : NI classification. Two stages might be suggested: The first, concerned with the perceptual, pre-categorical analysis of S_2, and the second concerned with retention of an increasingly sophisticated memory code which was based in the left hemisphere. Matching at brief ISI's might be mediated by 'template' correspondences between PI stimuli, which, if early perceptual analysis was right hemisphere based, would perhaps, result in a left field advantage. NI matches would have to utilise whatever information had been generated during perceptual processing to be analysed as categorical equivalents to the PI materials. Once early processing was complete, however, all matches could be based upon left hemisphere 'categorical' information, resulting in a right field advantage.

Although this model is highly simplistic (and by no means a full account either of visual field effects or asymmetries in 'Posner' tasks) it serves as an initial approximation to the type of account which might be able to 'explain' Wilkins and Stewart's results.

Kirsner (1979) has recently reported an attempted replication of Wilkins & Stewart, he obtained no asymmetries at 50 msec, and a right field advantage at longer retention intervals. However, as was pointed out in chapter 2, prolonged exposure durations of test stimuli may have produced anomalous results. Furthermore, his task resulted in somewhat different stimulus onset asynchrony times from Wilkins & Stewart, thus the possibility of asymmetries at very brief ISI's cannot be ruled out.

Kroll & Madden (1978) report overall right field advantage for NI and PI judgements in double letter stimuli at ISI's of 500 msec. Their data also leave open the possibility that asymmetries may vary as a function of ISI, when brief retention intervals are considered.

Research into asymmetries in early visual processing has occasionally supported this perspective. Masking studies tend to suggest left field advantages with brief intervals between target and mask (stimulus onset asynchrony - SOA) (Hellige & Webster, 1979, for example, see chapter 2 above) although there is some contradictory evidence (Moscovitch, 1979). Bryden & Allard (1976) suggest right hemisphere involvement in processing more complex type faces, as does Brooks (1973). Studies of retention interval effects have yielded complex, and often contradictory data. Moscovitch et al (1976) explored the effect of retention interval upon face recognition, and obtained left field advantages with 50 msec SOA's but not for shorter intervals. Their study also employed extremely long lateralised presentation times (300 msec) so it is not clear whether these findings can be directly compared with other investigations of visual field asymmetry. Studies employing other 'non-verbal' materials have yielded inconsistent results, and have been concerned with intervals considerably greater than those employed by Wilkins & Stewart (e.g. Dee & Fontenot, 1973; Honda, 1976).

The following experiment was devised in order to investigate the possibility of temporal changes in visual field asymmetry for double letter classifications employing retention intervals comparable to Wilkins & Stewart's. Since these materials yield a stable PI advantage, and one which is replicable under lateral presentation conditions, they provide a procedure whereby time based processing asymmetries may be evaluated independently from those involved with code alteration, as defined by the relative advantage of PI classifications.

Method

The method employed in the study was similar to that described in the 'General' section, but modifications had to be introduced in order to permit the investigation of brief retention intervals.

The stimulus materials were the same as in the previous studies, but order of presentation was changed in order to eliminate backward masking effects. On each trial the fixation cross appeared for 100 msec, after an interval of 100 ms. S_1 was shown in the centre of the screen. Following retention intervals of either 50ms or 990 ms (adopted from Wilkins & Stewart, 1974) S_2 was shown for 100 ms in either the RVF or LVF.

Order of trial presentation was determined by computer generated pseudo-random numbers. In order to eliminate any possible artifact from particular sequences of trials, these lists were given so that no two subjects within any of the experimental counterbalancing procedures received the same ordering of trials. No record was kept of the number of lists generated for this experiment. If a new sequence was required by a particular S, in order to prevent a duplication of lists within any particular condition, it was generated by the computer before that S performed the experiment.

Each S performed two blocks of 80 trials, within each block the retention interval was a constant 50 ms or 990 ms. Order of blocks was counterbalanced, half the Ss receiving the 50 ms condition first, and half the 990 ms, within conditions of response lateral-mapping and sex of S.

Sixteen student volunteers participated in the experiment, 8 male and 8 female. They were recruited from undergraduates and postgraduates in the Psychology department.

On arrival at the laboratory _S_ was given general instructions for performing the matching task. The importance of fixation was emphasised, and it was suggested that _S_s should aim to be focussing on the centre of the fixation cross whenever it was shown.

_S_ then performed 10 practice trials with an ISI appropriate to the first block of the experimental sequence. The experimental series was given without a break. On completion of the first block _S_ had a break of approximately ten minutes. During this time the computer was re-loaded with another random ordering for the stimulus materials. A print-out of the results of the first series was given by the teletype, but no specific feedback was given on performance all _S_s were told that they were "doing well", but reminded to continue to work as rapidly and as accurately as possible in the second block. Comments on _S_s strategy in performing the task were collected by _E_ at this stage.

Following this break _S_s were given 5 practice trials at the interval appropriate to the second block, (described as 'faster' or 'slower') and then completed the experimental sequence.

Results

(a) Qualitative

_S_s reported that they had been able to maintain fixation at the centre of the screen. When asked to comment on how they had performed the task the majority reported naming the letters, at the 990 ms ISI, and attempts to name them at 50 ms. The majority of _S_s were aware of errors that had been made in performing the task, these appeared to be due to speed-accuracy tradeoff, response anticipation, and difficulties in response selection.

(b) Quantitative

The data was submitted to ANOVA's as in the previous experiments. Since the possibility of fixation bias or 'scanning' arises with this presentation sequence, different classifications were subdivided into two categories (1)where the letter changed was on the right of S_1 (D_R) and (2) where it was on the left (D_L).

(i) Accuracy

There were two main effects significant at $p \leq .05$. The LVF was inferior to the RVF ($F1, 14 = 5.3$, $p < .05$) and NI classifications were inferior to either PI or different ($F3, 42 = 7.5$, $p < .01$). Visual field and ISI interacted ($F1, 14 = 4.6$, $p < .05$), the means for this effect are shown in Table 7.1. Visual field and classification also interacted ($F3, 42 = 4.6$, $p < .01$). This interaction is shown in Table 7.2.

(ii) Response Latency

Prior F_{max} tests indicated that between groups variances were stable (F_{max} 1.329 n.s.) as were between classification variances within groups (F_{max} 5.7).

The main effect of classification was significant and mirrored the pattern found in the accuracy analysis ($F3, 42 = 13.23$, $p < .001$). There was a three-way interaction between lateral mapping of response output, visual field, and classification ($F3, 42 = 5.19$, $p < .005$) which is presented in

Table 7.3.

No other effects reached significance.

Discussion

PI judgements were uniformly more accurate, and faster than NI in this experiment; the relative advantage of PI classifications did not vary as a function of ISI yet the data indicate some alteration in visual field asymmetry as retention interval was prolonged.

Prior to discussing these effects in detail, it is necessary to give some consideration to the relationship between speed and accuracy measures in this study. The means for visual field conditions were comparable in direction for both latency and error data; both analyses yield significant right field advantages across all conditions. However, the latency data produced one interaction which was not apparent in accuracy measures, that of response laterality, visual field, and classification.

This effect was a complex one, but the following features appear to be relevant: Subjects responding 'same' with their right hands showed right field advantages in PI judgements, but left field advantages in NI classification. left hand same subjects showed the opposite, and almost identical pattern of asymmetry. This effect might either reflect interference between output and processing demands, or an interaction between task complexity and S-R compatibility. The latter appears to be suggested by responses to 'different' judgements: Left-handed output produced relative advantage when the stimulus contained a distractor on the left of the array, right-handed output equivalent, but opposite results.

An alternative interpretation might be cast in terms of 'scanning' preferences interacting with output-processing demands. The data do not allow these accounts to be differentiated, although on the grounds of parsimony, the 'compatibility' account appears to be the more plausible.

This interaction does not materially affect discussion of the other results on visual field, ISI and classification factors, since the results tend to cancel each other out across lateral-output conditions leaving a small right field advantage overall. Thus in dealing with the accuracy data it is feasible to consider the latency data as indicative of minimal visual field and ISI effects, and to discuss patterns of error from an 'efficiency' perspective.

The interaction between visual field and classification indicated an overall right field advantage for NI judgements, and bilateral PI classification. Different judgements were indicative of considerable peripheral-central differences in the right visual field, but of no distractor location effect with left sided presentations. This result might be interpreted in terms of asymmetries in the representation of S_1. Memory stimuli were shown in the centre of the screen for a short time, and may have been 'lateralised' at input. If there were deficiencies in transfer from the right hemisphere to the left, then low accuracy would be expected for D_L stimuli shown in the right visual field. An alternative, but at least equally, plausible interpretation would be to account for these findings in terms of lateral masking within the test stimulus array. Polich (1978) reports comparable visual field asymmetry results for a range of stimuli, which may be indicative of right hemisphere superiority in early visual analysis. Retention interval effects suggest that memory coding was not lateralised in this manner, suggesting that there may be differences between input coding and retention interval asymmetries. These possibilities will be explored in subsequent experiments.

A right field advantage was obtained at the brief (50 msec ISI) for all stimuli. This finding stands in contradiction to Wilkins & Stewart's (1974) results which showed left field advantages at this interval. This discrepancy might be due to a number of factors: (i) 'Bilateral' presentation of memory stimuli might have induced a left hemisphere advantage in input processing resulting in early advantage when tests were presented in the right visual field (ii) The time structure of the task might have been of importance: Wilkins & Stewart employed variable ISI's, and it is possible that factors such as alertness or the detection of stimulus onset were of some importance in producing their lateral asymmetry effects (iii) Double letter stimuli appear to involve somewhat different memory systems from single letters (as seen in the different effects of ISI or latencies to classification of PI and NI stimuli) and the anatomy of such systems may be organised somewhat differently.

The right field advantage obtained in experiment 1 after 9 seconds would have led one to anticipate comparable field asymmetries after an ISI of 990 msec yet this experiment suggested an attentuation of visual field differences as the interval was prolonged. This may reflect interference between naming, as a preliminary to rehearsal, and left hemisphere function (see e.g. Kirsner, 1980).

Summary and Conclusions

Despite some complications in the interpretation of latency data this experiment indicated that at brief retention intervals PI judgements were based upon bilaterally organised systems. NI judgements produced a reliable right field advantage suggesting left hemisphere involvement. Different judgements gave no conclusive evidence with regard to 'scanning' biases, and suggested that either interhemispheric transfer or lateral masking effects had been involved.

Wilkins & Stewart's (1974) retention interval effect was not replicated, and there were indications that, for these materials, the right field advantage might be attenuated by 990 msec, possibly as a by product of rehearsal initiation (Kirsner, 1980).

It was determined to investigate the effects of ISI irregularity on lateral asymmetries on this task in order to provide a closer analogue to the Wilkins and Stewart (1974) investigation.

TABLE 7.1

Visual Field x ISI Interaction

Proportion Correct

ISI	Visual Field RVF	LVF
50	.81	.74
990	.84	.84

TABLE 7.2

Visual Field x Classification

Proportion Correct

Classification	Visual Field RVF	LVF
PI	.84	.84
NI	.79	.65
D_R	.87	.83
D_L	.78	.82

TABLE 7.3

Response Latency

Visual Field x Responding Hand x Classification

Hand	Classification	RVF	LVF
Right	PI	526	575
Right	NI	615	594
Left	D_R	670	725
Left	D_L	644	699
Left	PI	591	546
Left	NI	634	670
Right	D_R	667	665
Right	D_L	686	691

CHAPTER 8

Introduction

Wilkins & Stewart suggested that in sequential letter classification, the right hemisphere had access to a preliminary non-verbal code, which was superseded by 'verbal' coding in the left hemisphere. The preceding experiments did not support this model since despite the presence of large and reliable physical match advantages, there was no suggestion of a significant left-visual field bias. Such an effect would be expected from theoretical perspectives which emphasised either processing, or temporal variables as determinants of hemisphere functional asymmetries, and would, most certainly be predicted by the 'preliminary non-verbal code' model put forward by Wilkins & Stewart.

As was pointed out in Chapter 3 (above) there were quite serious problems in interpreting Wilkins & Stewart's data, perhaps the most serious being the lack of correspondence between response latency and accuracy measures. Their response latency analysis indicated higher level interactions, which were somewhat obscure, and tended to contradict their 'accuracy' patterns with respect to visual field effects.

Wilkins & Stewart argued that these results were possibly an artefactual by-product of violating the within cell 'equality of variance' assumptions of ANOVA. Unfortunately they did not present evidence based upon data transformed to meet ANOVA assumptions, so it is unclear whether this aspect of their findings was spurious, or evidence for speed-accuracy tradeoff.

It would, however, be premature to reject Wilkins & Stewart's data as 'unreliable'. The evidence presented thus far rests on tasks which differ in several respects from the single letter sequential classification conditions utilised by Wilkins & Stewart, so the possibility remains that a time course in lateral asymmetries may be obtained which parallels their results. At this stage in the presentation of this thesis, the evidence simply suggests that neither the general type of memory code, nor the level of its 'development' in time can be the sole determinant of a shift from right to left hemisphere 'dominance' in the letter classification task.

Wilkins & Stewart employed variable (and unpredictable; Wilkins pers. comm., 1977) retention intervals which may have affected the processing systems involved in task performance. The discussion in Chapter 7 emphasised one possible source of variance, namely the detection of stimulus onset, several other alternative hypotheses might also be advanced. For example, there may have been differences in the way that subjects performed classification judgements when variable ISI's were used.

Posner _et al_ (1969) suggest that there are no effects of time structure on stimulus coding, but this earlier evidence was based upon centrally presented stimuli, and variability in stimulus onset times, rather than upon conjoint variation in ISI and onset asynchrony as employed by Wilkins & Stewart.

The importance of ISI predictability was explored in the following pilot experiment. It was considered as a potentially relevant aspect of Wilkins & Stewart's methodology for two major reasons. Firstly, Wilkins & Stewart presented the first (and only) published evidence for an extremely early disadvantage in PI classification, which attenuated over time. This pattern of results (albeit within only half of their subject group) may be indicative of 'strategic' complications under variable ISI conditions. Secondly, the possibility arises that variable ISI's may change the relevance of S_1 in the classification task. Two principal functional attributes of the first stimulus in sequential classification have been discussed by Posner and his colleagues (e.g. Posner, 1975; Posner & Boies, 1971). (a) S_1 functions to provide information on which subsequent classifications are based, and (b) It serves as a warning stimulus, or temporal cue preparing the subject for subsequent response output.

Under blocked ISI conditions these two attributes of S will be combined: Input to the memory systems will occur in parallel with increasing facilitation of decision and response systems. Posner's (1975) model would predict an advantage for briefly presented stimuli which were input to channels more prepared for response and decision, and a somewhat speculative corollary of this view might predict right visual field advantages when the left hemisphere was more 'alerted' as a result of a 'verbal' warning signal (e.g. Bowers & Heilman, 1976).

With variable ISI's however, S_1 ceases to be a valid cue for response output, and evidence from simple R.T. studies (e.g. Näätänen *et al*, 1977) indicates that ISI duration becomes the functional preparatory cue. Naatanen and his colleagues have shown, for example, that the subjective probability of S_2 presentation increases over the apparent range of ISI's, and that latency decreases as a function of subjective expectation of the inoperative stimulus. Thus, blocked and variable ISI tasks may differ in their patterns of lateral asymmetry over time as a consequence of the alterations in the functional warning signal for response output; for blocked ISI's S_1 performs the functions of an alerting signal, whereas when ISI's are variable, the cues for response preparation may be internally generated, and be more closely related to estimates of the probability of S_2 presentation as the ISI is extended.

Thus it seems possible that such functional differences may be involved in the time-course(s) of lateral asymmetries. The following experiments were devised in order to explore these ideas.

Method

The procedure employed in this experiment differed from that of experiment III in the following manner:

A single list of eighty experimental trials was employed and the program controlling presentation was altered so that 40 trials at 990 msec ISI, and 40 at 50 msec could be given. These intervals were adopted from Wilkins & Stewart (1974). Within each ISI subset, PI, NI, D_R and D_L stimuli were equiprobable, five trials within each condition occurring in each visual field. Particular S_1 - S_2 combinations were presented twice at one ISI, with S_2 being shown once to the right and once to the left visual field. No combination of S_1 - S_2 was presented more than two times in the total 80 trial series: half the Ss received an arbitrarily selected subset of 20 S_1-S_2 stimulus combinations with 50 msec retention intervals, the remaining subjects matched these stimuli following a 990 msec ISI.

The pseudo-random number generator of UW/cig was employed to randomise visual field of S_2 ISI, and match type. Each subject received a different randomised ordering of the 80 trial series following practice.

The subjects were all recruited from the VIth form of a neighbouring school (Wiggeston Boys School, Leicester). In order to obtain sufficient subject numbers for this investigation right-handed subjects were asked to volunteer in order to win a prize of £5 which would be given to the fastest and most accurate subject. 22 Ss volunteered. As a precautionary measure, handedness data was collected prior to subjects participating in the experiment (Edinburgh Handedness Inventory).

Results

Two Ss data was rejected because they were left-handed for writing and several subsidiary skills, although describing themselves as "mostly right-handed". No further analysis of the inventory data was performed. The majority of Ss reported that they found the task "quite easy" but did not describe any systematic strategy in remembering the stimuli. Somewhat surprisingly only 4 subjects commented upon the irregular ISI conditions, the remainder were apparently unaware that this manipulation had been employed.

Quantitative Analyses

All subjects reported maintenance of fixation but the variance in individual Ss R.T.'s was large. Despite these problems, it was determined to analyse results in a manner similar to that described in the 'general method' section above and to treat this experiment as a pilot study, rather than as a definitive investigation.

Accuracy:

All data was submitted to ANOVA of the same design as experiment III. The effect of classification, and its interaction with ISI was reliable ($F_{3, 54} = 3.14$, $p < .05$ and for the main effect, $F_{3, 54} = 2.8$, $p < .05$ (Table 8.1).

The main effect of visual field approached, but did not achieve conventional levels of statistical significance ($F_{1, 19} = 3.9$, $p < .1$). RVF trials tended to be more accurate with 77% correct than LVF where 68% were correct.

Response Latency:

Prior F_{max} tests indicated that homogeneity of variance assumptions were violated. Variances for the classification factor were ordered PI NI Different. Since the most theoretically relevant comparisons were within 'same' and 'different' classifications separate analyses were conducted on this data. Analysis of different judgements yielded no significant main effects or interactions (all F's < 2). ($\bar{x}$ DR = 1012 msec, S.D. 351 msec $\bar{x}$ DL = 998 msec S.D. 310).

Analysis of same judgements yielded no significant effects or interactions with response-output conditions hence the data was collapsed on this factor. This analysis yielded a significant effect of visual field ($F_{1, 19} = 5.03$, p .05) with mean R.T. to RVF trials at 873 msec and LVF 910.5 msec. This analysis also indicated an interaction between classification and ISI ($F_{1, 19} = 5.03$, $p < .05$), the main effects of classification ($F_{1, 15} = 29.17$, $p < .01$) and ISI ($F_{1, 19} = 5.88$) were also reliable. These results are shown in Table 8.2.

Discussion

Due to the difficulties presented by the variability in individual Ss performance, the results of this experiment need to be treated with some caution. It is probably most suitably considered as a pilot investigation, from which some interesting effects appear to have emerged.

(1) Cognitive Variables

The trend of response latency and accuracy measures over the two ISI's employed was not comparable to the findings from variable foreperiod - simple R.T. experiments discussed in the introductory section of this chapter. Performance was best at the shortest ISI, rather than the longest, as would be anticipated on the basis of Näätänen's work. It is not clear why this difference emerged, although at least two major reasons might be suggested. (a) The choice R.T. task employed in the present experiment might have made different demands on the systems mediating alertness and preparation to those entailed in simple R.T. investigations and (b) the use of incentive may have contaminated any expectancy effects by establishing a high level of tonic alertness.

An important source of the relative impairment in performance at the 990 msec ISI appears to have been the slowing of PI classifications. This shift away from an overall PI advantage was totally unexpected. Whilst it is possible that the decline in PI effects was analagous to the 'loss of visual memory' obtained in single letter match experiments, and that this decline was a product of the variable ISI manipulation, the aforementioned problems with the data obtained in this study indicate that it would be desirable to replicate the effect with a larger number of Ss, and preferably without the contamination of an 'incentive' condition.

There was some indication of a criterion shift over ISI's in the accuracy analysis, both forms of 'same' judgement were improved, whilst different classifications were impaired at the 990 msec ISI. However, a straightforward change in (beta) could not be the only basis for this result, since D_R performance was selectively impaired, and NI judgements benefitted more than PI. There are no models suitable for accounting for this result, and any further interpretation would be purely speculative.

(2) Visual Field Differences

An overall right field advantage was apparent in the analysis of 'same' judgements, suggesting that the left hemisphere was involved in the processing of stimulus materials. Due to the high variability in latency shown by many Ss the possibility of an anticipatory strategy favouring the RVF cannot be eliminated. However, the general pattern of results does not appear to conform to that which would be predicted on the basis of such an anticipatory bias. The deficit in D_R classifications at 990 msec intervals indicates that at that ISI, Ss were not tending to look towards the right side of the display screen. Furthermore, there was a small, and insignificant trend towards a specific deterioration in LVF performance at the 990 msec interval ($F_{1, 18} = 2.6$, $p > .1$) suggesting that if an anticipatory strategy was involved then D_R materials would be 'boosted', rather than impaired specifically at 990 msec. The means for this interaction are presented in Table 8.3.

This effect bears some resemblance to the findings of Wilkins and Stewart (1974) and whilst it is tempting to infer that it suggests that increasing verbal emphasis on stimulus materials led to visual field asymmetries becoming more marked at the 990 msec interval, the interaction is not sufficiently reliable to allow such an inference to be drawn. Nevertheless, it provides some evidence contradicting a straightforward 'anticipatory bias' explanation of the field effects which were shown, and suggests that time structures may be of relevance in considering lateral asymmetries in this task. However, the visual field differences in this experiment appear to be most adequately accounted for in terms of the involvement of the left hemisphere in analysis of the materials at both ISI's.

General Discussion

No straightforward comparison can be drawn between the findings of the present experiment, and those of studies I - III above, because several independent variables were changed between the earlier investigations and this experiment. It is possible that the composition of the subject group may have been of importance, or that the 'incentive' manipulation somehow altered Ss strategy in dealing with the letter matching task. Subjects, and incentive conditions were altered in this experiment in order to permit research to be conducted after the undergraduate term had finished. With hindsight it was realised that this might affect comparability with the other experiments reported in this thesis, and hence it was decided to employ student volunteers consistently in subsequent experiments. These potential sources of difficulty will be briefly considered below.

1. The subject group was drawn from a less highly selected population in terms of verbal ability - namely potential university candidates, rather than selected university students. This variable would have been unlikely to lead to the change in emphasis from visual to verbal aspects of the stimulus material which was noted above, since Kroll & Parks (1978) have shown that (university) Ss scoring high on a measure of verbal ability were more likely to produce small PI advantages, thus tending to contradict a hypothesis 'explaining' the PI decline on the basis of sample composition.

The right field advantage might have been enhanced by the utilisation of a low verbal ability all male group, since there is evidence to suggest that for males language is less 'bilaterally' represented than for females. With this hypothesis in view, the data from the previous experiments was re-analysed, with sex of S as a blocking factor, but no main effects or interactions with this variable emerged. The size of the subject groups in the previous studies was not really adequate for a powerful test of a 'sex difference' hypothesis and hence no firm conclusions can be drawn on this matter.

2. Incentive

There have been no systematic investigations of the role of incentive in the sequential letter matching task. A survey of the literature pertaining to this 'paradigm' reveals that Posner and his associates commonly employed feedback of results following each matching trial, a manipulation which may have incentive-like effects (Broadbent, 1971). However, there is no clear evidence relevant to the letter classification task which permits a clear evaluation of the possible effects of 'incentive' under these conditions. However, it is conceivable that these conditions resulted in subjects becoming strategically biased towards processing the NI attributes of the stimulus materials.

Summary

The results of the present experiment indicated that the PI advantage for double letter stimuli was less stable than had been noted in studies I - III. Whilst the manipulation of temporal uncertainty with respect to S_1 presentation may have been of importance there are two alternative sources of the effect: subject population and incentive which may have been of relevance.

An overall right field advantage was noted, and a small interaction between visual field and ISI suggested that the left hemisphere was involved more than the right possibly as a consequence of increasing 'verbal' emphasis on the stimulus materials. Due to the high variability in individual Ss response latencies some form of anticipatory spatial strategy was considered possible, but did not appear adequate to account for the general pattern of results.

The difficulties noted with the data for this experiment indicate that it should be considered as a pilot study, rather than offering conclusive evidence either on the cognitive or hemisphere factors of interest in this thesis.

Experiment V

In the previous experiment the PI advantage was less stable than in other studies which have employed this type of stimulus material. The basis for a possible 'decline in visual memory' was not entirely clear since the conditions of experiment IV differed in two major respects from those of the other experiments which have been reported in this thesis, namely in the composition of the subject group, and in the use of incentive. The following study was devised in order to test the hypothesis that time structure, rather than the aforementioned variables was responsible for the instability of the PI effect.

Method

Since overall accuracy was so poor in the previous experiment it was considered desirable to reduce the visual angle subtended by the stimulus materials. Ss were seated at a table and viewing distance was constrained by the use of a chin-rest placed 1 metre away from the free-standing VR14 screen. Screen and table were arranged so that the centre of the chin-rest was horizontally aligned to the centre of the screen (the floor of the lab was marked so that necessary adjustments could be made before each S took part in the experiment). In order to control for postural variability Ss were asked to adjust the chair so that the fixation cross was central in their field of vision. The vertical height of the chin-rest was also modified (if necessary) at this stage.

The apparatus was positioned so that Ss back was to the experimenter. There were no objects in the immediate vicinity of the VR14 screen which was situated underneath a window completely covered by a light excluding matt-black blind. All main lights in the laboratory were extinguished after general instructions on task performance had been given, and prior to presentation of sample stimuli and practice trials. Background lighting was dim, provided by the console of the PDP8-E. (No detectable variation in illumination was cast on the VR14 screen by this small amount of background luminance).

Stimulus lists, and the structuring of ISI and trial presentation was identical to that employed in experiment IV.

Forty Ss were recruited on a volunteer basis from amongst undergraduate and research students at the University of Leicester. All were right-handed for writing (assessed on self-report). Twenty Ss were male, twenty were female.

Results

(i) Qualitative

Questioning the Ss revealed a degree of awareness of the variable ISI condition. All Ss were aware of at least some of their errors, and made quite good informal estimates of performance. When asked how the stimuli had been retained the majority claimed to have named them "when there was sufficient time to do so". All Ss reported maintenance of fixation as instructed, although standard deviations for latency tended to be somewhat greater than in previous experiments.

(ii) Quantitative

The overall pattern of Ss responses included occasional long R.T.'s. No S evidenced a combination of extremely brief and long latencies which would have been indicative of anticipatory strategies. An arbitrary criterion of 1500 msec was selected as a cut-off point for data to be entered into the latency analysis. Since both latency and R.T. were analysed, this procedure would not result in the absolute loss of any data. Peripheral causes of long R.T.'s might be assumed to have a random distribution (e.g. inflated latencies due to Ss blinking at an inappropriate time) and additional error variance would reduce the power of the ANOVA procedure.

(a) Accuracy

Sex of S was included in the accuracy analysis since it was considered that an N of 20 per group was suitable for a test of this factor. No significant main effects of sex or interactions were obtained. Two main effects were significant - interstimulus interval $F_{1, 36} = 4.9$, $p < .05$ and classification $F_{3, 108} = 22.8$, $p < .001$. Their interaction was also significant $F_{3, 108} = 2.78$, $p < .05$, and is presented in Table 8.4.

(b) Response Latency

Prior tests of within cell variance did not indicate any significant departures from ANOVA assumptions. The same factors were included in this analysis as in the accuracy ANOVA. The main effect of classification was highly reliable $F_{3, 108} = 26.9$, $p < .001$, as was that of ISI ($F_{1, 36} = 14.9$, $p < .001$). The interaction between ISI and visual field was also significant $F_{1, 36} = 7.1$, $p < .05$ and is shown in Table 8.5. Sex of S entered into a 3-way interaction with visual field and classification ($F_{3, 108} = 3.9$, $p < .05$) shown in Table 8.6. Visual field also interacted with hand of response and classification $F_{3, 108} = 3.9$, $p < .05$ as shown in Table 8.7.

Discussion

(1) Cognitive Variable

The decline in the relative advantage of PI judgements observed in experiment IV was shown in the accuracy data of this study. Judgements of NI, D_R and D_L improved as the retention interval was extended, but PI judgements were a mean 3% worse. Both the evidence for a specific deterioration in PI classifications, and the indication of somewhat different main effects of ISI, between this study and experiment IV suggest that these results were not merely an artefact of task difficulty, but represent alterations in the manner that stimuli were coded as the ISI was extended. Were they due to performance-resource artefact, then the pattern of NI facilitation would be expected to follow the same trend as did the ISI effects, namely an advantage at brief ISI's in experiment IV, and at longer intervals in experiment V. Since this did not occur then it is reasonable to conclude that coding changes may be obtained with double letter stimuli under variable ISI conditions. No sex differences were obtained on coding measures, eliminating the possibility that this variable was of relevance (as had been suggested in the discussion of experiment IV).

Kroll and his colleagues (op cit) have not reported data on the effects of ISI regularity in the double letter matching task. Kroll & Madden (1978) employed variable ISI conditions, but made no reference to coding interactions, suggesting that there were no trends such as those noted in these experiments.

This evidence appears to raise some problems for the 'difficulty in visual generation' hypothesis advanced by Parks & Kroll (1975) as an account of PI persistence in the double letter task when prolonged ISI's are employed. The present study yielded comparatively small advantages to PI judgements overall (55 msec) despite the use of a comparatively demanding set of conditions. If persistence in the PI advantage following long retention intervals was due to capacity limitations, as Parks & Kroll have suggested, then it seems paradoxical that increasing the complexity of task demands should make visual generation 'easier'.

Parks & Kroll's hypothesis might be rescued by suggesting that variability in the duration of the retention interval had provided an incentive, for subjects to engage in visual generation, which was somehow able to compensate for overall capacity limitations experienced when regular ISI's were employed. This possibility will be explored in subsequent experiments.

The results of these experiments do not indicate independence between coding and alerting functions of S_1, as was suggested in the introduction to this chapter. Rather, the effects of variable ISI manipulation appear to interact in a complex manner with subjects coding biases, raising the possibility that strategies of attentional deployment varied between experiment III, and experiments IV and V.

(2) Visual Field Effects

The results of this experiment indicated that there was an overall right visual field advantage, which was most pronounced after 990 msec ISI. This pattern of results needs to be qualified by considering the 'sex differences' interaction between classification and visual field, but as a general trend, it deserves some discussion in its own right.

The time course of lateral asymmetries noted in this experiment would be congruent with a model suggesting that an initial bilateral representation of S_1 memory codes was superseded by a left hemisphere superiority at longer retention intervals. This interpretation is quite similar to the Wilkins & Stewart (1974) position, but since the present data do not suggest a left field advantage at brief ISI's, there are no grounds for assigning a particular role to the right hemisphere in early visual processing of double letter stimuli.

The results of experiment III conflict with these ISI effects. It will be recalled that under blocked ISI conditions the evidence suggested an attenuation of the right field superiority by 990 msec which was hypothesised to arise from the involvement of 'naming' systems in short-term memory (after Kirsner, 1980). However, experiment III gave no suggestion of an ISI x classification interaction, thus it seems possible that the increase in right field advantages, observed in experiment V (and also, albeit less reliably in experiment IV), arose from asymmetries in the organisation of systems mediating NI transformation.

A 'processing' view of this type would possibly predict greater asymmetries in NI judgements since access to the appropriate transformation of S_1 would be required regardless of ISI (for these stimuli). As the interval was prolonged, all S_1 materials would be subject to comparable visual generation, or name-level processing, and overall visual field asymmetries would be expected to follow the same directional trend as that observed for NI classifications at shorter ISI's. However, the pattern of visual field asymmetries differed for males and females in NI, PI and 'different' judgements, and whilst males evidenced the required RVF advantage in NI classifications, the RVF advantage for females was more marked on PI judgements than on NI. There were no indications of any interaction between sex of subject and ISI, as would be anticipated on a coding model of the type outlined in the preceding paragraph.

Since overall classification asymmetries did not relate to the visual field x ISI interaction in any clear or straightforward manner, it is possible that the processing dimension implicated by ISI effects was largely independent of the PI/NI dichotomy. If this were the case, then the most likely source of visual field x ISI interactions would lie in the time structure manipulation, and might relate to differential 'alerting', or preparation for S_2 presentation under blocked and variable ISI conditions. In blocked ISI presentations S_1 functions both as a warning signal and as a provider of memory information; whereas with variable intervals, S_1 indicates the start of a waiting period, and also provides input to memory. Thus, it could be argued that initial levels of alerting were greater in the left hemisphere following an S_1 'time signal', but that the use of a variable ISI resulted in a more gradual build up of preparation which was incremental, and asymmetric at the intervals studied. Whilst a 'physiological' model of this form could, perhaps, account for the results of this experiment, it would be less satisfactory in 'explaining' those of experiment IV where despite output advantages at brief ISI's, similar ISI x VHF interactions were suggested.

The source of the ISI x VHF interaction is unclear, the most plausible structural account would be cast in terms of 'alerting' asymmetries, but the evidence on this point is far from convincing. The form of interaction noted in the present experiment would be congruent with an increase in 'capacity' at larger intervals (i.e. a performance-resource effect - see above) but the similar trends observed in the results of experiment IV, despite an overall <u>decline</u> in efficiency over

ISI's cast doubt on this interpretation.

If these points are accepted, then it appears reasonable to suggest that the ISI x VHF interaction arose from the involvement of processing, or attentional systems, which were correlated with a relative decline in the PI advantage, but were not isomorphic with it. It would be premature to define these variables as 'verbal', or 'attentional', and further experiments are required in order to tease apart the relative contributions of 'alerting', and 'strategic' components in the coding effects noted in these studies.

It is interesting to note that the pattern of visual field asymmetries observed in the female sub-group was comparable to that of the (predominantly female) 'high verbal' group studied by Kroll & Madden. This pattern of results is also very similar to that obtained in experiment I where a 'rehearsal interference' model was put forward to account for the minimal asymmetries obtained in NI judgements. A 'strategy difference' account of the visual field x classification x sex interaction cannot be ruled out, but in view of the similarities between males and females on the criterion coding measures, it seems unlikely.

The 'sex difference' effect was not confined to 'same' judgements. Males were apparently poorer at D_R judgements presented to the left visual field. The basis of this effect is not clear. In experiment IV it was noted that the male subject group showed an overall deficit in D_R classifications at the 990 msec interval, but that this did not interact with visual field of presentation. These effects may reflect a number of variables, scanning preferences, interhemisphere transfer, response biases, etc. No unambiguous interpretation of this observation is possible.

The interaction between output laterality, classification, and visual field indicated that left-handed output to both same and different classifications showed a greater degree of right field advantage than did right-handed output. The interaction with classification was apparently due to the between Ss assignment of the laterality x decision factor. Post-hoc this interaction might be interpreted as reflecting some form of 'interference' effect, but this account would not be satisfactory since there was no class-specific interaction (as was obtained in experiment III). The pattern of results which was observed is diametrically opposed to that which would be predicted on a 'spatial compatability hypothesis', and could reflect a compensatory strategy for the tendency to respond with the hand ipsilateral to the visual field of presentation. This explanation should however be equally applicable to right-handed output, and since no comparable effect was noted in that case, a 'compensatory strategy hypothesis' appears to be inadequate. A number of speculative interpretations could be put forward to account for this small effect, but there is no definitive model which could encompass all the data, and this particular observation.

Summary & Conclusions

The pattern of results from the variable ISI conditions of experiments IV and V showed that the stability of the PI advantage for double letter stimuli was dependent on the regularity of the time structure of the inter-stimulus interval, or perhaps of the global time structure of the task. Both experiments gave an overall right field advantage and an interaction between visual field and ISI, although this effect only reached significance in the larger scale study (experiment V).

The visual field effects observed in this study were complex and suggested that processing variables other than those indexed by the PI advantage were implicated. It was determined to investigate the 'PI decline' phenomenon in greater detail in subsequent experiments so that some effective interpretation could be achieved.

TABLE 8.1

Mean Proportion Correct

Classification x ISI (Standard Deviations in brackets)

Classification	ISI 50 msec	(SD)	ISI 990 msec	(SD)	$\bar{x}$
PI	.775	(.17)	.825	(.19)	.8
NI	.61	(.21)	.705	(.18)	.657
D_R	.795	(.19)	.695	(.27)	.745
D_L	.715	(.19)	.70	(.21)	.707

TABLE 8.2

Mean Response Latency (msec)

Classification	ISI 50	(SD)	ISI 990	(SD)	$\bar{x}$
PI	767	(137.1)	861	(212.5)	814
NI	970	(185.2)	968	(249.5)	969
$\bar{x}$	869		915		

TABLE 8.3

Proportion Correct

Visual Field	ISI 50 ms	ISI 990 ms
RVF	.78	.75
LVF	.74	.63

TABLE 8.4

Response Latency

Interaction between ISI and Classification (msec)

Classification	ISI 50	990	$\bar{x}$
PI	.92	.890	.905
NI	.755	.798	.776
D_R	.885	.915	.90
D_L	.83	.890	.861
$\bar{x}$	.847	.874	

TABLE 8.5

Interaction between ISI and Visual Field

ISI	Visual Field RVF	LVF	$\bar{x}$
50 ms	753	750	751
990 ms	690	732	711
$\bar{x}$	721.5	741	

TABLE 8.6

Response Latency

Interaction between Sex of S, Visual Field and Classification (msec)

	Classification	Visual Field RVF	LVF
Males	PI	640	649
	NI	704	745
	D_R	763	804
	D_L	754	751
Females	PI	663	718
	NI	731	743
	D_R	768	764
	D_L	742	762
	$\bar{x}$	721.5	741

TABLE 8.7

Response Latency

Interaction between Responding Hand, Visual Field & Classification (msec)

Hand	Classification	RVF	LVF
Right	PI	623	638
Right	NI	681	700
Left	D_R	727	778
Left	D_L	718	748
Left	PI	680	723
Left	NI	754	795
Right	D_R	780	789
Right	D_L	778	766

CHAPTER 9

Experiment VI

In studies of single letter sequential classifications the crucial variable appears to be the stimulus onset asynchrony (SOA), that is, the time intervening between S_1 onset and S_2 onset, rather than the inter-stimulus interval (ISI), the time between S_1 offset and S_2 onset. Posner _et al_ (1969) employed an unpredictable SOA, and found a change in the difference between NI and PI classifications, which closely resembled the results of an earlier experiment (Posner & Keele, 1969) where ISI was blocked, and S_1 exposed for a constant period of time (500 ms) over all ISI conditions.

These results appeared to cast doubt on the hypothesis that the change in R.T. patterns over time was a product of a passive decay in visual memory, and led Boies (1971) to conduct a series of experiments designed to test the hypothesis that PI decline was due to visual generation. Boies argued that during the retention interval _S_s engaged in generation of a visual representation of the opposite-case alternative to the stimulus which had been shown. Thus, an increase in decision time to PI matching was due to an increase in the size of the visual set through which _S_ must search in order to reach a satisfactory 'matching' judgement (after Sternberg, 1969). Boies performed a number of experiments, varying SOA, and match types within blocks of experimental trials (it is not clear from his thesis whether SOA was predictable or unpredictable in any single series). His results were complex, and not entirely congruent with the 'generation' model, although some trends in the predicted direction were shown, i.e. despite prolonged exposure of S_1, there was some tendence for PI latency to increase as the interval was extended, although this trend was not consistently shown in the reported experiments.

As has been mentioned previously, Kroll and his colleagues (Kroll & Parks, 1978) have agreed that the basis of the persisting PI advantage in double letter classifications was the prohibitive difficulty of producing a set of visual alternatives for such complex stimuli, a hypothesis which may not be fully supported by the indications of PI decline found in the previous experiments.

It is possible, however, that some form of 'visual generation' was occurring, rather than a 'passive' decline in emphasis on visual aspects of the stimuli. If this was the case, then the use of a variable (unpredictable) SOA should produce results which are comparable to those obtained in experiments IV and V, namely a decline in PI advantage as the SOA is increased. If, on the other hand, relative decline in PI was due to a 'passive' loss of visual information, then it is possible that continuous presentations of S_1 would serve to 'refresh' visual memory and so limit or prevent decline over time.

An additional interest of the present experiment was an examination of the laterality effects under conditions of brief and extended S_1 presentation. The possibility that elements of S_1 have been lateralised, and asymmetrically represented has been raised in the discussion of earlier experiments. Within the range of visual angles which have been employed in the series reported in this thesis, it seems likely that bilateral representation was achieved at very early levels of visual analysis (i.e. at the stage of primary visual cortex). However, the possibility of an asymmetric benefit in the development of processes correlated with the letter matching task cannot be eliminated on the basis of the present evidence. For example, it might be argued that the preponderance of right visual field effects was due to transfer asymmetries with left hemisphere to right hemisphere routes being less efficient than the opposite arrangement.

Whilst the use of different stimulus durations is a less than totally adequate means of investigating this hypothesis (since total 'processing' or 'analysis' time is confounded with bilateral or possibly 'lateralised' S_1 presentation), it does provide one approach to the problem. None of the experiments which have been reported so far have successfully eliminated the PI advantage, hence if the right hemisphere was implicated in the development, storage, or utilisation of PI 'codes' then a longer exposure duration should not entirely eliminate any right hemisphere advantage on this particular type of match. This prediction would be expected to be upheld under either a process-based or attentional-dominance model of hemisphere function, since the relative emphasis on name or visual aspects of the stimulus would be anticipated to favour 'visual' coding, (on the basis of the previous data presented on PI decline and stability).

Method

Stimulus materials and instructions were identical to those employed in the preceding experiment. There were two major modifications in procedure. The control program for stimulus presentations was altered so that S_1 was presented for either 1040 msec or 100 msec, so that the ISI was held constant at 50 msec. Order of trial presentation was randomised as before so that on any single trial S did not know whether the sequence would involve a brief or long presentation of S_1.

The experiment was conducted with the VR14, seating and chin-rest apparatus set up in a room adjoining the computer laboratory. The room was darkened by means of a light excluding blind, and there was no background illumination.

Twenty-four Ss were recruited from amongst undergraduate and graduate students at the University of Leicester, all were right-handed for writing as assessed on self report. 12 Ss were male, 12 female.

Results

No Ss data showed a pattern of extremely brief and long latencies. All reported compliance with fixation instructions and so the data was accepted for analysis. In order to cope with occasional 'outlier' response latencies, i.e. where latency was inflated, a criterion latency of 1500 msec was employed and resulted in the scoring of several accurate responses as errors (see previous experiment).

The majority of Ss reported a naming strategy "when there was sufficient time". Long S_1 presentations were subjectively assessed as 'being easier' because less effort was required to remember the first set of letters. Only one S reported a strategy approximating the 'visual generation' technique suggested by Boies, stating that he had tried to construct an anticipatory image of potential test stimulus candidates.

(1) Accuracy

No effects or interactions involving the sex of S factor were noted, and the data was pooled over this variable. Three effects were significant at $p < .05$. The main effect of classification ($F3, 66 = 7.4$, $p < .001$) interacted with visual field ($F3, 66 = 4.9$, $p < .01$) and is shown in Table 9.1. There was, in addition, a complex four-way interaction between all factors in the analysis ($F3, 66 = 3.1$, $p < .05$) shown in Table 9.2.

(2) Response Latency

The only effect to reach significance in this analysis was that of classification ($F3, 66 = 13.6$, $p < .001$). The means for this factor are shown in Table 9.3. Post-hoc Scheffe testing indicated that PI judgements were faster than other classifications at $\alpha = .01$.

Discussion

The PI advantage remained stable in this experiment as was predicted by the 'passive decline' model of visual memory under variable ISI conditions. However, there are difficulties in accepting this interpretation uncritically since the pattern of interaction between visual field and classification was similar to that obtained in experiment III where SOA and ISI were held constant within trial blocks.

This observation could be interpreted as evidence for a similarity in the way that stimuli were processed in blocked ISI conditions, that is, that a prolonged exposure of S_1 did not simply compensate for a passive decline in visual memory, but resulted in an alteration of the relevant task constraints which had provoked a 'visual generation' strategy for stimulus matching under variable ISI conditions.

It seems highly probable that the loading of _S_s attentional capacity would be greater when both SOA and ISI are unpredictable on any single trial. Kroll & Parks (1978), Posner _et al_ (1969) and Proctor (1978) have shown that the PI advantage is susceptible to attentional demands made during the ISI-retention interval. For single letter judgements both Proctor and Posner _et al_ found that the interpolation of a visually presented arithmetic task selectively interfered with the speed of PI judgements. Kroll & Parks replicated this effect with double letters, but also found that auditory presentation of the subsidiary task reduced the PI advantage. This finding contrasts with the single-letter conditions where clear modality specificity has been shown (see the discussion by Proctor, 1978). There are numerous differences between the single and double letter studies which preclude any straightforward comparison between them, but the main sources of variance are very probably stimulus complexity and retention interval. Proctor points out that the extremely long ISI's involved in Kroll & Parks' experiment

(12 seconds) would be likely to implicate longer-term memory systems than the 1 second ISI used in single letter judgements. Alternatively, a strong case could be made for the interaction between 'space' occupied by the memory stimuli and attentional demands. Phillips & Christie (1977) have shown that visual memory for random patterns is susceptible to disruption from both aural and visual presentation of subsidiary task material over ISI's of 2.5 seconds. Such stimuli are more "complex" than either single or double letters, (if defined according to communication/information theory or to extra experimental experience) and single and double letters could be distinguished on a familiarity complexity dimension in an analagous manner. Since the ISI's used by Phillips & Christie fall well within the limits of 'short term memory' tasks (see Baddeley & Patterson, 1971) it seems likely that certain aspects of visual memory for complex and/or unfamiliar configurations may be susceptible to disruption from a range of attention demanding tasks.

As was mentioned in the previous chapter, Phillips has recently shown that the use of a variable ISI can disrupt the short-term retention of complex pattern material, a finding which is congruent with the familiarity/redundancy argument presented above (since the same effect was shown in experiments IV and V). The question remains, however, of the manner by which such effects are mediated. The 'visual generation' argument is not invalidated by an 'attentional loading' interpretation of decline for letter stimuli, since there are, presumably, 'long-term' representations of upper-lower case transforms of letters. Thus while the effects of attentional 'pressure' may result in a net loss of information for random patterns, it is just conceivable that the same constraints could initiate a generation-like strategy for letter materials.

If the crucial difference between the present experiment and variable ISI conditions is the level of attentional demand placed on Ss during the retention interval then this experiment cannot distinguish between the decline/decay hypothesis and the 'visual generation' interpretation since both could account for the data equally well. In view of the similarity of the visual field x classification interactions obtained in this study and experiment III it would, in fact, be quite plausible to accept Parks & Kroll's 'visual generation' argument for conditions under which decline in PI was found.

Such acceptance would be premature because there is a possibility that varying the ISI unpredictably affected lateralised systems which were uncorrelated with those implicated in changing PI advantages. Such effects could range from an attentional or orientational bias towards the RVF, (perhaps as a result of changes in the level of 'arousal' in lateralised systems) to the adoption of sophisticated anticipation strategies in an attempt to compensate for a demanding task structure.

Furthermore, the experiments which have been presented so far do not allow a clear delineation of the respective roles of attentional interference, and longer-term 'task set'. The 'visual generation' viewpoint is dependent on the assumption that such a 'strategy' or process only occurs, or is only resorted to in the face of constraints on attentional capacity during the retention interval. Such an assumption is necessary in order to encompass the data from the first experiment of the present series where despite adequate time <u>S</u>s maintained a strong PI advantage during a 9 second retention interval.

To summarise the arguments which have been presented in this section: It was suggested that this experiment was inconclusive on the issue of visual generation versus passive decline in visual memory because the pattern of visual field effects closely resembled that of a previous experiment which employed blocked ISI's. The visual generation hypothesis could be salvaged by arguing that such a process only occurred under conditions of high attentional demand. However, the 'attentional loading' interpretation requires further investigation before it can be differentiated from a general 'task set' description of performance.

There was no sign of a reliable interaction between visual field and exposure duration of S_1, thus casting doubt on the hypothesis that the preponderence of RVF advantages shown in other experiments were simply a product of asymmetric transfer. However, this interpretation is complicated by the finding of a significant 4-way interaction involving all factors.

The importance of this effect is difficult to determine, however, in view of its bearing on the exposure duration and interhemisphere transfer question, it cannot be entirely ignored, although its complexity precludes an entirely satisfactory interpretation.

Inspection of the interaction shown in Table 9.2. indicates that there was a 13% drop in accuracy for right-handed

RVF, NI judgements as the interval progressed, and a comparable deterioration of 18% in PI judgements made by the left hand. A subsidiary ANOVA confined to 'different' classification only, did not yield a parallel interaction effect ($F_{2,22} < 2$). On a post-hoc basis, this effect might be interpreted as reflecting a pattern of early facilitation when input, analysis, and output systems overlapped, which reversed to 'interference' as the demands of retention were extended. It should be noted that the pattern of results is not congruent with an asymmetry of transfer hypothesis, but neither is it entirely compatible with an explanation in terms of bilateral PI analysis and left hemisphere-lateralised NI judgements, unless bilateral control of left hand 'same' responses is assumed.

No firm conclusions are warranted by this small effect which may be a product of the analysis technique. More conservative 'F' tests (e.g. reducing the degrees of freedom for the numerator) would eliminate this interaction, but would not affect the overall significance of other findings, which replicate the results of experiment III.

TABLE 9.1

Proportion Correct

Classification	Visual Field RVF	LVF	$\bar{x}$
PI	.865	.869	.867
NI	.779	.728	.75
D_R	.88	.87	.875
D_L	.808	.9	.854

TABLE 9.2

4-way Interaction - Proportion Correct

	RVF				LVF				
	PI	NI	D_R	D_L	PI	NI	D_R	D_L	
Short	.92	.87	.95	.79	.87	.72	.89	.85	Right Hand = Same
Exposure S_1	.85	.79	.92	.82	.95	.72	.92	.90	Left Hand = Same
Long	.85	.74	.85	.87	.9	.75	.80	.9	Right Hand = Same
Exposure S_1	.87	.74	.82	.77	.77	.77	.89	.95	Left Hand = Same

TABLE 9.3

Response Latency (msec)

Classification	
PI	612
NI	672
D_R	705
D_L	692

CHAPTER 10

Experiment VII

This experiment was devised in order to investigate the source of 'code changes' which were obtained in experiments IV and V. In those experiments subjects showed a decline in the advantage for PI match pairs in the sequential classification task. This relative change was the product of an increasing efficiency with name match stimuli, and a decrease in efficiency for physical matches.

Kroll and his colleagues (e.g. Parks & Kroll, 1976; Kroll & Parks, 1978) have argued that double letter stimuli were resistant to such effects of code change, because of the prohibitive difficulty of 'visual generation' (Boies, 1971), with double letter case transformation requirements. However, alterations in code in experiments IV and V were compatible with subjects use of a 'visual generation' strategy. This absolute level of decline in PI efficiency could be attributed to an increase in size of the visual memory set (Sternberg, 1969) as predicted by Boies (1971) model of visual generation.

The evidence from experiment VI above, failed to support the visual-generation model of code change. Under variable-duration exposures of S_1, both PI and NI matches remained at a consistent level over different SOA's. It was suggested that the visual generation hypothesis might be salvaged by proposing that initiation of this 'control' process for double letter materials was dependent on the imposition of certain levels of attentional and/or memory demand(s).

Prolonged presentation of S_1 stimuli might have resulted in changes in processing due to reductions in task complexity.

On empirical grounds, this suggestion seems somewhat implausible. Visual generation appears to be a time consuming, and attention-demanding process (Posner, 1978), and would therefore appear to be particularly ill-suited to a short duration demanding task.

An alternative hypothesis based on evidence from studies of temporal irregularity in short-term verbal memory (Crowder, 1971; Hamilton & Hockey, 1974) might be proposed. Hamilton & Hockey found that under instructions to actively rehearse and organise information, subjects showed a deficit with irregularily timed input. If subjects were asked to receive the information 'passively', then performance under 'temporal irregularity' conditions was significantly improved. An analogy between the 'time structure' effects obtained by Hamilton & Hockey, and the code change effects obtained in experiments IV and V, may be suggested. More specifically, it is proposed that temporal irregularity in the double letter matching task induces a 'passive' strategy whereby subjects are able to access the 'name' transformation of stimuli.

The 'active'-'passive' distinction outlined above provides a useful description of the phenomenology of two types of rehearsal strategy in auditory short-term memory tasks. Its application in the present context does not, however, imply assumptions on the extent to which the two tasks involve similar processes whether described in terms of phenomenal experience, or in terms of any putative information processing model. It seems likely that the evidence from two very different research techniques converges in suggesting, that the most efficient strategy under regularily paced conditions may not be suitable when the time structure of a task is irregular. However, the degree of similarity or difference between such strategies remains an empirical question.

To summarise the arguments which have been presented so far: although 'visual generation' appeared to be a possible explanation for the absolute decline in the advantage of PI matches in experiments IV and V, the data from experiment VI suggested that such effects were restricted to conditions of high attentional demand thus contradicting the available evidence on 'generation' requirements (see Posner, 1978). An alternative viewpoint was put forward, namely that subjects responded to temporal irregularity by a change in task set (after Hamilton & Hockey, 1974).

The evidence for the availability of alternative strategies with multiple letter arrays will be reviewed in the following section.

Strategy Effects

There are several independent sources of evidence which indicate that subjects may utilise two very different approaches for classifying letter arrays. Word-matches (Cortese & Scarborough, 1977) and acronym matches (Egeth & Blecker, 1971; Henderson, 1974) yield negligible effects of case similarity. However, if subjects are required to remember word stimuli and to recognise whether a particular item has occurred previously in the stimulus sequence (Hintzman & Summers, 1973; Kirsner, 1974) then same-case matches show an advantage over different case matches.

La Berge and his colleagues (La Berge _et al_, 1977) have shown similar types of effect with double letter stimuli. Their tasks required subjects to perform simultaneous classifications on lower-case digraphs (PI judgements). The digraphs could either consist of highly familiar letter combinations (e.g. ch/gl) termed _clusters_ or of unfamiliar letter pairs (e.g. hc/lg) termed _letters_.

In pure lists of either stimulus type (Peterson & La Berge, 1975, cited in La Berge _et al_, op. cit.) _cluster_ stimuli yielded more rapid 'same' judgements than did _letters_. Peterson & La Berge suggested that this finding reflected the involvement of two levels of stimulus processing 'letter' analysis and 'cluster' analysis.

When 'mixed' lists of stimuli were employed there were differential effects on latency to 'cluster' or 'letter' stimuli depending on the distribution of either classification type within a trial block. There were no significant differences between 'letters' and 'clusters' when letter stimuli were more frequent but 'letter' judgements were relatively impaired in the context of a list biased towards 'cluster' analysis. La Berge _et al_ (1977) suggest that the latter condition requires the involvement of an additional processing stage for letter stimuli. Due to the attentional demands of the 'cluster' task subjects were 'forced' to use both 'cluster' and 'letter' levels for analysing letter stimuli, whereas 'cluster' processing would be sufficient for familiar double letter combinations.

The data from La Berge _et al_ indicate that 'letter' matching in the 'visual' domain may be differentially affected by task set. However, their experiments might be criticised on the basis of Hintzman's (1969) findings. Hintzman argued that when 'easy' discriminations were embedded within a 'difficult' judgement set, performance might be affected by the level of set for the task as a whole. Thus easy judgements presented within a 'difficult' set would be impaired due to criterion effects rather than as a function of processing (d') variables. Whilst the potential influence of an artefact of this nature cannot be overlooked entirely, such an account cannot explain the relative impairment of 'letter' judgements within 'cluster'-biased lists of stimuli, or for La Berge _et al_'s observation that 'cluster' matches were equivalent in both mixed list conditions. It could even be argued that the effects noted by La Berge _et al_, were an underestimate of processing effects rather than an artefact of methodology.

The experiments which have been reviewed above indicate that task set, whether induced by instructions or by list context, may affect visual coding. La Berge _et al_ have suggested that 'attentional' bias may produce a relative slowing of PI judgements for non familiar letter combinations. Hintzman & Summers (1973), and Kirsner (1974) have indicated that same-case (PI) judgements may be facilitated when subjects are required to perform occurrence judgements on word stimuli.

Although this data could not be incorporated within any but the most speculative model of the processes involved in multi-letter stimulus classification, they do suggest that such tasks may be open to strategy effects and, as such, provide only a limited level of constraint on the options open to subjects.

The hypothesis put forward by Parks & Kroll (1975), namely that the persistence of PI advantage with double letter stimuli was the product of 'difficulty in visual generation' is dependent on the assumption that there is only one process (visual generation) by which code change for double letters can be mediated. However, since the evidence suggests that there may be alternative sources of code bias (as operationally defined by PI latencies) one is necessarily led towards the conclusion that Parks & Kroll's hypothesis provides, at best, an incomplete account of stable visual memory with such materials. Whilst 'visual generation' may be sufficient for changes in PI latency, it may neither be necessary nor inevitable.

The following section will deal with the 'strategy' concept in greater detail. In particular I shall be concerned with the problem of tonic and short-term fluctuations in coding bias, and an attempt to provide a preliminary mapping between the active/passive distinction and the effects observed in experiments IV and V.

The problem of variance produced by strategic differences in performing letter classifications has not been systematically addressed by any published investigation. The 'individual-difference' perspective has been utilised by a number of workers (e.g. Hunt et al, 1975; Friedricksen, 1978; Kroll & Parks, 1978; Parks & Kroll, 1975; Kroll & Madden, 1978). This approach has tended to focus on correlational evidence, which suggests a negative relationship between gross measures of 'verbal ability' and the difference between NI and PI latencies. The use of an index derived from NI and PI latencies in such a manner has some justification (see Cohen, 1974, for relevant arguments), but tends to ignore possible interactions between processing 'components' (constructs) defined in terms of absolute latency to NI or PI judgements. Thus, for example, Hunt et al (1975), obtained slower PI classifications from their 'low verbal' subjects, whilst Kroll & Madden (1978) obtained slower PI classifications from their 'high verbal' sub-group. Both effects occurred in the context of smaller differences between 'high' and 'low' verbal groups on the derived (NI-PI) latency index, but were largely ignored in favour of arguments for a common factor of 'verbal ability', in letter classification and measures of 'crystalised' verbal intelligence (Guildford, 1967).

The emphasis on 'efficiency' in performing a sub-set of 'verbal' skills leaves the question of differences between groups in their types of 'processing' wide open. Such difference scores could be the product of different rates of operation of fundamental processes (i.e. that common systems were available, and utilised by both subject groups but operated at different rates). Alternatively they could reflect the availability of 'sub-routines' for performance, such that groups differed in the processing systems utilised in making classification judgements, either as a function of task set, or 'long-term' individual (possibly structural - Kroll & Madden, 1978) differences.

As was noted in the previous section on multi-letter arrays, there is evidence suggesting that strategy effects may be involved in single letter judgement tasks. That such effects occur warns against the assumption that common systems are necessarily involved in the high/low verbal studies discussed above.

'Strategic' effects appear to be induced by list context; if a list is biased towards a particular type of judgement, then response output is facilitated for the more frequent classification (see e.g. Sternberg, 1969). However, encoding functions (Posner & Boies, 1971) may also be affected (Taylor, 1974; White, cited in Hockey, 1977) suggesting that 'bias' may operate from a comparatively early stage of input analysis. 'Pure' lists of PI judgements yield slower rates of visual memory 'decline' than do mixed lists (Boies, 1971; Posner _et al_, 1969), indicating that retention is subject to effects induced by task context also.

La Berge _et al_ (1977) have provided data on the overall stability of bias induced by different list contexts for double letter PI matches. The level of analysis adopted by subjects appeared to be a tonic or long term effect, rather than one which was subject to 'phasic' changes in processing. They attempted to vary the level of stimulus analysis within predominantly _letter_ or _cluster_ lists (see above) by presenting subjects with cues, informing them of match level, prior to the presentation of classification stimuli. The results of this manipulation indicated that list context was generally a stable and resistant influence on match strategy. Cueing had few reliable effects.

Snyder & Posner (cited in Posner, 1978) have also reported difficulty in cueing subjects for match type, but their task involved 'standard' mixed NI and PI classifications. PI matches were facilitated by a pre-classification cue irrespective of the degree of attention 'paid' to the cue. This finding replicated the data for pre-cueing simultaneous PI matches in 'pure' list presentation conditions (Posner & Snyder, 1975). However, NI matches were not amenable to 'automatic' ('passive' (Posner & Snyder, 1975a; 1975b)) priming under mixed list conditions. When NI judgements were 'facilitated' by a cue, 'active' attention was always required, resulting in a relative impairment of other classification types. Pure lists of NI judgements may be facilitated 'automatically' under some conditions (see Posner & Boies, 1971).

The name-level bias which was identified in experiments IV and V may be a long term, tonic effect, comparable to the context effects discussed above. If this were the case, then the active/passive distinction would be partially supported, since the auditory memory data indicates that such constructs relate to qualitatively different, tonic states (Hamilton et al, 1977). Alternatively, the 'bias' could be due to short term (phasic) fluctuations in attentional demand induced by variable retention interval conditions (see e.g. Phillips & Christie, 1977).

If the effect was one of task set, then a manipulation of temporal regularity which affects the time of stimulus input should have comparable effects to variability in ISI duration.

Hamilton & Hockey's (1974) experiments utilised 'running memory span' techniques, so that time of recall (retention interval) was equally uncertain for regular and irregular timing conditions. The crucial difference between regular and irregular conditions lay in the regularity of stimulus onset, rather than in 'retention interval' per se. This manipulation may be partially replicated by varying the time of S_1 onset in a sequential matching task. If such a procedure results in change in code bias over fixed retention intervals, then the evidence would suggest that there was a degree of correspondence between the type of strategy interactions noted by Hamilton & Hockey,(and those obtained with the variable ISI procedure discussed above.

The use of a time structure manipulation which is independent of ISI additionally provides a final crucial test of the 'visual generation' hypothesis. If code change were obtained when ISI was held constant then the 'task complexity' argument presented in the preceding chapters would be conclusively rejected.

The technique which was adopted consisted of variable duration presentations of a pre-classification warning stimulus (the fixation cross). The 'alerting' aspects of warning stimuli have been extensively discussed by Posner (1975; 1978); Posner & Boies (1971). The evidence suggests that, in the absence of strategic bias, there should be no interaction between warning stumulus and coding effects. The occurrence of an interaction would therefore provide some evidence for the type of 'bias' involved in variable time-structure tasks.

Prior to describing the experiment, it is necessary to mention the relevance of this study for the investigation of visual field asymmetries. Whilst it might be argued that the inclusion of a lateralised mode of presentation led to an over-complex study, it was considered necessary in order to allow a clear comparison between experiments. In addition, it was considered that potential interactions were likely to provide further insight into the relationship between memory code bias and visual field effects.

The technique of varying the time of S_1 onset mimics some of the variability in presentation time which is intrinsic to studies which utilise a two-field tachistoscope, or non-computer controlled, slide presentations. If different levels of 'alerting' were correlated with hemisphere, or attentional asymmetries then biased distributions of fixation cross duration might lead to results which were the product of an interaction between 'preparation' and stimulus coding, which, in the absence of a coding measure, could be misleading.

In addition, the effects of 'strategy' on visual field differences has been largely unexplored (Marshall, 1973). An attempt to manipulate strategy directly, therefore has the potential to provide an independent replication of the effects observed with variable ISI procedures.

Method

Sixty-four subjects of whom 32 were male took part in the experiment. All were right-handed for writing as assessed by self report. Ss were volunteer participants from amongst undergraduates at Leicester University.

Procedure

The apparatus stimulus materials and instructions, used in this experiment were identical to those described in experiment VI above. The control program for stimulus presentations was altered so that the fixation cross was shown for either 1090 ms or 150 ms with an interval of 100 ms prior to S_1 presentation. This latter interval was necessary to prevent forward masking of S_1. S_1 was shown for 100 ms. Half the subjects subsequently received an ISI (between S_1 and S_2) of 990 ms, the remainder an ISI of 50 ms. S_2 appeared in either the right or left visual field for 100 ms (as described above). Order of trial presentation was randomised so that the duration of the fixation cross, and visual field of S_2 were unpredictable on any single trial.

All appropriate counterbalancing procedures were taken such that each S received 20 trials at either 150 msec or 990 msec fixation cross durations, associated with S_2 presentation to a right or left visual field. Equal numbers of male and female subjects were assigned to 'response laterality' and ISI conditions.

Results

No subject showed a pattern of response latencies indicative of an anticipatory strategy. Hence all data was accepted for analysis on the criteria adopted for the previous experiment.

The design was suitable for 6-way analysis of variance. Between subjects factors were: ISI, sex of subject, and response mapping (right hand same response vs. left hand same response). Within subjects, factors included warning interval (fixation cross duration) visual field, and classification. With a design of this form, there is an increased probability of false positive results, (Type 2 error), and hence a criterion acceptability of $p < .01$ was adopted. Further discussion will therefore principally be confined to results reaching this criterion, although some mention of theoretically relevant effects, of lower reliability will be made, where necessary.

Accuracy

A table of all results reaching $\alpha = .05$ is presented in Table 10.1. Full ANOVA tables appear in the appendix.

The effects of ISI and classification were significant ($F = 20.9$, $p < .001$ d.f. 1,56; and $F = 18.6$, $p < .001$ d.f. 3,168 respectively). Of primary interest in the present experiments were the interaction between these two variables which yielded $F = 7.67$, $p < .001$ d.f. 3,168 shown in Table 10.2 below. A visual field x classification effect was also shown $F = 13.1$, $p < .001$ d.f. 3,168 presented in Table 10.3. There was, in addition, an interaction between the duration of warning interval and subsequent S_2 classification shown in Table 10.4 ($F = 4.8$, $p < .001$ d.f. 3,168).

Response Latency

A table of all results achieving $\alpha = .05$ is presented in Table 10.5. Full ANOVA tables are given in the appendix.

Analysis of response latencies showed the effect of fixation cross duration to be significant ($F = 51.5$, $p < .001$ d.f. 1,56) as was its interaction with: responding hand ($F = 13.5$, $p < .001$ d.f. 1,56); ISI ($F = 9.1$, $p < .01$ d.f. 1,56); and classification ($F3,168 = 5.4$, $p < .005$). These effects are tabulated below in Tables 10.6, 10.7 and 10.8 respectively. The only other effects to reach one per cent significance levels were visual field ($F = 24.7$, $p < .001$ d.f. 1,56) and classification ($F = 35.26$, $p < .0001$ d.f. 3,168). Their interaction was also reliable ($F = 5.4$, d.f. 3,168) and appears as Table 10.9.

Discussion

Cognitive Variables

ISI Effect:

The hypothesis that temporal uncertainty would produce an increase in NI match efficiency over a 990 msec ISI was supported in this experiment. The accuracy data indicated that NI and 'different' judgements were improved, relative to PI classifications following a prolonged retention interval. This pattern was not reliably reflected in the latency analysis ($F < 1$). A small three-way interaction did emerge, involving these factors and that of visual field ($F3,168 = 2.8$, $p < .05$). All latencies were somewhat prolonged following a 990 msec ISI, but those D_L stimuli presented in the LVF were especially slowed, from an initially rapid 750 msec, to 820 msec. This interaction was not entirely reliable since it did not emerge in a subsidiary analysis of 'different' judgements ($F < 1$).

Further analysis of latencies to 'same' judgements did not indicate any interactions between ISI and classification, neither was there a main effect of ISI. Hence the small difference between means for NI classifications at 990 msec and 50 msec retention intervals cannot be considered a reliable effect. To confirm this 't'-test comparisons were made between NI latencies at 50 msec and 990 msec, and these also failed to reach significance ($t < 1$).

The present data, like those of experiment V, suggest a degree of speed-accuracy tradeoff, with stable R.T.'s associated with changing levels of accuracy over ISI's. From the 'efficiency' perspective outlined in chapter 3, this pattern is congruent with functional alterations in memory and is supported by previous research (see Blake et al, 1970; Pachella, 1974, for discussion).

PI matches remained at a consistent level of efficiency over ISI's in this experiment (Table 10.2). This finding casts further doubt on the visual 'generation' interpretation, and considered in conjunction with the evidence for improved NI performance over retention intervals of 990 msec suggests that subjects were able to access alternative case (NI) stimulus representations without affecting the 'visual memory component' indexed by PI classifications.

Indeed, the change in visual memory inferred from declining PI efficiency in experiments V and VI may have been the product of demands on overall attentional capacity rather than a 'visual generation' effect. There is substantial evidence that PI judgements may be selectively affected by attentional demands. With single letter judgements such effects appear to be modality specific (Posner *et al*, 1969; Proctor, 1978), since visually presented subsidiary tasks are relatively more interfering than auditory presentation. Double letter materials, when shown at regular ISI's appear to be affected by both auditory and visual presentations of interfering (capacity demanding) tasks (Kroll & Parks, 1978). Similar effects to these noted for double letters have also been obtained in short-term memory for random matrix patterns (Phillips & Christie, 1977).

Variability in the retention interval may well operate as a 'demand' on the capacity available for the maintenance of a short term visual 'code'. A similar argument has recently been proposed by Phillips & Christie (1977) to account for the effects of variable ISI's on the retention of matrix patterns. Phillips & Christie found that short-term visual retention of such stimuli was reliably disrupted by the use of a variable ISI procedure. This effect is not apparent with single letter stimuli (Posner *et al*, 1969) suggesting that even under conditions of name-level bias double letter and single letters materials are subject to different constraints and therefore may require the utilisation of different systems.

This evidence suggests that PI decline, and NI enhancement in double letter classifications may be the product of two separable effects: NI facilitation may be due to task set, a strategic bias whereas PI impairment may be confined to situations when there is attentional demand during the retention interval.

The 'ISI' data reviewed above indicates that there may be a degree of correspondence between the conditions which result in strategy effects for auditory verbal short-term memory, and sequential letter classifications. Within the framework of Posner's (1978) theory the increase in NI performance as a function of ISI could be considered as the product of strategically driven 'automatic' access to the name-transforms of stimuli.

The problem of strategy effects will be considered in greater detail in the following section.

Warning Signal Effects:

The facilitating effects of fixation cross/warning signal duration followed the general time course described by Posner (1975, 1978) for 'alerting', or phasic changes in preparation for response output. Optimal benefits in speed of output were achieved with a warning signal duration of 150 msec ISI's (i.e. following a total preparatory interval between fixation cross onset and S_1 presentation of 400 msec). These effects dissipated quite rapidly when the total preparatory interval was extended to 1340 msec, and was equivalent for both 50 msec and 990 msec ISI conditions.

Within the framework of Posner's (1975; 1978) model, such effects would be expected to interact with classification type when 'conscious attention' is involved. Although the precise definition of 'conscious attention' is controversial, and need not concern us in this context, operationally, effects of a warning signal on classifications are expected when biased probability distributions of match-types are employed and strategy effects are elicited (Posner, 1978; White, cited in Hockey, 1977).

Posner argues that input to the 'sensory memory system' is an automatic process: alerting signals facilitate the operation of systems subsequent to input, and allow more rapid comparisons, and decision processes. When information is presented tachistoscopically such facilitation results in a greater level of efficiency, since transient levels input may be dealt with more rapidly, and prior to 'decay' in the input 'pathways'. For long presentations, speed accuracy tradeoff occurs as a product of 'over-rapid' responding. The involvement of 'conscious attention' would be expected to produce interactions between 'alertness' (as defined by response facilitation following a warning signal) and classification type due to selective facilitation of judgements requiring the use of 'pathways' for which the system was 'biased', Posner's model suggests that such facilitation should occur at the expense of other judgement types, due to 'inhibition' produced by the attentional system.

The effects of fixation cross duration interacted with classification type in this experiment. NI judgements were selectively facilitated at short warning intervals. These effects did not interact with ISI suggesting that the locus of facilitation was at or close to stimulus input. Brief warning intervals appear to have acted as an 'amplifier' for NI stimuli, boosting coding along that dimension. There was no evidence for any diminution over retention intervals of 990 msec. These effects did not appear to be the result of 'inhibition' of other decision types since PI matches remained at a constant level of efficiency, and 'different' judgements were also improved.

These effects may be contrasted with the findings of Snyder & Posner (cited in Posner, 1978). Snyder & Posner noted that cueing ('priming') subjects for simultaneous presentations of NI matches impaired performance on other decision types (irrespective of the 'reliability' (validity) of the cue). The variable warning interval effects noted above appear to have their 'locus' at a different level to 'priming' manipulation and are more congruent with a 'top-down' control of processing, i.e. a central control of coding strategy rather than one which is 'driven' by the stimulus display ('bottom-up'). Related evidence on the locus of 'strategy' effects may be drawn from the work of La Berge *et al* (1977) reviewed in the introduction to this chapter. It will be recalled that La Berge and his colleagues were generally unable to modify strategic 'sets' by the use of priming stimuli, indicating that bias towards a particular level of analysis was not amenable to 'phasic' alterations. These findings appear to indicate that such strategic biases are tonic 'state' effects, which are not easily modified under limited-time constraints. They may be contrasted with the 'time locked' effects of preparation, and coding, under conditions when strategy effects are (presumably) at a minimum (Posner & Boies, 1971).

The 'warning signal' results presented above suggest that subjects can selectively facilitate input 'pathways' in order to aid subsequent classification judgements. The facilitation appears to be 'automatic' as assessed by the criteria employed by Posner & Boies (1971) since there were no detrimental effects of name-level bias on other judgement types.

The data which has been reviewed above suggests that warning interval, and ISI effects are independent manifestations of a general strategic bias towards the name codes of stimuli under conditions of temporal uncertainty. Warning signals may independently facilitate coding at input, and ISI effects may reflect the time-course of processing in subsequent memory systems. Strategic bias appears to operate from comparatively early levels of stimulus analysis, and to operate by selective facilitation rather than by a process of facilitation and inhibition.

The present experiment has permitted a comparatively fine-grained analysis of coding effects in the sequential classification of double letter arrays. Such code changes over time were not, however, paralleled by systematic interactions with visual field of presentation. These 'negative' observations may well provide a clue to the locus of visual field effects within an information-processing sequence. The following section will deal with these points in greater detail.

Lateral asymmetries

The principal findings on visual field effects in this experiment replicated those obtained in three previous studies in this series (experiments III, V and VI). The general pattern was of a 'V' form interaction with a marked RVF advantage for NI judgements on both accuracy and latency measures, and a RVF advantage for PI stimuli on latency measures only. This general pattern of results appears to be quite 'reliable' (replicable) across a range of experimental procedures, visual angles, S_1 presentation durations, and crucially, across empirically determined 'coding' biases, suggesting that the aspects of function 'tapped' by unilateral visual field presentations of S_2 stimuli are independent of such factors.

The data on 'different' judgements gives no support to an unidirectional 'scanning bias' effect in this experiment. D_L stimuli were more efficiently classified in this LVF, and D_R when presented to the RVF: This pattern is generally congruent with a peripheral to central 'scan' (see e.g. Coltheart, 1973).

As noted above, there were no systematic interactions between visual field advantage and classification bias, either at S_1 input, or following a 990 msec retention interval. There were, however, a number of minor interactions involving responding hand with temporal variables, and their effects will be considered next.

The decision x responding hand factor interacted with warning interval showing that right hand/same subjects were especially fast following a brief presentation of the fixation stimulus (Table 10.6). Both 'same' and 'different' judgements were equivalently affected, and there was no reliable interaction involving response mapping, warning interval and classification. If the aforementioned interaction was due to selective 'activation' then a three-way effect would be expected since 'different' judgements were performed with the left hand.

A more complex model of 'decision laterality' or of 'activation' might be envisaged but does not appear to be warranted by the data: A small interaction involving warning signal, ISI, and response mapping was obtained in the latency analysis which supports this contention (Table 10.10). The effect was reliable at $p < .05$ ($F_{1,56} = 4.4$) and shows right hand/same output at short warning intervals was only superior to left hand/same conditions, at brief ISI's. This pattern would be congruent with the involvement of an additional 'stage' in processing left hand/same decisions which resulted in the highest level of relative impairment when time pressure was greatest.

Visual field and response mapping conditions showed a reliable two-way interaction in both speed and accuracy analyses (Table 10.11). Left hand/same subjects manifest on smaller degree of visual field asymmetry than the right hand/ same group.

If spatial 'S-R bias' were responsible for these findings then an interaction between visual field, response mapping and classification would be predicted since 'same' and 'different' judgements were performed by separate hands. A three-way interaction involving these factors was obtained, but does not lend itself towards any unequivocal interpretation (Table 10.12). The effect appears to be attributable to the relatively more rapid classification of 'different' stimuli presented to the LVF, when right hand/different responses were required. This pattern would not be congruent with a simple spatial compatibility effect but might conceivably be encompassed within a more sophisticated model of 'different' judgements. If spatial bias interacted with decision type, and task complexity to provide additional 'benefit' to different judgements when both decisional and field spatial hand mappings were 'convergent' (possibly at a comparison stage), then the aforementioned result could be accounted for.

Whilst the occurrence of these interactions involving output factors cannot be ignored, they do not appear to prejudice the interpretation of visual field asymmetries discussed previously. Even when such effects are taken into account, there is no evidence for an interactive effect involving code change and visual field which would be predicted by the 'prototypical' model of visual field asymmetries in the sequential classification task (e.g. Wilkins & Stewart, 1974).

Conclusion

The results of this experiment indicate that change in the NI 'code' may occur independently from alterations in visual memory. This result, suggests that such changes, in 'processing' over time may be due to strategic bias(es) which are independent of 'visual generation'. The pattern of interaction between warning signal duration and 'coding' supported a strategy interpretation, and indicated that an independent form of bias could operate at early stages of stimulus processing.

The strategy changes which appear to be elicited by variable time-structure tasks may, or may not, be comparable to those discussed by Hamilton & Hockey (1974). For the present, it appears reasonable to conclude that strategic bias may vary as a function of temporal demand in visually presented memory tasks. Further work, which would be beyond the scope of this thesis, is necessary to determine whether the cognitively defined functional components of memory are affected in a similar manner across auditory and visual modalities.

Visual field effects replicated the pattern of results obtained in three previous experiments (experiments III, V and VI) and showed no systematic alterations in type, or extent, as a function of code change.

Since double letter stimuli appear to be susceptible to 'strategy' effects, it is possible that they require a mode of processing which differs from the single letter task. Such differences might result in the involvement of lateralised systems which differed from those inferred from the preceding 'double letter' experiments. These possibilities will be explored in the following experiment.

TABLE 10.1

Accuracy Analysis

Between Subjects	d.f.	F	p
ISI	1,56	20.0	<.001
ISI x Classification	3,168	7.07	<.001
ISI x Sex x Warning Interval	1,56	4.2	=.05
ISI x Warning Interval x Visual Field	1,56	4.0	=.05
Response Mapping x Visual Field	1,56	5.6	<.05
Within Subjects			
Warning Interval	1,56	4.11	<.05
Classification	3,168	18.6	<.0001
Visual Field x Classification	3,168	13.1	<.001

Effects significant at $p \leq .05$

TABLE 10.2

Interaction between ISI and Classification

ISI	PI	NI	D_R	D_L
	Classification : Proportion Correct			
50 msec	.87	.71	.77	.71
990 msec	.87	.77	.88	.85

TABLE 10.3

Interaction between Visual Field and Classification

Visual Field	PI	NI	D_R	D_L
	Classification : Proportion Correct			
RVF	.879	.782	.863	.734
LVF	.864	.699	.791	.828

TABLE 10.3

Interaction between Warning Interval and Classification

Warning Interval	PI	NI	D_R	D_L
	Classification : Proportion Correct			
Short	.871	.78	.822	.801
Long	.872	.704	.832	.756

Legend:

PI = physical identity

NI = name identity

D_R = different change right letter

D_L = different change left letter

TABLE 10.5

Latency Analysis

Between Subjects	d.f.	F	p
Response mapping	1,56	6.5	.05
Response mapping x warning interval	1,56	13.5	.01
Response mapping x visual field	1,56	5.9	.05
Response mapping x ISI x warning interval	1,56	4.4	.05
Response mapping x visual field x classification	3,168	3.1	.05
ISI x warning interval	1,56	9.1	.01
ISI x visual field x classification	3,168	2.8	.05
Within Subjects			
Warning interval	1,56	51.5	.001
Visual field	1,56	24.7	.001
Classification	3,168	35.26	.001
Warning interval x classification	3,168	3.4	.05
Visual field x classification	3,168	5.4	.01

Effects significant at $p \leq .05$

TABLE 10.6

Response Latency : Interaction between responding hand assignment and duration of warning interval.

Responding Hand	Warning Interval	
	Short	Long
Right Hand = Same	711.1 msec	730.7 msec
Left Hand = Same	781.3 msec	842.1 msec

TABLE 10.7

Response Latency : Interaction between warning interval and ISI (interstimulus interval).

ISI	Warning Interval	
	Short	Long
50 msec	728.4 msec	785.7 msec
990 msec	763.9 msec	787.2 msec

TABLE 10.8

Response Latency : Interaction between warning interval and classification.

Warning Interval	Classification			
	PI	NI	D_R	D_L
Short	665.2 msec	736.1 msec	795.2 msec	795.7 msec
Long	722.9 msec	792.7 msec	838.0 msec	784.8 msec

TABLE 10.9

Response Latency : Interaction between visual field and classification.

	Classification			
Visual Field	PI	NI	D_R	D_L
Right	665.2 msec	736.1 msec	795.2 msec	795.7 msec
Left	722.9 msec	792.7 msec	838.0 msec	784.8 msec

TABLE 10.10

Response Latency : Interaction between response mapping, duration of warning signal and ISI.

		Warning Interval			
		Short		Long	
Hand	ISI	50	990	50	990
Right = Same		654.4	767.8	702.8	758.6
Left = Same		802.5	760.1	868.5	815.8

TABLE 10.11

Interaction between visual field and response mapping.

(a) Latency:

	Right Visual Field	Left Visual Field
Right = Same	693.6 msec	748.2 msec
Left = Same	802.4 msec	821.0 msec

(b) Accuracy:

	Right Visual Field	Left Visual Field
Right = Same	.83	.781
Left = Same	.80	.81

TABLE 10.12

Response Latency : Interaction between response mapping, visual field and classification.

	Right Visual Field				Left Visual Field			
Classification	PI	NI	D_R	D_L	PI	NI	D_R	D_L
Right = Same	598.9	710.2	722.7	742.8	665.3	754.4	799.2	773.8
Left = Same	731.4	762.0	867.7	848.6	780.5	830.9	876.9	795.8

CHAPTER 11

Experiment VIII

Although the previous experiments have shown a fairly consistent pattern of interactions between visual field and classification type when ISI is blocked; it would be premature to extend the inference of bilateral PI retrieval and predominantly left hemisphere NI retrieval, to single letter classifications. Double letter stimuli differ from single letters in the extent to which a PI advantage is maintained when regular ISI's are employed and hence, it might be argued that different systems are implicated in 'visual memory' for the two types of stimuli.

This possibility was explored in the following experiment. The experiment required subjects to classify single letters, as in the 'standard' procedure employed by Posner *et al* (1969). In addition a variable ISI condition was employed in order to provide a partial replication of the Wilkins & Stewart (1974) study. As will be recalled from the discussion of this investigation presented above (Chapter 3), Wilkins & Stewart obtained anomalous, negative PI effects with this procedure, which could possibly be accounted for in terms of the attentional demand hypothesis outlined in the previous chapter. Such an effect would pose problems for the proposed interaction between task difficulty and attentional demands which was proposed in order to account for stability in the PI effect under variable SOA conditions for experiment VI, and hence requires investigation in order to determine whether this interpretation is adequate. The evidence provided by Posner et al (1969) suggests that single letters are unaffected by ISI regularity, but the addition of spatial uncertainty conditions required by visual field investigations may result in a somewhat different pattern of ISI effects, due to the additional load which they may place on attentional capacity.

Method

This experiment required an alternative stimulus list which was constructed in the following manner. All letters of the stimulus set described in the general method section above were used. S_1 was always a single upper-case letter, S_2 was equiprobably upper or lower case. Half the trials of S_1-S_2 pairings required same judgements. Upper and lower case S_2 stimuli were equally represented in both 'same' and different categories. The entire stimulus list comprised eighty trials half of which were given at a 50 ms ISI, the remainder at 990 ms ISI. Exposure durations of S_1 and S_2 were identical to those described for double letter stimuli.

The matching categories described above were equally represented at both ISI's. Each S_1-S_2 pairing appeared twice in any experimental list, once with S_2 appearing in the RVF, and with S_2 in the LVF on another occasion. Stimuli appearing as PI matches or as capital (upper-case) mismatches at one ISI appeared as NI pairings or lower case mismatches at the other ISI. This factor was counterbalanced between Ss within conditions (see below) so that each S_1-S_2 pairing was tested an equal number of times at both ISI's. In order to achieve variable and fixed ISI conditions two different randomisation programs were used, one of which randomised all trials from the experimental list (as described in experiments IV-VII) and the other randomised trials within ISI categories.

The apparatus was identical to that described in the previous experiment.

Thirty-two _S_s were recruited, sixteen female, sixteen male, all of whom were right-handed for writing (self report).

Procedure

The procedure was very similar to that employed in the double letter matching task which has been described previously. S_1 stimuli were shown at the centre of the screen for 100 ms, and S_2 to the RVF or LVF at a visual angle coincident with the centre point of the double letter arrays used in the previous experiments for 100 ms.

The design of this experiment required some modifications in counterbalancing procedures from those described previously, namely, that within the blocked ISI condition half the _S_s received a 990 ms ISI followed by a 50 ms interval, and half the reverse order so that data would not be confounded by practice effects.

Practice

All _S_s were given 10 trials of practice before participating in the experiment. The organisation of practice trials was appropriate to the subsequent experimental conditions so that five trials, selected at random, were given with an ISI of 990 ms and five with a 50 ms interval. _S_s performing in the 'blocked' conditions received these practice trials in the same order as the experimental list (i.e. five at the first interval, followed by five at the second). Ss in the variable ISI condition received all practice trials in a random order. Ss in both conditions were informed that some presentation sequences would be 'very fast' and others 'slower', those receiving the blocked trials were made aware that the intervals involved in the experimental sequence would follow 'the same pattern' as those in the practice run, with forty trials being given at each ISI.

Following practice all Ss were given the first forty trials of the experimental list, and a short break was given for all Ss so that those in the 'blocked' presentations could be informed of the impending change in retention intervals. The Ss in the randomised ISI group were given a similar 'break' and merely informed that the experiment was half-way through. This procedure was adopted in order to eliminate any confounding due to different degrees of fatigue in the experimental groups.

Apart from the aforementioned modifications all aspects of stimulus presentation, fixation cross presentation, and instructions were identical to those described for the double letter task.

Results

Data was accepted for analysis following the same criteria as those described in the preceding experiment.

1. Response Latency

Preliminary analysis indicated no main effect or interactions with sex of S. The data was therefore subjected to a 5-way analysis of variance with response laterality, ISI regularity, between subjects, and ISI duration, classification and visual field within subjects. The only significant effect was that of classification ($F_{2, 56} = 5.2$, $P < .01$) shown in Table 11.1. There was no interaction between ISI regularity and classification. Six subjects showed an increasing PI advantage over the intervals studied in the variable ISI condition, and seven showed comparable effects when blocked ISI's were employed.

2. Accuracy

There was a pronounced ceiling effect in the accuracy data similar to that obtained by Wilkins & Stewart (1974). No significant effects were shown in analysis of 'different' responses but 'same' judgements indicated that right hand decisions were reliably more accurate than were left. The former group held a mean 9% error rate and the latter 16%. The effect of classification was not reliable in this data ($F_{1, 14} = 4.3$, $p > .05 < .1$) but there was an interaction between classification and visual field following the so-called 'prototypical pattern' shown in Table 11.2. ($F_{1, 28} = 7.5$, $p < .05$).

Discussion

The PI advantage obtained in this experiment was quite small (25 ms). Interpolation on the 'decay curve' provided by Posner *et al* (1969) would predict a PI effect of approximately 70 ms at the brief ISI employed in this experiment and of about 20 ms after a retention interval of 990 ms. The problems posed by a small (but reliable) effect are not that serious however, since Walker (1979) has recently shown that the magnitude of a single letter (simultaneous) PI advantage may be a function of the angle separating S_1 and S_2. No evidence for a 'decline' in PI effect was obtained in this experiment: This may, in part, be due to a confounding with low values of the PI effect (possibly approximating to a 'Law of Initial Values' e.g. Martin, 1973) or perhaps to individual differences operating prior to asymptotic levels of practice, and PI decline. A similar argument might be applied to the failure to demonstrate differential rates of PI decline in the variable and blocked ISI conditions. The data cannot provide any conclusive evidence on this point, although the absence of an interaction was predicted on the basis of Posner & Keele's (1967) study. Wilkins & Stewart's investigation did not show 'abnormal' rates of PI decline over ISI's which could be attributed to an acceleration of access to name codes, but their data was so complex on these 'coding' variables that no conclusion is warranted at this stage. Further work (which would be beyond the scope of this thesis) is required to establish whether variable ISI manipulations differentially affect centrally presented single and double letters. Central presentations would appear to be necessary in order to provide adequate levels of PI advantage at brief ISI's.

There was no evidence for a systematic negative PI advantage as found by Wilkins & Stewart (1974) in their left hand same group, neither was there any indication of an ISI by visual field interaction in this experiment. The reasons for this conflict in results are not clear but since comparable problems in replication have been noted by Kirsner (1979), it seems likely that the earlier data was not reliable.

Kirsner (1979) obtained an overall right field advantage for both PI and NI classifications, but his stimulus exposure durations were sufficiently long to permit lateral eye movements (200 msec). This may have reduced the sensitivity of his experiment to any left field component in the overall variance.

The error rates obtained by Wilkins & Stewart were somewhat lower than in the present investigation, suggesting that some variance may be accounted for by different levels of difficulty, and data classification between the two experiments. An appropriate analysis of the data provided by 'accurate' (errors of 10% or less N = 24) and inaccurate (errors of 11% and more N = 8) Ss was not possible since these categories were unevenly distributed within counterbalancing conditions. However, examination of mean latency and accuracy scores did not suggest that either the visual field x classification interaction, or the ISI x visual field interaction had been confounded by 'sloppy' responses from eight Ss. Full tables of raw data for this experiment are presented in the appendix to facilitate comparison with Wilkins & Stewart (1974).

It might also be argued that the hemifield x classification interaction obtained in this experiment was a product of difficulties in the perceptual analysis of stimuli. Such 'levels of difficulty' may, indeed, be a contributing factor towards hemifield asymmetries (see below) but the evidence does not suggest that this variable produced a spurious

PI/LVF advantage in this experiment.

Although the PI advantage was small in this investigation, it was reliable. The addition of random visual noise selectively slows the rate of PI judgements (Nickerson, 1975; Posner, 1978). Wilkins & Stewart's stimuli yielded a negative PI effect which may be indicative of difficulties at the level of perceptual analysis of stimuli. As Bryden & Allard (1976) have shown, placing greater demands on early levels of stimulus analysis may lead to an LVF advantage for alphabetic material (see also Umilta _et al_, 1979, _in press_). Since the group of _S_s who showed the largest 'negative PI' advantage in Wilkins & Stewart's experiment, also manifest the greatest LVF advantage, this account appears to indicate that their overall results were influenced by demands on right hemisphere systems arising from difficulties in dealing with stimulus materials. If this argument is valid, then the ISI interaction with visual field may reflect an activation, or a development, of _perceptual_ classification systems over time, rather than bearing any relationship to differential storage of memory codes.

General Discussion

The results of this experiment appear to indicate that different systems are implicated in performance of double and single letter tasks. This conclusion is supported by evidence for a bilateral mediation of PI judgements in the two-letter condition, and a selective LVF advantage for those materials when presented as single letter stimuli. Since the evidence from experiment VII demonstrated that visual field effects were more parsimoniously accounted for by <u>retrieval</u> parameters rather than in memory storage, the data cannot be validly utilised in order to argue for memory differences between constraints in coding of the two types of stimulus array. It therefore seems likely that the visual field effects are linked to systems operating from the time of S_2 presentation onwards.

Summary and Conclusion

This experiment showed a small reliable PI advantage for single letter stimuli which appeared to be mediated by right hemisphere systems. NI judgements showed an RVF advantage as in the previous experiments utilising double letter materials. It was argued that the different pattern of visual field effects obtained in double and single letter tasks appear to be due to retrieval demands rather than differences in memory storage.

TABLE 11.1

Response Latency

Classification	
PI	626 msec
NI	651 msec
Different	669 msec

TABLE 11.2

Proportion Correct

Classification	RVF	LVF
PI	.9	.94
NI	.88	.83

CHAPTER 12

12.1. Introduction

The experiments reported in this thesis have been concerned with the structural correlates of sequential letter matching. The evidence has enabled a detailed analysis of the functional properties of the double-letter matching task, and, in addition, has demonstrated a relative invariance in the pattern of structural dissociation despite the involvement of (strategic) coding bias.

In this chapter I shall discuss the implications of these findings, in terms of their relevance for models of hemisphere function, and for their bearing on issues concerning the sequential letter matching task. Prior to such discussion, however, it is necessary to put this research project into some context. To this end I shall initially be concerned with a summary of Posner's (1979) model of cognitive function (Section 12.2) since this provided the framework for the experiments which have been presented above. A variety of methodological issues are raised by these studies and these will be dealt with in section 12.3.

12.2.

Posner's model of cognitive function was utilised because its range incorporates many of the issues which have been raised in the investigation of hemisphere asymmetries in normal subjects. The sequential letter matching task, upon which much of Posner's theorising is based, provides an operational definition of behaviourally dissociable memory codes, and, additionally permits an investigation of the interaction between such variables, and attentional demand(s).

Posner's emphasis on dissociable subsystems in human memory is highly congruent with the current orientation, and data from, clinical neuropsychology (see e.g. Shallice, 1979; Warrington, 1980) and from studies of visual field asymmetry in neurologically intact subjects (see e.g. Cohen, 1975; Moscovitch, 1979; Walsh, 1978; Dimond & Beaumont, 1974). The letter classification task (Posner & Klein, 1967; Posner *et al*, 1969) has typically been used to define two such 'isolable subsystems' in memory, whose relative independence has been substantiated over a range of experimental procedures (Corcoran & Besner, 1973; Kroll, 1975; Pachella & Miller, 1976; Thompson *et al*, 1976; Posner, 1969, see Posner, 1979 for a detailed review).

The letter classification task requires subjects to judge whether two items are 'the same' according to experimenter defined rules, the most commonly used rules being name identity (NI) or physical identity (PI). The time course of memory code development may be operationally defined by latency or accuracy of such judgements (e.g. Pachella, 1974). The data from the sequential presentation of single letter arrays, word stimuli, and displays of three or more random letter strings, indicates that an initial advantage for PI judgements over NI declines to insignificance over a comparatively brief retention interval (see e.g. Posner, 1979, and references therein). Two letter arrays are anomalous in that they may show a PI advantage for as long as 12 seconds (Parks & Kroll, 1975; Kroll & Parks, 1978).

Posner accounts for the change in PI advantage by three different forms of system action and interaction. Decline in visual bias may be due to decay, or equivalently, to a passive decline of activation within the visual pathway. This was the view emphasised by Posner & Keele (1967) and Posner & Klein (1969). The second possible basis of change is more closely allied to the 'levels of processing' approach to memory (e.g. Craik & Lockheart, 1973). On this model, higher level (verbal) codes develop more slowly than do the lower level (visual). The decline in PI advantage therefore reflects a process of abstraction of information from visual input. The third model emphasises a feed-forward from an abstract, or verbal representation, to visual pathways, termed 'visual generation'. In his most recent discussion, Posner (1979) distinguishes the generation of a visual code from the generation of visual images in terms of phenomenological criteria. Subjects may be conscious of a visual image, but there can be evidence for the use of a visual code in the absence of awareness. Such evidence for code generation is drawn from two major sources: (a) decision latencies to cross modality matches which show rapid classification of auditory/visual stimulus presentation (e.g. Posner et al, 1969; Woods, 1974, 1977) and (b) investigations of salient dimensions of 'confusability' in 'different' judgements which suggest that decisions are performed on the basis of S_2 classifications (e.g. Tversky, 1969; Woods, 1977).

Posner's model is not restricted to an account of the time course of memory code development. His views on attentional involvement are highly relevant to Kinsbourne's (1973, 1975, 1978) model of the systems involved in producing visual field asymmetries (see also Moscovitch, 1979; Shallice, 1978).

Posner argues that input to the relevant memory subsystems is automatic, and places no demand on attentional capacity. Such stimulation results in the passive activation of a range of 'psychological pathways', whose extent is dependent on subjects prior knowledge of stimulus materials. For example, presentation of the letter 'A' would (at the very least) result in passive ('automatic') activation of a memory representation for the physical features of the letter, and for its alternate-case transform 'a'. Psychological 'pathways' are viewed by Posner, as components of the 'isolable subsystems' referred to above.

Although 'pathways' may initially be activated in an associationist -reflex arc manner, attention may subsequently be delegated to facilitate certain systems, and inhibit others. 'Selective attention' is considered to be an isolable subcomponent of cognition, which operates upon memory systems, and is subject to endogenous control. Posner's model of 'attentional bias' provides a plausible cognitive framework for examining the hypotheses of Kinsbourne on the topographical distribution of 'attention' as a function of priming effects (see chapter 2 above).

When subjects are 'biased' in their preparation, Posner suggests (1978, p.136) that interactions may be obtained between warning signal effects and task demands. This, he proposes arises as a consequence of the demands on capacity which derive from 'active preparation'. This account is supported by Norman & Bobrow's (1975) analysis of resource limited processes, which will be discussed in greater detail in section 12.4.

A somewhat different aspect of Kinsbourne's model could be subsumed within Posner's views on the effects of alertness. Posner argues that, in the absence of selective bias, alerting, induced by a warning signal, (and arguably, as a product of diurnal rhythm (Posner, 1975; 1978)) results in a speeding of the processes subsequent to initial activation of the input pathways. With tachistoscopic presentation of stimuli, increased alertness will therefore result in a performance increment since judgements, may be based on higher levels of information. With prolonged exposure, highly alert subjects may respond too rapidly (i.e. before maximum information has been derived from the array) producing a speed-accuracy decrement. Within Kinsbourne's model, this perspective would provide a rationale for material dependent asymmetric activation. The visual field contralateral to the more alert cerebral hemisphere would be "enhanced" under conditions of tachistoscopic exposure.

Since Posner's model addresses the issues of dissociable memory systems, and the effects of attention, it is not surprising that several investigations of visual field differences in 'normal' subjects have utilised his methodology. Indeed, Posner (1979) argues that the data from such experiments provides powerful converging evidence for the systemic fractionation he has posutlated on the basis of purely 'behavioural' studies (i.e. those which have not been concerned with structural correlates).

The experiments on visual field effects which are relevant to this issue were discussed in some detail in chapter 2 above, and will be considered in summary form in the following paragraphs. It should be noted, however, that those investigations have been, without exception, concerned with the question of a dissociation between NI and PI systems and have made no serious attempt to deal with the problems of attentional involvement. The labels of 'visual' and 'name', 'associative' or 'verbal' memory have been applied somewhat indiscriminately to the presumed effects of stimulus demand. Such labels provide a convenient shorthand for describing the systems involved in upper to lower case stimulus transformations, but it would be premature to assume that such systems are entirely parasitic upon some 'general purpose' linguistic or visual memory.

<u>Applications of Posner's task to investigations of visual field asymmetries.</u>

Simultaneous Presentation:

The review presented in chapter 3 of simultaneous classification of letter stimuli, indicated that there were no entirely consistent patterns of lateral asymmetry for either NI or PI judgements when 'mixed list' conditions were employed (i.e. those in which NI and PI judgements were equiprobable) several studies had indicated a (left hemisphere) right field advantage for NI classifications, and bilateral mediation of PI judgements (Ledlow <u>et al</u>, 1972; Ledlow <u>et al</u>, 1978; Gazzaniga, 1976). Geffen et al's (1973) study was the only investigation which pointed to a right hemisphere mediation of PI stimuli under such presentation conditions. It was suggested that the latter result might have been due to a bias on early visual analysis induced by the stimulus arrays employed by Geffen et al. Their name-match stimuli were equal in size (e.g. Aa), a manipulation which might affect the salience of featural analysis in visual processing (e.g. Bryden & Allard, 1976).

Sequential Classification:

Three investigations of sequential classification of letter stimuli have now been published. The presentation sequence employed in these experiments has followed the same pattern as that employed in this thesis, namely of central presentation of the memory item (S_1) followed by unilateral presentation of the test item (S_2) to right or left visual fields.

The first study to be reported was that of Wilkins & Stewart (1974). They employed single letter stimuli, and obtained a visual field x ISI interaction. Left field presentation was superior for PI judgements at 50 msec ISI, but after 990 msec an overall right field effect was shown. Unfortunately, half their subjects showed a negligible PI advantage at the short retention interval which increased in magnitude as the ISI was prolonged. There was no interaction involving subject groups which justified Wilkins & Stewart's ascription of early visual (i.e. PI) processing to the right hemisphere. Their arguments for ascribing an early visual trace to the right hemisphere, that was subsequently replaced by a left hemisphere verbal 'trace', may or may not be valid.

If valid, one is forced to conclude that the visual trace does not correspond to the operational definition provided by the PI : NI ratio.

More recently, Kirsner has reported an attempted replication of Wilkins & Stewart's study (Kirsner, 1979). He was able to obtain a reliable decline in the PI advantage over ISI's of 750 msec, in the absence of any field x match type interaction. An overall right visual field effect was found for all 'same' stimuli at ISI's of 150 msec or longer. Stimuli presented with a zero millisecond ISI but 50 msec SOA were equally rapid in both visual fields, athough showing an inflated error rate with left field presentations. Kirsner argued, therefore, that there was an overall left hemisphere advantage in matching efficiency, and that PI advantage or change in advantage, did not relate to alterations in right hemisphere 'visual memory'. His interpretation did not extend to an ascription of 'visual memory' for these materials to the left hemisphere. He suggested that the main effect of visual field was due to attentional bias, induced by the verbal demands of the task (after Kinsbourne, e.g. 1973).

In some respects, Kirsner's findings are compatible with those obtained in this thesis, since the experiments reported herein were also unable to demonstrate an interaction between operationally defined code changes over time, and visual field differences. However, the interpretation which will be offered differs from that put forward by Kirsner, and hence some consideration of the relevance of his attentional bias explanation is required.

Kirsner's explanation rests on the assumptions that left hemisphere 'activation', and thus, right visual field advantage (1) is non-additive in its effects and (2) is unrelated to the 'state' of memory coding, but acts in an all-or-nothing manner.

Non-additivity is required by Kirsner's failure to obtain visual field x classification type interactions: were PI matches 'normally' mediated by right hemisphere systems as the 'prototypical' model suggests, an additive effect of attentional bias, in the presence of right hemisphere 'advantage' would be expected to result in diminished asymmetries for PI judgements, and enhanced right field effects for NI judgements. Of course non-additivity is a plausible assumption but it results in difficulties with interpretation because a wide range of non-additive models could be applied. Amongst the possible structural correlates of a non-additive model are (a) change in the systems utilised in the mediation of an operationally defined memory code (a 'switch' from right to left hemisphere systems in the absence of coding shifts), (b) a tradeoff between interference and 'activation' within the left hemisphere, or (c) of interactions between coding and attentional 'benefits' operating in independence of structural constraints, such that PI matches received a greater attentional-locational weighting than did NI.

Assumption (2), that attentional bias is unrelated to the state of the memory code raises several problems. This assumption is necessary since there were no reliable effects of ISI (SOA) on visual field differences. The extent of 'verbal' (name-level) bias was operationally defined in

Kirsner's study by change in the relative advantages of PI to NI match-type, yet verbal demands (so defined) had no effect on the magnitude of the difference between visual fields. This 'all-or-nothing' influence of attentional effects is paradoxical, since within blocked presentation conditions verbal bias is likely to have been maintained at a consistent level for any SOA (viz. relative PI : NI latency effects). The evidence cited by Kirsner for simultaneous match conditions (Cohen, 1974; Geffen _et al_, 1973) showing PI right hemisphere effects (although of questionable importance in the former case - see chapter 3) is relevant in this context. Were subjects 'set' by the verbal nature of the task _per se_ then these experiments should also produce overall right field advantages rather than interaction (see also the discussion above).

To return to the problem of additivity,non-additivity in attentional bias: (see also Kinsbourne, 1978) neither (b) the activation-interference model, nor (c) the differential weighting of PI judgements can be accepted uncritically. In the case of the former interpretation: activation-interference should, arguably, bear some relationship to the development of the NI bias over time (Hellige & Cox, 1976).

The differential weighting hypothesis could be accepted only on the grounds that benefits to PI classification were operational at the time of S_2 presentation, had no relationship to memory code, and in addition were independent of structural parameters.

Kroll & Madden (1978) have reported two studies involving lateralised presentations of double letter stimuli. Seven experiments reported in this thesis employed a similar technique.

Kroll & Madden utilised variable ISI conditions in their first experiment, but omitted any analysis of code bias over time in their report. This was unfortunate since experiments IV, V and VII above suggested that these conditions were liable to affect the relative advantage of PI to NI matches. Their results did not show any interactions between visual field effects and retention interval, but gave a complex pattern of dissociation between visual field, match type, and subject group (defined on the criterion of 'verbal ability'). 'High verbal' subjects showed a pattern of visual field effects comparable to that obtained by the female subgroup in experiment V, and also shown, in a somewhat less reliable form, by all subjects in experiment I above. Low-verbal subjects manifest an overall right field advantage.

As was discussed above (chapter 3) Kroll & Madden's argument for differences between groups in terms of their functional lateralisation, and the corollary that cerebral organisation is causally related to verbal ability, cannot be accepted: Their first experiment showed an insignificant relationship between NI-PI indices and verbal ability scores. A follow-up study, with blocked ISI's, showed a more reliable correlation between a novel 'verbal ability' measure and the NI-PI index, but failed to replicate the visual field x match type dissociation between groups so categorised. Whilst the latter result might be 'explained' by regression towards the mean, the data from their initial study cannot be employed in arguing for a relationship between qualitative differences in functional organisation, and quantitative effects on 'processing', since no group differences were observed on the coding variables in question.

Their data may be summarised as follows: Under conditions of temporal variability in ISI, verbal ability measures predict visual field asymmetries but not coding bias. Under conditions of fixed (blocked) ISI and SOA, 'verbal ability', predicts coding differences but not visual field asymmetries. Since 'verbal ability' differed in its definition between their experiments, it is impossible to determine the role of time structure in the effects which were observed. We are, therefore, left with two sets of results which are primarily related in terms of stimuli. Despite Kroll & Madden's use of an index of cognitive processing, their inductive leap in attributing levels of skill as a function of cerebral organisation, rests on an ostensive (experimenter defined) categorisation of the task (see chapter 3 above).

Whilst Kroll & Madden's study gave consideration to NI and PI judgements as a definition of cognitive function, their emphasis on individual differences in cerebral organisation, and levels of verbal facility reduces the strength of the studies which they report. As was argued in chapter 3, the utilisation of constructs which are derived from or applicable to one set of experimental results in explaining another set, where that particular construct is inapplicable, or undefined, begs too many questions.

The review presented above indicates that there are, as yet, few conclusions which may be drawn from studies utilising letter classification judgements in investigations of visual field asymmetry. The 'prototypical interaction' (Hellige, 1976) between visual field and classification demands appears somewhat unreliable; furthermore, evidence favouring a dissociation of systems mediating NI and PI memory codes is only suggested by the earliest (and most seriously flawed) of the investigations reviewed above.

12.3 Methodology

The technique which was employed to investigate structural asymmetries was that of randomised unilateral tachistoscopic presentation to the right or left visual fields. Whilst this procedure was considered to be a 'noisy' one (see chapter 2) in that visual field asymmetries due to structural differences might be confounded with variance as a product of attentional (Kinsbourne, 1978) and/or scanning biases (e.g. White, 1973). It was argued in chapter 2 above, that a substantial proportion of the total variance involved in visual field effects was likely to be the product of hemisphere asymmetries in the systems required to perform a particular task.

The experiments which have been presented in earlier chapters support this contention. The effects which were obtained were more plausibly accounted for by a model postulating an interaction between the 'processing' demands of the task, and structural asymmetries in the representation, of a subset of systems, required for task performance, than to directional bias or attentional 'priming'.

More detailed discussion of the relevant evidence will be postponed to a later section of this chapter.

A range of important methodological questions are raised by the use of accuracy and latency measures as dependent variables, and it is to these problems that we must now turn. The employment of two dependent variables necessarily leads to difficulties in obtaining an unambiguous interpretation of results. This difficulty is compounded by the absence of any suitable analysis of covariance model for the (most probably) non-monotonic function for speed-accuracy tradeoff with tasks comparable to those utilised in this research series (Posner, 1975; 1978).

The principal difficulties raised may be defined as follows:

1. <u>The possibility that all findings were a function of speed-accuracy tradeoff</u>. Were this the case then latency and accuracy effects would be expected to show opposing trends rather than, as was noted in the studies reported above, a strong tendency to 'mirror' each other in their effects.

A pure speed-accuracy tradeoff interpretation would, for example, predict an RVF advantage in accuracy to be offset by an LVF advantage in latency. There was no reliable support for such a view, indicating that subjects were obedient in complying with demands to respond as quickly, and as accurately as possible.

2. <u>That there was no systematic relationship between speed and accuracy in task performance</u>, i.e. that the two measures do not provide convergent evidence for the systems under investigation.

There is no support for this view, either in the research reported above, or from tasks utilising single letter techniques (Blake <u>et al</u>, 1970; Taylor & Reilly, 1970; Pachella, 1974). Problems may arise in comparing and contrasting the magnitude of effects across speed and accuracy domains, but appear to be of little consequence in defining within domain effects.

3. The possibilities of statistical artefact.

(a) Latency measures: There were individual differences in the number of samples employed to produce a latency mean for any given cell of the overall ANOVA's. This might result in distortions of variance, which could violate the assumptions made by the analysis procedure.

This might occur as a consequence of the difference between cells in their allowance for variability in sample means. This consideration is especially troublesome, since the number of means which contributed towards any given cell in the ANOVA was not due to random variation, but the product of variance which was correlated with the factors under analysis (as indicated by the effects noted in analysis of accuracy data).

Whilst the involvement of such distortion cannot be ignored, there are sufficient grounds for considering it to be of minor importance when dealing with the results reported above. One consequence of the differences in the number of means, per subject, per cell, would be to increase the amount of 'noise' in a particular subset of the analyses. This would reduce the power of the experimental design, and increase the probability that 'significant' differences would be falsely rejected, rather than resulting in spurious effects. A second related consequence might be a violation of the homeoscedacidity assumptions of ANOVA by a disproportionate increase in variance in the subset of measures derived from such reduced samples. Since the number of measures contributing towards each cell was comparatively small (n = 5 from experiment III onwards) variance within each condition (per subject) would be large, and unlikely to be dramatically affected by the limited reduction of _n_ in the manner described above. As there was no evidence for serious violations of the equality of variance assumptions in any of the analyses which have been reported, it is unlikely that spurious 'significance' could account for the patterns of results which were obtained.

To summarise the points which have been made in this section so far: The use of speed and accuracy measures as two dependent variables has been considered. Firstly, it was argued that since speed/accuracy tradeoff showed a systematic inverse relationship in tasks comparable to those employed in this research project, the likelihood of interaction between functionally defined memory systems and criterion effects seemed small. Secondly, the possible sources of artefact on latency measures were considered, and it may be suggested on this basis that replication of effects is necessary for a satisfactory degree of confidence in findings.

(b) Accuracy measures:

The problems posed by the 'accuracy' data differ from those discussed above. For experiments I-IV, an absolute accuracy criterion was employed, with responses distinguished on the basis of correct vs. incorrect, without regard to the speed of any particular judgement. For experiments V onwards, however, a stricter criterion of 1200 msec was adopted for 'correct' classification judgements, decisions requiring 1201 msec or larger were defined as 'incorrect', and analysed as errors. The percentage of such responses was however extremely small for all subjects.

This approach was adopted in experiments V onwards because of an increase in the number of occasional long reaction times when time structure was uncertain (see experiments IV and V above). Although it might have been preferable to utilise an individually determined criterion for rejection or acceptance of latency values, it was considered that the additional power offered for analysis of accuracy data would be offset by a diminution in the reliability of estimation for the cells in the latency ANOVA. Thus the aforementioned compromise solution was employed in order to eliminate the more gross values.

Whilst the problems outlined above cannot be ignored, the use of an 'efficiency' approach yields practical, and theoretical, advantages. The use of a 'pure' accuracy measure would necessitate individually determined, brief exposure durations in order to eliminate 'floor' and ceiling effects that might result in changes in systems involved in classification judgements (Posner, 1978; Moscovitch, 1979). Exposure duration effects are not immune to criterion bias and would raise problems in utilising an appropriate model for covarying exposure duration and accuracy (see Levy & Reid, 1979 for one such attempt).

The alternative procedure, that of employing a 'pure' latency measure would, with hindsight, have been more desirable. Although this would not eliminate criterion differences (Ollman, 1977) it would have the advantage of providing a unitary dependent variable for subsequent analysis. However, the achievement of stable latencies, and low error rate, would have required prolonged practice sessions, and dedicated subjects (as e.g. employed by Posner et al, 1969). Additionally, Hellige & Cox (1976) have reported interactions between practice and visual field of presentation, and, although this pattern was not in evidence after between trials 91 and 180 in experiment III above, the possibility remains that extensive practice might confound, or alter critical aspects of task performance. The levels of practice adopted were therefore comparable to those employed by Kroll and his colleagues in their earlier experiments with similar materials (see e.g. Parks & Kroll, 1975). The slightly higher error rates obtained in the present series of experiments are hardly surprising since stimuli were presented for shorter periods of time, under conditions of random stimulation of right and left visual fields.

Despite the aforementioned difficulties presented by the use of 'two dependent variables' the theoretically relevant effects which were obtained in this series of experiments were, in general, replicated across a range of conditions. This suggests that despite certain drawbacks, the procedure which was adopted was satisfactory, albeit lacking in the refinements required for the 'ideal' experimental project.

The experiments presented in this thesis have necessarily involved a parallel consideration of 'cognitive' function, and structural interactions. For clarity, these aspects will be considered separately in the following two sub-sections. Subsequently, I shall be concerned with an attempt at synthesis.

12.4 Coding Effects

The results of experiments 1 and 2 replicated the 'prolonged' PI advantage for double letter stimuli reported by Parks & Kroll (1975) and by Kroll & Parks (1978). Over an unfilled retention interval of nine seconds a substantial effect of classification type was obtained with latencies ordered in the relationship PI NI Different. When a concurrent auditory shadowing task was utilised (experiment II), there was a selective deficit in NI performance, (by comparison with the 'unfilled interval' conditions of experiment I). This finding suggests that the systems required NI judgements may overlap with those involved in 'shadowing' performance (see also Posner, 1978).

This pattern of results may, or may not, reflect the operation of interference, within a system set involved in 'language processing'. Kahneman (1973) has drawn a distinction between interference in performance arising as a product of general constraints on 'processing capacity', and that which arises from 'structural interference' due to two tasks placing demands on a common processing system.

As Norman & Bobrow (1975) have pointed out, it may, in fact, be difficult to determine whether an effect, of the type discussed above, is the product of structural, or capacity interference. They have defined performance-resource functions which discriminate 'easy' and 'difficult' tasks in terms of their requirements on overall capacity (for related arguments see Navon & Gopher, 1978). When performance is described as a function of resource, the relationship is monotonic, and incremental to asymptote. Thus, 'easy' tasks would reach higher levels of performance under greater levels of capacity demand.

In the double letter matching task PI judgements may asymptote more rapidly than NI classifications. That is, subjects might achieve a (hypothetical) ceiling in performing an easier PI matching task under greater degrees of resource or capacity demand. A more 'difficult' NI match would require a greater degree of resource availability, and would thus deteriorate relative to such 'easy' judgements, when capacity demands were made. The differential effects of concurrent shadowing on classification types could, therefore, either arise as a consequence of differential resource requirements, or, alternatively from structural interference between common systems involved in NI analysis, and 'verbal' output.

The data does not allow the discrimination of these possibilities. This problem was not pursued in the research project as it was considered tangential to its overall aims. However, it does appear to be an important one requiring further investigation. The assumption that NI judgements are parasitic upon 'naming' systems requires formal testing, utilising the methodology suggested by Norman & Bobrow (1975), or the 'multiple resource' framework proposed by Navon & Gopher (1979).

Experiment III was devised to examine the effects of brief retention intervals on the sequential matching of double letters. The results of this study were broadly comparable with those of experiment I, showing a stable PI effect, and no interaction between performance on any classification type, and ISI.

The anomalous results on PI effects obtained by Wilkins & Stewart (1974) (see above) indicated that unpredictable ISI conditions might affect coding or visual field effects. Thus, random, distributions of equiprobable 50 msec and 990 msec ISI's were explored in experiments IV and V. The results were clear. When subjects were unable to anticipate retention intervals reliably, double letter stimuli showed a decline in the relative advantage of PI matches, contributed by a deterioration in PI judgements, and an improvement in NI and different classification. This result was accepted as evidence for code change or development over the retention interval (after Posner & Klein, 1967). It should be noted that performance-resource argument of the type utilised in discussing the results of experiments I and II is not applicable to these findings, since 'difficult' NI classifications improved over ISI's whilst 'easier' PI judgements deteriorated in efficiency. The monotonic relationship between performance and resource therefore fails to account for the data.

These results raised certain difficulties for the visual-generation explanation of the persistence of the PI advantage (Parks & Kroll, 1975; Kroll & Parks, 1978). It will be recalled that this hypothesis postulated that subjects were unable to engage in visual generation of mixed case two letter arrays because of 'task difficulty'. Such failure to utilise visual generation resulted in a persisting PI advantage for these materials. Kroll & Parks' explanation encounters problems in accounting for PI deterioration with multi-letter arrays (i.e. three or more stimuli) (see e.g. Posner, 1979; Cohen, 1974). In addition, it appears unreasonable to assume that such a task would be more difficult following ISI's of 8 or 12 seconds than when subjects were faced with unpredictable 990 msec intervals.

It seemed possible that visual generation might have been invoked as a strategy when time structure was variable, and so experiment VI adopted Boies (1971) methodology to investigate this hypothesis. Boies found that deterioration in the PI advantage was obtained even when a memory stimulus (S_1) was left in the field of view until the test stimulus (S_2) was presented. This finding indicated that a passive 'decay' of visual memory was not necessary for the relative change in code bias (as e.g. Posner & Klein, 1967, had argued). He proposed that subjects generated an additional item in their visual memory, and that PI decline was due to increased search latency (after Sternberg, 1969).

Thus experiment VI examined the effects of a variable SOA on classification judgements. The duration of SOA was identical to that employed in experiments IV and V, but manipulation of S_1 exposure allowed a constant 50 msec ISI for all subjects. Under these conditions there was no suggestion of a 'coding shift' as indexed by the relative latencies to NI and PI judgements. This experiment was considered as offering difficulties for Kroll & Madden's 'difficulty in visual generation' interpretation of code change, since this would require that such a strategy was restricted to conditions where attentional demand was great, and confined to the ISI.

Experiment VI, therefore, was devised in order to examine this possibility in greater detail. Variability in time structure was imposed by the use of an unpredictable warning stimulus duration, prior to S_1 exposure, while ISI was held constant for individual subjects. Thus comparability in time structure parameters obtained between this study and the three previous experiments (variation in total trial duration was identical in 3 of the 4 conditions), ISI demands were exactly the same as experiment III where 'coding' indices indicated stability in the PI advantage.

The results showed that performance in NI classifications was better following a 990 msec retention interval. This indicates that ISI specific demands are not a pre-requisite for such bias.

The results also showed that change in the efficiency of NI classification could occur in the absence of an absolute decline in PI efficiency. Experiment V had shown such a decline as a function of ISI, which was congruent with Boies (1971) increased search time account of generation. However, the results of experiment VII suggested that PI deterioration may be the product of attentional limitations, and may be more adequately described as a 'decay' of visual memory, rather than the consequence of visual generation.

Support for this account may be derived from the work of Phillips & Christie (1978) who obtained comparable temporal regularity effects on the short term retention of abstract visual patterns.

The results also showed that subjects were able to utilise the benefits of a brief warning interval to bias coding along an NI dimension. Posner (1979) has argued that under conditions of strategic bias, capacity limitations may result in an interaction between warning interval and coding measures. The data was therefore interpreted as evidence for a tonic task set towards NI judgements under conditions of temporal uncertainty. An alternative to the 'visual generation' hypothesis was put forward, emphasising similarities between time structure effects in visual and auditory short term memory tasks. Following Hamilton & Hockey (1974), Hamilton et al (1977), it was argued that subjects adopted a passive mode of retention when faced with unpredictable time structure (see also Broadbent, 1980). Under such conditions, subjects would be more likely to employ passive access to the appropriate stimulus codes rather than engage in 'active' rehearsal (e.g. Santa, 1975).

Single letter classifications showed no effects of ISI, or temporal variability in experiment VIII. This observation is not without precedence, and may reflect S_1 exposure duration (Eggers, 1975, cited in Posner, 1979). Alternatively (or additionally) the magnitude of PI bias may have been affected by the size of the visual angle separating S_1 and S_2 (Walker, 1979).

Since reliable effects of ISI were found on double letter stimuli, this result was surprising. However, it may reflect an under-estimate of the extent of NI bias with double letter arrays. Multi-letter arrays show a greater NI bias than do single letters (Posner & Keele, 1969), and if there were similarities between 'passively' treated double letters and larger arrays, then such a pattern would be expected.

Although the experiments reported above appear to offer little support for Kroll & Parks' hypothesis, there are several other studies which offer even less. Posner & Taylor (1969) and Cohen (1969, and pers. comm. 1978) utilised multi-letter arrays, and obtained PI effects of a considerably smaller magnitude than those reliably shown by double letter stimuli. On virtually any definition of processing load 3 or more random letters would appear to present greater 'difficulty' than two, yet such stimuli may even show a smaller PI advantage than single letters (Posner & Taylor, 1969).

This problem will be readdressed in the final section of this chapter, and an attempt will be made to develop a comprehensive, single model which can deal with the dynamics of code alteration in sequential letter judgements.

Summary

The studies discussed above replicated the effects of double letter stimuli on code bias, with prolonged retention intervals, and concurrent shadowing. Stability in coding was abolished by the use of temporal variability, either in the ISI, or in the duration of a pre-classification warning signal. It was suggested that these effects might relate to the active/passive coding dimension discussed by Hamilton & Hockey (1974) and Hockey (1977). The visual generation interpretation of 'stable' double letter coding was rejected and it was suggested that NI bias and verbal coding might implicate dissociable subsystems.

12.5 Visual Field Differences

The visual field effects obtained in this series of experiments did not reflect the coding biases discussed above. These findings therefore tend to argue against the strong form of the hypothesis that 'cognitive processing' determines hemispheric (sic) differences (Cohen, 1975). There were two main patterns of interaction between visual field and task demand with double letter stimuli: (a) An overall RVF advantage primarily contributed by NI classifications (experiments III, V, VI, VII) and (b) An overall RVF advantage, primarily contributed by PI judgements (experiments I and V).

Pattern (a) appears to be the most 'reliable' in that it was obtained in four separate experiments, and achieved acceptable levels of statistical confidence in each study. The ensuing discussion will therefore focus on that particular pattern. However, some comment is required by the 'pattern (b)' set of interactions since they have precedent (Kroll & Madden, 1978; Kirsner, 1980) the initial part of this section will deal with those effects.

The pattern (b) interaction emerged unreliably in experiment I, but was shown more acceptably in experiment V where the female sub-group were differentiated from the male group by the visual field x classification interaction. Although it would be simpler to write-off this effect as weak, and therefore, potentially spurious, such a course is precluded by the similarity of pattern (b) above, to the results for the 'high-verbal' subjects in Kroll & Madden's (1978) experiment 1, and to performance in Kirsner's (1980) recently presented series of experiments.

A 'structural' interpretation, such as that offered by Kroll & Madden (1978) does not appear to be adequate since females were apparently quite capable of producing pattern (a) in experiments VI and VII. Similarly, a 'strategy' account (cast in terms of verbal vs. visual code bias) appears inappropriate since, within the limits of the operational definition of strategy offered by the Posner task, males and females showed broadly similar coding biases in experiment V.

Kirsner (1980) has recently argued that active verbal processing (e.g. rehearsal) may interfere with left hemisphere mediation of letter judgements. Similar effects could, therefore, have contributed to the results of Kroll & Madden's study and to experiment I, and II above. However, this cannot be a complete account of the trend towards 'bilateral' NI judgements, since the time available for rehearsal did not selectively affect the laterality of PI or NI classifications in experiment III.

The only satisfactory conclusion which may be reached from this set of results, is to accept that under some conditions, it may be possible for the right hemisphere to make a greater contribution towards 'name', than towards physical matches.

Ongoing verbal activity may be one determinant of such effects, although other factors are likely to be involved. Concurrent verbal shadowing (experiment II) gave no evidence for a 'shift' to right hemisphere processing thus it appears as though the type of verbal performance which differentially involves right and left hemisphere systems in NI and PI judgements may either be of a lower level of complexity, or alternatively, may involve specific subsystems in the left hemisphere.

Furthermore, the results from experiments III and V suggest that systems other than those implicated in active or 'working' verbal memory (Kirsner, 1980) may contribute towards this pattern, since the effect was consistent across 50 msec and 990 msec ISI's.

The evidence from experiments III, VI, VII, VIII and from the male sub-group of experiment V suggested that left hemisphere systems may be differentially involved in NI matches. PI judgements were less reliably asymmetric in the double letter matching studies, but only yielded a clear left field advantage when single letters were employed (experiment VIII).

The most straightforward interpretation of these findings would be to consider S_2 name-level analysis as primarily dependent on left hemisphere systems, and to allow for bilateral equivalence in physical match judgements.

The latter conclusion requires the qualification that single letter PI judgements may be more dependent on right hemisphere systems.

Whilst this conclusion is the most straightforward, there are a number of other explanations which might be offered. The principal candidate interpretations of attentional bias, and scanning strategies will be considered in turn.

a) Attentional Bias:

Kinsbourne's model of attentional bias, which was discussed in chapter 2, might account for the apparent bilateral pattern of physical match mediation in terms of the verbal nature of the classification task. Such verbal demands would be greater when a memory load of two items was required, than when single letters were employed. Thus attentional effects would 'mask' the operation of right hemisphere systems in the former case (e.g. Hellige & Cox, 1976).

The results of experiment VII suggest that attentional bias may not be a fully adequate interpretation. Despite an early, and pronounced emphasis on name-level processing when short warning intervals were used, there was no interaction between field effects and the duration of warning interval. Were the left hemisphere selectively facilitated, or 'aroused' by such phasic priming (Shallice, 1978; Cohen, 1975), an interaction of this form would be expected. Furthermore, the visual field effects in the double letter matching task do not appear to relate to the extent of name-level bias in memory, since highly similar interactions were found whether the latency of NI judgements was stable over the retention interval (experiments III and VI), or improving (experiments V and VII).

An alternative to the 'phasic' attentional shifts considered above would be to consider overall task set to be a crucial variable. Despite the negligible effects of strategy in experiment VII (and V) it might be argued that attentional bias was somehow enhanced by the presence of two letters rather than one. The so-called 'prototypical' double dissociation between NI and PI judgements has been obtained with simultaneous presentation of two letter classifications (Geffen *et al*, 1974). If set effects were simply a function of array size, then similar 'attentional' phenomena should have been evoked by Geffen *et al*.

The 'attentional bias' interpretation might be salvaged by arguing that NI judgements were not a suitable operational definition of 'verbal' processing (see the discussion in 12.4 above). Whilst this could possibly salvage Kinsbourne's theory, it would necessarily entail that it was an inappropriate framework for interpreting the major results of these experiments.

Although Kinsbourne's framework is apparently unsuitable for dealing with the relationship between memory code alterations and visual field asymmetry, some variant of the 'attentional' hypothesis may be required in considering the ISI effects obtained in experiments III, IV and V. Experiment III gave evidence for a decline in visual field asymmetries as the interval was extended. Experiment IV suggested, and experiment V confirmed that under variable ISI conditions visual field differences were enhanced as the retention interval was prolonged. In discussing experiments IV and V it was suggested that the functional significance of S_1 as a warning stimulus may have interacted with lateralised 'alerting' systems in experiment III whereas some undefined process correlated with changes in the relative performance on NI and PI codes had produced asymmetric activation under the variable ISI procedure. In the light of the results obtained in experiment VII it seems plausible to suggest that this finding reflected the operation of alerting mechanisms specific to variable retention interval conditions, since comparable visual field x ISI effects did not emerge when code stability was influenced by the duration of a neutral pre-classification warning stimulus.

It seems likely that the results of experiments IV and V reflect the development of conscious-attentional biases over the ISI, and thus implicate direct, and increasing facilitation of left hemisphere 'pathways' for all classification types as the interval was prolonged. Simple 'alerting' processes may be less consistently lateralised over the retention intervals which were studied, or alternatively may be more prone to 'interference' effects resulting from the use of rehearsal and/or naming systems.

These considerations suggest that further work might fruitfully employ a model, such as Posner's in order to more clearly define the 'attentional' interaction hypothesised by Kinsbourne. The present research indicates that the hemisphere activation-inhibition framework he has proposed may bear some relationship interactions at the level of selectivity (Posner & Boies, 1971) or conscious attention (Posner, 1978).

b) Directional Scanning:

If subjects consistently 'scanned' from the fixation point to S_2, then a left to right bias could possibly account for the data on 'same' judgements. A hemisphere difference interpretation might, in fact, be invalidated by such an account. Were PI judgements less dependent on access to control processing mechanisms than were NI (e.g. Estes, 1975) visual field effects could be 'explained' by scanning alone.

The evidence from 'different' classifications is relevant in this context. Table 12.1 shows that (despite minor differences) over all subjects in experiments III, VI, VII, the proportions correct for both left, and right sided, substitution stimuli were equivalent in the left visual field. Right visual field judgements, however, showed a peripheral stimulus advantage, and a central stimulus disadvantage, for substituted items (when compared with LVF presentations).

A simple left to right model clearly fails to describe this data. The right field effects suggest a sequential, peripheral-central scan (White, 1976; Chastain & Lawson, 1979) whereas left field stimuli, though processed at an equivalent level of efficiency, appear to have been dealt with in parallel. Although stimuli at the extreme right of the display in the RVF were given some degree of 'priority', this effect alone cannot account for the adavantage of two stimulus items, in the RVF, when they constituted a NI mapping.

The gradient in 'different' judgements suggests that hemisphere differences may have been implicated in the way that these stimuli were processed.[1] However, it is not clear whether this may be described in terms of serial-parallel processing (e.g. Cohen, 1973), or to differential facility with feature analysis under conditions of lateral masking (e.g. Krumhansl, 1977). Further research might investigate same and different judgements to two item arrays when one stimulus was redundant to the classification. Varying featural 'confusability' parameters would be required to tease apart contributions of the serial-parallel or feature analytic systems.

The 'scanning' hypothesis does not appear to be supported by these findings. However, the possibility that such effects occurred, but were specific to 'same' judgements cannot be eliminated by the available evidence.

Despite this reservation, the hypothesis offered at the start of this discussion of pattern (a) interactions, appears to offer the most adequate account of coding interactions although attentional variables may be implicated by ISI effects. Asymmetrically represented systems appear to be required by NI judgements over a range of conditions. Double

1 The effects discussed herein do not appear to be due to transfer phenomena since they obtained over 2 different S_1 exposure durations (experiment VI).

letter 'PI' matches may be dealt with bilaterally.

The occurrence of a left field effect in single letter judgements of PI stimuli suggests that different systems may be implicated by one and two letter tasks. There is evidence from clinical studies of brain damage, that naming of multi-letter arrays may be impaired due to deficits in systems involved in selective attention. Such patients are reliable in naming individual letters, or letters flanked by digits, but are less able to name letters in a word, or to identify single letters flanked by others (Shallice and Warrington, 1977). Comparable systems to those damaged in such patients may have been implicated in the double letter matching task, leading to a 'bilateral' pattern of PI analysis.

Alernatively or additionally the data may support a dissociation between the visual memory systems involved in single and double letter judgements. The time course of the PI advantage is grossly discrepant with the types of material under central field blocked presentation conditions, suggesting a functional dissociation (e.g. Wickelgren, 1973). Performance on PI judgements of single letter materials might be mediated by rapidly accessed, specialised, right hemisphere systems, whereas double letter stimuli might be handled by maintaining a more primitive visual trace in both hemispheres. The present results do not allow any distinction between these possibilities. Future work might examine the effects of mixed stimulus types involving letters and numbers. The selective attention hypothesis would predict that such stimuli would be comparable to single letters in their dissociative pattern.

Summary

The evidence from visual field effects indicates that similar structural dissociations may be obtained across a range of code biases. When double letter stimuli are employed, the most reliable pattern of interaction was for a strong RVF advantage in NI judgements, associated with bilateral equivalence in PI classifications. The reverse pattern did occur (albeit weakly) in two studies. From this evidence it was concluded that NI classifications were predominantly reliant on left hemisphere systems. Bilateral equivalence in such processing may occur under same conditions, but the basis of this effect was unclear. Single letter PI judgements appeared to be dealt with by specialised right hemisphere systems in experiment VI, and it was suggested that different forms of visual memory, and/or attentional variables may have led to this discrepancy within double letter investigations.

12.6 Synthesis

In chapter 2 of this thesis, it was argued that neuropsychological dissociations were of relevance to theoretical accounts of functionally defined 'processes' such as 'memory' and 'attention'. This perspective has generally been adopted by many psychologists dealing with deficits resulting from brain damage (e.g. Warrington, 1980, in press; Saffran & Marin, 1977; Shallice, 1978; Marshall & Newcombe, 1973). However, it has largely been ignored in discussions of visual field effects which have tended to emphasise empirical 'dissociation', within a framework inherited from the 'structural' emphasis of physical/associationist models.

The techniques employed in this research, may, or may not have been appropriate for the diagnosis of left and right hemisphere involvement in sequential match performance. Even if the reader considers the case for structural dissociation unproven, it should be realised that the validity of inference based on interactions between cognitive processing demands and visual field asymmetries is not dependent upon the specific constructs employed to account for the determinants of such asymmetry. The ability to define relevant constructs adds weight to any argument, by suggesting alternative convergent procedures for investigating a particular set of postulates, but it is neither a pre-requisite, nor necessarily an end in itself.

'Visual field of presentation' may be regarded as functionally equivalent to any other dependent variable when evaluating, any implications for the identification of component 'processes' in cognitive performance.

The results of the sequential matching investigations reported above, indicated that visual field asymmetry was determined by S_2 processing demands, rather than by coding biases. This appears to resemble the evidence from a range of studies utilising central presentations where it has been noted that S_2 characteristics define the dimensions of coding (e.g. Cruse & Clifton, 1973; Swanson <u>et al</u>, 1972; Rogers, 1974; Tversky, 1969). 'Second stimulus' effects may be independent of code efficiency (as defined by relative latency to judgement types) and be unaffected by subjects' expectancy (Tversky, 1969; Wood, 1977). Posner (1979) describes these data as "powerful testimony to the general efficiency of recoding through generation" (p.51).

The latency of 'generation' may be extremely brief. Wood (1974; 1977) obtained second stimulus effects with an SOA of 350 msec, Posner et al, (1969) obtained equivalent between and within modality latencies after 100 msec, and Wood (1977) obtained auditory confusions in cross modal judgements during simultaneous stimulus presentations.

If this evidence is accepted then the 'feed-forward' model of generation discussed in section 12.2 seems somewhat inappropriate, since by definition, it is a time consuming process (Posner et al, 1969). In his most recent discussion Posner (1979) distinguishes 'generation' from 'imagery', suggesting that the latter may be attention dependent, whereas code generation may be inaccessible to conscious awareness. The dynamics of this 'recoding' system are not clearly expounded, although Posner suggests that pathway activation may be involved.

The visual field effects discussed in section 12.5 suggest that similar NI systems are employed over a range of 'coding' biases (i.e. that this particular 'second stimulus effect' is largely independent of ISI, and code). These findings would be more congruent with facility in accessing a particular pathway, or analytic system, than with generation and retrieval of a particular code, or 'quantum' of information. This interpretation does not preclude the recoding hypothesis but suggests that the two constructs of 'code' and 'pathway' may need to be more clearly distinguished. In Posner's model, they are functionally equivalent. In terms of theory, a particular 'pathway' is required to produce a particular code, whilst operationally, levels of activation within a pathway are defined in terms of judgement latencies (Posner & Boies, 1971) which, in turn, define codes. This circularity is not entirely vicious, and as I shall argue, provides a reasonable descriptive scheme for much of the matching data. However, in the case of the experiments reported here, it is not completely adequate and requires some modification.

In the following paragraphs, I shall attempt to provide an outline of the type of model which is required by this evidence. In essence, this scheme represents a development of Posner's position rather than a radical alternative.

(1) Stimulus presentation results in a rise in activation over a wide range of systems. Input effects are parallel (Treisman <u>et al</u>, 1977), pre-attentive (Posner, 1978) and probabilisitic (Rumelhart, 1977; Norman & Bobrow, 1975). In a probabilistic system the potential for overlap between the analytic processes dealing with e.g. C,c O,G, and Q would be allowed, but, all other things being equal, levels of activation would asymptote more rapidly for systems receiving greater levels of increment from sets corresponding to the stimulus as presented (Other things may not be equal if residual levels of activation remain from earlier stimulus presentations e.g. Gantz, 1975).

(2) Such activation would be initiated in parallel for all systems (including input, and decision levels) within the stimulus domain (e.g. McClelland, 1979; Rumelhart, 1977). Increments at one level of stimulus analysis would occur in parallel with, but be contingent upon, lower system activity. This perspective differs in two minor respects from Posner's. He suggests a temporally sequential, (but not necessarily contingent, or serial) mode of activation and also emphasises the 'codes' produced at each level. As McClelland (1979) points out it may be more apposite to consider output from each system subset, as a continuous variable, rather than a discrete code (a broadly similar point is made by Rumelhart, 1977).

(3) The results of input analysis would be temporarily held in short-term stores (or 'input buffers' (Hitch,1979)) which, after a sufficiently prolonged interval would hold information in the form of codes. Presentation of a formally identical second stimulus (e.g. NI or acoustic) would share some of the analytic pathways utilised by S_1. If residual activation from S_1 had not declined, such input would be 'facilitated' by a more rapid rise in the level of activity in shared pathways (Posner, 1979). On a temporal dimension activation in common pathways would be bimodal, with peaks for S_1 and S_2, enabling input buffers to be utilised as comparators by subsequent decision systems.

The concept of 'generation' is not required to account for 'second stimulus effects', or by the visual field results discussed in this thesis, since parallel activation of a wide range of codes is conceptualised as intrinsic to the analysis of all stimuli. Such effects are attributable to access to the appropriate analytic pathways and 'input buffers'. Indices of code dominance reflect the magnitude of activation, rather than its breadth, and, as will be argued below, in the way that subsequent systems utilise information from input storage.

The latter description would provide a fairly simplistic account of single letter matching effects. However, it is plainly inadequate, as it stands, to deal with double letter stimuli, and the effects of attention and strategy.

The evidence presented by Posner (1978) suggests that there are no inhibitory interactions in 'pre-attentive' processing. The evidence on this point is not entirely conclusive (see Shallice, 1978) since it depends on results which may be interpreted as a strategy effect, or criterion shift (e.g. Posner & Snyder, 1975). However, the double letter studies suggest that the systems described above are insensitive to operationally defined code alterations, and hence to 'inhibitory' effects arising as a consequence of attentional involvement. If such inhibition occurred over time, then any temporal changes in asymmetry would show a consistent interaction with code bias (and be indistinguishable from a 'transfer' model hemisphere specific coding). Furthermore, effects would be expected as a function of S_1 exposure duration (Shallice & McGill, 1978), yet none were reliably shown in experiment VI. Thus, it seems reasonable to place the locus of any inhibitory effects after 'buffer' storage, when double letter arrays are used.

(4) Posner & Boies (1971) and Posner's (1978) model of attentional effects on 'pathway' systems, would be slightly modified in this scheme. 'Facilitation' and 'Inhibition' of processing occur subsequent to 'storage' in input buffers, but prior to maintenance rehearsal, and decision systems. (In order to avoid premature commitment, I shall refer to such effects as weighting values, rather than facilitation/inhibition). Such values are assigned by high level control programs, and provide a means whereby dimensions may be intergrated, and utilised, in a task relevant manner. Although some level of attentional involvement in the assignment of such values is assumed (after Posner & Snyder, 1975a; 1975b) since 'costs' in processing are time linked to S_1 presentation (Posner, 1979) subsequent capacity limitations depend (a) on the utilisation of 'weighting' (as shown by deficits in latency to probe R.T., time linked to S_2 (Posner & Boies, 1971)) and (b) on the extent to which 'control programs' may be able to call up weighting sub-routines in an automatic, skilled manner (Posner & Keele, 1967).

Double letter stimuli may be considered as a novel conjunction (e.g. Treisman et al, 1977) which, under 'active' processing conditions result in the application of novel control processes (e.g. Kahneman & Henick, 1977). In this situation subjects would attempt to utilise verbal rehearsal as a means of addressing visual memory (Santa, 1975) and to achieve an integrated 'set' by weighting of phonemic and visual storage. Short term NI codes would remain available but relatively less accessible than their visual and verbal/ phonemic counterparts. (This could be tested by the use of 'confusability' techniques, see Posner, 1979).

The use of variable time structure may (Hockey, 1977) affect the efficacy with which relatively 'slow' active control processes can be applied. Under these conditions, double letter stimuli would either receive arbitrary, static, values, at post-STS weighting, or would be judged in a purely 'comparator' mode (see (3) above). Multi-item arrays may be handled in a similar manner, due to limitations on control system application (Kahneman & Henik, 1977). Kahneman & Henik suggest that the ease with which an array may be 'grouped' spatially may affect control system application. This suggestion might be tested empirically by comparison of PI and NI latencies to subsets of arrays with differing spatial organisations.

(5) For the sake of completeness, some discussion of the homunculic 'control programs' is required. Although highly speculative, such consideration is necessary in order to limit the range over which this particular model might apply. Perhaps the most adequate account of such systems is provided by Shallice (1978) in his discussion of 'action systems'. Action systems compete for dominance via activation/inhibition interaction.

The most highly activated system inhibits others, and results in 'conscious awareness'.

The model developed in (1)- (4) above would reflect the operation of two related 'systems' of this form, distinguished by their 'active' and 'passive' use of control processes. Input processing in a letter classification task would represent the utilisation of sub-routines common to both, which may, or may not overlap with those employed in e.g. lexical decision, or reading for meaning.

Input processing requires the use of long term memory skills and may be described (in terms of Schneider & Shiffrin, 1977a; 1977b) as activation of a subset of memory. In contrast to their views, I would argue that such activation occurs in an information or 'semantic' memory system (Tulving, 1972) (so as to accommodate neuropsychological evidence for the dissociation between STM, and subdivisions of LTM - see Warrington, 1980). The range of input activation is determined by constraints at the level of 'action systems', although overlap between input systems occur over a range of tasks (e.g. letter perception, reading). This would allow for considerable economies in processing over that described by e.g. McClelland where all word stimuli are necessarily analysed as letters, and as clusters. Under the appropriate task set the range of analytic 'nodes' (Shiffrin & Schneider, 1977a; 1977b) for, e.g. reading a word, need not include those used in letter judgements, but information accrual might, instead follow alternative 'routes' based on shape, and semantics (facilitated by priming). Phonemic information may be available, but not necessarily utilised (as with the NI material double letter classifications).

The cognitive model developed in the preceding pages has direct implications for theoretical accounts of visual field asymmetry. The model has two principal components: a structural one which incorporates 'input' systems such as semantic/information memory, and input buffers; and a dynamic aspect, which is concerned with interactions between control systems and weightings on buffer output which occurs in real time.

Processing strategies are the product of interactions between control systems and weighting 'functions' and as such are intimately related to, (although conceptually distinct from) 'attention'. Thus, within this framework it is largely meaningless to attempt to define 'processing bias' independently of 'attentional bias' (e.g. Cohen, 1979; Hellige et al, 1979) since selectivity in processing arises as a product of interactions between control systems and output weightings, whilst 'attention' is implicated by the interplay of various competing control, or 'action' systems.

The inhibitory/facilitatory interaction of control systems may bear more than a formal resemblance to Kinsbourne's 'orientational bias' theory of visual field differences. The present perspective could easily accommodate 'pre-stimulus' or 'strategy' interactions with visual field effect: control systems may interact and thus facilitate or inhibit the output from lateralised buffer-stores. Dimond's (e.g. 1978) argument for the involvement of callosal systems in attention, and awareness might relate to the deficits which arise as a product of surgical division of the routes by which such weighting functions were established on the output from lateralised buffer stores.

The net result of increased 'weighting' of a particular subset of outputs from buffer storage would result in increments in the rate at which decision could be reached, (or identification made) when appropriate materials were shown to the 'dominant' half of visual space (i.e. to the visual field contralateral to the hemisphere in which 'selected' systems are located). When tachistoscopic presentations are employed, this effect would result in asymmetric patterns of visual field performance, with more rapid and/or more accurate stimulus recognition specific to a particular <u>subset</u> of the processing domain for which the total system was 'biased'.

This aspect of attention needs to be distinguished from the less specific effects of 'activation' or alertness. Current evidence suggests that there are dissociable, lateralised alerting systems. For example, Bowers & Heilman (1976) have shown that attributes of warning signals (verbal or non-verbal) may determine the relative advantage of the right or left hand in simple R.T. to a neutral imperative stimulus. Electrophysiological evidence also tends to support this particular point (see chapter 2 above).

A consequence of increased levels of 'alertness' is an increment in the speed, and accuracy, of decisions to tachistoscopically presented materials (Posner, 1975). Facilitation of decisions when the system is alerted <u>would not</u> be expected to be specific to particular subsets of the processing domain.

If input buffers were bilaterally available, then asymmetric activation of the cerebral hemispheres would result in general facilitation of stimulus processing when materials were presented to the visual field, contralateral to the more 'alert' side of the brain. If buffers were asymmetrically distributed, increased levels of alertness on one side of the brain would produce increments in performance with ipsilateral buffer stores, and produce a decline in the lateral advantage for processing dependent upon the output from buffer stores located contralateral to the more 'alert' cerebral hemisphere.

The 'attentional' framework presented in the preceding paragraphs is a specific development of the cognitive model which was put forward on the basis of findings in the experiments presented in this thesis. The latter investigations were not devised in order to 'test' this model, but nevertheless it is useful to consider whether any indirect support may be drawn from this research.

The only clear indication of an 'attentional' effect was the increased right field advantage suggested in experiment IV, and supported by experiment V. This effect was not specific to particular codes, and thus more probably reflected asymmetries in alerting rather than selective weighting and control-system interactions.

Further research into warning signal effects is necessary in order to determine whether the 'alertness' aspect of this model has any validity. It should be possible, for example, to investigate asymmetric presentation of warning signals and/or to vary the properties of warning stimuli such that there is a high likelihood that unilateral alerting will arise. Subsequently, test, or imperative stimuli, could be compared under lateralised presentation conditions over a range of ISI's.

Selective processing, and activation/inhibition effects would probably be most appropriately studied employing different probabilities of stimulus types in order to produce processing biases. Alternatively 'pre-cueing' or 'cost-benefit' analyses (Posner & Snyder, 1975) might be explored, although care would be necessary in these cases in order to avoid confounding effects of 'pathway' or input system activation arising from repetitions, rather than output weightings. Pre-task warning signal duration might be employed as a 'test' of the extent to which 'strategy' effects were operative (cf. experiment VII above).

Since there was evidence for a degree of bilateral organisation in the buffer system for both PI and NI judgements of double letter stimuli, it is not surprising that interactions of the type discussed here were not obtained. However, in view of the preponderence of right field advantages in NI judgements, it might be proposed that there was a greater probability of left hemisphere buffer stores being selected and therefore that a temporal gradient in visual field correlates of alerting or selective processing would be expected. This argument is not a particularly strong one, and could be flawed on logical grounds, nevertheless it highlights a crucial problem area which requires some discussion, namely the relevance of null results as a 'test' of particular models of hemisphere-visual field interactions (e.g. Moscovitch, 1979).

1. Threshold Effects:

There may be a psychophysical function which could describe the magnitude of activation/inhibition effects which were a necessary pre-condition for asymmetries of the type described above. Since maximum levels of activation and inhibition are correlated with reductions in processing capacity it would be predicted that task complexity should bear a direct relationship to the magnitude of selective effects. This might be studied by employing same-different methodology, keeping memory stimuli at comparable levels of demand, but by varying the complexity of same-different judgements (by e.g. employing auditory or visual distractors in the test stimulus set). A metric of task complexity could be established and correlations between lateral advantage and this measure devised. Indirect support for the relevance of this point may be drawn from Jonides (1979) who showed that increasing visual complexity stimulus detection produced a left field advantage while increased phonemic similarity resulted in an RVF bias.

2. Anatomical Considerations:

The 'locus' of visual field asymmetries in terms of areas of cortex has yet to be established. The prototypical 'mass action' perspective on hemisphere function in visual field tasks may, or may not be valid, but it is naive to assume that it is necessarily true for all conditions. For example, neurological evidence (e.g. Luria, 1973) suggests that impairment in the systems concerned with semantic processing, and input buffer storage is correlated with damage to parietal regions, whereas 'attention' may be affected by damage to areas in medial, subcortical and anterior loci. If visual field effects were correlated with parietal function and dysfunction, then lateralised tachistoscopic presentation methodology may be inappropriate as a test of attentional interactions. It would be quite premature to attempt to assess the relevance of this argument, since it would be necessary first to demonstrate that visual field stimulation techniques were insensitive to regional differences in brain function and dysfunction by convergent analysis of neurologically validated tasks under lateralised presentation conditions and to conduct electrophysiological research into asymmetries in the latencies of involvement of various areas of the brain following lateral tachistoscopic presentation.

3. Asymmetries in the efficiency of particular 'arousal' or selective systems:

This possibility requires detailed electrophysiological investigation, which could be conducted on intact, pathological, or pharmacologically treated subjects. The evidence from experiments IV and V suggested left hemisphere advantages in alerting following variable foreperiod conditions, but it is not clear whether this reflected functional properties of the 'timing' component in the 'warning signal' utilised by subjects, or indicated asymmetric benefits in preparation arising from more fundamental physiological asymmetries.

Overall this analysis suggests that both process and attentional models of visual field differences are potentially of relevance. Processing theories may be appropriate descriptions of the representation of information memory and input buffers. Whilst attentional models may be more adequate to describe effects which arise from the involvement of alerting, or selective (strategic) processing. A tentative first approximation to the general model suggested by this analysis is drawn in figure 1.

Whilst this model is speculative, all its components are in principle isolable by behavioural techniques, and are amenable to operational definition and quantification. This framework goes beyond Kinsbourne's in that it provides an alternative set of procedures to 'dual task' methodology, and is thus, potentially more powerful. Dual task procedures may provide information with regard to attentional effects but they present the researcher with tremendous problems in interpretation, and experimental control. Warning signal, and stimulus probability manipulations provide a direct means of assessing the involvement of and interactions between alerting and selectional components of attention.

This model is intended as a functional analysis of the organisation of systems implicated by lateralised tachistoscopic presentation. In essence, this framework is an abstract description of sub-components of functioning which appear to be implicated by a circumscribed set of task constraints, rather than a putative mapping of cognitive processes onto a neurological substrate. It should be understood as an attempt to systematise the available information into a format (analagous to systems analytic techniques) which may have some predictive utility.

It is not necessary that any, or all of the sub-components of this model should have discrete neurological loci. For example 'buffer storage' might be interpreted as a particular state, of the total system, rather than a circumscribed area of the brain. Neuropathological evidence does suggest that the limitations imposed by parietal damage may affect this aspect of performance, but it does not necessarily follow that there are specialised 'stores' in these areas of the brain. All that the present evidence allows one to conclude is that different functional attributes of performance are differently affected by the constraints imposed by localised brain damage, and that there is a correlation between site of pathology, and cognitive deficit (e.g. Hécaen & Albert, 1978).

The crucial tests of the functional attributes of performance highlighted in the present model would rest on their potential for dissociation in terms of normal cognitive performance, in relation to visual field differences, and in relation to neuropathological subject groups.

Although there are inevitable imperfections in the present project, the writer hopes that, at least, it provides some illustration of the utility of functional models of performance in studies of visual field effects: as Vygolsky stated in 1962.

> "the problem of <u>what</u> can be localised is not at all irrelevant to the problem of how it can be localised in the brain"

The writer agrees.

In conclusion: Although cognitive psychology, and the study of lateral asymmetries have been estranged for the past ten years or so, a reconciliation is possible, and long overdue. The process is not likely to be without its difficulties (as the present thesis shows) but the likely benefits to both areas of research are of sufficient magnitude to outweigh the costs which may arise.

TABLE 12.1

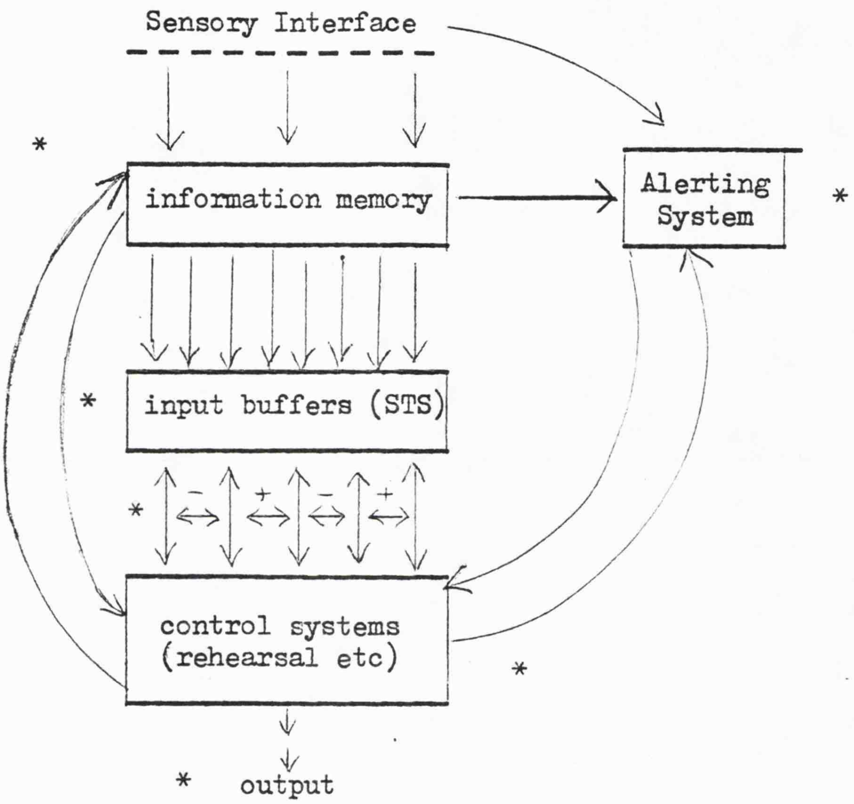
Proportion Correct

Different Judgements

	RVF		LVF	
Experiment	D_R	D_L	D_R	D_L
III	.87	.78	.83	.82
VI	.86	.73	.79	.82
VII	.88	.81	.87	.9

FIG. 1

Preliminary Model of Attentional and Strategic Interactions with Stimulus Coding



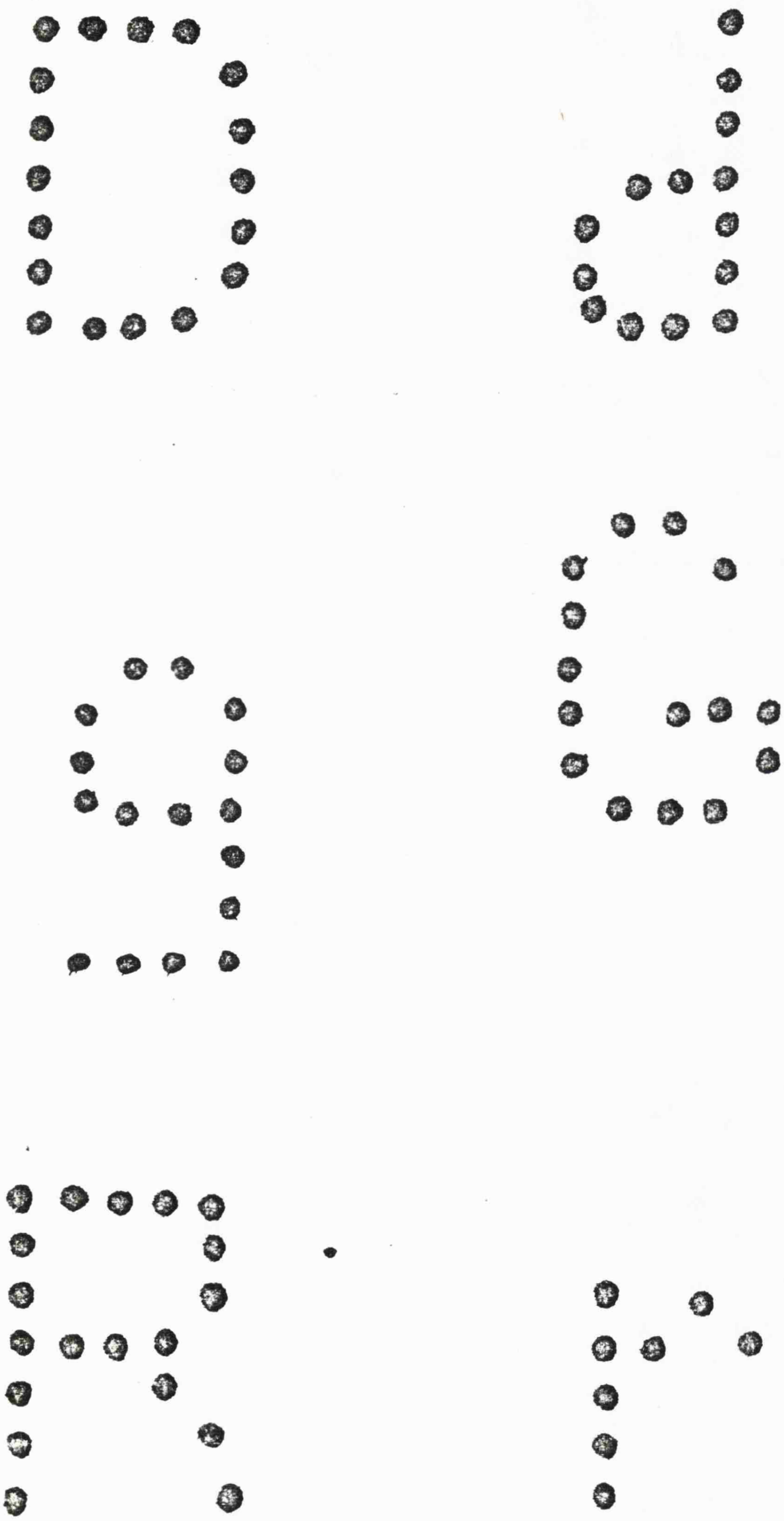
* points in the system with which behavioural asymmetries may be associated.

A1 EXAMPLE: Programs and Stimulus Materials

Program employed to create letter stimuli.

```
C U/W-FOCAL:  PROG1   NO/DA/TE

Ø2.1Ø D 11;S Z=1;D 8;F I=1,2;S Z=Ø;D 8
Ø2.2Ø T !"GIVE POINTS (X,Y) UNTIL END=1"
Ø2.25 S Z=7;D 8
Ø2.3Ø A X;I (X-1)2.4,2.5
Ø2.4Ø S Z=X-1Ø24;D 8;A Y;S Z=Y-1Ø24;D 8;G 2.3
Ø2.5Ø R

Ø3.1Ø O O STIM
Ø3.2Ø S E=FD(Ø);T E;F I=,E;T FD(I)
Ø3.3Ø O C

Ø4.1Ø O I STIM
Ø4.2Ø A E;F I=,E;A X;X FD(I,X);N;O I,E

Ø8.1Ø X FD(FD(),Z);S Z=FD(Ø,FD()+1)

1Ø.1Ø X FDO(6,Ø)

11.1Ø S Z=FD(63,FD(63)+1);T !"NAME"%2,Z
11.2Ø S Z=FD(Z,FD());T "  START"%4,Z
11.3Ø S Z=Ø;D 8

12.1Ø S A=FD(63);I (-A)12.2;T !"??";R
12.2Ø X FD(A,FABS(FD(A))) FDO(6,2);R

13.1Ø S Z=1Ø;D 8;A !"NAME"Z;S Z=FABS(FD(Z));D 8
13.2Ø A !"NAME"Z;S Z=FD(Z,-FD(Z))
13.3Ø A !,?A?,"  ",?B?

22.Ø1 C LIST DISBUF
22.1Ø F J=,FD(63);T %4,FD(J)
22.2Ø F J=6Ø,1Ø,FD();T !;F K=,9;T FD(J+K)

31.1Ø  O O PTP:;W
31.2Ø O C; O I,E
```

Examples of Upper and Lower Case Stimuli as used in the Experiments reported Above



Program Used to input letter combinations for memory and test Stimuli.

```
Ø1.1Ø F I=1,8Ø;D 2
Ø1.2Ø O O ORD4
Ø1.3Ø F I=1,4ØØ;T FG(I)
Ø1.4Ø O C;Q

Ø2.1Ø T !, %2,I;A D(1),D(2),D(3),D(4),D(5)
Ø2.2Ø F J=1,5;X FP((I-1)*5+J,D(J))

25.1Ø O I ORD4;F I=1,4ØØ;A Z;X FP(I,Z);N;O I,E
25.2Ø A "TRIAL" T;I (T)25.6,25.6
25.3Ø T !"FIVE NUMBERS"
25.4Ø F I=1,5;A N;X FP((T-1)*5+I,N)
25.5Ø G 25.2
25.6Ø O O ORD4;F I=1,4ØØ;T FG(I)
25.7Ø O C;Q

26.1Ø F Z=1,5,399;T !,%4,FG(Z),FG(Z+1),FG(Z+2),FG(Z+3),FG(Z+4)
*
```

Program for regular timing sequences

```
01.10 T !!"PROGRAM RM 1"
01.20 T !"SHOWS STIMULI, EXAMPLE TRIALS, THEN 80 TRIALS"
01.30 C NEEDS 'PICS' FOR STIMULI, 'ORDER' FOR TRIALS
01.40 C CALLS 'ANAL' TO ANALTSE RESPONSES
01.50 C BLOCK 2 = INITIALISATION + PRACTICE
01.60 C       3 = MAIN TRIAL LOOP
01.70 C        4 = SHOWS STIMULI IN ORDER
01.75 C        6 = DISPLAY LOOP
01.80 C        7 = SETS ORIGIN AND TURNS ON DISPLAY
01.90 C        9 = TURNS FILES ON/OFF

02.10 D 10;X FDO(2,-2,-100,2695)
02.20 O I PICS;A E;F I=,E;A X;X FD(I,X);N;O I,E
02.30 O I ORD4;F I=1,400;A X;X FP(I,X);N;O I,E
02.33 T !"SAMPLE STIMULI - DIGIN TO STEP"
02.35 X FDO(2,-3,-500);F I=1,20;D 4
02.40 A !"RUN TRIAL NO.?"I;I (I-1)2.5;D 3;G 2.4
02.50 T !"HIT TTY TO START";A :-1
02.80 F K=,7;D 27
02.90 L C ANAL

03.10 S J=I*5,O=-150,L1=FG(J+1),L2=FG(J+2);D 7
03.20 S DE=300;D 6;S Z=L1;D 9;S Z=L2;D 9
03.30 S DE=600;D 6;S Z=21;D 9;S DE=200;D 6
03.40 S O=FG(J+3),L1=FG(J+4),L2=FG(J+5)
03.45 D 7
03.50 X FDO(2,-3,-10);S Z=21;D 9;S Z=L1;D 9;S Z=L2;D 9
03.60 X FDO(2,1);S Z=FDO(2,-3,-1000);S B=FD(-4)
03.70 X FP(401+I,Z) FP(501+I,B)
03.80 S DE=300;D 6;X FDO(2,1)

04.10 S Z=I;D 9;X FDO(2,-3,-100)
04.20 X FDO(2,1);S Z=FDO(2,-3,-1000,4)
04.30 X FDO(2,1);S Z=I;D 9

06.10 S Z=FDO(2,-3,-DE)
06.20 I (Z) 6.3,6.3;S DE=DE-Z;G 6.1
06.30 R

07.10 X FD(2-FD(L1),O) FD(2-FD(L2),O+160)
07.20 S Z=L1;D 9;S Z=L2;D 9

08.10 X FD(FD(),Z);S Z=FD(,FD()+1)

09.10 X FD(Z,-FD(Z))

10.10 X FDO(6,0)

11.10 S Z=FD(63,FD(63)+1);X FD(Z,FD());Z Z;D 8

12.10 S A=FD(63);I (-A)12.2;T !"??";R
12.20 X FD(A,FABS(FD(A))) FDO(6,2);R

23.10 F J=,10,FD(63);T !;F K=,9;T %4,FD(J+K)
23.20 S P=FD();I (-P)23.3;S P=P+4096
23.30 A !"FROM? "Q
23.40 F J=Q,10,P;T !;F K=,9;T FD(J+K)

27.10 T !"WAITING";A :-1
27.20 F L=,9;S I=K*10+L;D 3
*
*L C PROF
*W 3
03.08 S DE=100;D 6;X FDO(2,1)
03.10 S Z=21;D 9;S DE=100;D 6;S Z=21;D 9
```

Preliminary Analysis Program

```
Ø1.1Ø C ANALYSIS PROGRAM FOR RM 1
Ø1.2Ø Z;S A=-1;T !!"LEFT VISUAL FIELD";D 2
Ø1.3Ø Z;S A=1;T !!"RIGHT VISUAL FIELD";D 2
Ø1.4Ø Q

Ø2.1Ø F I=,79;D 4
Ø2.2Ø I (SN-1)2.4;I (1-SN)2.3;Z SS;G 2.4
Ø2.3Ø S SM=SM/SN,SS=FSQT(SS/SN-SM*SM)
Ø2.4Ø I (NN-1)2.6;I (1-NN)2.5;Z NS;G 2.6
Ø2.5Ø S NM=NM/NN,NS=FSQT(NS/NN-NM*NM)
Ø2.6Ø I (DN-1)2.8;I (1-DN)2.7;Z DS;G 2.8
Ø2.7Ø S DM=DM/DN,DS=FSQT(DS/DN-DM*DM)
Ø2.8Ø D 3

Ø3.1Ø T %6,!!"                    CORRECT TRIALS"
Ø3.2Ø T !"                   NUMBER   AVE RT   SD RT"
Ø3.3Ø T !!"SHAPE ID     "SN,SM,SS,!"NAME ID      "NN,NM,NS
Ø3.4Ø T !"DIFFERENT   "DN,DM,DS
Ø3.45 I (A)3.6
Ø3.5Ø T %4,!!;F I=,5,155;T !;F J=1,5;T FG(4ØØ+I+J),FG(5ØØ+I+J)
Ø3.6Ø C *** ADD VARIABLE FILENAME OUTPUT HERE?

Ø4.1Ø S J=I*5;I (FG(J+3)*A)4.9
Ø4.13 I (FG(J+1)-FG(J+4))4.3,4.15,4.3
Ø4.15 I (FG(J+2)-FG(J+5))4.3,4.2,4.3
Ø4.2Ø I (1-FG(5Ø1+I))4.9
Ø4.25 Y SN;S SM=SM+FG(4Ø1+I),SS=SS+FG(4Ø1+I)↑2;G 4.9
Ø4.3Ø S X=FG(J+1),Y=FG(J+4);I (X-Y)4.35;S X=FG(J+4),Y=FG(J+1)
Ø4.35 S X=X+1Ø;I (X-Y)4.7,4.4,4.7
Ø4.4Ø S X=FG(J+2),Y=FG(J+5);I (X-Y)4.45;S X=FG(J+5),Y=FG(J+2)
Ø4.45 S X=X+1Ø;I (X-Y)4.7,4.5,4.7
Ø4.5Ø I (1-FG(5Ø1+I))4.9
Ø4.6Ø Y NN;S NM=NM+FG(4Ø1+I),NS=NS+FG(4Ø1+I)↑2;G 4.9
Ø4.7Ø I (FG(5Ø1+I)-2)4.9
Ø4.8Ø Y DN;S DM=DM+FG(4Ø1+I),DS=DS+FG(4Ø1+I)↑2
Ø4.9Ø R
```

Randomisation Program: Employed to provide Irregular Timing Sequences.

```
*W
C U/W-FOCAL:  PROG4   NO/DA/TE

01.20 C GENERATES RANDOM NUMBERS FOR EACH TRIAL SEQUENCE

12.10 S D=0;S U=0;X FP(600+U,D)

13.10 F U=,79;D 14
13.20
13.60

14.04 S N=FRAN()*80
14.10 S N=FITR(N)+1
14.11 F Q=600,600+U;D 18
14.20 I (C-1)14.4,14.04,14.4
14.40 S D=N;X FP(600+U,D);R

18.10 S R=FG(D)
18.11 I (R-N) 18.3,18.2,18.3
18.20 S C=1;R
18.30 S C=0;R
```

```
C U/W-FOCAL:  PROGV1  NO/DA/TE

01.10 C THIS PROG IS FOR VARIABLE ISI TRIALS I -

02.10 D 10;X FDO(2,-2,-100,2695)
02.20 O I PICS;A E;F I=,E;A X;X FD(I,X);N;O I,E
02.30 O I MAT2;F I=1,240;A X;X FP(I,X);N;O I,E
02.33 T !"SAMPLE STIMULI - DIGIN TO STEP"
02.35 X FDO(2,-3,-500);F I=1,20;D 4
02.40 A !"RUN TRIAL NO.?"I;I (I-1)2.5;D 3;G 2.4
02.50 T !"HIT TTY TO START";A :-1
02.80 F K=,7;D 27
02.85
02.90 L C ANAL

03.08 S DE=100;D 13;X FDO(2,1)
03.10 S Z=21;D 9;S DE=100;D 6;S Z=21;D 9
03.20 S DE=10;D 6;S J=I*5,O=-150,L1=FG(J+1),L2=FG(J+2);D 7
03.30 S DE=10;D 6;S Z=L1;D 9;S Z=L2;D 9
03.40 S O=FG(J+3),L1=FG(J+4),L2=FG(J+5)
03.42 D 15
03.50 X FDO(2,-3,-10);S Z=L1;D 9;S Z=L2;D 9
03.60 X FDO(2,1);S Z=FDO(2,-3,-1000);S B=FD(-4)
03.70 X FP(401+I,Z) FP(501+I,B)

04.10 S Z=I;D 9;X FDO(2,-3,-100)
04.20 X FDO(2,1);S Z=FDO(2,-3,-1000,4)
04.30 X FDO(2,1);S Z=I;D 9

06.10 S Z=FDO(2,-3,-DE)
06.30 R

07.10 X FD(2-FD(L1),O) FD(2-FD(L2),O+160)
07.20 S Z=L1;D 9;S Z=L2;D 9
07.25 R

08.10 X FD(FD(),Z);S Z=FD(,FD()+1)
08.20 R

09.10 X FD(Z,-FD(Z))
09.20 R

10.10 X FDO(6,0)

11.10 S Z=FD(63,FD(63)+1);X FD(Z,FD());Z Z;D 8

12.10 S A=FD(63);I (-A)12.2;T !"??";R
12.20 X FD(A,FABS(FD(A))) FDO(6,2);R

13.10 S Z=FDO(2,-3,-DE)
13.20 I (Z) 13.3,13.3,S DE=DE-Z;G 13.1
13.30 R

15.05 C THIS BLOCK SORTS FOR ISI
15.10 I (I-40) 15.3,15.2,15.2
15.20 S DE=5;D 13;D 7;R
15.30 S DE=99;D 13;D 7;R

07.20 F L=,9;S I=FG(600+K*10+L);S I=I-1;D 3
```

A2 Statistical Tables

TABLE A1 EXPERIMENT I

Analysis of Variance: Latency

A = Response Laterality B = Visual Field C = Classification

Source	DF	MS	F
Between Subjects	15		
A	1	304.59	<1
A x SWG	14	3462.5	
Within Subjects	80		
B	1	207.09	3.71
AB	1	5.51	<1
B x SWG	14	55.79	
C	2	2353.3	8.652**
AC	2	55.97	<1
C x SWG	28	271.99	
BC	2	158.09	1.30
ABC	2	143.96	1.18
BC x SWG	28	122.1	

** $p \leq .01$

TABLE A2 EXPERIMENT I

Analysis of Variance: Accuracy

A = Response Laterality B = Visual Field C = Classification

Source	DF	MS	F
Between subjects	15		
A	1	259.12	3.16+
SWG	14	82	
Within Subjects	80		
B	1	355.81	7.4 *
AB	1	60.45	1.25
AB x SWG	14	48.02	
C	2	430.4	3.1
AC	2	85.99	< 1
AC x SWG	28	138.9	
BC	2	249.72	3.036+
ABC	2	143.95	1.75
ABC x SWG	28	82.252	

* $p < .05$
\+ $p < 1$

TABLE A3 Combined Analysis : EXPERIMENTS I and II

Response Latency

A = Experiments (Shadowing vs Silent) B = Response Assignment
C = Visual Field D = Classification

Source	DF	MS	F
Between Subjects	31		
A	1	2765.82	1.03
B	1	1992.38	<1
AB	1	1052.26	<1
SWG	28	2685.26	
Within Subjects			
C	1	31.01	<1
AC	1	309.38	1.6
BC	1	279.07	1.44
ABC	1	126.01	<1
C x SWG	28	193.36	
D	1	7065.63	21.6**
AD	1	395.51	1.209
BD	1	0.63	<1
ABD	1	43.95	<1
D x SWG	28	327.11	
CD	1	146.63	<1
ACD	1	106.95	<1
BCD	1	21.95	<1
ABCD	1	354.45	2.1
CD x SWG	28	168.7	

** $p \leq .01$

TABLE A4 Combined Analysis : EXPERIMENTS I and II

Accuracy

A = Experiments B = Response Assignment C = Visual Field
D = Classification

Source	DF	MS	F
Between Subjects	31		
A	1	717.5	2.566
B	1	16.5	<1
AB	1	349.64	1.251
SWG	28	279.57	
Within Subjects			
C	1	40.64	<1
AC	1	412.14	5.477*
BC	1	1.22	<1
ABC	1	97.84	1.3
C x SWG	28	75.24	
D	2	2977.18	11.7
AD	2	676.71	2.66+
BD	2	50.09	<1
ABD	2	38.66	<1
D x SWG	56	254.45	
CD	2	101.68	1.461
ACD	2	215.67	3.1*
BCD	2	69.98	1.006
ABCD	2	84.86	1.3
CD x SWG	56	69.57	

* $p < .05$
+ $p < .1$

TABLE A5 EXPERIMENT III

Analysis of Variance: Response Latency

A = Response Assignment B = ISI C = Visual Field
D = Classification SWG = Subjects within groups

Source	DF	MS	F
Between Subjects			
A	1	11.82	<1
SWG	14	1813.4	
Within Subjects			
B	1	492.29	<1
AB	1	164.16	<1
SWG	14	515.96	
C	1	197.75	3.87
AC	1	154.7	3.02
SWG	14	51.1	
D	3	2021.2	13.23**
AD	3	89.7	<1
SWG	42	152.74	
BC	1	77.66	1.9
ABC	1	9.38	<1
SWG	14	40.87	
CD	3	21.55	<1
ACD	3	315.55	5.19**
SWG	42	60.79	
BD	1	74.91	1.02
ABD	1	39.18	<1
SWG	14	73.44	
BCD	3	62.35	<1
ABCD	3	125.00	1.7
SWG	42	73.53	

** $p \leq .01$

TABLE A6 EXPERIMENT III

Analysis of Variance: Accuracy

A = Response Assignment B = ISI C = Visual Field
D = Classification SWG = Subjects within groups

Source	DF	MS	F
Between Subjects			
A	1	15.02	<1
SWG	14	444	
Within Subjects			
B	1	1340.9	3.6
AB	1	16.6	<1
SWG	14	366.4	
C	1	518.6	5.32*
AC	1	49.83	<1
SWG	14	97.44	
D	3	1538.27	7.5**
AD	3	149.28	<1
SWG	42	205.1	
BC	1	766.01	4.6*
ABC	1	25.87	<1
SWG	14	167	
CD	3	573.8	4.6**
ACD	3	25.87	<1
SWG	42	124.7	
BD	1	242.19	1.7
ABD	1	21.37	<1
SWG	14	142.46	
BCD	3	91.34	<1
ABCD	3	266.37	2.13
SWG	42	125.06	

* $p \leq .05$
** $p \leq .01$

TABLE A7 EXPERIMENT IV

Analysis of Variance: Response Latency

A = ISI B = Visual Field C = Classification

Source	DF	MS	F
Within Subjects			
A	1	2179	5.88
SWG	19	370.6	
B	1	1729	5.61
SWG	19	308.1	
C	1	6233.7	29.17
SWG	19	213.7	
Interactions			
A x B	1	125	<1
A x C	1	1179.9	5.03
B x C	1	362.7	1.32
A x B x C	1	55.1	<1

TABLE: A8 EXPERIMENT IV

Analysis of Variance: Accuracy

A = Response Laterality B = ISI C = Visual Field

D = Classification

Source	DF	MS	F
Between Subjects			
A	1	38.74	<1
SWG	18	992.16	
Within Subjects			
B	1	.51	<1
AB	1	32.12	<1
SWG	18	226.56	
C	1	420.4	3.9
AC	1	61.88	<1
SWG	18	107.79	
D	3	1201.76	3.14
AD	3	38.47	<1
SWG	54	382.73	
B x C	1	342.97	2.6
A x B x C	1	11.33	<1
SWG	18	131.9	
C x D	3	144.46	<1
A x C x D	3	144.29	<1
SWG	54	162.17	
B x D	3	391.09	2.82
A x B x D	3	144.29	1.04
SWG	54	138.81	
B x C x D	3	158.01	1.47
A x B x C x D	3	51.32	<1
SWG	54	107.44	

TABLE: A9 EXPERIMENT V

Analysis of Variance: Response Latency

A = Hand of Response B = Sex of Subject C = ISI D = VHF

E = Classification

Source	DF	MS	F
Between Subjects			
A	1	6008.6	2.5
B	1	84.83	< 1
A x B	1	8244.08	3.5
SWG	36	2403.1	
Within Subjects			
C	1	2276.33	14.9
A x C	1	54.64	< 1
B x C	1	13.51	< 1
A x B x C	1	30.19	< 1
SWG	36	152.69	
D	1	900.13	9.6
A x D	1	116.45	1.1
B x D	1	2.63	< 1
A x B x D	1	100.01	1
SWG	36		
E	3	3613.58	26.9
A x E	3	152.93	1.1
B x E	3	124.36	< 1
A x B x E	3	47.16	< 1
SWG	108	134.33	
C x D	1	545.75	7.1
A x C x D	1	35.63	< 1
B x C x D	1	12.38	< 1
A x B x C x D	1	236.44	3.1
SWG	36	76.9	
C x E	3	75.09	< 1
A x C x E	3	77.69	< 1
B x C x E	3	75.26	< 1
A x B x C x E	3	113.68	1.1
SWG	108	103.4	
D x E	3	57.16	< 1
A x D x E	3	287.86	3.9
B x D x E	3	287.42	3.9
A x B x D x E	3	64.57	< 1
SWG	108	73.7	
C x D x E	3	65.03	< 1
A x C x D x E	3	73.13	< 1
B x C x D x E	3	151.04	2
A x B x C x D x E	3	93.88	1.24
SWG	108	75.49	

TABLE: A10 EXPERIMENT V

Analysis of Variance: Accuracy

A = Hand of Response B = Sex of Subject C = ISI D = VHF

E = Classification

Source	DF	MS	F
Between Subjects			
A	1	211.49	1.3
B	1	3.69	< 1
A x B	1	297.57	1.83
SWG	36	162.43	
Within Subjects			
C	1	369.1	4.9
A x C	1	26.9	< 1
B x C	1	20.1	< 1
A x B x C	1	63.36	< 1
SWG	36	75.3	
D	1	58.98	1.1
A x D	1	225.67	4.0
B x D	1	29.19	< 1
A x B x D	1	5.0	< 1
SWG	36	56.3	
E	3	1775.78	22.8
A x E	3	14.46	< 1
B x E	3	19.23	< 1
A x B x E	3	61.23	< 1
SWG	108	77.9	
C x D	1	.05	< 1
A x C x D	1	41.3	< 1
B x C x D	1	17.21	< 1
A x B x C x D		111.36	1.9
SWG		58.6	
C x E	3	135.21	2.75
A x C x E	3	55.9	1.13
B x C x E	3	55.00	1.18
A x B x C x E	3	77.12	1.56
SWG	108	49.16	
D x E	3	140.14	2.16
A x D x E	3	54.49	< 1
B x D x E	3	85.36	1.3
A x B x D x E	3	26.6	< 1
SWG	108	64.8	
C x D x E	3	59.81	< 1
A x C x D x E	3	10.57	< 1
B x C x D x E	3	103.71	1.7
A x B x C x D x E	3	12.45	< 1
SWG	108	61.00	

ANOVA TABLE A11

Experiment VI : Response Latency

A = Response Laterality B = Exposure Duration
C = Visual Field D = Classification

Source	DF	MS	F
Between Subjects			
A	1	2628.7	<1
SWG	22	24330.5	
Within Subjects			
B	1	95353.1	3.04
A x B	1	218.0	<1
SWG	22	31366.2	
C	1	5543.4	<1
A x C	1	975.1	<1
SWG		1230.4	
D	3	24814.2	17.7**
A x D	3	792.2	<1
SWG	66	1401.9	
B x C	3	87.9	<1
A x B x C	1	27.2	<1
SWG	22	3070.1	
B x D	3	432.0	<1
A x B x D	3	413.5	<1
SWG	66	1315.9	
C x D	3	759.8	<1
A x C X D	3	413.5	<1
SWG	66	1379.1	
B x C x D	3	744.39	<1
A x B x C x D	3	1168.4	<1
SWG	66	1404.6	

** $p \leq .01$

ANOVA TABLE A12

Experiment VI : Accuracy

A = Response Laterality B = Exposure Duration
C = Visual Field D = Classification

Source	DF	MS	F
Between Subjects			
A	1	18.96	<1
SWG	22	210.4	
Within Subjects			
B	1	367.9	3.5
A x B	1	44.6	<1
SWG	22	105.1	
C	1	34.9	<1
A x C	1	211.4	2.8
SWG	22		
D	3	958.6	7.4
A x D	3	17.1	<1
SWG	66	75.5	
B x C	1	141.5	2.9
A x B x C	1	28.0	<1
SWG	22	48.8	
B x D	3	151.38	1.6
A x B x D	3	72.9	<1
SWG	66	94.6	
C x D	3	354.6	4.9**
A x C x D	3	44.5	<1
SWG	66	72.37	
B x C x D	3	95.7	1.5
A x B x C x D	3	206.1	3.2*
SWG	66	64.4	

* $p \leqslant .05$
** $p \leqslant .01$

TABLE: A13 EXPERIMENT VII

Analysis of Variance: Response Latency

A = ISI B = Response Laterality C = Sex D = Fixation Cross Duration E = Visual Field F = Classification

Source	DF	MS	F
Between Subjects			
A	1	877.64	<1
B	1	21115.7	6.5
C	1	72.3	<1
A x B	1	11183.06	3.4
A x C	1	274.32	<1
B x C	1	7.56	<1
A x B x C	1	1309.54	<1
SWG	56	3248.6	
Within Subjects			
D	1	4144.14	51.46
A x D	1	739.16	9.1
B x D	1	1089.0	13.5
C x D	1	194.25	2.2
A x B x D	1	358.63	4.4
A x C x D	1	138.06	1.7
B x C x D	1	145.5	1.8
A x B x C x D	56	1.56	<1
SWG		80.65	
E	1	3422.25	24.7
A x E	1	19.69	<1
B x E	1	826.56	5.9
C x E	1	67.04	<1
A x B x E	1	119.63	<1
A x C x E	1	28.89	<1
B x C x E	1	0.04	<1
A x B x C x E	1	56.25	<1
SWG	56	138.55	
F	3	7108.87	35.26
A x F	3	73.26	<1
B x F	3	627.65	<1
C x F	3	173.38	<1
A x B x F	3	324.66	1.6
A x C x F	3	139.54	<1
B x C x F	3	18.58	<1
A x B x C x F	3	79.06	<1
SWG	168	201.6	
D x E	1	20.82	<1
A x D x E	1	87.89	<1
B x D x E	1	339.94	3.0
C x D x E	1	10.36	<1
A x B x D x E	1	284.77	2.8
A x C x D x E	1	28.22	<1
B x C x D x E	1	17.02	<1
A x B x C x D x E	1	20.82	<1
SWG	56	113.313	

Source	DF	MS	F
D x F	3	448.58	3.4
A x D x F	3	82.08	<1
B x D x F	3	204.03	1.5
C x D x F	3	16.0	<1
A x B x D x F	3	71.09	<1
A x C x D x F	3	3.31	<1
B x C x D x F	3	114.95	<1
A x B x C x D x F	3	21.32	<1
SWG	168	131.9	
E x F	3	670.84	5.4
A x E x F	3	350.55	2.8
B x E x F	3	388.99	3.1
C x E x F	3	12.31	<1
A x B x E x F	3	33.03	<1
A x C x E x F	3	50.63	<1
B x C x E x F	3	223.97	1.7
A x B x C x E x F	3	400.41	3.2
SWG	168	124.2	
D x E x F	3	115.54	1.1
A x D x E x F	3	100.94	<1
B x D x E x F	3	61.23	<1
C x D x E x F	3	96.21	<1
A x B x D x E x F	3	79.14	<1
A x C x D x E x F	3	75.39	<1
B x C x D x E x F	3	4.41	<1
A x B x C x D x E x F	3	44.96	<1
	168	105.03	

TABLE: A14 EXPERIMENT VII

Analysis of Variance: Accuracy

A = ISI B = Response Laterality C = Sex D = Fixation Cross Duration E = Visual Field F = Classification

Source	DF	MS	F
Between Subjects			
A	1	6405.8	20.9
B	1	136.3	<1
C	1	87.2	<1
A x B	1	85.7	<1
A x C	1	165.8	<1
B x C	1	137.8	<1
A x B x C	1	29.0	<1
SWG	56	315.7	
Within Subjects			
D	1	596.2	4.11
A x D	1	123.9	<1
B x D	1	32.08	<1
C x D	1	179.41	1.2
A x B x D	1	370.1	2.3
A x C x D	1	615.58	4.2
B x C x D	1	68.1	<1
A x B x C x D	1	3.46	<1
SWG	56	145.1	
E	1	217.02	2
A x E	1	161.9	1.5
B x E	1	615.08	5.6
C x E	1	27.81	<1
A x B x E	1	1.24	<1
A x C x E	1	27.14	<1
B x C x E	1	13.34	<1
A x B x C x E	1	61.03	<1
SWG	56	109.84	
F	3	2769.8	18.6
A x F	3	1051.33	7.1
B x F	3	111.03	<1
C x F	3	167.86	1.1
A x B x F	3	25.44	<1
A x C x F	3	41.52	<1
B x C x F	3	355.58	2.3
A x B x C x F	3	226.03	1.6
SWG	168	148.8	
D x E	1	7.61	<1
A x D x E	1	649.35	6.3
B x D x E	1	42.22	<1
C x D x E	1	36.45	<1
A x B x D x E	1	49.1	<1
A x C x D x E	1	14.33	<1
B x C x D x E	1	5.97	<1
A x B x C x D x E	1	18.1	<1
SWG	168	103.1	

Source	DF	MS	F
D x F	3	550.06	4.8
A x D x F	3	243.83	2.1
B x D x F	3	21.21	<1
C x D x F	3	32.51	<1
A x B x D x F	3	66.31	<1
A x C x D x F	3	125.27	1.1
B x C x D x F	3	167.97	1.5
A x B x C x D x F	3	50.49	<1
SWG	168	114.5	
E x F	3	1524.19	13.1
A x E x F	3	393.58	3.38
B x E x F	3	92.27	<1
C x E x F	3	162.46	1.4
A x B x E x F	3	149.69	1.1
A x C x E x F	3	239.19	2.0
B x C x E x F	3	19.39	<1
A x B x C x E x F	3	40.23	<1
SWG	168	116.35	
D x E x F	3	180.45	2.0
A x D x E x F	3	204.31	2.2
B x D x E x F	3	56.84	<1
C x D x E x F	3	43.68	<1
A x B x D x E x F	3	112.31	1.2
A x C x D x E x F	3	26.93	<1
B x C x D x E x F	3	7.82	<1
A x B x C x D x E x F	3	48.46	<1
SWG	168	90.23	

TABLE: A15 EXPERIMENT VIII

Analysis of Variance: Response Latency

A = Blocked vs. Random B = Response Laterality C = ISI
D = VHF E = Classification

Source	DF	MS	F
Between Subjects			
A	1	40255	1.25
B	1	57327.2	1.7
A x B	1	746.4	1
SWG	28	31988.3	
Within Subjects			
C	1	51.1	<1
A x C	1	1042.7	<1
B x C	1	238.5	<1
A x B x C	1	1618.5	<1
SWG	28	1966.8	
D	1	370.6	<1
A x D	1	1783.5	1.5
B x D	1	3180.9	2.7
A x B x D	1	7.7	<1
SWG	28	1178.1	
E	2	6274.1	5.26
A x E	2	2691.4	2.3
B x E	2	170.5	<1
A x B x E	2	2147.3	1.8
SWG	56	1192.8	
C x D	1	574.27	<1
A x C x D	1	22.1	<1
B x C x D	1	1291.5	1.6
A x B x C x D	1	120.8	<1
SWG	28	807.2	
C x E	2	2898.1	<1
A x C x E	2	692.7	<1
B x C x E	2	311.1	<1
A x B x C x E	2	671.4	<1
SWG	56	18733.8	
D x E	2	18.5	<1
A x D x E	2	1247.7	2
B x D x E	2	657.5	1.08
A x B x D x E	2	1278.4	2.1
SWG	56	608.8	
C x D x E	2	1109.4	2.05
A x C x D x E	2	28.9	
B x C x D x E	2	54.9	<1
A x B x C x D x E	2	266.0	<1
SWG	56	539.4	

TABLE: A16 EXPERIMENT VIII

Analysis of Variance: Accuracy

A = Blocked vs. Random B = Response Laterality C = ISI

D = VHF E = Classification

Source	DF	MS	F
Between Subjects			
A	1	96.99	<1
B	1	946.84	5.8
A x B	1	58.62	<1
SWG	28	163.24	
Within Subjects			
C	1	3.01	<1
A x C	1	29.31	<1
B x C	1	4.19	<1
A x B x C	28	117.54	1.1
SWG			
D	1	0.11	<1
A x D	1	24.95	<1
B x D	1	58.63	1.01
A x B x D	1	38.73	<1
SWG	28	58.04	
E	1	834.84	4.3
A x E	1	682.7	3.5
B x E	1	76.6	<1
A x B x E	1	331.14	1.6
SWG	28	198.0	
C x D	1	110.27	1.8
A x C x D	1	34.61	<1
B x C x D	1	1.61	<1
A x B x C x D	1	5.7	<1
SWG	28	61.26	
C x E	1	57.1	<1
A x C x E	1	26.0	<1
B x C x E	1	120.93	<1
A x B x C x E	1	0.09	<1
SWG	28	74.6	
D x E	1	234.84	7.5
A x D x E	1	0.68	<1
B x D x E	1	2.57	<1
A x B x D x E	1	0.03	<1
SWG	28	31.32	
C x D x E	1	68.59	1.2
A x C x D x E	1	2.02	<1
B x C x D x E	1	86.01	1.5
A x B x C x D x E	1	0.67	<1
SWG	28	57.15	

A3 Raw Data - Experiment VIII

RAW DATA - EXPERIMENT VIII

(a) Response Latency

RANDOM ISI

50 msec ISI						990 msec ISI					
RVF			LVF			RVF			LVF		
PI	NI	Dif	PI	NI	Dif	PI	NI	Dif	PI	NI	Dif
696	1012	913	838	882	967	708	842	839	872	910	838
464	552	473	444	476	508	470	426	500	442	502	481
446	466	393	340	394	490	404	456	348	306	342	492
576	840	556	540	602	557	608	464	570	675	582	622
682	490	505	628	602	632	440	376	515	508	418	556
534	494	461	452	408	432	744	450	488	512	518	561
530	574	512	418	526	565	510	684	606	574	718	723
696	714	637	700	804	663	732	656	681	892	704	592
740	690	798	794	702	704	810	820	680	1154	670	783
512	570	822	506	364	694	754	512	637	600	580	648
456	808	640	778	680	686	512	406	686	598	700	622
616	700	590	498	584	632	670	575	667	577	543	618
620	586	552	700	600	711	562	664	648	464	426	489
706	868	721	606	684	671	734	642	757	768	830	733
556	530	557	682	630	569	484	546	576	430	430	590
790	756	929	772	764	640	698	810	917	562	528	669

BLOCKED ISI

308	322	425	374	392	420	340	382	500	346	416	468
478	494	444	436	448	468	374	476	506	462	584	483
684	758	754	678	772	917	777	662	999	796	876	1112
322	392	381	386	364	448	438	448	453	458	500	515
698	632	589	640	836	694	606	606	799	538	548	696
732	920	725	714	854	721	618	618	626	554	820	739
586	490	658	578	460	567	488	476	488	490	506	609
1076	1092	1190	1390	1080	1105	942	1046	946	1212	1016	1040
776	600	742	700	912	712	928	888	982	794	948	873
688	920	892	626	770	739	534	910	955	482	986	809
458	414	537	378	442	532	618	532	537	618	480	532
476	672	628	534	642	598	586	620	702	576	580	570
876	972	894	902	1036	1008	875	868	972	922	1247	1198
806	1048	892	656	778	863	866	678	910	738	712	786
598	526	544	512	756	663	724	588	608	660	710	663
606	864	621	830	864	658	640	536	663	612	556	642

RAW DATA - EXPERIMENT VIII

(b) Same Judgements

Errors (max = 5)

RANDOM ISI

	50 msec ISI				990 msec ISI			
	RVF		LVF		RVF		LVF	
	PI	NI	PI	NI	PI	NI	PI	NI
Right Hand - Same	0	0	0	1	0	0	0	0
	0	1	0	1	0	0	0	0
	0	1	1	0	1	1	0	0
	0	0	0	0	0	0	0	0
	0	1	0	1	1	1	1	1
	1	1	0	0	1	1	0	2
	2	1	0	0	0	0	0	0
	2	0	0	0	0	1	0	1
Left Hand - Same	1	1	1	2	0	0	3	2
	0	0	0	0	2	2	3	1
	2	1	0	1	0	1	0	0
	2	0	1	0	1	0	0	0
	0	0	0	1	0	0	0	0
	1	0	0	1	1	1	1	0
	0	1	0	0	1	0	0	0
	0	1	0	1	1	0	1	3

BLOCKED ISI

	50 msec ISI				990 msec ISI			
	RVF		LVF		RVF		LVF	
	PI	NI	PI	NI	PI	NI	PI	NI
Right Hand - Same	0	1	0	1	0	0	0	1
	0	0	0	1	0	3	1	3
	0	1	0	2	1	0	1	0
	0	0	0	0	1	0	0	1
	2	0	0	0	0	0	0	0
	0	2	1	0	0	0	0	0
	0	0	0	1	0	0	0	0
	0	0	0	0	1	0	0	1
Left Hand - Same	1	0	0	1	2	1	1	0
	0	1	0	1	0	0	2	1
	0	0	0	2	0	1	0	0
	1	3	0	2	0	3	0	4
	0	0	0	1	0	0	0	0
	0	2	0	1	0	0	0	1
	0	3	0	4	1	3	0	2
	2	1	1	1	0	0	1	0

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