Visual Perception and Curve Tracing in Form and Integrative Agnosia

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Thesis Abstract

The work presented within this thesis has explored distinctions between form and integrative agnosia and figure ground perception in patients with dorsal and ventral extrastriate lesions. SA was distinguished as having a dorsal extrastriate lesion and a form agnosia - an impairment in coding basic aspects of shape and lesions of the dorsal extrastriate region. HJA, our case of integrative agnosia was able to code basic aspects of shape but impaired in segmenting and grouping more complex items.

SA was impaired on object recognition but showed improved performance with animate objects relative to inanimate whilst HJA showed the opposite pattern. It was suggested SA was able to make use of top-down knowledge here. HJA demonstrated intact discrimination of simple shapes but struggled to separate figure from ground on line drawings with internal detail compared with outlines consistent with poor forming of parts into wholes.

We identified curve tracing as a useful test of figure ground segmentation in these cases. SA was highly impaired on all such tasks despite an intact ability to shift attention. HJA in comparison, showed a similar pattern of performance to controls suggesting that he was serially scanning and shifting attention at a normal rate.

HJA was found to have a strong global bias to identifying the overall letter when presented with hierarchical stimuli, while SA demonstrated a strong local bias. We suggested that this could be reflect global form proving more salient to HJA compared with local form in SA and that these biases have influenced figure ground segmentation.

Key words: curve tracing, agnosia, local and global processing, segmentation, figure ground.

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Chapter 1: Introduction

Introduction

The human visual system rapidly and seemingly effortlessly computes the different properties and spatial relations faced in visual scenes and environments. In order to recognise visual objects and to successfully navigate scenes we are quickly able to see and consider the relations between various elements. Some aspects of scene processing can be performed in a parallel, bottom-up fashion without focussed attention while others rely on stored knowledge. Early theorists argued that a visual scene can be parsed into areas of figure and ground preattentively (Marr, 1982, Neisser, 1967). Ullman (1984) distinguished these early processes from later ones where focused attention or so-called 'visual routines' operate on the earlier representations to allow the perception of shape properties and spatial relations. Scene segmentation is suggested as occur via spatial distribution of attention (Posner, 1980; Treisman, 1980) or by object based attention (Duncan, 1984).

Within this thesis I will be exploring visual object processing in neuropsychological cases. The focus will be on Visual agnosia. Visual agnosia is a rare deficit in visual object recognition distinguished by Lissauer (1890) as impairments in: (i) Apperception the forming of a percept from visual input or (ii) Association- the linking of a percept to stored object (top down) knowledge (Riddoch & Humphreys, 1997). The study of visual object recognition deficits in stages of visual processing have provided a picture where the human mind is not effortlessly computing the different properties and spatial relations faced in visual scenes and provide important insight into what is required to effortlessly see.

Base and incremental representations. What is a visual routine?

Within this introduction I summarise Ullman's (1984) lengthy article on visual routines and their role in visual processing. The term visual routine was used by Ullman

(1984) to describe different elementary visual operations which comprise the ‘basic instruction set’ for more complex processes allowing perceiving and recognising. These routines consist of both overt and covert shifts of attentional focus which allow the pinpointing of areas for further processing. The routines can be assembled and applied to determine different properties and spatial relations, for example in discriminating inside/ outside relations, in the tracing of curves, the indexing of locations, bounded activation and marking. The implementation of visual routines distinguishes base from incremental representations with routines acting on base representations and in this way creating and modifying incremental representations.

Ullman (1984) makes a distinction between and base and incremental representations describing two main stages in the processing of visual information: bottom-up and top-down. Ullman’s (1984) base representations are local descriptions of properties including depth, orientation, colour, direction of motion. They are spatially uniform with similar processes and properties represented or applied across the visual field. As viewer-centred representations, the properties and descriptions of different parts are relative to the viewer rather than image properties. As bottom-up base representations they depend on visual input alone and not guided by any processing goals or ‘visual routines’. They are created prior to the action or use of any visual routine and an image always produces the same base representation. Visual routines act upon base representations and further ‘incremental’ representations are created and modified as a result. In this ‘top down’ stage incremental representations are produced to establish properties and spatial relations not represented in the initial bottom-up stage. Top-down processing relies on knowledge visual input and is guided by the goal of processing to integrate the properties and relations extracted. The same visual input can lead to different incremental representations and information within these depending on the visual routines used, whereas base representations are viewer-centred and remain unchanged. Incremental representations can hold information gathered from visual operations which can be used for later tasks.

Ullman (1984) claimed elemental operations are applied in visual routines. Indexing is an operation which allows to shift the focus of attention to special 'odd-man-out' locations. This is done in parallel and these locations (the 'anchor points') can serve as a starting point for applying visual routines. There are three stages involved to identify the 'odd-man-out' items. Firstly, indexable properties such as colour or motion need to be identified. To single an item out in the visual field requires that one of the present items has a distinct feature (e.g., a red letter among green letters). These item properties are represented in retinotopic maps. The next stage involves the comparison of the different properties represented in retinotopic maps across different locations to define the indexable 'odd-man-out' location. The outcome of this computation leads to an 'odd-man-out' signal at each location; a shift of attention will be to the strongest signal location (cf. , spotlight metaphor). After this, visual routines can be applied to identify the figure.

Local vs global

There is evidence that perception can be progressed from local-to-global as well as from global-to local. Local perception involves only the recognition of local components such as colour or shape, whereas global perception means that the global figure (e.g., the global letter H) is perceived without recognising the individual letters it is made off, the so-called tree before the forest phenomena (Navon, 1977). This could be done by applying grouping processes (Gestalt laws) prior to using visual routines, whereas applying appropriate routines could also lead to the same result of perceiving the whole figure (Ullman, 1984).

Colouring – finding the interior of a region by spreading activation within its boundaries.

Colouring or bounded activation is defined as the spread of activation from a given point until a boundary is reached. The activation will be either inside or outside the curve depending on the starting point; this can effectively separate between inside and outside. Colouring allows defining larger units and consecutively other routines can be applied for recognition. The activation process is more complicated in case of discontinuity boundaries, leading to longer processing time. Colouring relies on simple operations, resulting in two network maps: an activation map and a map of discontinuity boundaries. The activation map defines the activation spread which is initiated as soon as one element is activated (‘activity layer’). The discontinuity boundaries map serves as ‘control layer’ (Ullman, 1984).

Boundary tracing

Boundary tracing (curve tracing) is considered a basic operation on the base representation (Ullman, 1984). An example to illustrate curve tracing is the problem whether or not a curve is open or closed. To answer this question, the curve is traced and the absence or presence of contour terminators is registered. The same visual routine would be used for detecting multiple indexable items; however, the tracing will be more elaborated (a chain of processing). Tracking several contours requires the simultaneous activation of several contours either by means by parallel or sequential tracking. Boundary tracing is not only useful in single contour detection but also facilitates detection of different types of contours and discontinuity boundaries. For example, texture boundaries which define a recognisable letter promote shape recognition. However, it should be noted that fast recognition requires that the defining boundaries are already presented in the base representations.

Curve tracing is easy to perform with isolated and well-defined contours. Incomplete contours or boundaries, in contrast, cause noise and lead to insufficient contrast during the imagine processing. Other factors such as tracing across intersections and branches rely on adjustments. For example, it needs to be decided whether the current branch belongs to the curve or not. The decision can be affected by colour, contrast or motion. Interestingly, tracing can be done at a local or at a global level. Global processing involves tracking of the whole letter (e.g., h) without recognising the individual components of the letter (the ‘forest before the tree’ phenomena; Navon, 1977). It is assumed that Gestalt principles are involved, while it could be also possible that appropriate routines are applied to a low resolution copy of the image (Ullman, 1984).

Marking

Ullman (1984) describes Marking is an operation used for remembering already processed locations by marking these. For example, in order to determine whether or not a contour is closed we would mark the starting point and then trace the curve. The tracing is done if we re-visit the starting point. In this case, the contour is closed. Reference frames or spatial maps are required to remember previously visited locations. For example, an internal ‘egocentric’ spatial map can be used to mark the position of an item with respect to a prominent feature nearby (external reference).It is important to highlight that the marking map is stable across eye movements. Even if our gaze is directed to another part of the scene the properties of (incremental representations) and spatial relations among the items (marking map) is preserved.

Marking also involves visual counting (e.g., how many distinct features are present?). Counting can be performed by specialized networks or visual routines. In case of network counting (Minsky and Papert, 1969) the presence of M items is directly computed in parallel over the entire field. In contrast, counting using visual routines involves shifting the focus to the next location with the strongest signal either by systematically scanning or without scanning (travelling scheme). An example for the travelling scheme is the ‘single point detection’ task described by Ullman (1984). Here subjects are required to respond ‘yes’ (the strongest signal) if only one point is lit up, otherwise ‘no’. The choice of scanning method depends upon the number of items. Not surprisingly, the accuracy of visual counting is affected by the accuracy and spatial resolution of basic operations such as indexing, marking and boundary tracing. For example, it has been shown that ‘lateral masking’ occurred despite accounting for eccentricity (Riggs, 1965). Counting based on visual routines has two major advantages: it relies on the decomposition of a sequence of elementary operations regardless of the number of items and importantly these elementary operations are the same as used in other visual routines. Ullman (1984) assumes that visual counting is not an elementary operation instead counting is the result of our ability to employ visual routines (including elementary operations).

Figure ground perception

Within this thesis figure ground segmentation refers to the grouping of elements and separating them from background (Super& Lamme, 2007). See figure 1 for examples of such tasks.

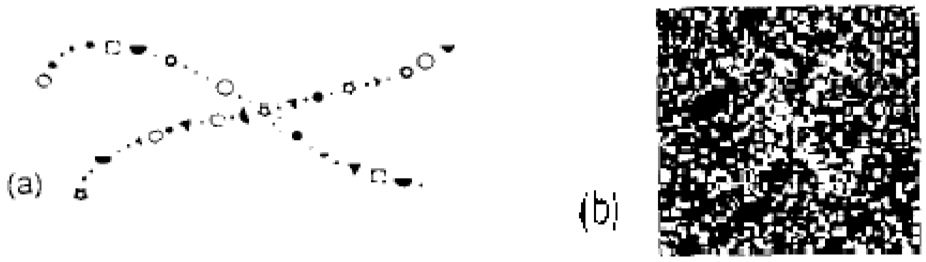

Figure 1. An illustration from Davidoff and Warrington (1993a) of the type of stimuli that have been used to test figure-ground perception. Figure 1a was used to test a patient's ability to segment by continuity. They were asked to describe the figure and trace the overlapping lines. Figure 1b is from a shape detection test and required determination of whether an X is present in a degraded or noisy image.

Although the separation of figure from ground elements has traditionally tended to considered a pre-attentive process there are now a number of theories suggesting this is not the case and that attention is necessary for figure ground discriminations and in perceptual grouping. Theories of space and object-based attention have been proposed and there are interactive models suggesting a pre-, interactive and post-attentive role in figure ground segmentation (Vecera and O'Reilley, 1998; Petersen and Kimchi). This remains a 'fuzzy' and ongoing debate but it is clear that neuropsychological cases of patients with impaired form and figure ground perception have been important in developing this discussion and the associated research. It is clear that attentional demands vary depending on task and this can determine whether deciphering figure from ground involves lower level or higher level visual processing or as recurrent processing.

Curve tracing as a procedure for figure ground segmentation

There is considerable evidence that curves, contours, and boundaries play a fundamental role in visual perception with many tasks requiring the integration of information from contours (Biederman & Ju, 1988). McCormick & Jolicoeur (1992) have argued that curve tracing forms a part of figure ground separation and within this thesis we have set up a number of curve tracing experiments to test figure ground segmentation. Roelfsema (1999) also suggested curve tracing can be solved by grouping based on Gestalt principles of connectedness and collinearity. It is claimed that by separating task relevant (curves and target locations) from non task-relevant regions, figure is discriminated from ground.

The curve tracing paradigm has been described as an elementary visual operation for more complex processes and requires segmentation of figural elements from background. Curve tracing can easily be adjusted to alter the difficulty of figure-ground discriminations and does not appear to rely on shape, object knowledge or recognition. Such a task could be highly useful to exploring figure ground segmentation abilities in patients with visual recognition difficulties and some such cases are included within this thesis.

Within this thesis we shall present findings from experiments on curve tracing and other tasks requiring visual segmentation. Jolicoeur, Ullman and MacKay (1986) examined the perception of shape properties and of spatial relations with different curve tracing tasks. They proposed that, in order to determine that two X’s lie on the same curve, observers must first locate an X to determine whether it does lie on a curve and mark the position before continuing to trace the curve until another X is seen. If another X is found along the same line it becomes evident that the X’s lie on the same and not on different curves. The steps taken in making such a determination are described as elementary processes which make up a visual routine (Ullman, 1984). The curve tracing routine would combine information from sequential attentional shifts to identify the same curve. Two X’s could be detected by local processes acting on the parts of an image. This local information could be integrated by a more global process to make a 'same' determination.

Figure 2. An example of the type of stimuli used by Jolicoeur, Ullman, McKay (1986). The dots shown along the curves indicate the possible locations of the second X. Jolicoeur et al. (1986) created further stimuli from this pattern.

The results of these early studies indicated that the human visual system is able to rapidly and internally trace curves in a display such as that shown in Figure 3 (Jolicoeur, Ullman and MacKay, 1986; Pringle and Egeth, 1988). Correct responses could be made even with brief stimulus presentations (180ms and 250-msec) suggesting that the effect is not dependent on eye movements as there is not enough time for meaningful movement (Jolicoeur, 1991). A covert curve tracing operation or routine was suggested as being used to integrate local information along a curve. Typically studies of curve tracing reveal the time taken to perform the task increases with increases in the distance separating targets (Jolicoeur, 1988; Jolicoeur, Ullman, & Mackay, 1986, 1990; McCormick & Jolicoeur, 1990; Pringle & Egeth, 1988). This distance effect was observed even where the Euclidian distance between targets was maintained. Response times were also longer where the X's were located on different curves as would be expected if subjects traced an entire curve in search of a second X before responding 'different' if one was not found (Jolicoeur, Ullman and Mackay 1986, 1991; Jolicoeur and Ingleton, 1991).

There have been two main theories on how attention is deployed in curve tracing. The first of these, the zoom-lens model of curve tracing where selective visual attention plays a role, was proposed by McCormick and Jolicoeur (1991, 1994). The second theory is one of object-based attention (Roelfsema, 1998). McCormick and Jolicoeur's (1991, 1994) zoom lens model was influenced by the attentional theories at the time; for instance, Posner's spot-light of attention model which held that processing is enhanced at the focus of attention (Posner, 1980) and Eriksen's zoom lens account (holding that the area covered by the spotlight may be manipulated (Eriksen, 1986). McCormick and Jolicoeur's (1991, 1994) zoom-lens model views curve tracing as the serial tracking of a curve by an operator having zoom-lens properties. The curve tracing operator is able to keep tracking the curve being traced. However, the size of the 'zoom lens' is restricted by different curve properties. Only one curve can be contained within its receptive field. When there is more than one curve within the receptive field, it becomes "unsafe" for the operator. A shift to a new part of a curve in this situation could result in shifting to the incorrect curve. Therefore, it is important for the zoom lens operator to process selectively only one curve at a time. When the zoom lens does shift to a different segment of a curve the receptive field will contain part of the previously traced curve.

Jolicoeur, Ullman and Mackay (1991) and Jolicoeur and Ingleton's (1991) showed that increased curvature and proximity of distractor curves have an adverse effect on curve tracing causing a slowing of the rate of suggesting a contraction of the zoom lens whereas distant curves would allow it to expand. The rate of tracing would be related to the size of the tracing operator. Van Selst and Jolicoeur (1995) have also proposed within figure processing with closed shapes as involving the use of a between dot scanning of attention operation similar to the visual routine proposed for curve tracing.

Roelfsema (1998) has proposed an object based account after demonstrating that neurones in V1 of the macaque monkey fired simultaneously when the monkey viewed different sections of a target curves. The responses were enhanced relative to those evoked by viewing a distractor curve, and the effects could be demonstrated even when the two curves crossed each other. On the basis of subsequent work with his collaborators, Roelfsema and colleagues have argued that rather than a moving attentional zoom lens there is a gradual spread of attention during mental curve tracing until the whole curve is activated or tagged (Houtkamp, Spekreijse & Roelfsema, 2003; Roelfsema & Spekreijse, 2005; Roelfsema, Lamme Spekreijse, 1998; Scholte, Spekreijse, & Roelfsema, 2001). Curve tracing is described as involving the binding of spatially separate contour segments into a ‘coherent representation’ of the traced curve. The Gestalt laws of collinearity and good continuation or connectedness are used to group the contour segments for a single target curve and segregate from distractor curves. It is suggested that object based attention is applied to curve tracing in segregating spatially overlapping objects and in the spread of attention to an entire curve.

A substantial increase in reaction times was observed where a curve that needed to be traced intersected with another. It is suggested that where curves intersect, collinearity is the remaining cue to segregate curves and to avoid attention leaking onto an intersecting distractor curve. Local grouping of elements in curve tracing can be pre-attentive but involves attention and feedback from higher visual areas when correct global segmentation requires joint integration of many local groupings.

Both Jolicoeur and Roelfsema and their co-workers suggest that visual routines of this sort are achieved by a ‘curve tracing’ visual operation or ‘routine’ in which attention is scanned serially along curves. However, The two theories differ in one important aspect as in the Jolicoeur et al. (1986, 1991) model once the spotlight has travelled on a point of the curve, the activation dies while, in the spread of attention model (Roelfsema, 2001), attention is spread along the curve until the entire curve is activated and with curve tracing involving feedback from higher visual areas. Crundall, Cole and Underwood (2008) also explored the attentional and automatic process in curve tracing questioning if tracing is obligatory and found that attention is able to skip non-task relevant parts of a curve before the tracing operations start as well as continuing past the task-relevant parts of a curve.

Neurophysiological evidence in Curve tracing

Until relatively recently there was no neurophysiological research on curve tracing. This changed with publications from Roelfsema, Lamme, & Spekreijse (1998) and Roelfsema et al., (2000) where monkeys performed a curve tracing task while neuronal activity in the primary visual cortex was recorded using electrodes implanted in their brain. These single cell studies showed enhanced neuronal responses in area V1 for segments of entire curves which connected the fixation point to the correct target relative to distractor/ irrelevant curves. It was suggested that response times during curve tracing reflected the delay that occurs during the distribution of attention.

Even more recently in a response to questions raised by Roelfsema et al (1998; 2000), Lefebvre, Jolicoeur and Roberto Dell’Acqua (2010) presented new findings in a study of brain activity during curve tracing in humans. Lefebvre et al. (2010) recorded electrical activity during curve tracing in human participants. Human participants were asked to identify the end of a target curve among presented distractor curves. Lefebvre et al. (2010) found a sustained posterior contralateral negativity associated with the side on which the target curve was presented. It is suggested that this provides further support for the spread of attention model. These are however, provisional findings and should be treated with some caution. The overall reaction times in this study were highly variable and it is suggested this may reflect an overlap in trials that are being traced before and after the crossover from stimuli in the upper/ lower part of the hemifield within the same condition and if these elements were controlled findings may not support a spread of attention model. Whilst there is support for a spread of attention model this requires further investigation.

Neuropsychological Evidence

There is now neurophysiological evidence available from curve tracing in monkeys and a recent study has examined event related potentials in humans (Roelfsema et al., Lefebvre et al. discussed above). It has been suggested that curve tracing involves feedback from higher level regions of the ventral cortex to areas of the primary visual cortex in order to trace larger areas rapidly. However, despite a detailed search I have found no work on curve tracing and curve tracing processes of the sort described by Jolicoeur et al (1987), Ullman (1984), Roelfsema (2001) in neuropsychological cases outside of this thesis. Within this thesis there is very much a neuropsychological focus. One of the ways used to distinguish between distinct brain processes has been to assess whether there are neuropsychological deficits associated with processing of spatial relations and here we assess visual processing with a focus on figure-ground segmentation to include curve tracing.

Figure ground segmentation in neuropsychology

A number of interesting case studies with patients with deficits in figure ground segmentation and some dissociations have been reported in neuropsychology literature. Behrmann, Mosovitch and Winocur (1994) described a patient with visual agnosia following a closed head injury. CK was highly impaired in visual object recognition but maintained intact visual imagery. CK was found to be impaired on tasks where he was required to trace or match overlapping object line drawings. CK was able to match local aspects but unable to integrate entire objects to segment complex displays. CK was also impaired on a version of the Shape detection task from Warrington and James (1991) VOSP particularly where the background was more fragmented. CK was unable to segment figure from ground whilst remaining able to match shapes on the Efron test. It seemed that CK's deficit in object processing was related to impaired segmenting and grouping of elements whilst mental imagery remained intact.

Kartsounis & Warrington (1991) described a single case, FGP who struggled to identify objects and was unable to detect a simple shape against a pattern background. FGP had partial cortical blindness and demonstrated a dissociation with preserved shape and size discrimination and severely impaired figure ground discrimination. FGP was unable to segment overlapping geometric shapes such as triangles or circles but struggled to group subjective contours and to link these with collinearity cues. Katsounis and Warrington

(1991) have suggested FGP's impairment reflected a failure to code basic visual information rather than a higher level perceptual deficit.

In neuropsychological literature patients such as FGP have struggled to segment figure from ground and overlapping figures with particular difficulties on degraded figures and in tracing boundaries particularly at intersections. Curve tracing provides a highly relevant to the study of such cases as a task that does appear to be demanding of top down processes. Curve tracing could be helpful in highlighting deficits at different levels of visual perceptual organization in the early stages of the visual system.

In distinguishing between form and integrative agnosis we have tested ability to recognise overlapping line drawings. We used both outline forms and drawings that included internal details. Riddoch and Humphreys (1987a) found that HJA was particularly impaired at recognising objects with internal detail. HJA was found to use internal details to segment objects incorrectly into separate parts. Such stimuli require intact stored knowledge to identify objects. Within this thesis we also examined performance on curve tracing tasks using abstract stimuli to limit the influence of stored knowledge and internal detail on performance whilst allowing us to test ability to segment stimuli

Overview of thesis

This thesis is set out in 4 chapters focused on neuropsychological research with patients with visual perceptual deficits. Chapter 1 provides a review of research into curve tracing and figure ground perception and their relevance to the study of visual agnosia.

In Chapter 2, I present a case study comparing the visual processing of two patients with visual agnosia. It is unusual to have an opportunity to be able to directly compare single cases something we were able to do here through behavioural testing and scans. Patients SA and HJA each had bilateral occipital lesions but were distinguished by having dorsal and medial, ventral extrastriate lesions respectively. Here, we examined differences in the visual processing of these two patients including assessing their function on a range of visual perceptual tasks. Both SA and HJA demonstrated perceptual deficits but differed on tests of shape perception and SA was identified as a form agnosic whilst HJA as an integrative agnosic. This work was published in Cognitive Neuropsychology and is the first of 2 experimental chapters reporting on patients HJA and SA. Within this chapter we examine SA and HJA's abilities to separate figure from ground, to curve trace and their responses to local and global aspects of hierarchical compound letters. I was a contributing though not lead author on this paper and as part of this role I worked with HJA, SA and age-matched controls conducting research. I contributed to the analysis and write-up. In Chapter 3, we further test these patients ability to segment different curve tracing tasks. Up to now there has been no published study of curve tracing in patients with neuropsychological deficits something we address within this thesis. In Chapter 4 we provide a general discussion of our findings.

Chapter 2:

A tale of two agnosias: Distinctions between form and integrative agnosia

Riddoch, M. J., Humphreys, G. W., Akhtar, N., Allen, H., Bracewell, R. M., & Schofield, A. J. (2008). A tale of two agnosias: Distinctions between form and integrative agnosia. Cognitive Neuropsychology, 25, 56–92

Abstract

The performance of two patients with visual agnosia was compared across a number of tests examining visual processing. The patients were distinguished by having dorsal and medial, ventral extrastriate lesions. While inanimate objects were disadvantaged for the patient with a dorsal extrastriate lesion, animate items are disadvantaged for the patient with the medial, ventral extrastriate lesion. The patients also showed contrasting patterns of performance on the Navon Test: the patient with a dorsal extrastriate lesion demonstrated a local bias while the patient with a medial, ventral extrastriate lesion had a global bias. We propose that the dorsal and medial, ventral visual pathways may be characterised at an extra-striate level by differences in local relative to more global visual processing, and that this can link to visually-based category-specific deficits in processing

Introduction

Agnosia[1] was first described by Lissauer (1890) as a modality-specific disorder of visual recognition (which cannot be attributed to poor sensory processing such as impaired acuity, reduced visual fields or deficits in colour, movement or depth perception). Lissauer distinguished between apperceptive agnosia (impairment in perceptual processing) and associative agnosia (impairment either in accessing stored memories of visual concepts, or a deficit with the concepts themselves). Over the last 20 years or so these two broad categories of deficit have been fractionated and behaviourally-different subtypes of apperceptive and associative agnosia have been identified. We focus here on subtypes of apperceptive agnosia.

Traditionally two simple clinical tests have been used to establish the integrity of apperceptive processes: shape discrimination and shape copying (for a discussion see Riddoch & Humphreys, 2003). A patient failing these tasks would be classified as suffering from apperceptive agnosia, while patients who succeeded would be classed as having associative agnosia. A number of early cases were described that conformed to these distinctions (for apperceptive agnosia, Efron's patient, Mr. S, (Efron, 1968); for associative agnosia Riddoch and Humphreys' patient JB (Riddoch & Humphreys, 1987b)). However, in 1987, Riddoch and Humphreys described a case of apperceptive agnosia (HJA) who succeeded well on shape discrimination and shape copying tasks, but who failed on more stringent tests of visual perception (such as distinguishing the individual items in an overlapping figures test, or detecting targets embedded in displays of homogeneous distractors (Riddoch & Humphreys, 1987a). Riddoch and Humphreys (1987) argued that HJA

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[1] This term was originally coined by Freud (1891).

had impaired perceptual integration of shape elements into perceptual wholes, a disorder they termed integrative agnosia. Patients with a similar pattern of spared and impaired abilities have since been reported in the literature (Amicuzi et al., 2006; Behrmann & Kimchi, 2003; Butter & Trobe, 1994; De Renzi & Lucchelli, 1993; Grossman et al., 1997). Indeed, it seems likely that Lissauer's original case, GL, may also fall within this group (for a discussion on this, see Riddoch & Humphreys, 2003). Such patients may be distinguished from cases where shape discrimination and copying abilities are severely impaired, a disorder we label as form agnosia (Adler, 1944; Benson & Greenberg, 1969; Campion & Latto, 1985; Davidoff & Warrington, 1993; Efron, 1968; Milner et al., 1991; Vecera & Behrmann, 1997). Form agnosia, as a concept, is not uncontroversial, Warrington and co-workers have argued visual sensory processing can only be considered intact if the patient is able to detect "differences between non-representational patterns" (p174, Warrington & Rudge, 1995) and argue that patients with form agnosia are best described as 'pseudo-agnosics'. Against this, studies have been performed where low-level visual processes have been stringently assessed and found to be normal in patients with disorders of this type (e.g., De Haan et al., 1995; Efron, 1968; Milner et al., 1991). Farah (1990) argued that patients where a perceptual processing problem underlay a visual recognition deficit formed a very heterogeneous group. She used the term "apperceptive agnosia" in a "narrow sense" to refer to patients with form agnosia, as these formed a relatively homogeneous subgroup. More recently, she has acknowledged that form agnosia is the more generally accepted label, being first proposed by Benson and Greenberg (1969; Farah, 2004).

One of the problems inherent in reports of single cases of patients with visual agnosia is that there is little consistency in the diagnostic tests used. A further problem is that until recently, it has not been possible to accurately pinpoint areas of damage in such patients. However, as more cases are reported, some consistency in the areas of damage is revealed. Most of the documented cases of form agnosia have suffered carbon monoxide poisoning (e.g., Adler, 1944; Benson & Greenberg, 1969; Campion & Latto, 1985; Efron, 1968; Milner et al., 1991), two exceptions are SMK who suffered anoxia following an assault (Davidoff & Warrington, 1993) and JW who suffered anoxic encephalopathy following a cardiac event (Vecera & Behrmann, 1997). In general, patterns of diffuse damage have been reported. Recently James et al. (James et al., 2003) from a high-resolution structural MRI, showed that one form agnosic, DF (see Milner et al., 1991), has severe bilateral damage to the ventral, lateral occipital complex (slightly worse on the right than on the left). The primary visual cortices and the fusiform gyri were spared. There was additional tissue lost in the intra-parietal sulcus, and evidence of generalised atrophy. In the case of JW, Vecera and Behrmann (1997) report multiple hypodensities in both occipital lobes and in the right parietal area, based on CT-scan.

Lesion information is also available for patients with integrative agnosia. Cases here have been reported following stroke (e.g., Grossman et al., 1997; Riddoch et al., 1999; Shelton et al., 1994); traumatic brain injury (De Renzi & Lucchelli, 1993; Delvenne et al., 2004; Marotta et al., 2001; Ricci et al., 1999), Alzheimer's disease (Grossman et al., 1997), an anoxic episode following myocardial infarction (Behrmann & Kimchi, 2003; Marotta et al., 2002) and progressive multifocal leukoencephalopathy (PML) (Butter & Trobe, 1994). A developmental case has also been reported (Amicuzi et al., 2006). In all instances resulting from stroke, bilateral posterior lesions are again reported. MRI scans for HJA show bilateral lesions of medial, ventral occipito-temporal regions, including inferior temporal gyrus, the fusiform gyrus and the lingual gyrus (see Figure 1 here, also Allen et al., 2007; Riddoch et al., 1999). Lesion information for patient LWT (Shelton et al., 1994) appears similar (on CT scan, the lesion was localised to the inferior temporal lobes bilaterally involving the temporal, fusiform and lingual gyri). For patient SZ (Grossman et al., 1997), the lesion affected the middle and inferotemporal cortices and spared the primary visual cortex. The right occipito-temporal region is implicated in one of the four cases with traumatic brain injury (e.g., De Renzi & Lucchelli, 1993; Marotta et al., 2001); a further case had bilateral occipito-temporal lesions (Delvenne et al., 2004); and for one case, no abnormalities were shown on the MRI scan (Ricci et al., 1999). However, it should also be noted that the anoxic patient (RN) had bilateral parieto-temporal lesions (Behrmann & Kimchi, 2003; Marotta et al., 2002), the developmental case had bilateral occipito-temporo-parietal lesions (Amicuzi et al., 2006) and the case with PML also demonstrated bilateral occipito-temporal lesions on MRI (Butter & Trobe, 1994). In summary, cases with integrative agnosia appear to have more medial, ventral lesions than patients with form agnosia, with the lesions also tending to encroach into the posterior temporal lobes, but the picture is not completely uniform.

These conclusions are limited by the lack of direct comparisons between patients, both in terms of the scanning protocols and the functional tests being administered. In the present paper we aim to remedy this by reporting experimental and imaging data that enable a direct comparison to be made between a patient with form agnosia and an integrative agnosic patient. The cases (SA and HJA) both present with bilateral occipital lesions, but the lesions involve dorsal extrastriate cortex in the case of form agnosic (SA), and medial, ventral extrastriate cortex in the case of integrative agnosia (HJA). The patients also differ functionally. SA, the form agnosic, shows better identification of animate than inanimate items and a tendency to process visual stimuli at a local rather than a global level. HJA, the integrative agnosic, is better able to identify inanimate than animate items and shows a tendency to process visual stimuli initially at a global rather than a local level. We discuss the implications of these results for theories of visual object processing and for understanding perceptual variants of category-specific disorders.

The data are reported in two sections, following case reports of high resolution structural MRIs. The aim of the experiments was to demonstrate differences in visual processing consequent on the different lesions. In the first section (Section A) we report data that (i) classify both patients as agnosic, (ii) demonstrate that both patients have perceptual deficits, but that (iii) the two patients diverge on tests of shape perception, resulting in a diagnosis of form agnosia for SA and integrative agnosia for HJA. In Section B, we report experimental data on other perceptual abilities in the patients, including figure-ground coding, the use of top-down knowledge, curve tracing and the perception of hierarchical stimuli. Perceptual differences between the patients are documented in each case. We review the implications for theories of object recognition in the General Discussion.

Section A: Defining the type of agnosia

Case Histories

1. SA, a hospital clerical worker, suffered a bilateral occipital stroke in 1997 at the age of 50 years. She attended for testing 4 years post lesion, in 2001. Figure 1 presents the results from a high resolution (3T) structural scan (1mm isotropic) performed in February 2006.

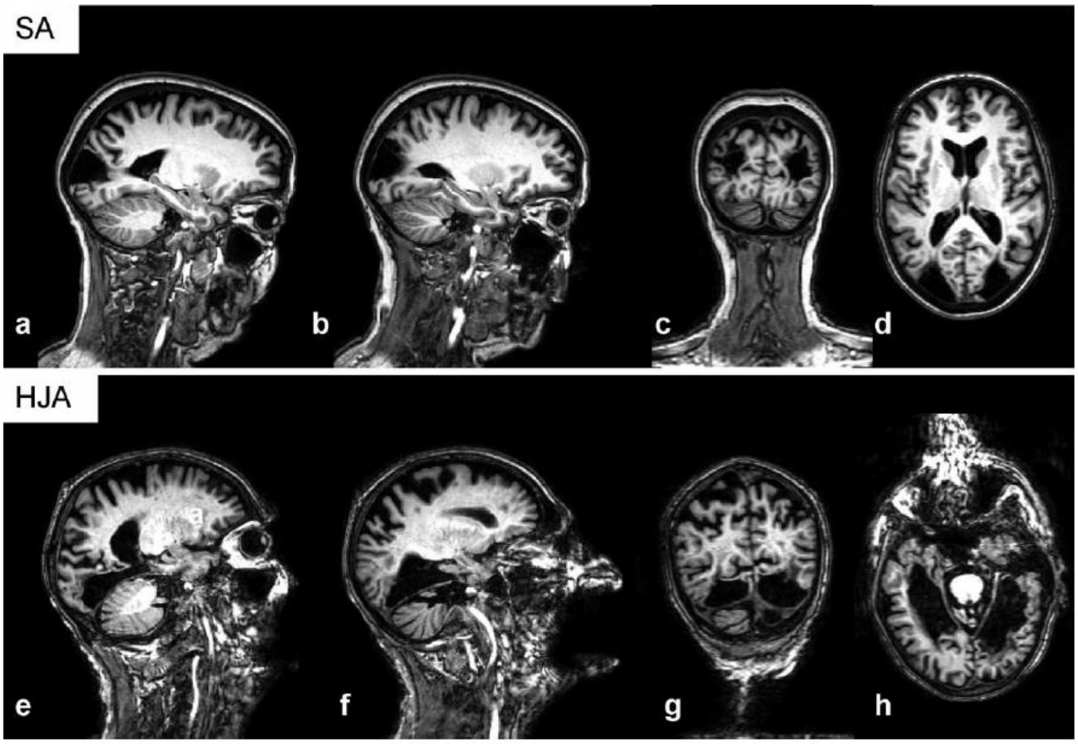

Figure 1. *(a)–(d): Functional magnetic resonance imaging (fMRI) showing a dorsal extrastriate lesion (S.A.). (e)–(h): fMRI showing a ventral extrastriate lesion (H.J.A.).*

This revealed a sparing of the calcarine cortex (although there was some involvement on the left) and the ventral extrastriate areas (including the lingual and fusiform gyri). The lesion involved the dorsal extrastriate cortex, including the right intraparietal sulcus. Areas MT, LOC, PEF and V4 were spared (see Figure 1b). SA lived with her husband and had an independent life, including a part-time clerical job. She self-reported with some difficulties in object recognition and reading. Her colour naming was relatively spared. There was some impairment in face recognition. She scored 38/54 on the Benton Face Recognition Test (Benton et al., 1983), thus falling into the 'moderately impaired class'. On the Warrington Recognition Test (Warrington, 1984) she scored 34/50 for faces and 46/50 for words. Age-matched control scores are 42.7 (sd 3.8) for faces and 43.2 (sd 4.0) for words (from the Warrington Recognition Test Manual). SA's recognition memory for faces is therefore impaired relative to that for words.

2. HJA was aged 82 years at the time of the present investigations. He had suffered a posterior cerebral artery stroke perioperatively in 1981 resulting in a dense visual agnosia, prosopagnosia, alexia without agraphia, achromatopsia and topographical impairments. Neurological and psychological investigations have been reported in detail previously (Boutsen & Humphreys, 2002; Humphreys & Riddoch, 1984; Humphreys & Riddoch, 1987; Riddoch & Humphreys, 1987; 1999). The stroke resulted in bilateral lesions of the occipital lobe, extending anteriorly towards the temporal lobes. Figure 1 presents the results from an MRI scan using the same protocol as that for SA conducted in 2005. This shows bilateral lesions of the inferior temporal gyrus, the occipitotemporal gyrus, the fusiform gyrus, and the lingual gyrus; ventral V2, V3 and V4 were likely to be included. The stroke did not impinge on the parietal lobes. There was also some age-related atrophy in this scan, mostly in superior parietal regions. HJA's residual visual abilities have remained relatively constant since his initial lesion, although there is evidence of a loss of stored visual knowledge about particular objects (Riddoch et al., 1999). HJA had markedly poor visual recognition affecting objects from all categories, but being most pronounced with animate objects (Humphreys & Riddoch, 1984, 1987b; Riddoch & Humphreys, 1987a; Riddoch et al., 1999); see also Section B here). HJA continues to be largely independent in everyday life, although he lives in sheltered accommodation.

Demonstrating visual agnosia

The characteristic feature of visual agnosia is the impaired ability to recognise visually presented objects. HJA's object recognition difficulties have been documented previously (e.g., Humphreys & Quinlan, 1987; Riddoch & Humphreys, 1987a; Riddoch et al., 1999), and further tests of picture naming are reported here. SA's object recognition was initially assessed using a computerised version of the Snodgrass and Vanderwart (1980) cohort of line drawings (pictures were presented with unlimited durations using E-Prime software). Naming data were scored for accuracy. SA scored 155/260 (59.6%), whereas HJA scored only 48/260 (18.5%) correct. As a control, using the same presentation conditions, SA's husband (KA) scored 236/260 (90.8%). SA's performance was clearly worse in this case ($X^2_{(1)} = 146.2$, $p<0.0001$). SA's errors were either 'don't know' (67/105, 63.8%), visual/semantic 25.7% (27/105) (e.g., mouse>squirrel), or visual 5.7% (6/105), (e.g., sock>banana). A small percentage of errors involved giving the superordinate name (1.9% items, 2/105), or an unrelated response (1/105, cherry>rabbit). With these stimuli, HJA tended to make more errors when naming animate than inanimate items (10.7% vs. 22.2% correct, Fisher's Exact Test $p<0.05$). KA showed a similar pattern of performance to HJA (85.5% vs. 90.5% correct for animate and inanimate items respectively). However, the patterns of performance for SA were similar for both sets of items (60.2% and 59.6% correct for animate and inanimate items respectively). SA gave no evidence of knowing the identity of objects she was unable to name. HJA made 36.3% 'don't know' responses (77/212), 27.4% visual (58/212), 26.9% visual/semantic (57/212), 10/212 superordinate, and 10/212 unrelated errors.

In an additional test of object naming, SA, HJA and KA (as a control) were given a subset of stimuli from Riddoch and Humphreys (2004). These stimuli were full coloured images of objects that could be identified from their outline shapes (by controls; see Riddoch et al., 2004). There were 15 animate and 15 inanimate items. The stimuli were standardised for size (their longest dimension was 4.5 inches) and presented for 200ms using EPrime at the centre of a computer screen, viewed from 50cm. SA named 10/15 animate and 3/15 inanimate items. Her errors were mostly ‘don’t know’ responses (N=8) plus either visual-semantic (N=6) or visual errors (N=3). HJA named 5/15 animate and 11/15 inanimate items. His errors were visual-semantic (N=10) or visual (N=4). KA performed at ceiling (30/30 correct). Binary logistic regression using the backward method revealed significant effects for Patient (with HJA naming more items overall than SA), and Animacy (more animate items were named than inanimate items). There was also an interaction between Patient and Animacy which indicated that HJA performed better with inanimate items than animate items ($X^2_{(1)} = 4.8$, $p<0.03$), while the reverse was true for SA (Chi-square$_{(1)}$ = 6.7, $p<0.01$). The output from the analysis is given in Table 1.

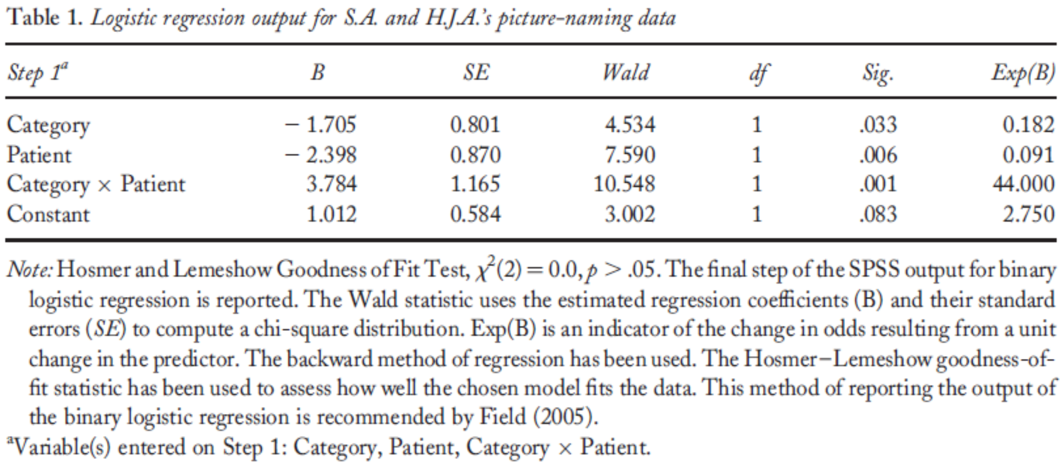

Table 1. *Logistic regression output for S.A. and H.J.A.'s picture-naming data*

Step 1[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Category	− 1.705	0.801	4.534	1	.033	0.182
Patient	− 2.398	0.870	7.590	1	.006	0.091
Category × Patient	3.784	1.165	10.548	1	.001	44.000
Constant	1.012	0.584	3.002	1	.083	2.750

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(2) = 0.0, p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer−Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a]Variable(s) entered on Step 1: Category, Patient, Category × Patient.

When given the names of the objects afterwards, both patients were able to provide accurate definitions of the stimuli, indicating that the problems did not arise at a conceptual level. Though Riddoch et al. (1999) report that HJA suffered some loss of visual knowledge, this was not evident for the items presented here.

These data indicate that both SA and HJA are impaired at object recognition compared with control performance. SA performed better than HJA with unlimited presentation times but this advantage decreased with briefer exposures (also see below). Also, while SA showed no difference between animate and inanimate items with unlimited exposures, she was better with inanimate items when presentation times were limited (again see below), HJA was better at identifying inanimate than animate items at both exposures. The patients made predominantly visual-semantic or visual errors (or ‘don’t know’ responses for SA), indicating that the problem was one of recognition rather than name retrieval. Also the patients were able to give accurate definitions to the names of objects, suggesting no deficit at a conceptual level. These naming data conform to a pattern of visual agnosia.

The perceptual locus of the deficit

A diagnosis of apperceptive agnosia is made when patients with impaired visual naming show impairments in perceptual processing and have no accompanying deficit in semantic knowledge. In 1987 we demonstrated that HJA’s picture naming ability was abnormally reduced if stimuli were presented at reduced exposures, consistent with an underlying perceptual deficit (Riddoch & Humphreys, 1987a; Riddoch et al., 1999). For instance, identification for one set of drawings decreased from 80% to 45%, 40%, and 15% correct at unlimited, 1000ms, 500ms and 100ms exposure durations respectively. We also explored the effects of manipulating exposure duration with SA. She was asked to name a subset of the Snodgrass and Vanderwart (1980) line drawings. There were 76 stimuli made up of 38 animate and 38 inanimate items, half with high and half with low name frequencies. There were 5 different exposure durations: 1000ms, 500ms, 250ms, 100ms and 50ms. Each set was presented in a different test session at 4-weekly intervals. Like HJA, SA’s naming performance was affected by the reduction in exposure duration, particularly at the shorter exposure durations. The percent correct at each exposure is shown in Table 2 below. KA, given the stimuli at the same exposures, showed no deterioration in performance.

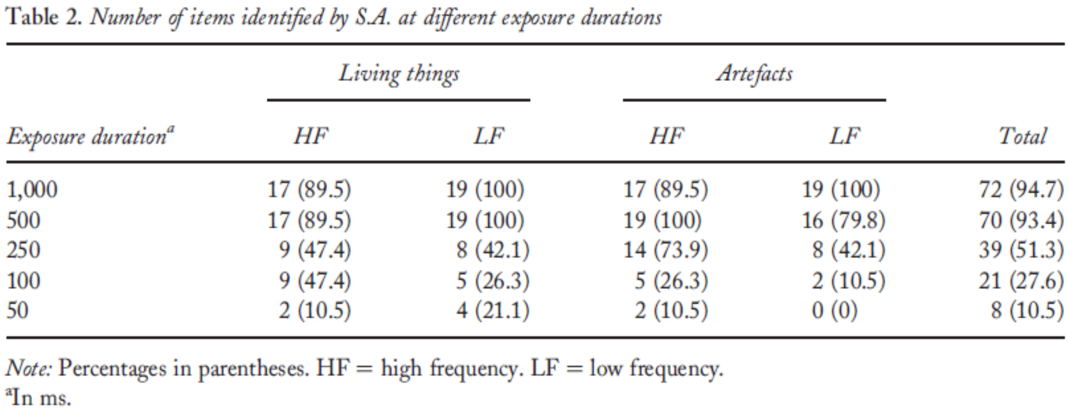

Table 2. *Number of items identified by S.A. at different exposure durations*

	Living things		*Artefacts*		
Exposure duration[a]	*HF*	*LF*	*HF*	*LF*	*Total*
1,000	17 (89.5)	19 (100)	17 (89.5)	19 (100)	72 (94.7)
500	17 (89.5)	19 (100)	19 (100)	16 (79.8)	70 (93.4)
250	9 (47.4)	8 (42.1)	14 (73.9)	8 (42.1)	39 (51.3)
100	9 (47.4)	5 (26.3)	5 (26.3)	2 (10.5)	21 (27.6)
50	2 (10.5)	4 (21.1)	2 (10.5)	0 (0)	8 (10.5)

Note: Percentages in parentheses. HF = high frequency. LF = low frequency.
[a] In ms.

Although overall there was not much difference in the naming of animate and inanimate items (57.4% vs. 53.7% correct respectively), at short exposures SA showed a clear advantage for animate items. The trend became more exaggerated if the responses to the shorter two exposures only were taken (26.3% and 11.8% correct for living and non-living items respectively; see Table 1, $X^2_{(1)} = 5.12$, $p<0.02$). The deficit for inanimate items, here, cannot be linked to SA making better use of colour information for animate items, since only black and white line drawings were used.

These data show that picture naming is abnormally impaired for SA, like HJA, under conditions where perceptual processing is stressed. This provides evidence for a perceptual locus for the deficit. When given the names of objects used in these tests, SA was able to provide an adequate definition in all 76 cases. Thus, there was no evidence for a semantic component to the deficit, along with positive evidence for a perceptual contribution (an abnormally increased effect of exposure duration). Riddoch and Humphreys (1987; Riddoch et al. 1999) also reported evidence on the sparing of semantic knowledge in HJA. Thus, for both cases, the data indicate a perceptual rather than a semantic locus to the deficit – apperception is impaired.

Further tests were administered to examine low level perceptual processing. SA's performance is contrasted here with published data from HJA. SA's judgements of similarities and differences in line length, line orientation, circle size, position of a gap in a circle circumference, and angle size were assessed. The first four of these were examined using subtests from BORB (Birmingham Object Recognition Battery, (Riddoch & Humphreys, 1993). There were equal numbers of 'same' and 'different' trials (N=15 for all subtests except for the position of gap where N=20). SA performed each test 3 times. On the first 2 occasions stimuli were presented side-by-side, and on the third occasion stimuli were presented one above the other. On the second occasion when stimuli were presented side-by-side SA was allowed to trace the items with her finger. There was no significant difference in the scores collapsed across the 4 tests on the three different occasions of testing ($X^2_{(2)} = 4.9$, $p>0.05$). The data were therefore averaged across the three occasions of testing. HJA performed similar tests on one occasion only (see Humphreys & Riddoch, 1984) and his data are presented here for comparison (see Table 3).

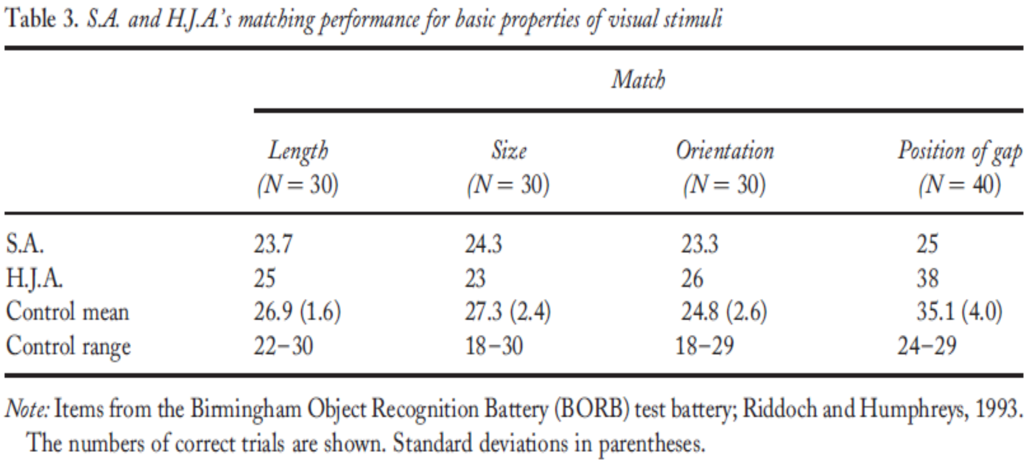

Table 3. *S.A. and H.J.A.'s matching performance for basic properties of visual stimuli*

	Match			
	Length ($N = 30$)	*Size* ($N = 30$)	*Orientation* ($N = 30$)	*Position of gap* ($N = 40$)
S.A.	23.7	24.3	23.3	25
H.J.A.	25	23	26	38
Control mean	26.9 (1.6)	27.3 (2.4)	24.8 (2.6)	35.1 (4.0)
Control range	22–30	18–30	18–29	24–29

Note: Items from the Birmingham Object Recognition Battery (BORB) test battery; Riddoch and Humphreys, 1993. The numbers of correct trials are shown. Standard deviations in parentheses.

The scores for both patients fell within the control range on all the low-level perceptual tests in BORB[2]. We also measured acuity and contrast sensitivity functions for the patients, using sine wave gratings varying in spatial frequency. SA was compared with KA, and both were tested using the method of adjustment. Measurements were taken at 2 viewing distances (47 and 190cm). HJA was tested using a forced choice staircase procedure. The data are shown in Figure 2. The results suggest that both HJA and SA had decreased sensitivity, especially for higher contrast sensitivities (however, the relations between contrast sensitivity functions and performance with supra-threshold stimuli as reported through the rest of the paper is far from clear). Snellen acuity, with correction, was normal for both cases (6/6).

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[2] Although we note that SA was at the low end of the control range on the position of the gap task.

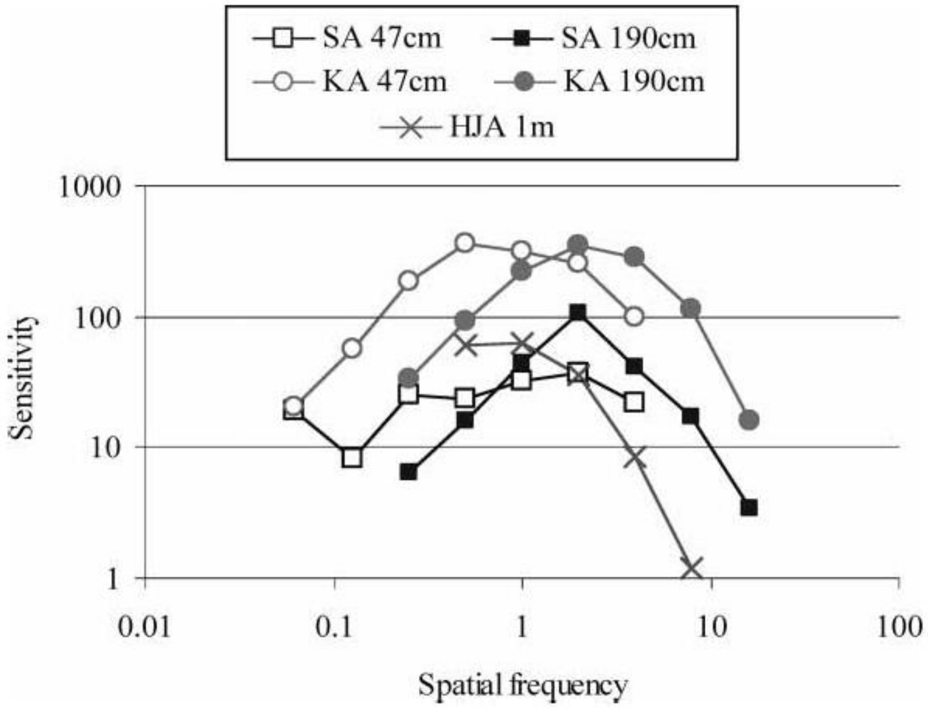

Figure 2. *Contrast sensitivity functions for S.A., H.J.A., and K.A. (control). Measurements for S.A. and K.A. were performed at two viewing distances (47 and 190 cm). The viewing distance for H.J.A. was 1 m.*

Distinguishing form agnosia and integrative agnosia

A standard test of form perception, where patients with form agnosia have consistently been shown to be impaired, is the Efron shape test (Efron, 1968). Interestingly, Humphreys et al. (1992) reported that HJA had intact performance on this task, suggesting that his level of deficit occurred at a level of processing after simple form coding had been achieved. Consequently we evaluated SA's performance on the Efron shape test. We also re-evaluated HJA. Subsequently we examined form processing using simple copying tasks and tests of figure-ground segmentation.

a. The Efron Shape Test

The test used here was similar to that described by Efron (1968) and involved judging whether a 2D shape was a rectangle or a square. There were 50 trials in total, with an equal number of squares and rectangles. All items were presented as black outlines on a white background. Squares were 1in x 1in. There were 5 grades of difficulty with the rectangles. The vertical sides were always 1in; the horizontal edges were 1.025in, 1.25in, 1.5in, 1.75in and 2in. There were 5 trials for each of the different rectangle sizes. SA performed the test on two separate occasions scoring 37/50 on both occasions. She never made errors in judging the square (100% correct on both occasions). On 'rectangle' trials, she performed particularly poorly with the rectangles that were closest in size to the square (0/10 on both test occasions). She scored 10/10 on the easiest discrimination, 9/10 for the next easiest, and 5/10 for the intermediate discrimination. HJA performed at ceiling on this task (100% correct). Ten controls (mean age 66.2 years, sd 6.8) scored an average of 46.9/50 (sd 3.6) on this task; SA's score fell more than 2sd below the control mean.

b. Copying

Examples of the copies produced by HJA and SA are shown in Figure 3. Copies of simple geometric shapes taken from the Birmingham Object Recognition Battery (BORB, Riddoch & Humphreys, 1993) are shown in Figure 3a. Target stimuli are shown on the left. HJA's copies are relatively accurate and are similar (or slightly larger) in size to the target stimuli. While asked to produce copies similar in size, SA's productions were much smaller than the originals, and her accuracy was poor. Both patients were asked to copy a more complex stimulus (the Rey-Osterith Figure, Meyers & Meyers, 1995)(see Figure 3b). While some inaccuracy was shown by both patients, this was particularly pronounced for SA. Both HJA's and SA's reproductions of the Rey figure were submitted to 15 raters who were asked to grade the accuracy of the copies relative to the original. A scale of 1-10 was used with 10 being a perfect score. HJA obtained a mean score of 7.8 (sd = 1.3), and SA a mean score of 5.2 (sd = 2.0). The difference in ratings scores was significant (Sign Test Exact Significance $p<0.0001$).

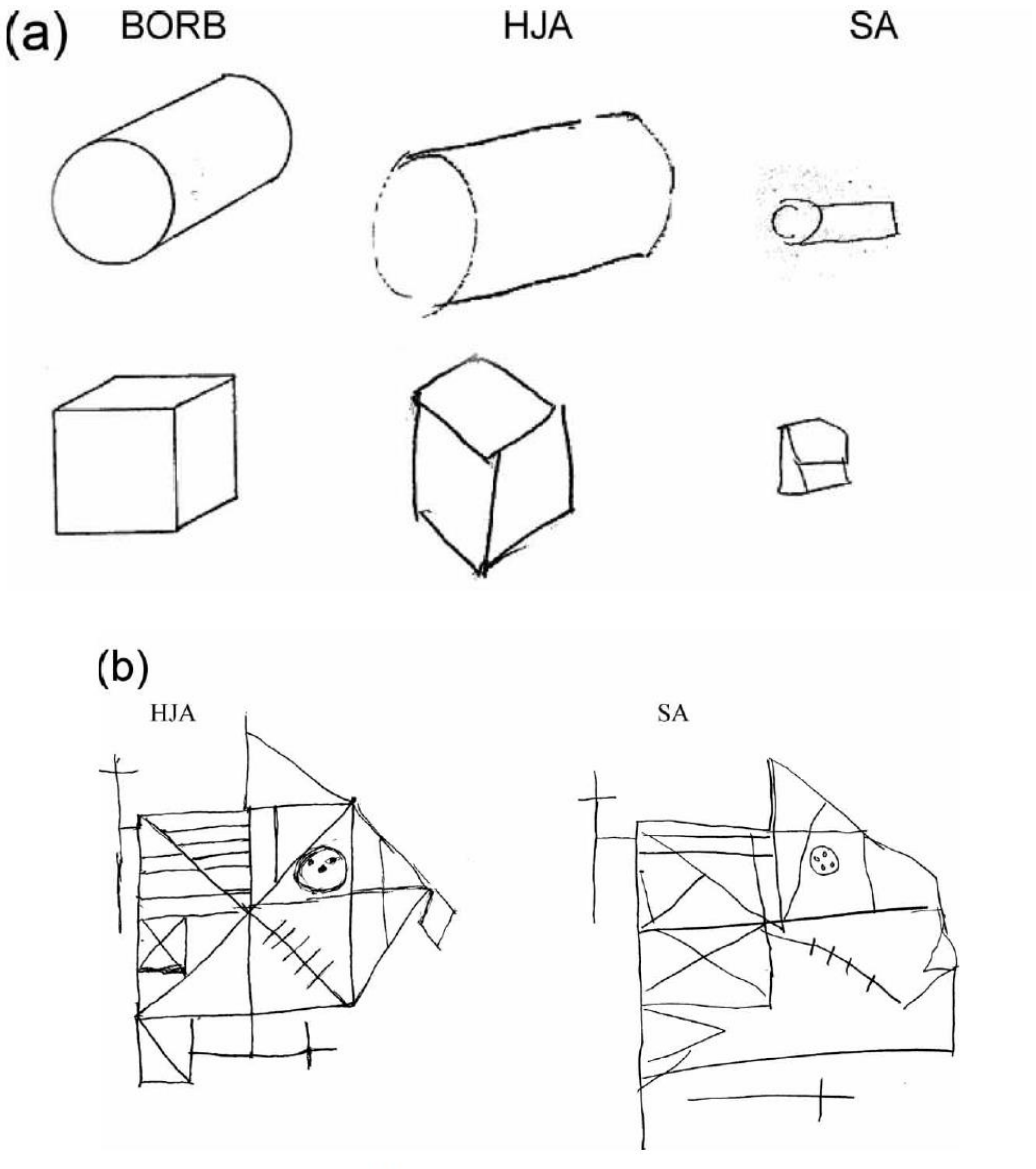

Figure 3. *Illustrations of copying performance. (a) On the left are examples of a cube and a cylinder from the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993). In the centre and to the right, respectively, are H.J.A.'s and S.A.'s copies. (b) H.J.A.'s (left) and S.A.'s (right) copies of the Rey–Osterrieth Figure.*

c. Figure-ground segmentation

1. Shape judgement (VOSP)

A basic examination of figure-ground segmentation was provided by the shape detection test from VOSP (the Visual Object and Space Perception Battery, (Warrington &

James, 1991). Participants are asked to detect an X (which may either be present or absent) in the presence of background noise. Performance can be based on local pooling of luminance. Both patients performed within the normal range. SA scored 18/20 (control score = 19.9, range = 18-20), and HJA scored 20/20 (100% correct) on this task. Basic aspects of figure-ground performance were performed reasonably well.

2. Overlapping Figures Test

To test figure-ground segmentation based on edge cues, the patients performed the overlapping figures test from BORB (Riddoch & Humphreys, 1993). SA showed a ratio of 1:1.4 in her naming times to pairs of non-overlapping and overlapping letters, and this ratio increased to 1:1.8 for triplets of letters. The control mean was 1:1 for both pairs and triplets of letters (as provided in BORB).

As previously reported, HJA also found it difficult to identify letters in the overlapping relative to the non-overlapping conditions. His ratio for paired non-overlapping to paired overlapping was 1.0:2.0, and for the same conditions with triplets of letters was 1.0:1.7 (see Riddoch et al., 1999). Thus, relative to the controls, both SA and HJA were impaired in performance in the overlapping relative to the non-overlapping condition.

Discussion

Both SA and HJA were impaired in naming visually presented objects. Although both patients showed some spared perceptual abilities (e.g., when required to match basic visual features), both demonstrated perceptual impairments. Both patients were abnormally affected by decreasing the exposure duration, and both were impaired at tests of figure-ground perception dependent on the segmentation of overlapping letters. Furthermore, both patients had good semantic knowledge about the objects they failed to recognise as line drawings (see Riddoch & Humphreys, 1987a; Riddoch et al., 1999, for additional data on HJA). These data indicate that both patients have apperceptive agnosia. However, alongside these similarities, the patients also clearly differed. In particular, HJA performed at control level in the Efron shape matching test whilst SA was impaired. In addition, HJA showed accurate copies of even complex stimuli, whilst SA's drawings were often inaccurate. SA's impairments at the Efron shape test and copying are characteristic of form agnosics, who seem impaired at coding basic aspects of form (see Adler, 1944; Behrmann & Kimchi, 2003; Benson & Greenberg, 1969; Campion & Latto, 1985; Davidoff & Warrington, 1993; Efron, 1968; Milner et al., 1991; Vecera & Behrmann, 1997). HJA's good performance on these tests, when contrasted with his difficulties in figure-ground perception, are consistent with a diagnosis of integrative agnosia; in this form of agnosia, the basic coding of shape is intact, but grouping and segmentation of more complex shapes (where segmentation cues are ambiguous) are impaired.

SECTION B

In Section B, we present data from an experimental analysis of object processing in SA and HJA. Three experiments are reported. Experiments 1 and 2 examined figure-ground segmentation in more detail, to assess whether, at a finer-grained level, differences exist in the procedures which determine figure-ground perception in the patients. Experiment 1 used overlapping line drawings, but instead of requiring picture naming (Section A), we used either name verification (Experiment 1a) or visual tracing of an exemplar (Experiment 1b-d). We examined how well the patients performed with drawings that were simply outline forms or drawings that included internal details (see Figure 4). Riddoch and Humphreys (1987a) reported that HJA was particularly impaired at recognising objects with internal detail, with internal details being used to segment objects inappropriately into separate parts. Here we test whether this over-segmentation could be observed directly, with a production task that shows the output of the segmentation process; we also test whether the same held for SA. The contrast between name verification (Experiment 1a) and visual tracing (Experiment 1b-d) evaluates a further factor, which is the extent to which a patient may be able to use top-down knowledge to ameliorate a perceptual deficit in object processing. Note that top-down processing is more likely to play a role in the name verification task (Experiment 1a) than in visual tracing (Experiment 1b-d). The data presented in Section A indicated that SA had an 'earlier' perceptual impairment than HJA (e.g., in basic form coding itself), yet her identification of line drawings was somewhat better. One contributing factor might be that SA is better able to use her (spared) top-down knowledge to interpret degraded perceptual input. This was tested more directly in Experiments 1b-d. However, while the data from Experiment 1c revealed that while SA was better able to use top-down information than HJA in a name verification task (Experiment 1a), it was insufficient to help her to segment target contours within a set of overlapping stimuli. In a further experiment (Experiment 1d) we examined whether SA was able to segment a defining feature – rather than the whole contour – of the target item.

In Experiment 2 we employed a different approach to figure-ground segmentation by examining performance on contour tracing tasks. In these experiments abstract stimuli were used, where stored knowledge could not influence performance. There were 3 separate sub-experiments. In the first (Experiment 2a), two overlapping contours were presented (Figure 5a). There were also 2 'beads' present which could either fall on the same or on different contours. The task was to indicate whether the beads fell on the same or on different contours. Work with normal participants (Jolicouer, Ullman & MacKay, 1986), plus single cell recordings in the monkey (Roelfsema, Lamme & Spekreisje, 2000), suggest that this task is achieved by a 'curve tracing' operation, in which attention is scanned serially along the lines. Is this process spared in the patients? In the second sub-experiment (Experiment 2b), the contours formed irregular 'amoeba-like' shapes. The two beads either both lay within the shape, or one lay inside and the other outside (Figure 5b). Here we examined whether patients were able to use the global shape of the form to make figure-ground judgements (see Van Selst & Jolicoeur, 1995 for prior evidence with normal participants). In the third experiment (Experiment 2c), two "amoeba-like" shapes overlapped (Figure 5c). The beads lay either on the contour of a single shape, or one bead lay on the contour of each shape. The task was to decide whether the beads lay on the same shape or on different shapes. In this last experiment there is additional stress on any figure-ground segmentation procedures since judgements require correct contour assignment globally across the shapes. We test whether performance can be maintained by the patients under these more taxing conditions. Experiment 3 assessed the ability of the patients to derive global and local form-information using a compound letter task in which the patients had to identify letters at either the local or global levels.

Experiment 1: Segmenting overlapping line drawings

Method

Stimuli

Forty items were selected from the Snodgrass and Vanderwart (1980) set of line drawings. There were equal numbers of animate and inanimate items. According to the ratings provided by Snodgrass and Vanderwart, the mean familiarity was 2.7 (sd 0.7) and 3.7 (sd 0.8) ($t_{(38)} = -4.3$, $p<0.0001$) for the animate and inanimate items respectively. The mean complexity was 3.7 (sd 0.7) and 2.6 (sd 0.6) ($t_{(38)} = 5.7$, $p<0.0001$) for animate and inanimate items respectively. A measure of the similarity of the outlines of the shapes, the mean contour overlap was 18.8 (sd 5.7) and 13.8 (sd 5.9) ($t_{(38)} = 2.5$, $p<0.02$) for animate and inanimate items respectively (Humphreys, Riddoch & Quinlan, 1988), consistent with the animate objects belonging to categories with globally similar exemplars (Humphreys & Forde, 2001; data from Humphreys et al., 1988). Individual object stimuli were normalised for size and fitted into a 7x7cm virtual box. Three overlapping stimuli fitted into an 8x8cm virtual box.

In the name verification condition (Experiment 1a), either a single item or 3 overlapping items were presented. There were 3 overlapping items: the target and two other items drawn at random from the Snodgrass and Vandervart set (these items were never repeated). The stimuli were presented either as outlines, or as detailed line drawings. There were 40 trials for each category of stimulus. The stimuli were randomised for presentation. All items were presented twice, once with the correct and once with the incorrect name (this was the name of the visually similar distractor from the match-to-sample study) (N=80 trials for both detailed and outline drawing conditions).

For the matching tasks (Experiments 1b and c), the same items as in the name verification task, above were used. In addition, two individual items (the target and another, different distractor) were placed approximately 10cm below the overlapping items, 5cm apart. The distractor item was selected to be visually similar to the target when presented in outline. In general, the target and distractor came from the same category (living thing or artefact)(e.g., cup and bowl, apple and strawberry), although a few distractors crossed category in cases where the line drawings corresponding to these items were visually similar (e.g., fork and celery, screw and caterpillar). As before, the stimuli were presented as both detailed line drawings and outlines. The task was to trace around the item within the overlapping set that was physically identical to one of the two items below. Only SA performed Experiment 1c and d. In both experiments, stimulus presentation was identical to that in Experiment 1a. The name of one of the three overlapping items was presented auditorily, and SA was asked to trace around that item (Experiment 1c) or to trace around its identifying feature (Experiment 1d).

Procedure

The matching task was performed before the name verification task and there was an interval of 3 months between Experiments 1a and 1b. Experiment 1c (matching to a written name) was performed 9 months after Experiment 1b. Experiment 1d, segmentation of an identifying feature of a target, took place 2 months after Experiment 1c.

(a) Name verification (Experiment 1a): The single stimuli and overlapping stimuli were presented in two separate blocks. Within each block, the stimuli were randomised across items and across stimulus type (detailed line drawing vs. outline). Each patient was asked to study the stimuli and to write ‘yes’ or ‘no’ if the written name corresponded to an item present.

(b) Matching task (Experiment 1b): The stimuli were presented in a random order. Each patient was asked to compare the two single items at the bottom of the page with the three overlapping items above. Using a coloured pen, the patients were then asked to trace around the item in the overlapping set that was physically identical to one of the two stimuli shown below. There were no time constraints, and no constraint on revisiting the items at the bottom of the page.

The data from Experiments 1a and b revealed a discrepancy between relatively good name verification and poor matching and contour tracing in SA. This discrepancy was explored in two further conditions where only SA took part.

(c) Tracing from a name (Experiment 1c): The procedure was identical to that described for Experiment 1a except that SA was asked to trace around the item corresponding to the name printed at the top of the stimulus array.

(d) The final experiment in this series was a feature detection task. The stimuli and procedure were identical to those described for Experiment 1a, except now the instructions were to trace around an identifying feature of the target item. Data were collected for the detailed line drawings only. Subsequently, SA was presented with single detailed line drawing and asked to name the identifying feature. In a further session, SA was given the name of the target items and asked again what constituted that item's identifying features.

Data Scoring

In the name verification task (Experiment 1a), responses were scored as either correct or incorrect. In the matching tasks (Experiments 1b and 1c), the data were scored in two ways. First we noted whether the target was traced correctly. Second, we noted whether the patients included contours from the distractors in their tracing. In Experiment 1d, the identity of the feature traced was noted. As in Experiments 1a and b we also noted whether distractor lines were included in addition to or as well as the target feature. We also coded the traced feature according to whether it fell within or protruded from the set of 3 overlapping pictures. The data from the sessions where SA was asked to identify the salient feature of the target items given either a picture of the item or its name were pooled to maximise the number of salient features associated with each target item.

Results

Examples of HJA's (detailed line drawings) and SA's (outlines) performance for Experiment 1b are shown in Figure 4.

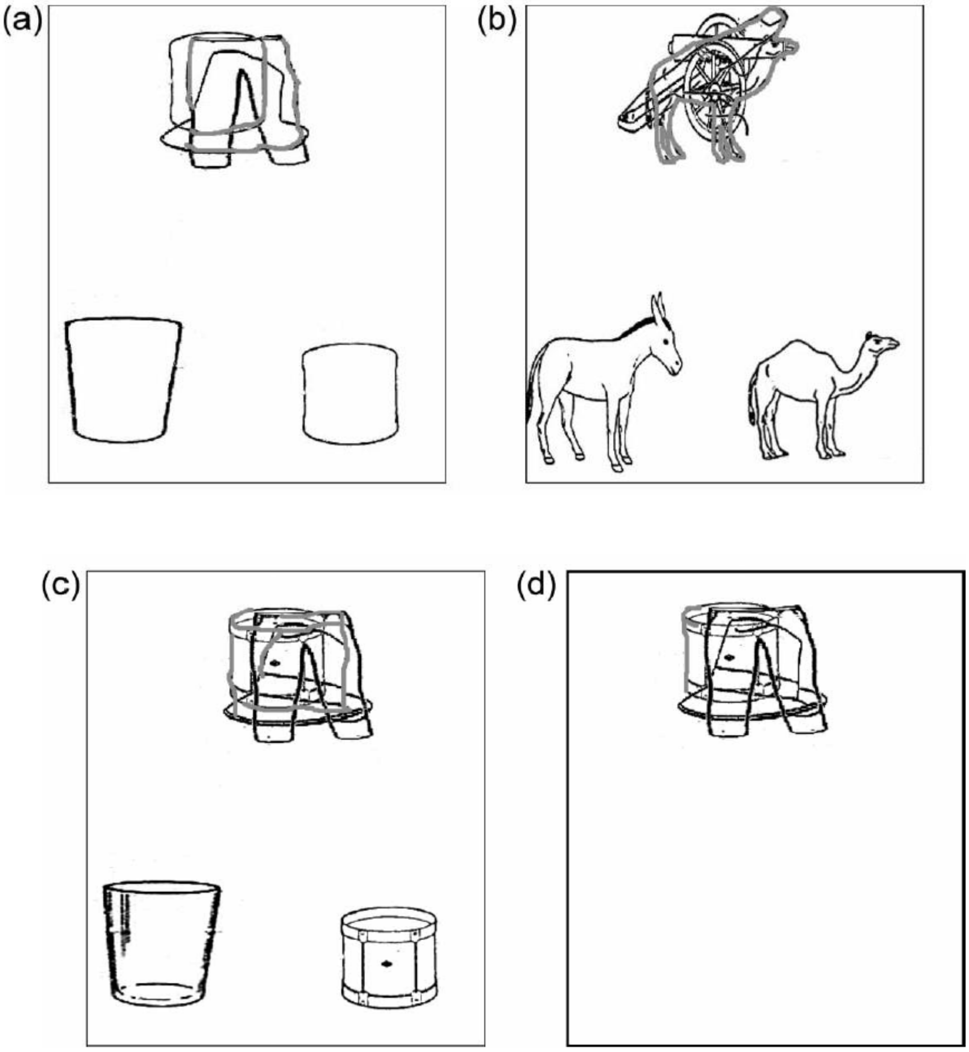

Figure 4. *Examples of the stimuli used in Experiment 1. (a) An example of S.A.'s tracing round an outline within overlapping figures (target = drum; Experiment 1b). (b) An example of H.J.A.'s tracing round a detailed line drawing within overlapping figures (target = camel; Experiment 1b). (c) An example of S.A.'s tracing round the contour of a drum (detailed line drawing) within overlapping figures (Experiment 1b). (d) S.A.'s depiction of a "critical feature" of a target object (drum). When asked to specify the critical feature of a drum, either from a line drawing or from the object name, she stated "skin top" for the picture and "round, with a skin top for banging" given the name (Experiment 1c). (Figure can be seen in colour online.)*

Experiment 1a: Name Verification

The data are presented in Table 4.

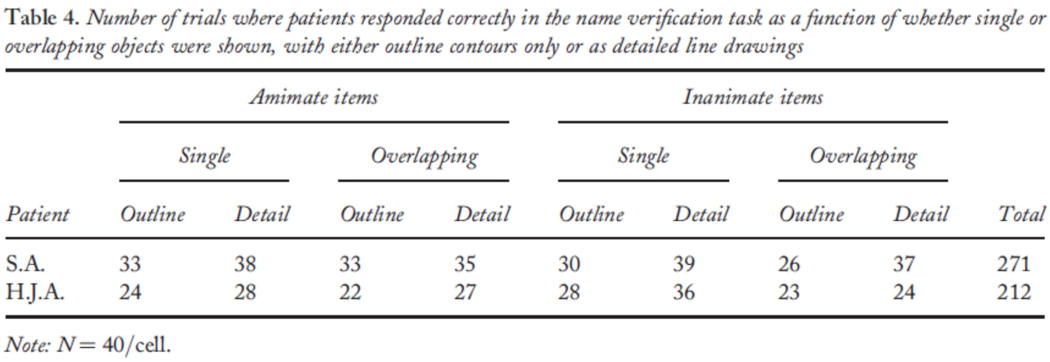

Table 4. *Number of trials where patients responded correctly in the name verification task as a function of whether single or overlapping objects were shown, with either outline contours only or as detailed line drawings*

	Amimate items				*Inanimate items*				
	Single		*Overlapping*		*Single*		*Overlapping*		
Patient	*Outline*	*Detail*	*Outline*	*Detail*	*Outline*	*Detail*	*Outline*	*Detail*	*Total*
S.A.	33	38	33	35	30	39	26	37	271
H.J.A.	24	28	22	27	28	36	23	24	212

Note: $N = 40$/cell.

The results were analysed separately for single and for overlapping drawings using binary logistic regression with the Factors being Patient (SA and HJA), Animacy (Animate vs. Inanimate), Picture Type (Outline vs. Detail) and Match (Correct Name Match vs. Incorrect Name Match).

(i) Single Drawings

The significant effects from the SPSS output at step 4 of the regression are displayed in Table 5. The main effect of Animacy proved significant, indicating that overall performance was more accurate for inanimate items (133/160 and 123/160 for animate and inanimate items respectively). The main effect of Picture Type was also reliable indicating better performance for detailed than for outline shapes (141/160 vs. 115/160 for detailed and outline shapes respectively). The main effects of Patient and Match, and all two-way and three-way interactions were unreliable (all p>0.05). The four-way interaction (Patient x Picture Type x Animacy x Match) was also insignificant (p>0.05). The patients did not differ when required to verify single line drawings).

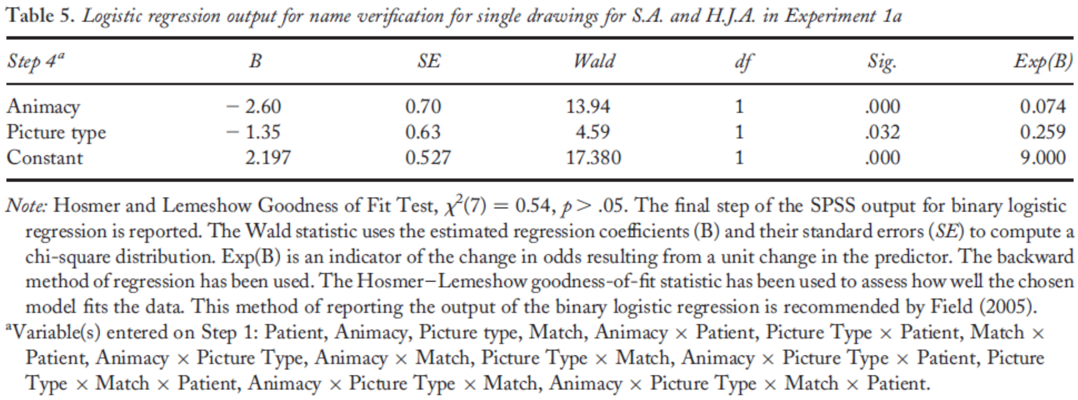

Table 5. *Logistic regression output for name verification for single drawings for S.A. and H.J.A. in Experiment 1a*

Step 4[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Animacy	− 2.60	0.70	13.94	1	.000	0.074
Picture type	− 1.35	0.63	4.59	1	.032	0.259
Constant	2.197	0.527	17.380	1	.000	9.000

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(7) = 0.54$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer−Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a] Variable(s) entered on Step 1: Patient, Animacy, Picture type, Match, Animacy × Patient, Picture Type × Patient, Match × Patient, Animacy × Picture Type, Animacy × Match, Picture Type × Match, Animacy × Picture Type × Patient, Picture Type × Match × Patient, Animacy × Picture Type × Match, Animacy × Picture Type × Match × Patient.

(ii) Overlapping drawings

With overlapping drawings there were significant main effects for Patient and Match and a reliable interaction between Picture Type x Match. There was also a significant three-way interaction between Animacy x Picture Type x Match (see Table 6 for step 11 of the logistic regression output). Further separate analyses were performed for animate and inanimate items to locate the locus of the interaction.

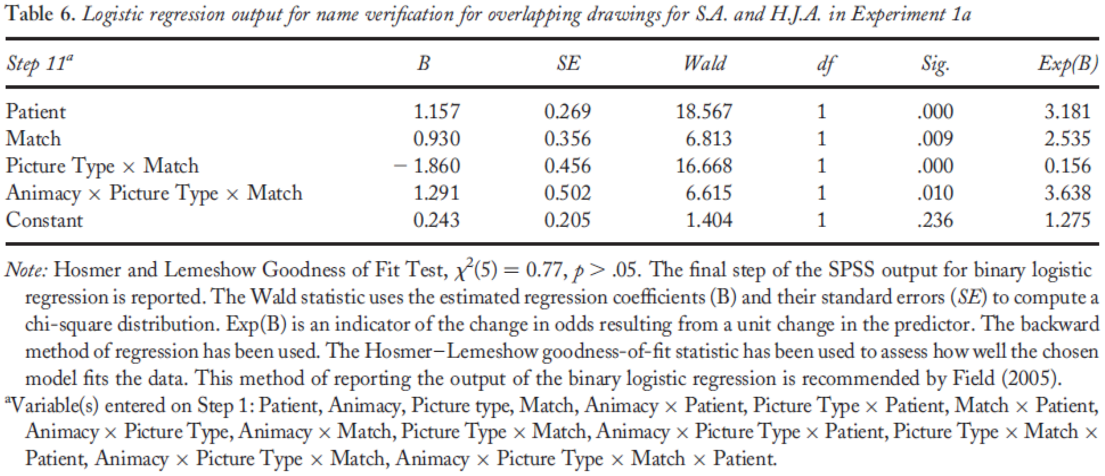

Table 6. *Logistic regression output for name verification for overlapping drawings for S.A. and H.J.A. in Experiment 1a*

Step 11[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Patient	1.157	0.269	18.567	1	.000	3.181
Match	0.930	0.356	6.813	1	.009	2.535
Picture Type × Match	− 1.860	0.456	16.668	1	.000	0.156
Animacy × Picture Type × Match	1.291	0.502	6.615	1	.010	3.638
Constant	0.243	0.205	1.404	1	.236	1.275

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(5) = 0.77$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a] Variable(s) entered on Step 1: Patient, Animacy, Picture type, Match, Animacy × Patient, Picture Type × Patient, Match × Patient, Animacy × Picture Type, Animacy × Match, Picture Type × Match, Animacy × Picture Type × Patient, Picture Type × Match × Patient, Animacy × Picture Type × Match, Animacy × Picture Type × Match × Patient.

For animate items, there was a significant main effect of Patient indicating that SA performed better than HJA (68/80 vs. 48/80 correct) (Wald (1) = 10.74, p<0.001). The main effects of Match and Picture Type were not reliable (p>0.05). None of the two-way nor the three-way interaction were significant (all p>0.05).

The results for inanimate items are shown in Table 7. There were significant main effects of Patient (with SA (60/80 correct) performing better than HJA (47/80 correct)), Picture Type (there were more correct matches for detailed line drawings than for outline drawings (58/80 vs. 49/80)) and Match (the rejection of the incorrect name was more accurate than acceptance of the correct name (56/80 vs. 54/80)). There were two significant two-way interactions: the Picture Type x Match interaction showed that the patients were less likely to select the correct than the incorrect name for outline objects (19/40 vs. 30/40 for correct and incorrect name matches respectively), while the reverse was true for detailed drawings (35/40 vs. 26/40 for correct vs. incorrect name matches respectively). The Picture Type x Patient interaction showed that HJA performed at a similar level for both outline and for detailed line drawings (23/40 vs. 24/40 for outline and detailed drawings respectively) while

SA performed better with detailed line drawings (26/40 vs. 34/40 for outline and detailed drawings respectively).

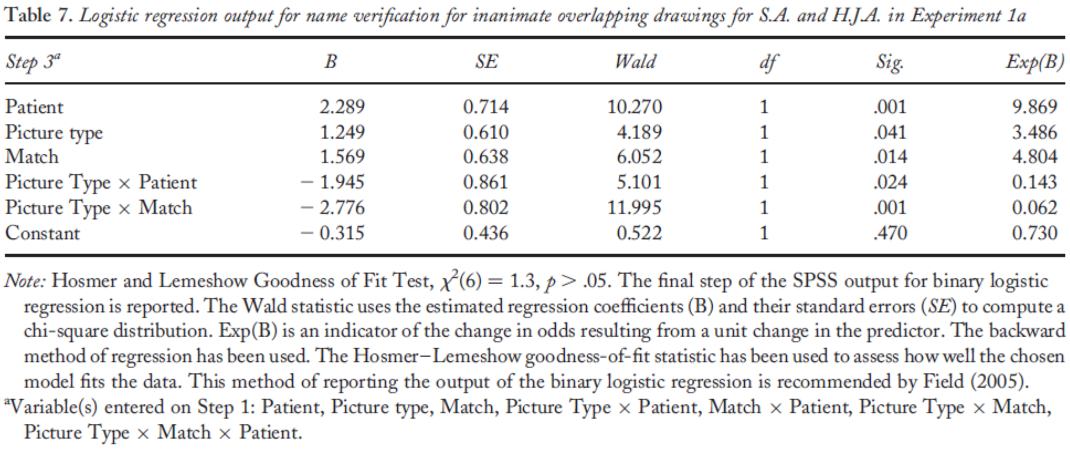

Table 7. *Logistic regression output for name verification for inanimate overlapping drawings for S.A. and H.J.A. in Experiment 1a*

Step 3[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Patient	2.289	0.714	10.270	1	.001	9.869
Picture type	1.249	0.610	4.189	1	.041	3.486
Match	1.569	0.638	6.052	1	.014	4.804
Picture Type × Patient	− 1.945	0.861	5.101	1	.024	0.143
Picture Type × Match	− 2.776	0.802	11.995	1	.001	0.062
Constant	− 0.315	0.436	0.522	1	.470	0.730

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(6) = 1.3, p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a] Variable(s) entered on Step 1: Patient, Picture type, Match, Picture Type × Patient, Match × Patient, Picture Type × Match, Picture Type × Match × Patient.

Experiment 1b: Matching and Tracing Task

1. *Total completions*

Overall, SA performed poorly. She completed 2/40 (one animate and one inanimate drawing) of the outline line drawings, and 2/40 for the detailed line drawings (again, one animate and one inanimate drawing). HJA performed relatively better. His data were analysed using binary logistic regression with the factors being Animacy (living thing vs. artefact), Picture Type (outline vs. line drawing) and Score (whether a target item was completed or not). The statistical output is presented in Table 8. There was a significant main effect of Animacy with HJA scoring better with inanimate than with animate items (13/40 vs. 28/40 for animate vs. inanimate items respectively. There was also a main effect of condition with better performance for outlines (27/40 correct) than for detailed line drawings (14/40 correct).

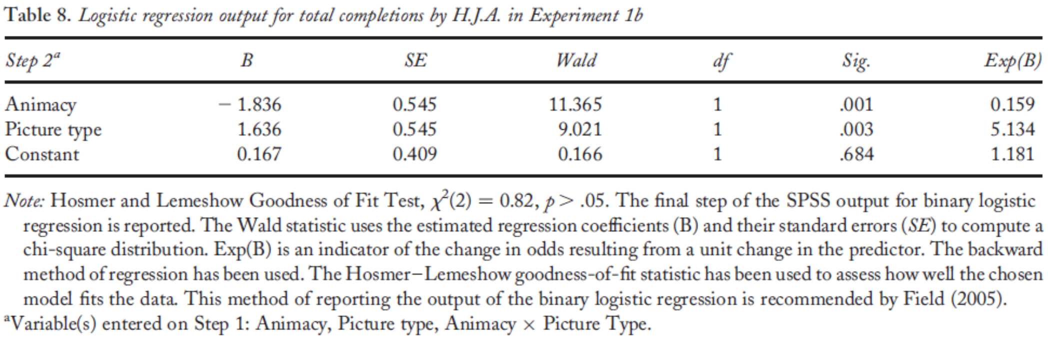

Table 8. *Logistic regression output for total completions by H.J.A. in Experiment 1b*

Step 2[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Animacy	− 1.836	0.545	11.365	1	.001	0.159
Picture type	1.636	0.545	9.021	1	.003	5.134
Constant	0.167	0.409	0.166	1	.684	1.181

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(2) = 0.82$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a]Variable(s) entered on Step 1: Animacy, Picture type, Animacy × Picture Type.

The scores indicating whether contours from the distractors were included in the response are presented in Table 9 (the maximum score per cell, had distractor contours been included on every trial, was 20). These data were subjected to binary logistic regression with the factors being Patient (SA and HJA), Animacy (animate vs. inanimate), and Picture Type (outline vs. detail). Distractor Inclusion was the dependent variable (whether contours from the distractor were included in the response or not). The output for step 4 of the regression is shown in Table 10.There was one main effect of Animacy and a significant 2-way interaction between Animacy x Picture Type. The Animacy x Picture Type interaction showed that there was little difference between animate and inanimate items whether distractor lines were included in outline drawings (13/40 vs. 15/40 for animate vs. inanimate items respectively), but with detailed drawings distractor lines were more likely to be included with animate targets (26/40 vs. 16/40 for animate vs. inanimate items respectively).

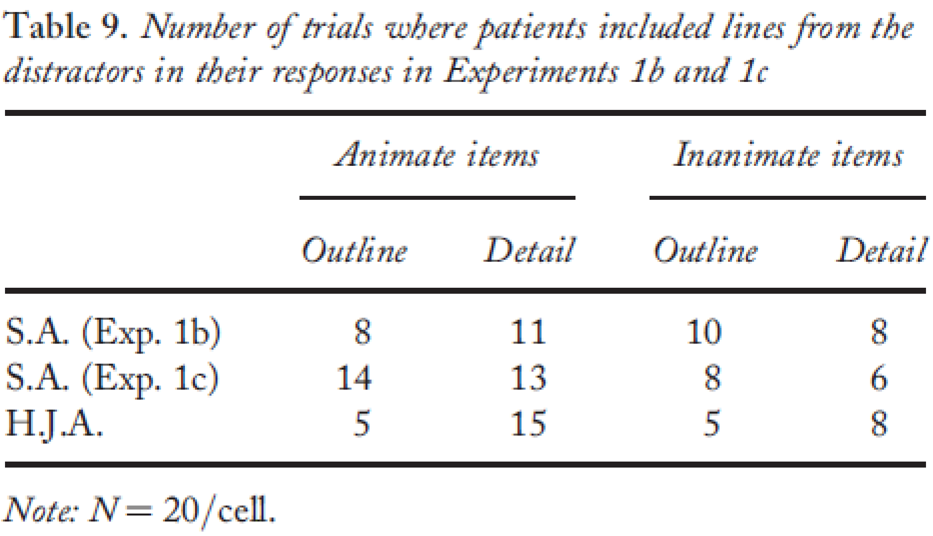

Table 9. *Number of trials where patients included lines from the distractors in their responses in Experiments 1b and 1c*

	Animate items		*Inanimate items*	
	Outline	*Detail*	*Outline*	*Detail*
S.A. (Exp. 1b)	8	11	10	8
S.A. (Exp. 1c)	14	13	8	6
H.J.A.	5	15	5	8

Note: $N = 20/\text{cell}$.

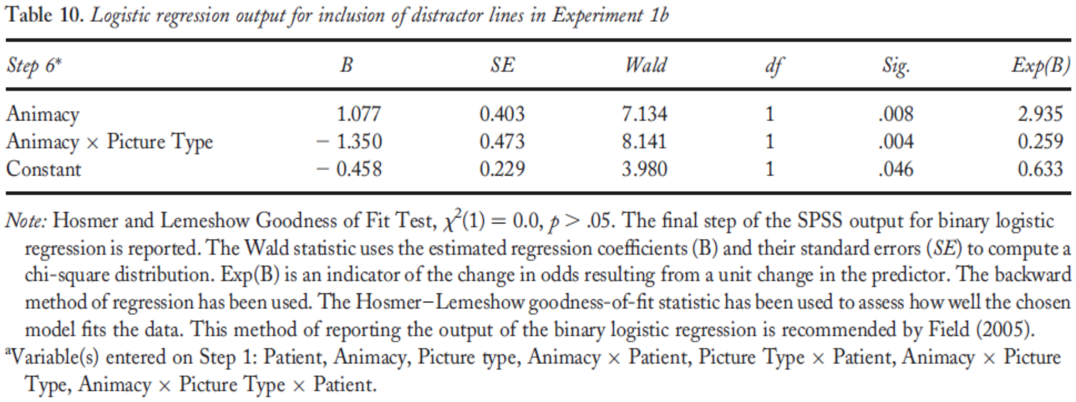

Table 10. *Logistic regression output for inclusion of distractor lines in Experiment 1b*

Step 6[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Animacy	1.077	0.403	7.134	1	.008	2.935
Animacy × Picture Type	− 1.350	0.473	8.141	1	.004	0.259
Constant	− 0.458	0.229	3.980	1	.046	0.633

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(1) = 0.0$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a] Variable(s) entered on Step 1: Patient, Animacy, Picture type, Animacy × Patient, Picture Type × Patient, Animacy × Picture Type, Animacy × Picture Type × Patient.

Experiment 1c: Tracing from a name

The data from Experiments 1a and 1b reveal a contrast that is particularly striking for SA. She was better than HJA at verifying if a named stimulus was present in a set of overlapping figures (Experiment 1a), while she was strikingly poor at tracing a target in the overlapping set when given a visual exemplar (Experiment 1b). In Experiment 1c SA had to trace a target in the overlapping set when she was given the object’s name. She remained very poor at this, completing correctly only 7/40 outline drawings and 1/40 detailed line drawings (Fisher’s Exact Test p>0.05). As in Experiment 1b, she had a tendency to include distractor lines in her response (see Figure 4c). The numbers of trials where a distractor contour was included are presented in Table 9. These data were subjected to a binary logistic regression with the factors being Experiment (1b and 1c), Animacy (animate vs. inanimate), Picture Type (outline vs. detail). Distractor Inclusion (inclusion vs. no inclusion) was again the dependent variable. The output from step 6 of the regression is presented in Table 11. The main effect of Animacy was reliable, and indicated that SA was more likely to include distractor lines from animate items (46/80) than from inanimate items (32/80). The main effect of Experiment and the interaction between Experiment and Animacy approached significance. SA tended in include more distractor lines in Experiment 1c than in 1b (37/80 vs. 41/80 for Experiment 1b and 1c respectively), and the effect was particularly apparent for animate items (27/80 vs. 19/80 for inclusion of distractor lines with animate targets vs. 18/80 vs. 14/80 80 for inclusion of distractor lines with inanimate targets in Experiments 1c and 1b respectively).

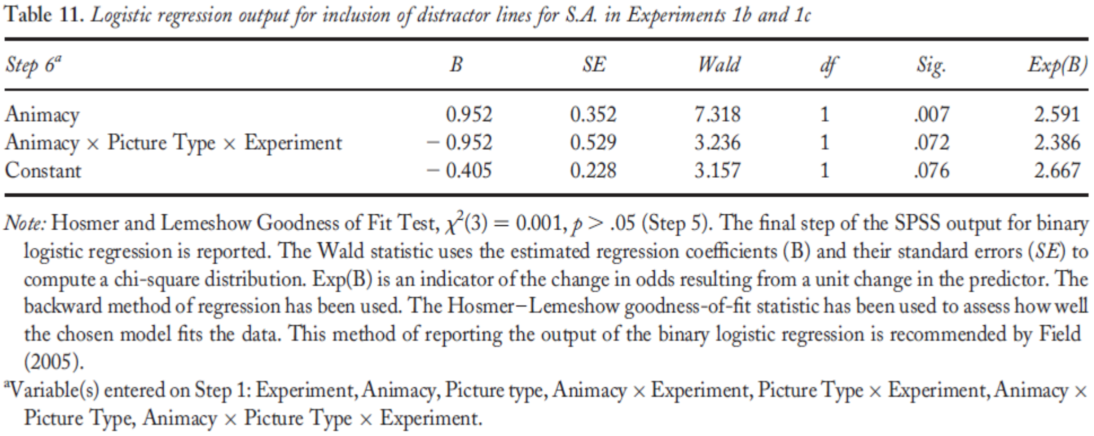

Table 11. *Logistic regression output for inclusion of distractor lines for S.A. in Experiments 1b and 1c*

Step 6[a]	*B*	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Animacy	0.952	0.352	7.318	1	.007	2.591
Animacy × Picture Type × Experiment	− 0.952	0.529	3.236	1	.072	2.386
Constant	− 0.405	0.228	3.157	1	.076	2.667

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(3) = 0.001, p > .05$ (Step 5). The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (*SE*) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

[a] Variable(s) entered on Step 1: Experiment, Animacy, Picture type, Animacy × Experiment, Picture Type × Experiment, Animacy × Picture Type, Animacy × Picture Type × Experiment.

Experiment 1d: Detecting distinctive features

Given that SA remained poor at tracing, even when presented with the name of the target object (Experiment 1c), the question remains as to how she could verify a target amongst overlapping distractors. Experiment 1d assessed whether SA's good verification performance (Experiment 1a) arose because she could detect critical features of stimuli even when they were overlapping. Here she was asked to trace the critical features of a named target (e.g., Figure 4d shows her performance in response to the target name 'drum'). Performance with overlapping stimuli was compared with her performance with single stimuli and when she was asked to describe verbally the critical features for identification, when given the object's name. Did SA use the same features with overlapping and non-overlapping items?

First, we compared SA's success at tracing a part of the target object, without including contours from distractors, when she was asked just to trace a critical feature compared with when she had to trace the whole stimulus (Experiment 1b). SA was more accurate in tracing a feature than in tracing the entire contour of the target object (34/40 vs. 2/40 correct for the feature vs. the entire contour correct respectively, Fisher's Exact Test, $p<0.0001$). Three errors represented a failure to include any contours of the target object (axe, salt cellar, toaster), for a further three items she selected a component of the correct contour whilst also including contours from distractor items (thimble, beetle and pepper).

SA listed 47 critical features when viewing a single picture while she listed 50 features when given the object's name. There were a total of 57 different features listed. SA traced only 14/57 (24.6%) of these features when tracing with overlapping forms (including all the features listed from single objects and from names. SA was much less likely to indicate the same critical feature for overlapping stimuli than for single objects; Chi-square$_{(1)}$

= 38.4, p<0.0001. When asked to depict the critical feature in a display, SA was more likely to trace the un-occluded contour of the target item than an occluded contour. Of the 34 items where she correctly traced a feature from the correct object in an overlapping set, there were only 6 (17.6%) where she included a feature that overlapped with the other stimuli in the display, and for 28 items she traced a non-overlapping feature. For 16/28 (57.1%) of the items, this depicted feature was not part of the composite list generated for single stimuli and for names.

Discussion

There are several interesting points to note. Perhaps most striking is the contrast between the patients on the matching and name verification tasks (Experiments 1a and 1b). Using the same overlapping stimuli, HJA was much better than SA when the task required tracing around a target shape based on at least some form of match with the sample stimuli shown below the overlapping forms. SA was at floor on this version of the task. However, when the task was name verification, SA performed better than HJA. These data confirm the presence of a perceptual impairment in both patients since both were far from ceiling with the overlapping stimuli. However, there is also a considerable contrast in the abilities of the two patients to use top-down knowledge to match to their impaired perceptual representations: SA is much better than HJA at doing this, despite appearing to have a worse perceptual deficit in segmenting the figures in the first place. A deficit between apparently poor perceptual encoding and relatively good object recognition has been noted before in some patients, consistent with patients sometimes remaining able to use top-down knowledge to mask a deficit (Charnallet et al., 1996). However, to the best of our knowledge this is the first demonstration of a direct contrast between two patients using the same stimuli. Experiments 1c and 1d also provide information about how SA was able to use her top-down knowledge to facilitate object verification. Experiment 1c showed that SA remained poor at tracing objects even when given their name, suggesting that top-down knowledge did not help her overcome her basic deficit in segmenting overlapping shapes. In Experiment 1d SA depicted non-overlapping parts of overlapping shapes, when asked to indicate a distinctive feature of an object and the distinctive feature she listed in this case very often differed from the distinctive feature she depicted in a non-overlapping shape or when verbally describing the critical aspects of an object. These last results indicate that SA continued to have difficulty in segmenting overlapping stimuli, but she was able to apply top-down knowledge in a highly flexible manner, allowing her to verify an object from non-overlapping features that were not (in other circumstances) judged critical.

Second, HJA was worse in segmenting detailed line drawings compared with outline forms (at least in Experiment 1b), which fits with previous work showing that HJA is impaired at processing objects with local internal detail (Lawson & Humphreys, 1999; Riddoch & Humphreys, 1987a). Here we extend previous results on object recognition to a task where only a form of copying was required. This provides direct evidence for a perceptual locus to the effects of internal detail observed with HJA.

Third, in the match-to-sample task of Experiment 1b, HJA performed better with inanimate than with animate items. This fits with HJA's naming data (Section A), and indicates a problem in the perceptual processing of animate items. SA's performance at this same task was close to floor and it was not therefore possible to test for an effect of object category. Nevertheless, it is interesting to note that, when tracing from a name, SA tended to include more distractor lines when reproducing animate than inanimate objects. This may reflect the greater complexity of animate items, but it does not match with her better identification of animate items.

Experiment 2: Curve tracing

Experiment 2 examined curve tracing with simple lines (Experiment 2a), single “amoeba” (Experiment 2b), and overlapping “amoebae” (Experiment 2c).

Experiment 2a: Simple lines

Method

On each trial two pieces of ‘string’ were represented in a 2D drawing (see Figure 5a). There were also 2 ‘beads’ which could either be positioned on the same or on different strings. In both instances the distance between the beads was manipulated (1, 2 and 3cm). There were 120 trials in total (60 same and 60 different). For both same and different trials there were equal numbers of trials with the beads 1, 2 and 3 cm apart. SA and HJA’s performance was compared with that of 10 control participants (mean age 66.2 years, sd 6.8). Stimuli were presented individually on cards, participants were allowed unlimited viewing time.

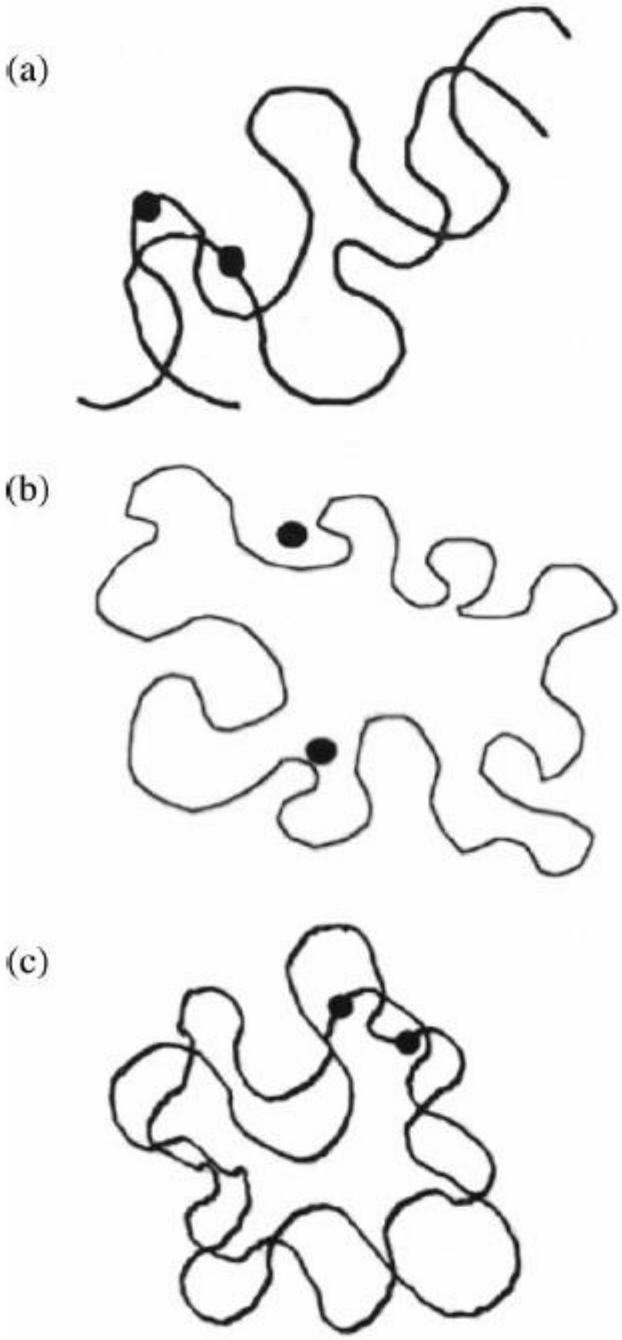

Figure 5. *Stimuli used in Experiment 2. (a) Overlapping "strings" (are the dots on the same or different strings?). (b) Single shapes (are the dots both inside, both outside, or one in and one out?). (c) Overlapping amoebae (are the dots on the same or different shapes?).*

Results

(i) Accuracy data

The data are presented in Table 12.

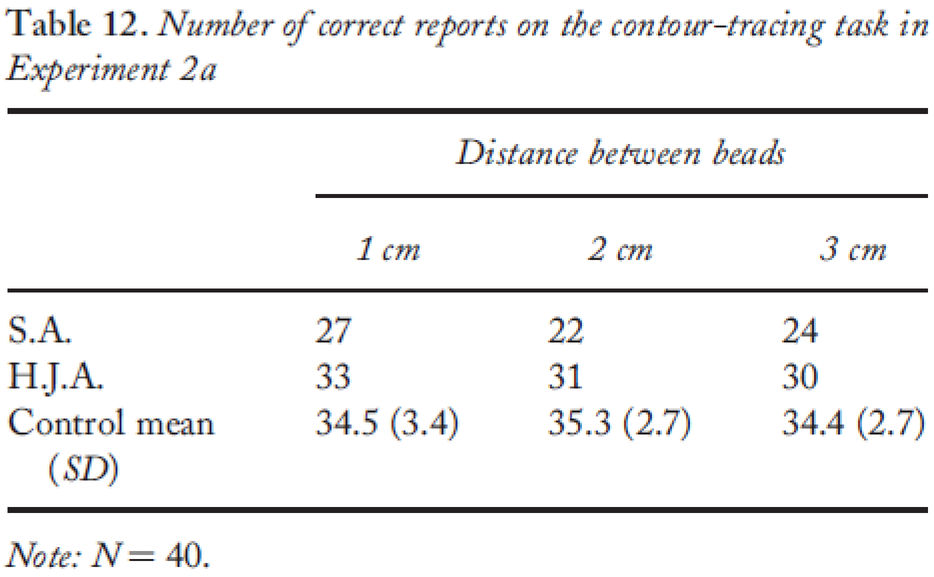

Table 12. *Number of correct reports on the contour-tracing task in Experiment 2a*

	Distance between beads		
	1 cm	*2 cm*	*3 cm*
S.A.	27	22	24
H.J.A.	33	31	30
Control mean (*SD*)	34.5 (3.4)	35.3 (2.7)	34.4 (2.7)

Note: N = 40.

SA found the task very difficult and performance was close to chance (she scored 56.7% correct for 'same' and 68.3% correct for 'different'). Accuracy on same and different trials did not differ significantly (Chi-square $_{(1)}$ = 1.7, p>0.05) and was therefore collapsed to determine whether varying the spacing of the beads affected performance. SA scored 67.5%, 55.0%, and 60% correct for 1, 2, or 3 cm apart respectively. There was no significant difference in these scores (Chi-square $_{(2)}$ = 1.3, p>0.05).

Overall, HJA performed better than SA (94/120 vs. 73/120) (Chi-square $_{(1)}$ = 8.6, p<0.003). Performance on same and different trials did not differ significantly (Chi-square $_{(1)}$ = 0.79, p>0.05) and was collapsed to determine the effect of spacing the beads. HJA scored 82.5%, 77.5%, and 75% correct for 1, 2, or 3 cm apart respectively There was no significant difference in these scores (Chi-square $_{(2)}$ <1.0, p>0.05).

The controls scored 86.5%, 88.3% and 86.0% for bead spacing 1cm, 2cm and 3cm apart respectively ($F_{(2,18)}$ = 0.75, $p>0.05$).

(ii) RT data

Since SA's accuracy was close to chance, her RTs could not be analysed. For the remaining participants, the RT data were trimmed. Any data point more than 2sd from the mean of that condition was removed and treated as an error. The data for HJA and the controls are shown in Table 13.

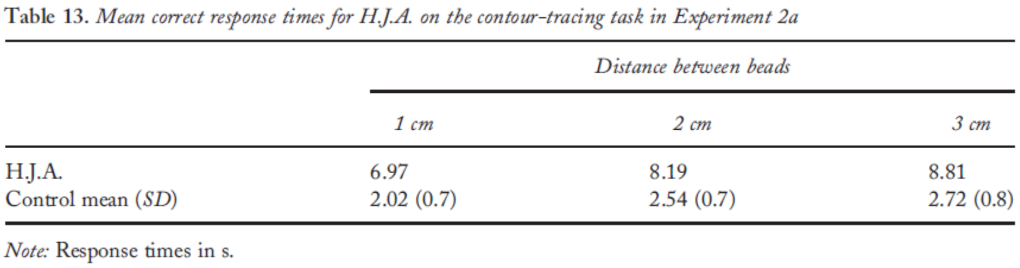

Table 13. *Mean correct response times for H.J.A. on the contour-tracing task in Experiment 2a*

	Distance between beads		
	1 cm	*2 cm*	*3 cm*
H.J.A.	6.97	8.19	8.81
Control mean (*SD*)	2.02 (0.7)	2.54 (0.7)	2.72 (0.8)

Note: Response times in s.

HJA's data were analysed by treating each RT as a separate subject which were entered into a single factor ANOVA (see Young et al., 1987). There was a significant main effect of Distance ($F_{(2,93)}$ = 4.18, $p<0.02$), with a significant linear component (linear regression; $F_{(1,8)}$ = 8.12, $p<0.005$). Post-hoc tests revealed that performance when the dots were 1cm apart was quicker than when they were 3cm apart ($p<0.02$); no other comparisons proved significant (all $p<0.05$).

There was also a significant effect of distance for the controls ($F_{(1,9)}$ = 23.2, $p<0.001$) and again the linear component was reliable ($F_{(1,9)}$ = 23.1, $p<0.001$). The rate of increase in RTs, as the distance between the dots increased, was comparable for HJA and the controls, when scaled by the overall mean RT to respond (HJA: 230ms/cm., control mean 280ms/cm.).

Experiment 2b: Inside-outside relations in an “amoeba”

Method

Enclosed “amoeba” shapes with irregular boundaries were created. The shapes were categorised as large or small (5.5x5.5cm and 2x2cm respectively). There were 30 large and 30 small shapes. Each shape was presented with two black dots which could either both fall within the shape, both outside the shape, or one could fall inside the shape while the other fell outside. For each shape size there were 10 trials for each of the different dot conditions. The task was to identify the locations of the dots as quickly as possible. Responses were timed with a stop watch, and numbers of errors were recorded. Stimuli were presented on cards, viewing time was unlimited. Examples of the stimuli are shown in Figure 5b.

Results

The data for large and small displays were very similar and so the results were pooled. The results are presented in Tables 14 and 15.

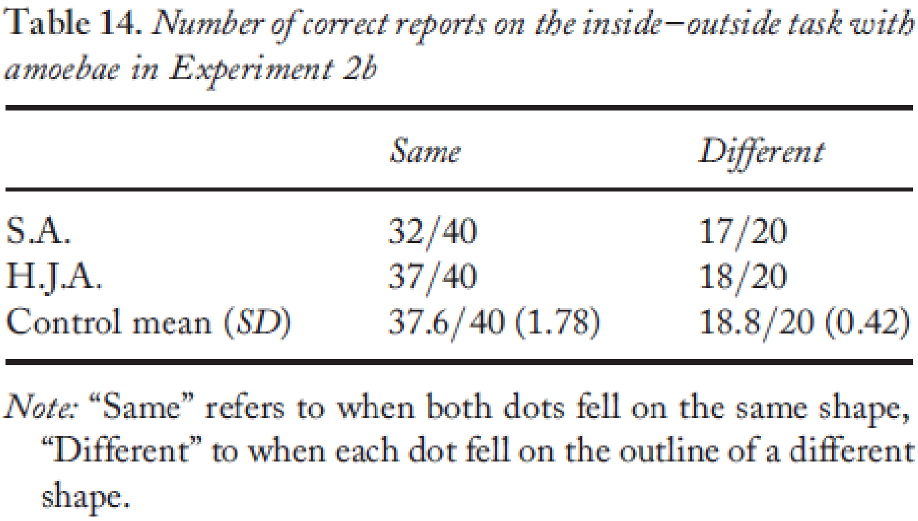

Table 14. *Number of correct reports on the inside–outside task with amoebae in Experiment 2b*

	Same	*Different*
S.A.	32/40	17/20
H.J.A.	37/40	18/20
Control mean (*SD*)	37.6/40 (1.78)	18.8/20 (0.42)

Note: "Same" refers to when both dots fell on the same shape, "Different" to when each dot fell on the outline of a different shape.

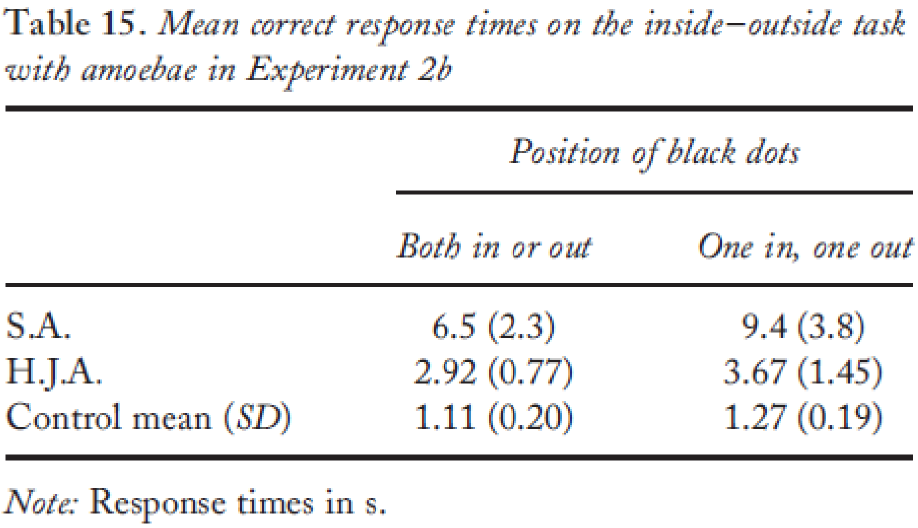

Table 15. *Mean correct response times on the inside–outside task with amoebae in Experiment 2b*

	Position of black dots	
	Both in or out	*One in, one out*
S.A.	6.5 (2.3)	9.4 (3.8)
H.J.A.	2.92 (0.77)	3.67 (1.45)
Control mean (*SD*)	1.11 (0.20)	1.27 (0.19)

Note: Response times in s.

The RT data were trimmed as in Experiment 2a. SA found the task difficult. She had very slow RTs (overall average RT for SA = 8.5secs (sd = 4.9)), and her error rate for 'same' responses fell more than 2sd outside the control mean. HJA made few errors and these fell within the control range. HJA's RTs were slower than the controls but it is difficult to assess if this is a general RT slowing rather than an indicator of perceptual difficulty.

Experiment 2c: Overlapping amoebae

Method

Similar shapes to those used in Experiment 2b were used but in this case the shapes were overlapping (for examples of the stimuli, see Figure 5c). The displays either consisted of 2 small or 2 large shapes (60 trials each). Two dots were also presented on each trial, and these either fell on the outline of a single shape or they fell on the outlines of different shapes. The dots were 1cm, 2cm, or 3cm apart (40 trials each). The task was to indicate whether the dots fell on the same or on different shapes. Reaction times were measured with a stop-watch and errors were recorded.

Results

SA was unable to perform the experiment which was abandoned after 60 trials. She indicated that she was simply guessing and the data showed she was at chance (23/60, 38.3% correct). The results for the control participants and HJA are presented in Tables 16 and 17.

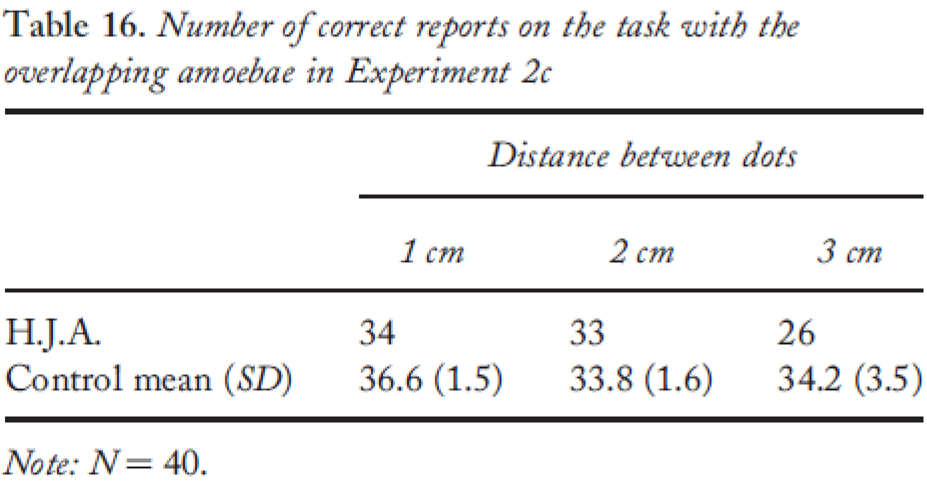

Table 16. *Number of correct reports on the task with the overlapping amoebae in Experiment 2c*

	Distance between dots		
	1 cm	*2 cm*	*3 cm*
H.J.A.	34	33	26
Control mean (*SD*)	36.6 (1.5)	33.8 (1.6)	34.2 (3.5)

Note: N = 40.

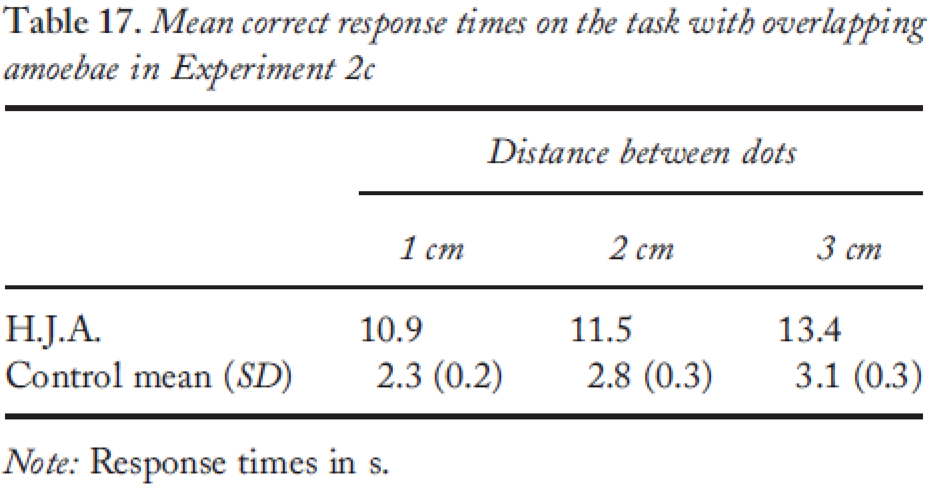

Table 17. *Mean correct response times on the task with overlapping amoebae in Experiment 2c*

	Distance between dots		
	1 cm	*2 cm*	*3 cm*
H.J.A.	10.9	11.5	13.4
Control mean (*SD*)	2.3 (0.2)	2.8 (0.3)	3.1 (0.3)

Note: Response times in s.

HJA's errors were similar to the controls when the dots were 1cm and 2cm apart, but they fell 2sd outside the control mean when the dots were 3cm apart. HJA's RTs were analysed by treating each RT as a separate subject in a single factor ANOVA (see Young et al., 1987). There was a significant main effect of Distance ($F_{(2,90)} = 3.4$, $p<0.04$), and a reliable linear component (linear regression; $F_{(1,91)} = 6.1$, $p<0.02$). The controls also showed a linear effect of distance on RTs ($F_{(1,9)} = 13.2$, $p<0.005$.). As with Experiment 2a, the RT increase as the distance between the dots increased was similar for HJA and the controls when scaled by the mean RT (HJA: 210ms/cm; mean controls 290ms/cm). It is noteworthy that the rates here are close to those in Experiment 2a.

Discussion

The data demonstrate that SA was extremely impaired at curve tracing, with simple (Experiment 2a) as well as complex stimuli (Experiment 2c), and she was also poor at judging inside-outside relations in complex, unfamiliar shapes (Experiment 2b). Thus her problems with tracing contours in Experiment 1 were not due to impairment in eye-hand co-ordination, given that no motor responses were required here. In contrast, although his overall RTs were longer than the controls, HJA performed relatively normally on these tasks, with his accuracy falling below control levels only under the more difficult condition (with widely spaced dots on overlapping amoebae, in Experiment 2c). In addition, HJA presented evidence of serially shifting his attention at a normal rate to carry out the curve tracing tasks, since the effects of distance on his RTs were similar to those found with control participants (when the effects of distance were scaled by absolute RTs). This fits with prior data showing intact serial scanning of attention in search tasks in HJA (Humphreys et al., 1992).

SA's deficit on these tasks may be attributed to various impairments. One could be a problem in scanning spatial attention, which prevents her (internally) tracing along the contours. However, we doubt this is the case. In a standard serial search task, requiring the detection of a colour-form conjunction target (green triangle vs. red triangle and green circles; Treisman & Gelade, 1980), SA showed a search rate comparable to that of age-matched controls (when scaled by absolute RT's her search rate increased by a ratio of 0.03 per item, whilst controls increased by a ratio of 0.04 per item; search accuracy was normal).

Note that this pattern of performance also distinguishes SA from cases of 'dorsal simultanagnosia', who are typically very impaired at conjunction search tasks (Friedman-Hill et al., 1995; Humphreys et al., 2000). In this 'purer' test of attention scanning, SA was normal. A second, more likely, possibility is that SA is impaired on these tasks because she is poor at encoding more global aspects of shape, so that for her any curve tracing operation is not guided by global constraints (e.g., that where two lines cross, there is better continuation along the 'same' curve than along the 'different' curve – a judgement that requires relative weighting outside the local spatial region of the two possible continuations of the lines). If curve tracing is based only on local coding of the lines, then it will break down when the lines cross (Experiments 2a and c), or when more global shape information should be held to distinguish whether dots are inside or outside the overall contour (Experiment 2b). This proposal that SA operates locally when processing form information was tested more directly in Experiment 3, where the patients (and controls) were required to respond to hierarchical forms. In contrast to SA, HJA's relatively normal performance on the curve tracing tasks suggests that he is able to compute information across wider spatial regions.

Experiment 3: Responding to hierarchical forms

In Experiment 3 we presented the patients with hierarchical compound letters and required them to respond to either the local or global forms. In many cases participants respond with a bias towards responding to global forms, showing faster overall RTs to global stimuli and interference when global forms are incongruent with the responses required to local forms (Navon, 1977). However, this 'global precedence' effect does depend on a number of factors including the size of the stimuli (Kinchla & Wolfe, 1976) and the density of the letters (Martin, 1979). Here we used stimuli with a size and density that induced a mild global precedence effect in normal participants (see Mevorach et al., 2005a). We assessed whether this effect would be increased or reduced in SA and HJA.

A number of recent imaging studies have shown distinctions between local and global processing in early prestriate cortex (e.g., using PET, Fink et al., 1997, and fMRI, Sasaki et al., 2001). Sasaki et al.(2001) demonstrate that attention to local targets activates medial areas of the occipital cortex, while attention to global targets activates more lateral areas (see also Boeschoten et al., 2005; Lux et al., 2004). A previous study with HJA demonstrated an increased global precedence effect which is consistent with the argument that medial occipital cortex sub serves attention to local parts of shape (Humphreys et al., 1985).

Method

Participants

SA and HJA's performance was compared with that of 10 control participants (mean age 66.2 years, sd 6.8).

Stimuli

Examples of the stimuli are shown in Figure 6. The global letter subtended 1.27º x 1.66º of visual angle (in width and height respectively), and each local letter subtended 0.26º x 0.38º. The inter-element distance was 0.1º (see Mevorach et al., 2005a) Target letters (D or H) were present at either a global and/or a local level. In the global condition, the target letter could be the same as the local letter (global D, local D) (congruent condition), or the local letter could be associated with the opposite response (e.g., global D, local H) (incongruent condition), or the local letter was not associated either response (e.g., global D, local I) (neutral condition). In the local condition, the global letter could be congruent with the local letter (local D, global D), incongruent (local D, global H), or neutral (local D, global I). All the stimuli were presented centrally and consisted of white letters against a black background. There were two further conditions, one where a single block letter was presented the size of the local shape, and one where it was the size of the global shape (see Figure 6b).

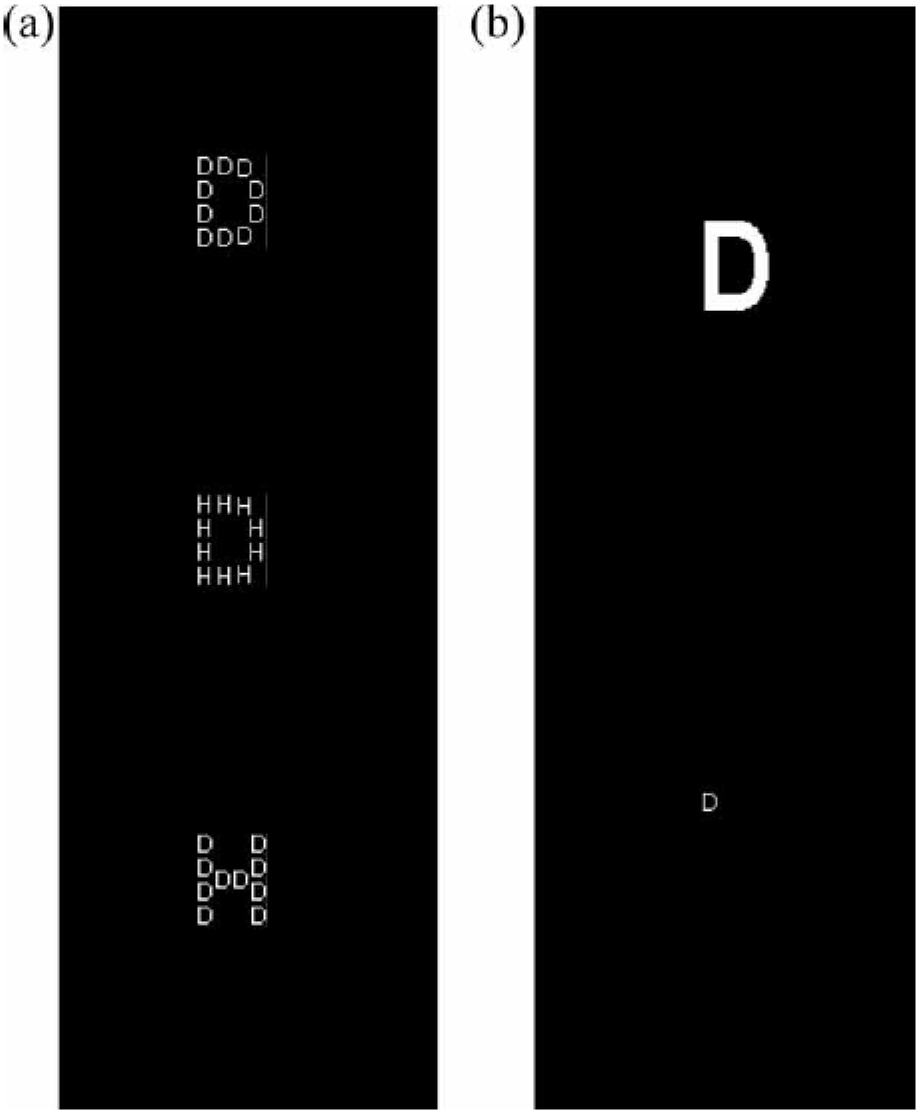

Figure 6. *(a) Hierarchical stimuli used in Experiment 3. (b) Examples of the single letters.*

Procedure

The stimuli were presented on a PC using EPrime software. Participants responded via the keyboard. The keys assigned to the target letters were counterbalanced across the experimental conditions. For each participant, there were 4 experimental conditions: two with hierarchical forms (respond local or global) and two with single letters. The order of the different conditions was randomised over participants. There were 120 trials for each task with the hierarchical forms (40 each where global and local letters were congruent, incongruent and neutral), and 40 trials where the block letters were presented in isolation (20 for each of the target letters)[3]. Prior to each experimental condition, instructions were given which key should be used to respond to D and which to H, participants were instructed to respond as quickly and accurately as possible.

Results

For all the participants the data were trimmed as in Experiment 2.

(a) Control participants

The RT data were initially entered into a 2-factor repeated measure ANOVA. The factors were Level (report of the letter at either the local or global level), and Congruency (the target letter was congruent, incongruent or neutral with respect to the other letter in the display). Both main effects were significant (for Level $F_{(1,9)} = 5.3$, $p<0.046$, for Congruency $F_{(2,18)} = 33.6$, $p<0.0001$). However, while the lower bound Epsilon for Level was 1, it was 0.5 for Congruency suggesting a violation of sphericity; the data were therefore entered into a

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[3] HJA performed the non-hierarchical conditions twice, a total of 80 trials each.

2–factor repeated measure MANOVA. There remained a significant main effect of Congruency ($F_{(2,9)} = 15.66$, $p<0.002$) (Wilks' Lamda = 0.203, $F_{(2,18)} = 15.7$, $p<0.002$). Pairwise comparisons revealed that the congruent (mean 614ms) and neutral (mean 631ms) conditions were significantly different from the incongruent condition (mean 701ms) ($p<0.001$ and $p<0.01$ for congruent and neutral conditions respectively), but that the congruent condition did not differ from the neutral condition ($p>0.05$). For the MANOVA neither the main effect of Level, nor the interaction between Level and Congruency were reliable (both $p>0.05$), although the trends were for RTs to be faster to global than to local figures, and for interference effects (on incongruent trials) to be stronger on local responses. The means for each condition are shown in Figure 7a.

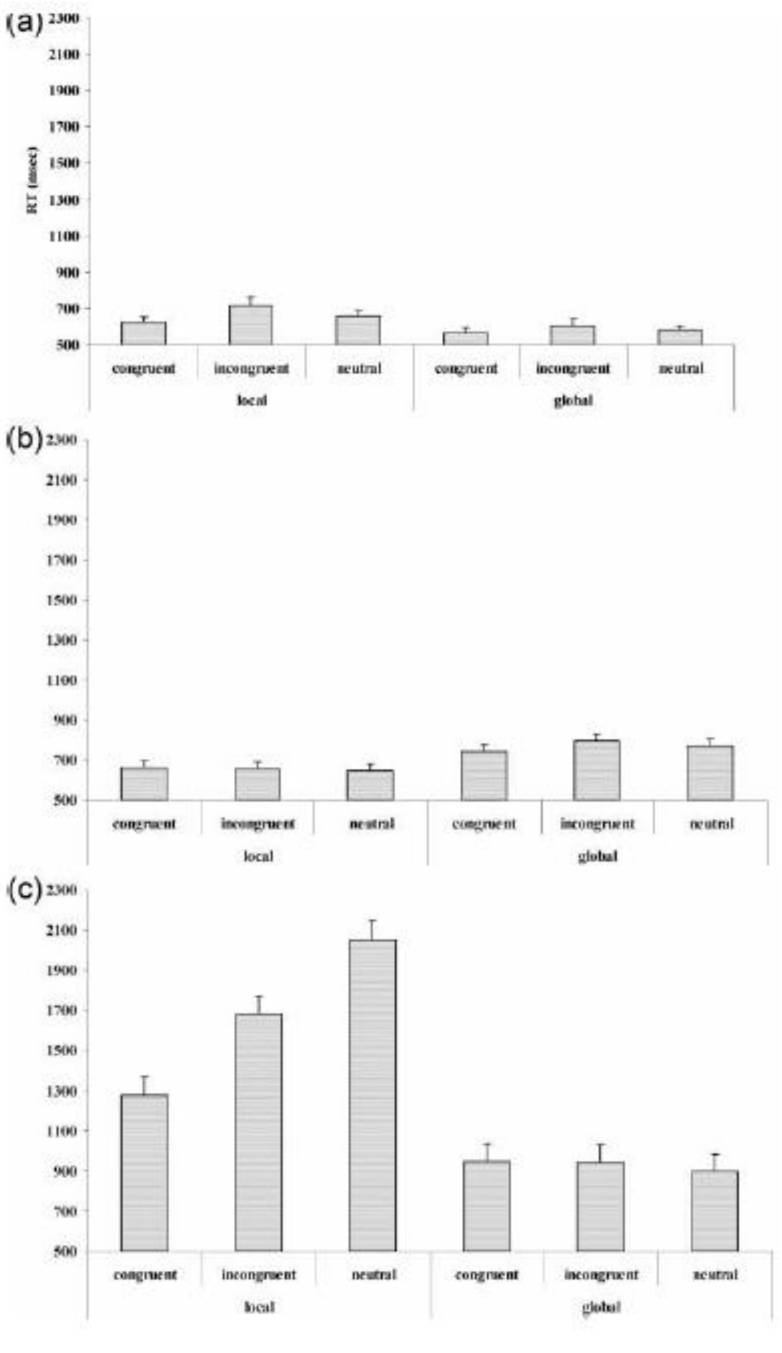

Figure 7. *Response times for responses to the global or local letter in the congruent, incongruent, and neutral conditions in Experiment 3. (a) Data from controls. (b) Data from S.A. (c) Data from H.J.A.*

The RTs for the single letters were entered into a paired t-test. The mean RT to the small letter was 586ms, and to the large letter 495ms; this difference was significant ($t_{(9)} = 2.9$, $p<0.02$). Control participants were faster to respond to the larger than to the smaller letter. Errors followed the RT data and showed no evidence of a speed-accuracy trade-off. Errors were thus not analysed further (see Table 15).

(b) Patient data

SA: The analysis revealed a significant main effect of Level ($F_{(1,217)} = 17.95$. $p<0.0001$) indicating faster responses to local (655ms) than to global stimuli (769ms). Neither the main effect of Congruency nor the interaction between Level and Congruency reached significance (both $p>0.05$). The means for each condition are shown in Figure 7b. For the single block stimuli, SA responded more quickly to the small than the large letter (556 vs. 612ms) ($t_{(75)} = 29.5$, $p<0.0001$). There were no signs of a speed-accuracy trade-off (see Table 15).

HJA: The RT data for HJA showed a significant main effect of Level ($F_{(1,211)} = 102.5$, $p<0.0001$) and Congruency ($F_{(2,211)} = 8.04$, $p<0.0001$). HJA responded faster to global than to local forms (928ms vs. 1658ms for global and local respectively) and faster to congruent than to incongruent and neutral stimuli (a post-hoc Tukey test showed that responses to congruent stimuli were significantly faster than those to neutral stimuli ($p<0.001$), but that there was no difference between congruent and incongruent, and incongruent and neutral (both $p>0.05$)). The 2-way interaction was significant ($F_{(2,211)} = 10.2$, $p<0.0001$), indicating that the congruency effect was greater for local than for global arrays. See Figure 7c for the means in each condition.

With the single stimuli, HJA’s average RT to large stimuli were faster than those to small stimuli (644ms. vs. 1142ms ($t_{(149)} = 23.8$, $p<0.0001$)). There were again no signs of a speed-accuracy trade-off (Table 15).

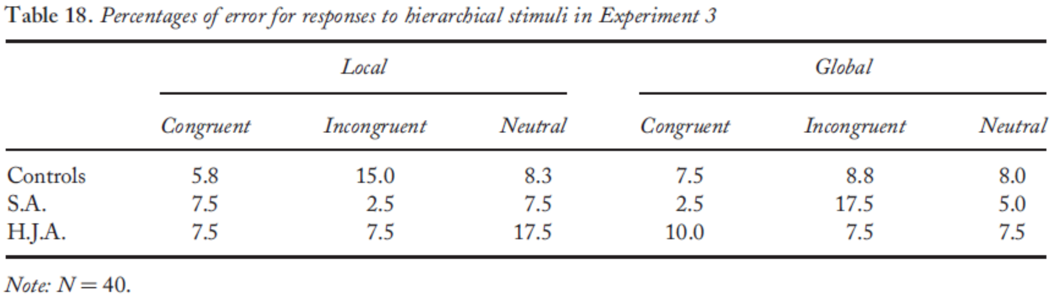

Table 18. *Percentages of error for responses to hierarchical stimuli in Experiment 3*

	Local			*Global*		
	Congruent	*Incongruent*	*Neutral*	*Congruent*	*Incongruent*	*Neutral*
Controls	5.8	15.0	8.3	7.5	8.8	8.0
S.A.	7.5	2.5	7.5	2.5	17.5	5.0
H.J.A.	7.5	7.5	17.5	10.0	7.5	7.5

Note: $N = 40$.

Discussion

The results were very clear. Under conditions in which control participants showed a mild global precedence effect (Figure 7a), SA demonstrated a reverse, local precedence effect (Figure 7b) and HJA an exaggerated global precedence effect (Figure 7c). For HJA the magnitude of the global advantage (730ms) was 78% of his RT to global stimuli, whereas the global advantage for the controls (100ms) was just 19% of the RT to global forms. These effects were mirrored to some degree in the responses by the participants to single stimuli matched to the size of the local and global letter, except that, for the patients, the magnitudes of the differences in RTs to large and small stimuli were increased when the stimuli were presented in hierarchical displays. For SA, there was a 56ms advantage for small over large single letters, which was doubled when responses were made to hierarchical forms (an advantage of 115ms for local over global stimuli, averaging across the congruent, incongruent and neutral conditions). For HJA there was an advantage of 498ms for single large over small letters, relative to an overall advantage of 730ms for global over local forms. In contrast, the differences shown in control participants in responding to the single large and small letters (91ms) was close to the contrast between responding to local and global hierarchical forms (100ms). Thus, over and above any effects of size per se, the patients showed effects of attending to the elements in the context of hierarchical forms. This mirrors previous data reported with HJA (Humphreys et al., 1985).

The results for SA indicate that she has an abnormally strong bias to attend to local elements (reversing the pattern present in controls). This fits with the idea that the dorsal occipital cortex is important for mediating attention to global aspects of shape. In contrast, HJA, with a more ventral and medial occipital lesion, has an abnormally strong bias to attend to global shape; for example, the size of the overall global advantage for HJA was around four times as large as that observed with the controls, even when differences between global and local responses were scaled by absolute RTs to local forms. This is consistent with ventral, medial occipital regions being necessary for attention to local form, and with HJA having abnormal difficulty in this process. The two patients show a dramatic difference in their processing of hierarchical forms.

The contrast between the processing of local and global aspects of hierarchical forms could reflect differential biases in responding to high and low spatial frequency information. Global aspects of form can be conveyed through low spatial frequency components and more local aspects through high spatial frequency components (Badcock et al., 1990). We have noted, also, that the patients show decreased contrast sensitivity functions. HJA's poor sensitivity for high spatial frequencies could be contributing to his global bias. However, a spatial frequency bias is unlikely to provide a full account of these results given that the patients showed opposite patterns also when responding to control (block) letters differing in size but not in critical spatial frequency components. Also, SA showed a decreased sensitivity for high spatial frequencies too relative to the controls, and yet she presented with a local advantage (opposite to controls). An alternative idea is that HJA's lesion leads to coarsened initial grouping of stimuli, generating a global percept but with reduced local detail. We elaborate on these ideas more in the General Discussion. Whatever the case, the important point is that both patients show increased effects when they are presented with hierarchical forms compared with block letters. This suggests that there are effects of differential saliency of the local and global forms for the two patients. The patients find it difficult to attend to the low saliency aspect of a hierarchical form mainly when there is competition from a higher saliency competing aspect (cf. Mevorach et al., 2005a; 2005b); this competition is absent when block letters are presented. This differential competition also accounts for why patients show greater interference effects than the controls (albeit in opposite directions in the two patients).

General Discussion

We have presented data documenting differences in object processing in two types of apperceptive agnosia: form agnosia (patient SA) and integrative agnosia (patient HJA). Both patients suffer from impaired object recognition that is perceptual in origin and leads to visual/visual-semantic or 'don't know' responses in object naming. Both are impaired at figure-ground organization based on edge contours and both are abnormally affected by stimulus exposure duration. However, in other respects, the object processing capacities of the patients differed. HJA was worse at identifying animate than inanimate items (see also Riddoch & Humphreys, 1987a; Riddoch et al., 1999), and he was also more impaired at segmenting animate items when they were presented overlapping with other drawings (Section B, Experiment 1a). In contrast, SA was better at identifying animate than inanimate items, especially with reduced exposure durations. In addition to this, SA was worse than HJA at segmenting line drawings when the task required matching to a visual sample, and she was worse at contour tracing and at deciding whether pairs of dots were both inside and outside complex, unfamiliar shapes (“amoebae”; Section B, Experiments 1b and 2). Yet, despite this evidence for many aspects of early visual processing being worse in SA, she was generally better than HJA at recognizing familiar objects (Section A) and her ability to segment overlapping figures showed greater improvement when she was cued to find a particular target (with SA performing better than HJA in the verification task; Section B, Experiment 1a). Finally, whilst HJA demonstrated an exaggerated bias towards global processing of hierarchical forms (see also Humphreys et al., 1985), SA produced an opposite effect with the same displays, with her performance being biased to local elements (Section B, Experiment 3).

The contrast between these two patients provides the first direct evidence of a qualitative difference in object processing in form and integrative agnosia using the same tests in patients, consolidating the argument for these two forms of apperceptive agnosia being distinct. This is also reinforced by the contrasting dorsal and more ventral, medial lesions suffered by SA and HJA, linking the two forms of agnosia to different underlying neural substrates.

Integrative agnosia

We propose that normal object recognition depends on participants concurrently coding global aspects of shape with local detail about the parts of stimuli (Humphreys & Riddoch, 2006). Previously we have defined integrative agnosia as being due to a problem in this last process, of integrating local parts with more wholistic properties of objects. As a consequence, patients have an impoverished visual representation of objects. In addition, due to the poor part-whole integration, such patients have difficulties in decomposing scenes with complex figure-ground relations; they can misattribute edges between shapes (Giersch et al., 2006; Giersch et al., 2000) they group parts incorrectly, and they can over-segment objects with high internal detail (Lawson & Humphreys, 1999; Riddoch & Humphreys, 1987a). This is demonstrated here by HJA's performance with overlapping line drawings (Section B, Experiment 1), where he frequently made mis-segmentation errors, with this problem being exacerbated when the stimuli had internal detail (Section B, Experiment 1B).

Although HJA is impaired at integrating part with whole information, the present results confirm that he is able to respond to simple global compound letters, and indeed shows a stronger global precedence effect than normal participants (Section B, Experiment 3; see also Humphreys et al., 1985). This may reflect a relatively spared ability to respond to low spatial frequency components in images, since global precedence can be supported by low spatial frequency information (Badcock et al., 1990; Lamb & Yund, 1996; Shulman et al., 1986), though the effects of size even with block letters suggest that low spatial frequency dominance does not provide a full account. A further possibility is that there is a coarse initial grouping process supported by his spared early visual cortex, which averages across elements in a non-optimal manner (for direct evidence see Allen et al., 2007). This can explain the problems HJA has due to the mis-assignment of edges in complex scenes, if edge information is pooled inappropriately (Giersch et al., 2000). Whichever is the case, the resulting global represent1ation that HJA is able to form is under-specified and lacking in detailed part information due to the deficit in part-whole integration (see Humphreys & Riddoch, 1987a); as a consequence object recognition is impaired. Indeed, when attempting to identify objects HJA often follows a piecemeal approach in which different parts are not considered together (see Humphreys & Riddoch, 1987b, for examples). We attribute this to local parts, when undergoing integration with global representations, tending to segment the wholistic form, and to HJA adopting a strategy of attending to local parts serially, due to his global form representations being under-specified.

Our data also indicate that HJA has problems in identifying animate items (see also Riddoch & Humphreys, 1987a; Riddoch et al., 1999). It is possible that this deficit could reside at several levels of processing, including reflecting a loss of semantic knowledge about animate items (Caramazza & Shelton, 1998; Humphreys & Forde, 2001). We have previously reported that, in the period since his lesion, HJA suffered some degradation of knowledge for animate items (Riddoch et al., 1999). We have attributed this to the importance of perceptual updating of stored visual knowledge, and to this being particularly important for classes of stimuli which have many perceptual neighbours and/or stimuli for which perceptual features are central to their stored representations. There are grounds for arguing for both of these last factors being critical for animate items (see Farah & McClelland, 1991; Gaffan & Heywood, 1993; Humphreys & Riddoch, 2003; though see Laws, 2005, for an alternative view). However, we think a loss of stored perceptual knowledge is unlikely to account for the full pattern of the present data. HJA gave accurate descriptions of the set of animate items he failed to identify here (Section A). Moreover, HJA's ability to match objects to sample, when figures were overlapping was worse for animate than inanimate items. This result points to a perceptual contribution to the deficit. The particular perceptual deficit in HJA, where there is rapid but coarse coding of global shape along with impaired integration of part information, may be important here. Measures of contour overlap indicate that animate items tend to have similar global shapes, and they also tend to have many common parts (head, body, legs, wings), at least at a coarse level of description (Humphreys et al., 1988). The similarity of the initial coarse description that HJA derives for different animate items s can, in turn, make it difficult for him to identify individual items. This may be particularly the case if he also finds it difficult to isolate parts within the coarse visual description, making him insensitive to the local differences that may help to differentiate different animate items. This problem may be less pronounced for inanimate items if their global structures are less similar. On this account, the category-specificity in object recognition demonstrated by HJA is at least partly a function of a visual processing deficit (see also Humphreys & Riddoch, 2003). We return subsequently to consider the relation between HJA and other patients with category-specific deficits for animate items.

Despite the problem in part-whole integration, Experiment 2 (Section B) showed that some aspects of visual processing remain relatively intact for HJA – notably the ability to carry out contour tracing (at least until complex, unfamiliar shapes were overlapping and the dots to be compared were spaced far apart). This is of some interest because Roelfsema and colleagues (e.g., Roelfsema et al., 2000) have argued that contour tracing depends on feedback from higher-level regions in ventral cortex (e.g., area V4) to primary visual cortex, so that tracing can operate across larger regions than those typically covered by the receptive fields of neurons in primary visual cortex. These higher-level regions are lesioned in HJA (Allen et al., 2007), so the current data are consistent with tracing being conducted within early visual areas (such as V1) which are spared in his case. For HJA, activation in early regions may be supported by feedback from global shape representations coded outside of medial ventral extra-striate cortex (i.e., regions spared in his case), along with voluntary attentional processes in parietal cortex (cf. Corbetta & Shulman, 2002). The linear functions in the time taken by HJA to match increasingly spaced dots are consistent with some degree of serial attentional involvement in the contour tracing tasks. Note that the estimated rate of these functions was close to those found for the control participants, indicating intact attentional scanning in this patient (see also Humphreys et al., 1992).

Form agnosia

SA showed a primary diagnostic feature of form agnosia, namely an inability to perform the Efron shape matching task. The data presented here indicate that SA's basic ability to segment shapes was also worse than that of HJA, given her poor level of performance in the match-to-sample task with overlapping shapes (Section B, Experiment 1b), and she was very impaired at contour tracing (Section B, Experiment 2). The deficits in tracing a target in a set of overlapping stimuli cannot be simply due to poor eye-hand co-ordination, since similar impairments arose with contour tracing (where hand responses were not required). These deficits also cannot be attributed to impairments in scanning spatial attention, given that SA was able to perform serial visual search efficiently (Section B). One possibility is that the impairments reflect a tendency for SA to focus on local image features, making her insensitive to more global properties of shape. For example, focussing on a local part of a shape would disrupt Efron shape matching, where sensitivity to co-variation along two dimensions is critical. Similarly, the ability to judge if two stimuli lie inside or outside an 'amoeba' shape requires perception of the global properties of the shape (Section B). Some support for SA showing a local bias in shape processing comes from the data on processing hierarchical forms, where she generated a pattern of local bias contradicting the normal profile (Section C).

In contrast to HJA, SA showed a tendency to find animate items easier to identify than inanimate items, especially when presentation durations were limited. Given that SA was able to give accurate descriptions of the stimuli from their names (Section A), and she was also able to list critical visual features (Section B), we think it is unlikely that a semantic deficit plays a major contributory role here. It is possible, though, that a bias towards local processing may be important. The local parts of many inanimate items tend to be similar (handles, blades, containers) and it is the particular combination of these parts that defines the object (cf. Biederman, 1987). In contrast, the local parts of animate items may either have distinctive shapes (the ears or the nose of an animal) or textures (the coat of a tiger, the skin of an orange) that enable them to be identified from a part processed in isolation. We have some preliminary evidence for this. We have presented normal participants with line drawings of inanimate and animate items where only one local area is presented at a time (using a moving window technique). An advantage for animate over inanimate items emerges under these conditions (Demeyere, Humphreys & Riddoch, in preparation). The evidence for SA's advantage for animate items emerging under short presentation conditions would also fit with the idea that her problems are exacerbated when she has only to code a few parts of stimuli.

Top-down processes

One other substantial contrast between SA and HJA is their ability to use top-down information to facilitate object recognition. Despite performing worse at several tasks tapping early perceptual abilities, SA was better at object identification than HJA (Section A) and she benefited more from top-down cueing with overlapping shapes (Section B, Experiment 1a). This last result is striking and points to there being a distinction between bottom-up and top-down contributions to object recognition – and notably, good top-down processes can help to compensate for a bottom-up processing impairment. The data reported in Experiment 1 also indicate the way in which top-down information was beneficial for SA. With overlapping shapes, SA denoted different distinctive features in objects relative to when the objects were presented alone or described verbally. This suggests that top-down knowledge did not enable SA to segment the overlapping shapes, since we would predict that she should select the same critical features in all cases. Instead, it appears that SA was able to fit top-down knowledge in a flexible manner to parts of objects that were not overlapping with other stimuli. This ‘fitting’ of perceptual features to stored knowledge occurred even when the available features were not the distinctive parts that could normally define an object. Moreover, given the differential sites of the lesions in HJA and SA, we also propose that top-down processes for visual object recognition are mediated by medial ventral extra-striate cortex extending to posterior temporal cortex (lesioned in HJA). This fits with data on brain imaging reported by Dolan et al. (1997). They imaged participants when presented with ambiguous figures either before the participants saw disambiguating visual information or after, and found increased activation in the fusiform gyrus when the disambiguating visual information could be used in a top-down manner to interpret the stimuli. Our data suggest that the fusiform gyrus, perhaps along with other medial, ventral extra-striate regions, is necessary for top-down effects to be implemented.

Relations to other patients and evidence from brain imaging

To what extent do our arguments for a contrast between integrative and form agnosia, and for the functional consequences of the visual processing deficits, hold across other patients? The ability to process local and global elements of form has been examined now in a small number of apperceptive agnostic patients. The well-documented form agnosic patient DF, like SA, appeared to show a local bias in interpreting hierarchical stimuli. Thus Milner et al. (1991) report that DF tended to focus on the local elements in forms of this type and found it difficult to perceive the global shape. Similar results have been reported by Charnallet et al. (1996), Piccini et al. (2003) and Ricci, Vaishnavi and Chatterjee (1999). Behrmann and Kimchi (2003) examined the report of local and global shapes in two patients described as integrative agnosics on the basis of the patients showing reasonable copying, a spared ability to match objects across views but an impaired identification of overlapping shapes and visual/visual-semantic errors in picture naming. One of these patients, like HJA, showed a global advantage when identifying hierarchical forms but the other produced a local advantage. At present the reason for this last result is unclear, though, as we have noted above, patients may focus attention on local parts when the global representation is impoverished, so it is possible that this strategy might be applied with hierarchical stimuli not forming a particularly strong global shape even for control participants. We also note that the patients described by Behrmann and Kimchi (2003) had more anterior temporal lesions than HJA and this may be critical. If the posterior lesion in HJA leads to coarse grouping, with a loss of part-detail, then he may tend to show a stronger global precedence than is the case in patients with more anterior damage. Indeed, other evidence suggests that the right anterior temporal lobe is important for focussing attention on the global aspects of form (Lamb et al., 1990; Robertson et al., 1988). Thus it is possible that lesions in this region lead to performance being biased to local shapes as Behrmann and Kimchi (2003) observed. On this view, such patients may suffer an attentional bias towards local forms, which in turn leads to problems with other perceptually difficult stimuli (e.g., overlapping forms). In contrast, patients such as HJA and SA, with more posterior occipital lesions, have difficulty either in computing integrated part-whole representations

(HJA) or computing local forms (SA), and suffer perceptual deficits for these reasons. We note too that the patients reported by Charnallet et al. (1996) and Milner et al. (1991) were both impaired at the Efron shape-matching test (data are not reported for the other patients), and their pattern of local dominance fits with the pattern presented by SA. It would clearly be of interest to assess whether the other cases in the literature also have difficulty with contour tracing tasks, which we link to attending very locally to the parts of patterns.

As noted in the Introduction, patients similar to SA, who presenting with local dominance and poor perception of basic forms, have been reported with a variety of lesions. For example, the case of Charnallet et al. (1996) had bifrontal lesions and a right parieto-occipital lesion extending into the white matter. Piccini et al.'s (2003) case was documented with degenerative changes affecting the right angular gyrus, while DF is reported with damage to the LOC plus posterior parietal damage. Patient JW, reported by Vecera and Behrmann (1997), who also showed poor performance in the Efron task, had bilateral occipital along with right parietal damage. In the other cases with local bias, either no damage has shown on scan (Behrmann & Kimchi, 2003) or diffuse damage was likely (Ricci et al., 1999). With the possible exception of DF, these patients all appear to have suffered relatively dorsal involvement of occipital-parietal cortex, and even in DF's case there was some parietal damage in addition to bilateral lesions to LOC. Hence there is a case here for the argument that dorsal occipital-parietal damage, evident in a circumscribed way in patient SA, at least contributes to the local bias and impaired shape perception in these patients – even if damage to other regions (e.g., LOC) also plays a role. SA's case, though, demonstrates that damage to LOC is not necessary to generate form agnosia.

A local bias in responding to hierarchical forms has also been noted in patients with Balint's syndrome following bilateral parietal damage (e.g., Huberle & Karnath, 2006; Jackson et al., 2004; Karnath et al., 2000; Shalev et al., 2005) Such patients show an additional impaired ability to shift attention across space (Friedman-Hill et al., 1995; Humphreys et al., 2000) and only appear aware of single objects at a time. SA did not manifest such signs of simultanagnosia. As we have noted, she showed a normal rate of serial search for colour-form conjunctions, and in other tests we failed to find evidence of extinction with letters presented simultaneously for 50ms (cf. Kinsbourne & Warrington, 1962). However it may be that, in simultanagnosic patients, we witness the presence of two deficits due to the typically extensive parietal lesions – a problem in attending to global form (as in SA here) and a problem in shifting attention. This would still fit with the argument for a role of dorsal occipital-parietal regions in attending to global shape. It is also of interest to note that simultanagnosic patients can show some problems in object recognition, despite having more ventral visual cortex intact, and their recognition errors often reflect the parts and/or surface textures of objects (Riddoch & Humphreys, 2004). Again there is a suggestion of a local bias in their identification performance.

Riddoch and Humphreys (2004) further reported that their simultanagnosic patients were relatively better at identifying animate than inanimate items, despite, like SA and HJA here, having relatively good semantic knowledge about objects. In that paper we suggested that this non-semantic category effect may reflect some residual wholistic perception in these patients. However, given SA's severe problems in wholistic processing not only with hierarchical forms but also with relatively simple contour tracing tasks, we suggest that our earlier account is probably incorrect. It is more consistent to argue that these patients were locally biased in object identification as well as in other aspects of form processing, and that animate items were easier to identify due to their having identifiable local parts and textures. In contrast, inanimate items are difficult to identify because their local parts, computed in isolation, are not diagnostic of the whole object's identity – the relations being the parts being critical in this case. The opposite pattern then arises in a patient such as HJA who has initial access to global representations of objects, but these holistic representations are not embellished by part-details. We suggest that animate items are more difficult for such patients to identify because they have similar global forms.

Recently Thomas and Forde (2006) have made a different argument to the one we have just voiced, based on a single case study (patient DW) who showed a local bias with hierarchical stimuli and a category-specific deficit for animate items. They argue that DW's local bias led to the category-specific impairment. However, as we have noted (Humphreys & Riddoch, submitted), DW had impaired semantic knowledge for animate items, as evidenced by his poor drawing from memory, his impaired verbal definitions and a deficit in naming animate items from verbal definitions (see Riddoch & Humphreys, 1992; Thomas et al., 2002 for earlier descriptions of his case). Hence the argument presented by Thomas and Forde rests on an association between two potentially separable effects: a bias on perception/attention and impairment in semantic memory. The problem here is that a deficit for animate items in semantic memory could over-ride any differential perceptual effect favouring animals. Here we too make an argument based on association, but an association in the opposite direction to that proposed by Thomas and Forde. We have reported one case where a bias to global selection co-oocurs with a deficit with animate items (HJA), and another where a bias to local selection co-oocurs with a deficit with inanimate stimuli (SA). This Double dissociation, using the same stimuli, indicates at the very least that there is no necessary relation between a local bias in perception and a deficit for naming animate stimuli, contrary to Thomas and Forde (2006). In addition, the associations we report with our patients are stronger than the one found by Thomas and Forde, since our patients did not have semantic problems and thus problems at ‘late’ as well as earlier stages of object recognition. For HJA and SA, it is more difficult to make an argument that opposite effects, at different stages, cancel each other out. In contrast, patients such as SA and HJA do not have a semantic deficit, making a clearer case for a relation between their perceptual deficit and the category effect on object identification. Furthermore, patients such as HJA demonstrate that there can be a global bias in perception along with selectively poor identification of animate items (see Humphreys et al., 1985; Riddoch & Humphreys, 1987, for prior evidence), indicating no necessary relation between a local bias and a deficit for naming animate items. We go further than this and propose there is no relation.

A final point concerns the link between work using neuroimaging and our argument for local and global biases in perception and attention being mediated, respectively, by inferior, medial ventral extra-striate cortex and more dorsal occipital-parietal cortex. There is evidence for the perception of local parts in hierarchical figures being mediated by inferior, medial occipital cortex, particularly on the left (e.g., Fink et al., 1997, 1999). Evidence for the involvement of more dorsal occipital-parietal areas in the perception of global forms is less clear (Heinze et al., 1998; Weissman & Woldorff, 2005; Yamaguchi et al., 2000). In a recent paper, Himmelbach et al. (in press) have reported imaging data from a simultanagnosic patient, separating trials where a global hierarchical form was perceived from those where it could not be reported. They report that this contrast between seeing and not seeing the global form was associated with activity in dorsal occipital cortex/ventral precuneus. These authors suggest that activity in this region is typically not seen in subtractions between responses to global and local levels of hierarchical forms because normal participants perceive the global form even when set to select local elements. However, as their patient sometimes failed to perceive the global form and detected only local elements, the role of the region in the conscious discrimination of global forms could be revealed. The data on SA are entirely consistent with this proposal.

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Chapter 3:

Curve Tracing and Attention in Form and Integrative Agnosia

Abstract

In the present chapter curve tracing is examined in a case of form agnosia (SA) and an integrative agnosia (HJA). Here we examined performance on simple curve tracing experiments and on a test of attention. We found patient SA, who has shown a particular impairment in curve tracing was impaired even when presented with simplified non-overlapping stimuli. SA showed no evidence of serial scanning of curves or of distance on curve tracing experiments though she was able to orient and shift attention as demonstrated on a Posner cueing task. This rules out the possibility of an impaired attentional scanning impeding segmenting of curves. SA was observed to trace curves the wrong way at intersections where there was overlap and was not able to mediate this using perceptual cues such as collinearity or connectedness.

Introduction

Agnosia and visual processing

Cases of agnosia are far from a homogenous group in terms of damage or perceptual functioning and a distinction has been made between integrative and form agnosia. The two cases of apperceptive agnosia reported within this thesis exemplify this distinction. SA was distinguished as having a dorsal extrastriate lesion and a form agnosia - an impairment in coding basic aspects of shape and lesions of the dorsal extrastriate region. HJA, our case of integrative agnosia was able to code basic aspects of shape but impaired in segmenting and grouping more complex items (Adler, 1944; Benson & Greenberg, 1969; Campion & Latto, 1985; Davidoff & Warrington, 1993; Efron, 1968; Farah, 2004; Milner et al., 1991; Vecera & Behrmann, 1997).

This fractionation of traditional definitions of agnosia (Lissauer, 1890) to include form agnosia has been disputed including by a suggestion that any impairment of shape discrimination is a sensory impairment and not an agnosia (Warrington and Rudge, 1995). Nonetheless cases showing patterns of performance comparable to SA are increasingly being identified as form agnosics. One such case was reported by Davidoff and Warrington (1993) in comparing patients SMK with FGP and reporting an unusual dissociation between shape and figure ground perception. SMK was unable to discriminate between shapes but was able to perceive figure from ground to detect shapes amongst fragmented backgrounds and to perceive subjective contours. SMK was able to perceptually group information using cues such as closure, proximity and continuity and to integrate collinear segments to form a triangle. In comparison FGP whilst able to discriminate shapes was unable to detect shapes in a fragmented background or to perceive subjective contours when lines were not continuous or when shapes became more complex or overlapped somehow. FGP was unable to separate figure from ground and it was suggested that figure ground perception is independent of shape information but that each is needed for normal object recognition. (Kartsounis & Warrington, 1991). SMK is now identified as a form agnosic within neuropsychological literature.

These changes in definitions of agnosia have in part allowed a shift toward considering more intermediate stages of visual processing within theories of object recognition. Humphrey & Riddoch (1987) and Warrington (1982) have made their own differing contributions to theories of visual processing with each acknowledging figure ground segregation to be key. Humphrey & Riddoch (1987) have identified basic coding of shape, figure ground segregation and the integration of perceptual information as key to object identification.

Figure ground segmentation in Agnosia

Rizzi et al. (2010) reported on FP who showed a dissociation with impaired face and object recognition but intact reading and semantic knowledge. FP was able to detect figure from ground when presented with fragmented shapes until they became more fragmented and struggled to trace overlapping geometric shapes. Rizzi et al. (2010) noted difficulties on intersections suggestive of a deficit in grouping and meaning FP unable to discriminate which lines to follow. Its suggested local information interfered with integration to a whole perceptual representation with FP unable to trace contours in overlapping figures as unable to separate the two items and to extract relevant aspects to an object. Although semantic knowledge was intact she was unable to access top down knowledge and attend to salient information when presented with competing information. FP was unable to recognise faces but was able to identify gender by using local cues. FP showed a strong local bias when presented with hierarchical stimuli comprising letters which made up a larger letter and was entirely unable to report global aspects when asked to do so. It is suggested that FP displayed an integrative deficit in intermediate processing and was unable to combine perceptual information to a global representation. Nonetheless FP appeared able to use top down knowledge to identify an image where given bottom up input. (Humphrey & Bruce, 1989; Riddoch and Humphrey, 1987).

Behrmann et al. (1994) described patient CK to have a deficit in involving intermediate stages of visual processing with an inability to distinguish objects from their background. CK was unable to separate and distinguish overlapping objects and when asked to trace around presented overlapping objects he unable to continue when faced with intersecting lines. It is suggested he was unable to extract and integrate the key information to allow identification of objects. CK was also impaired on shape detection where he was required to segment an ‘x’ from a fragmented background as the background became increasingly fragmented. CK was able to discriminate shapes and had a pattern of impaired recognition but with intact visual imagery demonstrated in an ability to draw from memory but not recognise the object. CK was able to perceive parts but struggled to group and integrate information into a whole.

Figure ground as pre versus attentive

There has been considerable debate as to whether figure ground processing occurs at a preattentive or attentive level. Vecera & O’Reilly (1998) described a parallel distributed processing model of information processing to explain figure ground perception. This model explains effects of familiarity in figure ground in terms of a hierarchical model where there is no assumption of pre-figural object processing and it is suggested that lower levels interact with top-down information such as stored knowledge or object representations which can affect bottom-up processing. This can be done in a serial or parallel operation. This idea fits with evidence from studies in monkeys which have suggested recurrent processing is key to processing figure from ground and shown impaired figure ground recognition after lesions on such areas (Roelfsema et al, 2001).

It is suggested assigning figure to ground depends on perceptual grouping including gestalt rules on closure, connectedness, similarity and symmetry to assign figure to ground (Ullman, 1984; Roelfsema et al, 2001).

Previously within this thesis we have compared HJA, a case of integrative agnosia with SA, a case of form agnosia on a range of tasks examining their abilities and impairments. Curve tracing was one such task utilised to examine segmentation. SA demonstrated a severe impairment on these task both on simple intersecting curves and on more complex overlapping amoeba shapes. We were able to rule out the involvement of an impairment in eye-hand co-ordination as she was not required to provide a motor response. HJA, however performed at a level comparable with controls on the simple overlapping curves task with response times similarly increasing as target beads were further apart.

Previous study of curve tracing suggested this is a task which requires recurrent processing (Roelfsema, 1998 Roelfsema et al, 2001). However in Chapter 1, Patient HJA was able to perform curve tracing at a level comparable to controls despite having damage to areas suggested as being important in curve tracing. HJA did however struggle when asked to segment overlapping amoebae shapes in a more difficult condition. In particular HJA performed at a level below controls where dots were spaced at a greater distance apart. SA in comparison was impaired on all curve tracing tasks performing at chance on curve tracing and unable to complete the more difficult condition where she was required to segment amoeba shapes.

It has been suggested impaired integration of parts to form a whole and a global bias has been responsible for HJA's impaired performance on other tests of visual segmentation particularly where there are increased internal details as well as complex shapes providing particular difficulty. In SA's case it is suggested that difficulty encoding basic aspects of shape alongside a local bias which is not mediated by top-down information interferes with forming a whole percept. This can also lead to SA struggling at intersections and following distractor curves and explains her poor segmentation of curves

In the present chapter I report on a further case comparison of these two patients, SA and HJA. In Experiment 1a we re-test patients HJA and SA on the simple curve tracing task employed in Chapter 2 . In experiment 1b we report on SA, who has particularly struggled to segment curves. We test curve tracing with larger intersecting strings which have been manipulated to make curve tracing easier for SA whilst still allowing testing of distance effects upon performance. In Experiment 1c, we tested SA ability to shift attention something which has been suggested as necessary to this task (Roelfsema et al. 2000). Finally in Experiment 1d we compared HJA and SA's performance on simple non-intersecting curves.

Experiment 1a: Tracing and Segmenting Curves

Experiment 1a examines performance on a curve tracing task. Patients SA and HJA previously completed this task (at least twelve months previously) where the stimuli were presented on cards this is reported in Chapter 1. SA found the task difficult and performance was close to chance while, HJA performed similar to controls. Presenting the stimuli in this way however, results in a rather unconstrained task, collecting RTs with a stop watch is not ideal. Here the task was repeated but now the stimuli were scanned in. Here the stimuli were scanned and presented using E Prime software on a 17" Gateway PC monitor (1024x768 pixels). The viewing distance was approximately 45cm with each onscreen cm representing 1.27 degrees of visual angle. In this experiment, I assessed the patients' performance segmenting dots placed 1, 2 and 3 cm apart on the same or different intersecting curves. I also tested 9 healthy participants on the same task to assess normal control performance levels.

Method

Participants

SA, a patient with form agnosia and HJA an integrative agnosic (Case histories previously described in Chapter 2) are compared with 9 neurologically intact, healthy controls (3 females and 6 males; mean age: 66.1, SD= 9.6; age range 58-80) who were recruited through a University of Birmingham volunteer panel. All had normal or corrected-to-normal vision.

Stimuli

Images were represented as 2 dimensional drawings and created in Claris Works Draw program. Each stimulus consisted of 2 intersecting curves or strings on which 2 beads

(2mm in diameter) appeared. The location of the beads was manipulated with beads appearing on the same, single curve on 60 trials (same trials) and 2 different intersecting curves on the remaining 60 trials (different trials). For half of the stimuli the strings had 3 concavities, while the remaining featured 5 concavities. The distance between the beads on any trial was also manipulated with beads placed at distances of 1, 2 and 3cm apart, with 20 trials each in the same and different conditions (10 trials with strings with 3 concavities and 10 with strings with 5 concavities). The stimuli were originally compiled by Ackroyd (1993). Examples of stimuli are presented in Figure 4.1.

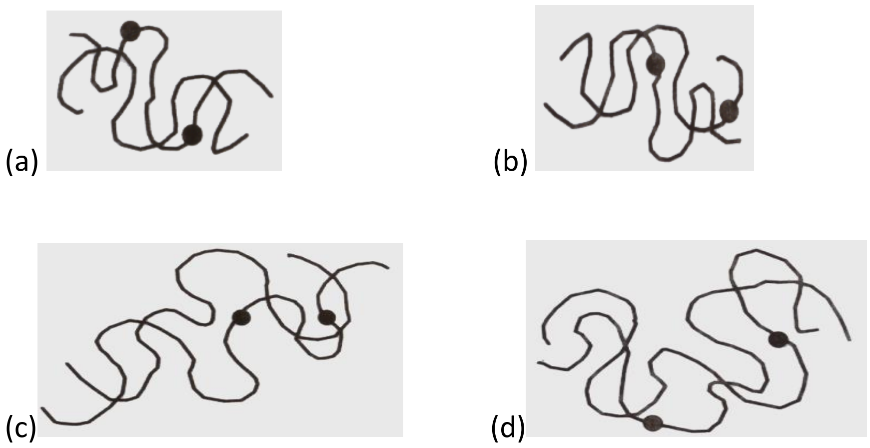

Figure 1: (a) represents a ’same’ trial and (b) a different trial with 3 concavities, c) and d) represent ‘same’ and ‘different’ trials with 5 concavities respectively.

Procedure

Prior to the experiment there was a 6 trial practice block. Practice stimuli were representative of the experimental stimuli, but were not identical to them. Each trial commenced with a black fixation cross at the centre of a white screen for 1000ms followed by the presentation of the stimulus. There were no time constraints on performance and participants were asked to respond by pressing ‘1’ when beads appeared on a single curve and ‘2’ where beads appeared on different curves. Participants were asked to respond as quickly and accurately as possible following the practice block. There was an equal number of each trial type (same 1, 2 and 3cm, different 1, 2 and 3cm). Accuracy of performance and reaction times were recorded. Each trial began once the participant was ready and focusing on the screen. The total number of trials was 120 which took approximately 15 minutes to complete.

Results

Accuracy

The data are shown in Table 1 (performance on 'same' and 'different' trials) and Table 2 (performance as a function of the distance between the beads).

SA found this task very difficult performing at chance with only 55 of 120 trials correct (45.8%) compared with HJA's score of 98/120 (81.6%). SA's performance was collapsed over 'same' and 'different' trials and compared after no significant differences ($p>0.05$) were found on 'same 1cm', 'same 2cm', 'same 3cm' and 'different' 1, 2 and 3cm trials respectively. SA was significantly more accurate on 'Different' trials compared with 'Same' trials, χ^2 (1) = 17.75, p=0.001. She scored 60% correct on 'different' trials compared with 31.7% on 'same' trials indicating a bias to making 'different' decisions.

Overall, HJA performed significantly better than SA (94/120 vs. 73/120), χ^2 (1) = 33.34, p= 0.001. He also showed better performance for 'different' compared with 'same' trials (88.3% correct compared with 71.7%), χ^2 (1) = 5.21, p= .022. HJA's error rate for 'same' responses fell more than 2 standard deviations outside the control mean, while performance on 'different' trials was at control level.

Control accuracy scores were subject to an ANOVA with Location (same vs. different), and Distance between beads (1, 2 and 3cm) acting as within subjects factors. A reliable main effect of distance between beading was observed, F (2, 16) = 17.897, P = .001. Unlike in the case of the patients, the controls performance did not significantly differ on 'same' compared with 'different' trials (85% and 83% correct for 'same' and 'different' trials respectively).

Table 1: *No. Of correct responses on Experiment 2a: Tracing and Segmenting Curves*

	Same	**Different**
SA	19	36
HJA	43	53
Control mean *(SD)*	51 (2.78)	49.8 (2.44)

Note: N=60

Performance as a function of the distance between the beads

SA's performance did not significantly differ as a function of distance, X^2 (2) = 1.43, p=0.49, p>0.05 (1cm apart (47.5%) compared with 2cm (37.5%) or 3cm apart (50%). HJA scored 82.5%, 80% and 72.5% for beads 1cm, 2cm and 3cm apart and performance was at control level but did not significantly differ as a function of distance, X^2 (2) = 1.37, p=0.50, p>0.05.

The controls scored 88%, 84.25% and 79.5% for beads spaced 1, 2 and 3cm apart, respectively (F(2,16)=6.86, p=.001, p>0.05). Bonferroni-corrected comparisons confirmed this effect to be reliable and revealed performance at 1cm apart were more accurate and differed significantly from performance at beads 3cm apart.

Table 2: *No. Of correct responses on Experiment 1a: Tracing and Segmenting Curves*

	Distance between beads		
	1cm	*2cm*	*3cm*
SA	19	15	20
HJA	33	32	29
Control mean *(SD)*	35.2 (0.83)	33.7 (2.35)	31.8 (3.27)

Note: N=40

Reaction Times

Only correct responses were included in further analyses. Since SA.'s accuracy was close to chance, her response times were excluded from analysis. For the remaining participants responses 2 SD outside the mean were excluded as errors and the resulting mean response times (RTs) are represented in Tables 3 and 4.

HJA's response times were compared with those of controls in a factorial ANOVA. Each of HJA's reaction times was treated as a separate subject in a between subjects ANOVA; (see

Young, Hellawell, & Hay, 1987)in a between subjects ANOVA. A significant between subjects effect was observed, (F(1,20) = 73.25, p = .001. HJA's overall response times were extended compared to those of controls.

HJA's data were analysed in a factorial ANOVA treating each RT as a separate subject (ANOVA; see Young, Hellawell, & Hay, 1987). There was a significant main effect of location, F(1,12) = 187.01, p= 0.001. A reliable main effect of distance was also observed, F(2,24) = 194.82, p= 0.001. A distance by location interaction was observed, F (2,24) = 6.23, p =.007. These effects showed HJA to be responding most quickly on trials where beads were closest together at 1cm apart and on trials where beads appeared on different lines. Overall response times increased with distance between beads with the exception of different trials where beads were 3cm apart and response time were faster than when beads were 2cm apart. Performance on same trials slowed compared with different ones.

A single factor ANOVA comparing 'same' 1, 2 and 3 cm trials and 'different' 1,2 and 3cm trials revealed a significant effect of location in controls (F(1,8) 5.41, p = .049. A significant main effect of distance, F(2,16)=28.13, p=.001, and a significant Distance*Side interaction, F(2,16)=7.37, p =.023. Bonferonni-corrected comparisons showed that responses were significantly faster on 'same' trials (2002.78ms) compared with different trials at all distances (2002.78ms), and response times were shown to increase with distance between beads. However, although response times on different 3cm trials were significantly longer than on different 2cm trials the difference was reduced compared with all other comparisons.

Table 3: *Mean correct response times Experiment 1a: Tracing and Segmenting Curves*

	Same (ms)	**Different (ms)**
HJA	7074.12 (1694.22)	6743.92 (1823.41)
Control mean *(SD)*	1917.20 (730.02)	2392.40 (1140.80)

Note: N=60

Table 4: *Mean correct response times Experiment 1a: Tracing and Segmenting Curves*

	Distance between beads		
	1cm	*2cm*	*3cm*
HJA	6228.21 (1870.13)	7534.88 (1792.20)	7238.16 (1729.98)
Control mean *(SD)*	1859.70 (749.20)	2251.60 (688.30)	2585.00 (709.04)

Note: N=40

SA's accuracy on this task was compared with their performance on this task when it was presented on card. No significant differences were observed as a function of distance (X2 (5)= 4.17, p >0.05) and Location effect (X2 (2)= 1.843, p >0.05). HJA's scores did not significantly differ when compared with previous scores (X2 (5)= .466, p >0.05) No same/ different effect (X2 (4)= 1.224, p >0.05).

Discussion

In Experiment 1a, we re-tested both SA and HJA on a curve tracing task having changed stimuli presentation from card to on a screen. SA was severely impaired in segmenting two overlapping curves and had shown a similar pattern when performing this. SA continued to make increased errors on same trials. It appears that any local operation she is using to segment these simple overlapping curves is failing to take in the relevant aspects of the curves. In chapter 1, SA was observed to trace curves the wrong way at intersections where there was overlap and was not able to mediate this with top down knowledge or perceptual cues such as collinearity or connectedness.

HJA in comparison performed within control range for accuracy and was performing more quickly where beads were closer together at 1cm compared with their furthest distance apart of 3cm but was particularly slow on trials at 2cm apart. It is not clear why HJA did not demonstrate the previously observed increase in response times as a measure of distance and it would be useful to perform a further test of curve tracing where target stimuli are further apart and there is a need to scan spatial attention across a larger distance to confirm the previous pattern of performance.

Experiment 1b: Tracing and Segmenting Large Curves

Experiment 1a presented participants with overlapping curves. These stimuli were designed to examine visual routines in participants and specifically their ability to trace and segment such curved stimuli. In Experiment 1a, SA’s performance was particularly poor and as such stimuli has been manipulated to make curve tracing easier. In Experiment 1b we present SA with larger overlapping curves. These curves are not as crowded together meaning it should easier to segment the two strings and follow the curve in the right direction. The distance between targets was also increased to better see any effects of distance.

Method

Participants

SA who has previously struggled with curve tracing (Case history previously described in chapter 2) is compared with 10 neurologically intact, healthy controls (5 females and 5 males; mean age: 65.1, *SD= 4.6)* who were recruited through a University of Birmingham volunteer panel. All had normal or corrected-to-normal vision. Unfortunately HJA was unavailable for further testing here because of ill-health.

Stimuli

Images were represented in 2 -dimensional drawings and created in Microsoft Word. Each stimulus consisted of 2 intersecting curves or strings on which 2 beads (2mm in diameter) appeared. The location of the beads was manipulated with beads appearing on the same, single curve for 30 trials and 2 different intersecting curves on the remaining 30 trials. The images presented comprised larger overlapping curves and differ in size compared with those in Experiment 1a. The distance between the beads on different trials was manipulated with beads placed at distances of 2.5, 5 and 7.5cm apart (inclusive of the point of intersection), with 20 trials each in the same and different conditions. Examples of stimuli are presented in Figure 2.

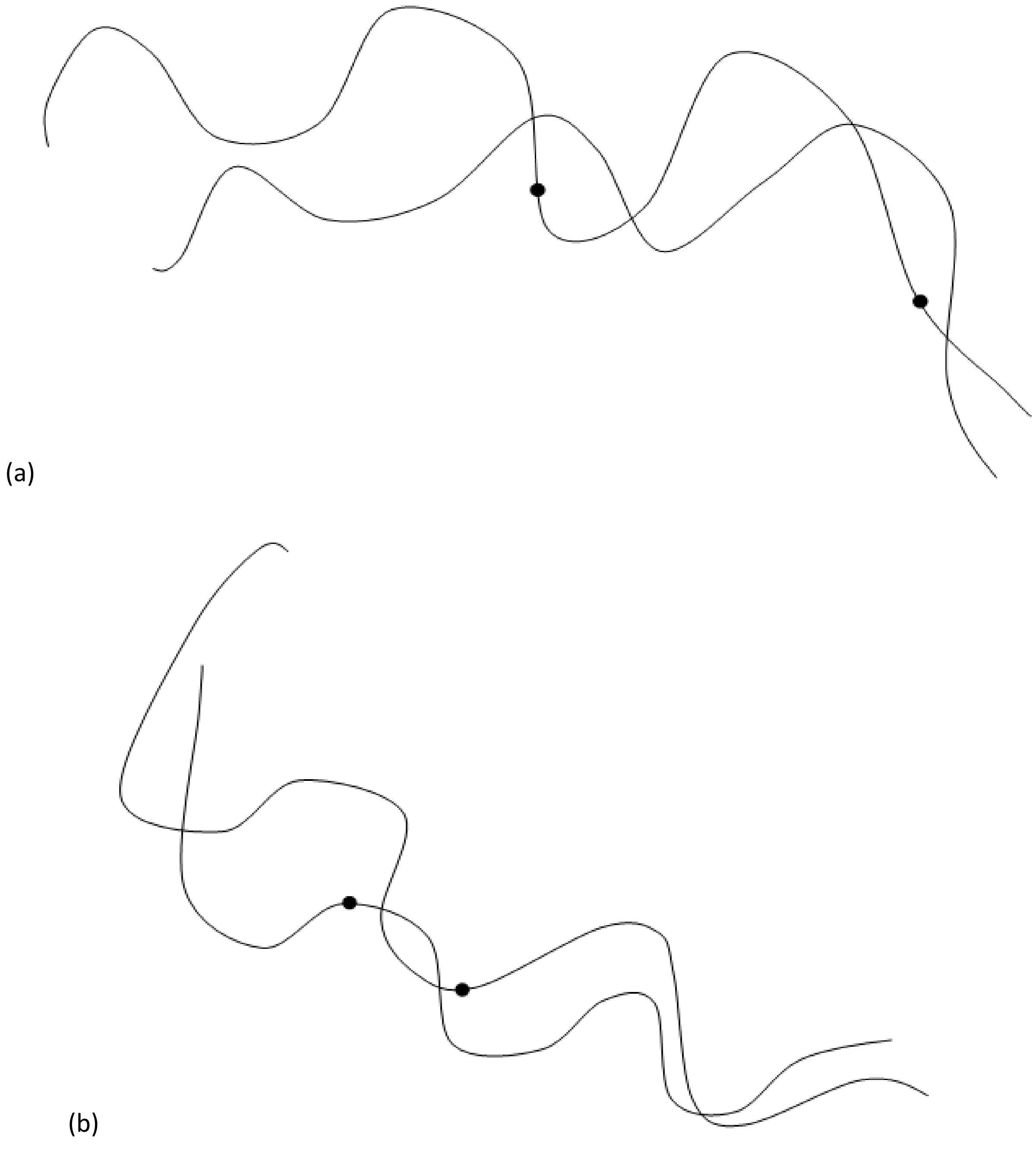

Figure 2: a) represents a ’same’ trial and (b) a different trial for strings.

Procedure

The procedure was as described in Experiment 1a. All participants were presented with a black fixation cross at the centre of a white screen for 1000ms. This was followed by the experimental trials. There were no time constraints on performance, and participants could view the strings as long as they wished before responding (pressing ‘1’ when beads appeared on a single curve and ‘2’ where beads appeared on different curves). Participants were asked to respond as quickly and accurately as possible following a 6 trial practice block. There was an equal number of each trial type (same 2.5, 5and 7cm; different 2.5, 5and 7cm). Accuracy of performance and reaction times were recorded. Each trial began once the participant was ready and focusing on the screen. Participants were then presented with 60 trials taking approximately 10 minutes to complete.

Results

Accuracy

SA found this task very difficult performing close to chance for both ‘same’ (56.7%) and ‘different’ (63.5%) trials. There were no significant differences in performance on ‘same’ compared with ‘different’ trials (X^2 (2)= 0.13, p=0.92 (p<0.05) or of distance. SA’s error rate fell more than 2 standard deviations outside controls scores (Same: 90.7%, Different: 91%). Accuracy in controls did not differ significantly on same compared with different trials F (1, 9)= 0.043, p=0.83 p>0.05 and no other effects proved significant. Tables 5 and 6 represent correct responses on same compared with different trial and as a function of distance respectively.

SA did appear to find this task somewhat easier than experiment 1a, X^2 (1)= 6.504, p=0.011 with correct responses on 60% of trials here compared with 46.67% previously but remained highly impaired. SA was impaired on this task relative to control performance with task accuracy over 2 SD outside control means. Control performance was improved on this task compared with experiment 1a, X^2 (1)= 20.388, p=0.001. No further reliable effects were observed.

Table 5: *No. Of correct responses on Experiment 1b: Tracing and Segmenting Curves*

	Same	**Different**
SA	17	19
Control mean *(SD)*	27.2 (1.23)	27.3 (1.42)

Note: N=30

Table 6: *No. Of correct responses on Experiment 1b: Tracing and Segmenting Curves*

	Distance between beads		
	2.5cm	*5cm*	*7.5cm*
SA	12	13	11
Control mean *(SD)*	18.7 (0.48)	18.2 (1.03)	18.1 (0.88)

Note: N=20

Reaction Times

Only correct responses were included in further analyses. As SA's accuracy was close to chance, her response times were excluded from analysis. For remaining participants responses 2 SD outside the mean were excluded as errors and reaction times are represented on same and different trials and as a function of distance are represented in Table 7 and 8, respectively.

Controls data was analysed in a single factor ANOVA. There was a significant effect of location (F(1,9) = 19.42, P= 0.002, p>0.05 and performance was faster where beads appeared on 'same' compared with 'different' lines (p<0.001). A main effect of Distance was observed (F(2,18) = 101.647, p = .001, with controls responding more quickly were beads were closest at 2.5cm followed by 5cm and 7.5cm apart.

<u>Table 7:</u> *Mean correct response times (ms) on Experiment 1b: Tracing and Segmenting Curves*

	Same	**Different**
Control mean *(SD)*	1483.39 (208.79)	1777.48 (281.22)

Note: N=30

Table 8: *Mean correct response times (ms) Experiment 1b: Tracing and Segmenting Curves*

	Distance between beads		
	2.5cm	*5cm*	*7.5cm*
Control mean *(SD)*	1382.80 (232.42)	1688.00 (202.24)	1890.85 (253.57)

Note: N=20

Discussion

This data shows SA to be highly impaired at separating figure from ground on curve tracing tasks. This is the case even where stimuli has been manipulated to make curve tracing easier. Here curves were not as crowded together meaning it should easier to segment the two strings and follow the curve in the right direction. The distance between targets was also increased to better see any effects of distance.

SA has previously shown increased errors on same trials on curve tracing experiments and this was suggested to be evidence of SA struggling to integrate more global parts and to trace an entire curve which would facilitate segmentation of one curve from another particularly where there are intersections. Here this pattern was reversed where stimuli has been manipulated to make curve tracing easier by presenting larger overlapping curves. These curves are not as crowded together meaning it should easier to segment the two strings and follow the curve in the right direction. The distance between targets was also increased to better see any effects of distance. The opposite error pattern on this task may relate to SA not being able to apply her preferred - though inadequate - local strategies on this task as curves were covering a wider spatial area as did targets and thus attempting to scan the wider area but unable to succeed because of her strong local bias interfering.

In chapter 2, it was suggested that SA was able to scan spatial attention something Roelfsema, et al. (2001) suggested was required for efficient curve tracing and at this point we will test her performance on such a task to confirm this is the case before moving forward.

Experiment 1c: Posner cueing paradigm and Inhibition of Return

In the Posner cueing paradigm - a task examining automatic and voluntary orienting in visual attention (Posner, 1980; Posner, Walker, Friedrich & Rafal, 1984, 1987) - automatic mechanisms have been reported as operating reflexively in shifting attention to stimuli. Endogenous mechanisms are however, voluntary and orient attention deliberately and when there is an equal likelihood of targets appearing at the cued and uncued location attention is said to reorient exogenously. In this task, Posner and colleagues presented participants with three boxes and instructed them to fixate on the central box and to respond to a target appearing in either of the two peripheral boxes. The target would be preceded by a either a central cue (an arrow pointing towards a peripheral box) or a peripheral cue (a brightening of one of the peripheral boxes).

In a Posner cueing task responses to cued compared with uncued targets have been reported to be faster where intervals between cue and target onset are short (usually from 250- 300ms stimulus onset asynchrony) and slower at longer SOA's. These shorter reaction times are reflective of the reported facilitatory effect of reflexive orienting of attention toward a given cue. Inhibition of return (IOR) however occurs in exogenous conditions and is reflected in the slower responding to targets at the cued location at the longer SOA's and has been explained as an inhibiting of reorienting to recently attended regions and encouraging efficient search (Posner and Cohen, 1984).

Posner, Walker, Friedrich, and Rafal, (1984) and Posner and Cohen (1984) described three stages in covert orienting of visual attention suggesting that first attention is disengaged from the current target or attentional focus, in a second stage attention is reoriented attention towards a new target, and at the third stage the new target engages attentional focus. Previous research has shown inhibition of return to be reduced in patients with parietal damage (Posner et al (1984); Vivas, Humphreys, & Fuentes, 2003, respectively).

SA was tested on this orienting task in order to determine whether an impairment in shifting of attention may be contributing to her impaired segmentation of curves (Jolicoeur et al., (1986), Roelfsema et al., (1998; 2001).

Method

Participants

SA and nine age-matched controls (four males, five females, mean age = 62 years, SD = 3.7) took part in this experiment.

Stimuli and procedure: This task was a variation on Posner, Inhoff, Friedrich and Cohen's (1987). Participants were presented with two horizontal boxes (see figure 8) and instructed to fixate on the fixation cross at the centre of the screen. There were 60 trials with valid cues comprising 100ms stimulus onset asynchrony (SOA), 500ms SOA and 1000ms SOA respectively (20 trials each). The different SOAs were also equally represented in invalid. These were non-informative peripheral cues with targets equally likely to appear at cued and non-cued locations.

Each condition was equally represented in a single randomised block. Stimuli were presented using E Prime software on a 17” Gateway PC monitor (1024x768 pixels) and response times were recorded. Participants were instructed to respond with a key press as soon as a target ‘#’ appeared in either of the two boxes. Catch trials with cues but no targets were included to discourage anticipatory responses. A peripheral cue preceded the target (in 120 of the 140 trials), and this was a brief brightening of one of the target boxes.

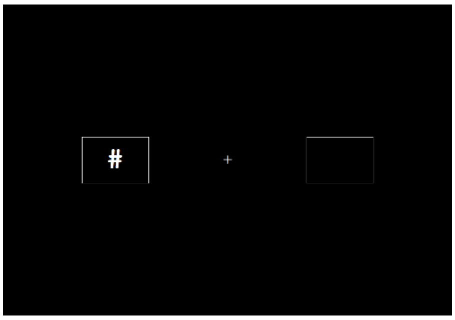

Figure 3: A target present trial is represented above. In a valid trial the left rectangle would be cued prior to the hash appearing. The cue would be a brief brightening around one of the boxes.

Results

SA reaction times: Response times for SA are presented in Figure 9 alongside age-matched controls. SA's response times were subject to a repeated measures ANOVA, (ANOVA; see Young, Hellawell, & Hay, 1987) where within subject factors were cue validity (2 levels: valid, invalid) and SOA (3 levels: 100ms, 500ms, 1000).

A significant main effect of cue validity was observed (F(1, 18)= 4.864, p<.05) with Bonferroni-corrected comparisons confirming this to be reliable (p<.05) overall responses were faster on valid trials (412.37ms) compared with invalid (425.07ms). A main effect of SOA was significant F (1.273, 22.913) = 465.45, p =.001 and Bonferroni corrected comparisons revealed only SOA 500 and SOA 1000 did not differ significantly (p>.05). All other differences were reliable and response times were fastest at SOA 100 (300.05ms) compared with SOA 500(478.37ms) and SOA 1000 (477.74ms). A significant cue validity by SOA interaction (F(1.415, 25.464)= 26.799, p<0.01) was observed which further demonstrated responses were faster to valid (267.10ms) compared with invalid trials at SOA 100 (333ms), and slower on valid (492.35ms) compared with invalid (463.10ms) trials on SOA 1000. On SOA 500 there was little difference in response times to valid (477.62ms) compared with invalid (479.10ms) trials.

Age-matched controls: Only correct responses were included in further analysis and any responses 2 SD outside the respective condition means were excluded. Response times were subject to a repeated measures ANOVA, where within subject factors were target presence (present, absent) and array size (one, four, eight or sixteen). Analysis revealed no main effect of cue validity (F(1, 8)=.726, p>.05). A main effect of SOA was observed (F(1.256, 10.051) = 362.012, p<.01). Bonferroni-corrected comparisons confirmed differences between SOA 100 and 500 and SOA 100 and 1000 (p<.001) resulting in a quicker response time. SOA 500 and 100 did not significantly differ (369.79ms and 381.92ms). A cue validity by SOA interaction was observed (F(1.827, 14.618) = 19.800, p=<.01) with faster responses on SOA 100 overall and also on valid compared with invalid cue trials (valid: 176.05ms; invalid: 216.42ms). Response times at SOA 500 (valid: 378.18ms; invalid: 361.40ms) and 1000 (valid: 404.216ms; invalid: 359.63ms) remained slower than at SOA 100.

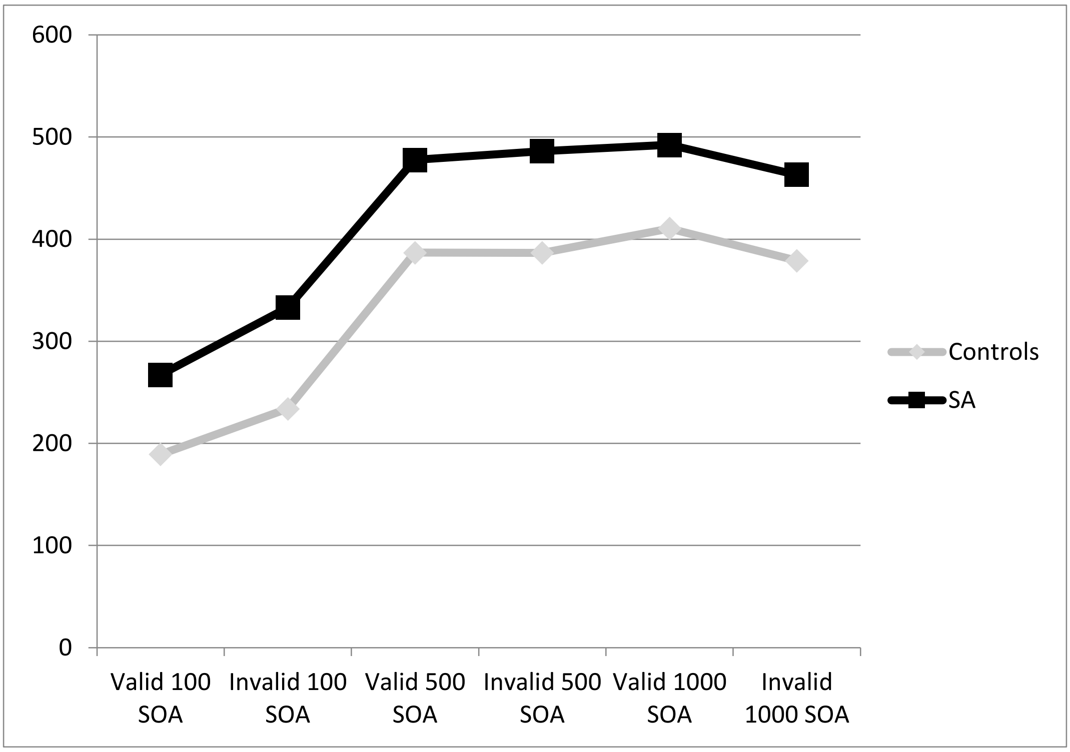

Figure 4: Patient SA’s mean response times compared with age-matched controls on valid and invalid cue trials at SOA 100, 500 and 1000.

Discussion

Both SA and age-matched controls displayed facilitation at 100 ms SOA and inhibition of return at the longer SOA's. However, age-matched controls displayed faster reaction times overall compared with Patient SA. SA showed slower responses to targets at the cued location on the longer SOA's. SA though slow relative to controls is showing the same pattern of performance. SA's performance suggests she does not have a problem in shifting attention (a feature of simultanagnosia) and is able to orient and shift attention ruling out the possibility of an impairment in spatial scanning impeding curve tracing.

Experiment 1d: Tracing and segmenting non-overlapping lines

In this experiment stimuli were manipulated to see if SA's difficulties in curve tracing would continue with simple non-intersecting curves. Since SA has continued to have difficulty with intersecting curves and was shown to be misdirected to distractor lines in Chapter 1, we were interested to discover whether her difficulties would remain when curves are no longer intersecting. In this condition it should prove easier to segment one line from the other. Curve size is manipulated with respect to number of concavities to test whether this affects curve tracing in patients SA and HJA (Jolicoeur, Ullman and MacKay, 1986). SA's performance is compared with HJA as well as 5 healthy participants in order to assess normal control performance levels on this task.

Method

Participants

SA, a patient with form agnosia and HJA a integrative agnostic are compared with 5 healthy controls (3 males and 2 females, mean age: 60, *SD= 6.1)*

Stimuli

Stimuli comprised 2 non-intersecting curving lines or ‘strings’, one above the other. On these strings appeared 2 black circular beads, 2mm in diameter and presented 2.8cm apart. The beads either appeared on the same single string or upon 2 different strings. Two identical curved strings were created in Microsoft Word program. One string was then lowered to the required distance while ensuring the strings did not overlap. Two beads were then placed on the strings at a distance of 2.8cm apart. On 60 of the trials the beads appeared on the same string compared with 60 trials with beads on different strings. In order to create different trials one of the beads was moved onto a separate curve while maintaining a distance of 2.8cm. Here the number of concavities are increased to test whether a greater number of concavities leads to a significant difference. A further 30 of the trials within the same and different groups comprised small strings with 5 concavities, the remaining 30 strings were large with 7 concavities, see examples presented in figure 5.

Procedure

Stimuli were presented using E Prime software on a 17” Gateway PC monitor (1024x768 pixels). The viewing distance was approximately 45cm with each onscreen cm representing 1.27 degrees of visual angle. All participants were presented with a black fixation cross at the centre of a white screen for 1000ms. This was followed by an image comprising 2 curving strings. Participants were required to determine whether the 2 beads as appeared on the same or on different strings. Stimuli were not time-limited and participants were asked to respond as quickly and accurately as possible by pressing ‘1’ when beads appeared on the same curve and ‘2’ where beads appeared on different curves). Participants were presented with 120 trials in a single block. The order was randomised and preceded by a 10-trial practice block. The experimenter began each trial once the participant was ready and focusing on the screen.

Figure 5: represents non intersecting curves with a) ’same’ trial with 5 concavities, (b) a different trial for 5 concavities, c) a same trial with 7 concavities and d) a different trial with 7 concavities.

Results

Accuracy

SA correctly responded to 85 of 120 trials correctly (70.7%), X^2 (1) = 2.0, p = 016, improved from performing at chance at previous curve tracing tasks but remaining impaired compared with HJA’s score of 111/120 (92.5%), X^2 (1) = 3.45, p = 063. SA’s performance was explored in a loglinear analysis comparing performance on same trials with 5 concavities, same trials 7 concavities' and different trials with 5 and 7 concavity trials respectively but no significant effects were observed in any of these conditions, (X^2 (3) = .33, (p>.05). The data shown in Table 8 represent correct responses on 'same, small'- trials w 5 concavities, same large w 7 concavities, different small and different large trials.

HJA's performance on same trials with 5 concavities, same trials 7 concavities' and different trials with 5 and 7 concavity trials was compared with no significant effects observed (X^2 (3) = .23, (p>.05). HJA's performance on these trials was at control level.

Control accuracy scores were subject to an ANOVA with Location (same vs. different and Curve size (5 and 7 concavities) acting as within subjects factors. No reliable effects were observed (p>.05)

Table 8: *No. Of correct responses on Experiment 1d: Tracing and Segmenting non-intersecting Curves with 5 and 7 concavities*

	Same 5	**Same 7**	**Different 5**	**Different 7**
SA	24	16	18	27
HJA	27	29	29	26
Control	27 (1.87)	26.6 (1.67)	27.4 (3.65)	27.2 (4.72)

Note: N=30

Reaction Times

Only correct responses were included in further analyses. All responses 2 SD outside the mean were excluded as errors and the resulting mean response times (RTs) are represented in Table 9.

SA and HJA's data were analysed in a mixed factor ANOVA treating each RT as a separate subject. Location (same vs. different) and Curve size (5 and 7 concavities) acted as within subjects factors and Patient as a between subjects factor (ANOVA; see Young, Hellawell, & Hay, 1987). There was a no significant main effect of Patient F(1,42) = .389 p= 0.536. Here SA and HJA's response times did not significantly differ. A significant effect of Curve size was observed, F(1,42) = 4.184, p= 0.047 but no other effects were observed. When SA's data was analysed in a separate ANOVA there was no evidence of a reliable effect of curve size and no further effects were observed (p>.05). SA's response times were compared with those of controls in a factorial ANOVA. A significant between subjects effect was observed, (F(1,21) = 101.14, p = .004. SA's overall response times were extended (1450.47 ms) compared to those of controls (855.49ms).

HJA's data were also analysed in a separate factorial ANOVA treating each RT as a separate subject (ANOVA; see Young, Hellawell, & Hay, 1987). There was a reliable main effect of curve size indicating HJA performed more quickly on trials with 5 concavities (1322.35ms) compared with 7 concavities (1462.37ms). No other reliable effects were observed (p>.05). HJA's response times were compared with those of controls in a factorial ANOVA. A significant between subjects effect was observed, (F(1,29) = 31.09, p = .001.

HJA's overall response times were extended (1392.36ms) compared to those of controls (855.49ms).

A factorial ANOVA comparing Location (same vs. different) and Curve size (5 and 7 concavities) acting as within subjects factors revealed a marginally significant effect of curve size in controls (F(1,4) 4.77, p = .068, with controls responding more quickly on trials with 5 compared with 7 concavities. No other main effects were observed.

<u>**Table 9**</u>: *Mean correct response times on Experiment 1c: Segmenting non-intersecting Curves with 5 and 7 concavities*

	Same 5	**Same 7**	**Different 5**	**Different 7**
SA *(SD)*	1430.54(642.79)	1489.93 (583.51)	1348.60 (647.58)	1532.78 (573.95)
HJA *(SD)*	1302.31(176.51)	1480.68(312.08)	1342.37 (255.69)	1444.06 (238.55)
Control mean *(SD)*	735.67 (114.69)	886.0(156.23)	849.50 (76.60)	950.79 (201.80)

N=30

Discussion

These results demonstrate SA to be impaired curve tracing even when there is no overlap. SA finds even simple and non-intersecting curves problematic compared with HJA as well as the control group. It has been evident that SA had a particular deficit in segmenting overlapping lines but simplifying this task has not made much of a difference and she continues to show impaired segmentation of curves.

General discussion

SA has previously been shown (in chapter 2) to struggle on tasks requiring visual segmentation. Even on simple tasks SA would trace distractor curves indicating difficulties where there was overlap in determining which lines to follow. Here we have found her to be highly impaired even where stimuli were altered and made easier and intersections removed. Whilst, SA is able to scan spatially and shift attention in tests of attention such as Posner cuing and visual search tests which have been reported by Roelfsema et al. (1998, 2001) to be necessary to curve tracing it is unclear whether she is able to do this when required to segment curves. This deficit on even simple stimuli raises question as to the curve tracing operation she is using here. There is no evidence of serial scanning of curves or of distance and her error rates show an unclear and thus uninformative pattern.

Roelfsema et al, (1998) describe Gestalt grouping rules for collinearity and connectedness are used to successful group pertinent parts of a curve. It is clear that SA shows a failure of such grouping and this is impeding segmentation particularly in response to overlapping figures. Whilst previously able to use top down information to aid segmentation in response to individual stimuli on a name verification task in chapter 1, SA was unable to use such information to segment and trace overlapping figures. On the curve tracing tests presented SA was not able to use top down knowledge and was unable to segment figure from ground. SA shows a deficit in basic coding of shape as well as having difficulty following relevant curves at overlap and integrating global information. Super and

Lamme (2007) have pointed to differential responses in the primary visual cortex when an animal has successfully perceived figure from ground compared to when such recognition is absent and reported impaired figure ground perception in a monkey following removal of dorsal extrastriate areas. Super and Lamme (2007) have added to the considerable recent evidence that recurrent processing via feedback from the extrastriate region to the primary visual cortex as crucial to visual recognition. They found evidence that the dorsal extrastriate region in monkeys supports feedback and is crucial to figure ground segmentation and it is notable that SA has a lesion of this region.

It has been suggested impaired integration of parts to form a whole and a global bias has been responsible for HJA's impaired performance on other tests of visual segmentation particularly where there are increased internal details. HJA notably performed at control level on tasks of curve tracing except for on most difficult conditions. While his pattern on the initial experiment here differed to previous testing it is difficult to reach conclusion on why this might be without further investigation. In SA's case it is suggested that difficulty encoding basic aspects of shape alongside a local bias which is not mediated by top-down information interferes with forming a whole percept. This can lead to SA struggling at intersections and following distractor curves and explains her poor segmentation of curves.

Rizzi et al. (2010) have previously reported on patient FP who displayed difficulties on intersections similar to SA suggestive of a deficit in grouping particularly collinearity and was unable to discriminate which lines to follow as stimuli became more fragmented. It was suggested a bias toward local detail interfered with. FP appeared unable to separate two figures and to extract relevant aspects of objects. Despite intact semantic knowledge she was unable to access top down knowledge and attend to salient information when presented with competing information (Humphrey & Bruce, 1989; Riddoch and Humphrey, 1987).

Behrmann et al. (1994) described a comparable case in CK who also demonstrated a difficulty in separating and distinguishing overlapping objects. When asked to trace around presented overlapping objects he was unable to continue when lines intersected. CK was also impaired on more basic tasks of shape detection where he was required to segment an ‘x’ from a fragmented background he would struggle as the background became increasingly fragmented. CK while to perceive parts but struggled to group information into a whole.

In SA’s case it is suggested that difficulty encoding basic aspects of shape alongside a local bias which is not mediated by top-down information interferes with her utilising perceptual grouping cues to form a whole percept. This can also lead to SA struggling at intersections and following distractor curves and explains her poor segmentation of curves

For further study it would be interesting to test visual segmentation of letter and non-letter outlines particularly in HJA. These would contain no internal detail besides any targets to be detected and non-letters would not require semantic knowledge. Ullman (1984) has made a distinction between and base and incremental representations that might also be explored by looking at priming. Further study using priming to examine whether SA shows priming from a stimulus she can't discrimination when she then performs a task she can do but the same relationship is followed across stimuli – for example, if they are both inside a shape.

Chapter 4

General Discussion

General discussion:

The work presented within this thesis has explored distinctions between form and integrative agnosia and figure ground perception in patients with dorsal and ventral extrastriate lesions, respectively. As part of this in chapter 2, we compared visual processing performance in form and integrative agnosia. We found patient SA to be highly impaired on Efron's (1968) shape discrimination task and on copying relative to HJA and identified to have a deficit in the coding of basic shape. We found SA and HJA to perform similarly on low-level BORB perceptual tasks such as line orientation and to demonstrate intact semantic knowledge and shape detection amongst fragmented backgrounds.

SA has been found to be highly impaired on object recognition but was able to show some improved performance with animate objects relative to inanimate on shorter exposures whilst HJA showed the opposite pattern at all exposures. It was suggested SA was able to make use of distinctive local features in animate objects and was able to make use of top –down knowledge here. Both SA and HJA were able to detect fragmented shapes but struggled to segment and identify overlapping letters where they were required to segment based on edge cues. (Riddoch et al. 1998; Charnalett et al. 1996). HJA demonstrated intact discrimination of simple shapes but found it harder to separate figure from ground on line drawings compared with outlines and struggled with internal detail appearing to use local information incorrectly (Lawson & Humphreys, 1999; Riddoch & Humphreys, 1987a). HJA was better able to identify outlines rather than drawings with internal detail consistent with poor forming of parts into wholes consistent with Lawson & Humphreys (1999) and Riddoch and Humphreys (1987a).

Local/ Global

In Chapter 2, we reported on HJA and SA’s performance on a task where they were presented with hierarchical stimuli – a compound letter comprising smaller letters. HJA was found to have a strong global bias to identifying the overall letter while SA demonstrated a strong local bias. This is consistent with HJA having a bias to whole and global information to the deficit of more local and parts while SA shows the opposite pattern. We suggested that this could be reflect global form proving more salient to HJA compared with local form in SA. We claimed that both HJA and SA find it difficult to attend to the low saliency aspect of a hierarchical form when there is competition from a higher saliency competing aspect (cf. Mevorach et al., 2005a; 2005b). We suggested the respective local and global biases evident here influenced performance in figure ground segmentation (discussed further below). There has been recent support for global form to be more salient to HJA compared with local aspect to SA. Riddoch, Chechcacz, Mevorach, Mavitsaki, Allen & Humphreys (2010) reviewed neuropsychological studies of visual selection operations. As part of this they referred to a recent study by Mevorach et al. (2010) where fMRI was performed on SA (earlier described to have bilateral dorsal occipito-parietal lesions) and HJA (reported to have bilateral ventral occipito-temporal cortical lesions) while they responded to hierarchical stimuli. Mevorach et al. (2010) found HJA demonstrated a global precedence effect on this task and a strong response in the dorsal occipital region while SA showed a local bias and a strong response in occipito-temporal areas. This neuronal activity appeared to be reflective of HJA and SA’s global and local bias on this task with SA showing a heightened response in the region of HJA’s lesion whilst, HJA demonstrated a similar response in the SA’s lesion site. An increased response was evident in the left intra-pariatel sulcus when HJA was asked to respond to local elements of hierarchical stimuli whilst SA demonstrated a similar pattern when asked to respond to global information. Both patients showed increased activity in the intra-parietal sulcus an area associated with the selection of low saliency targets. These finding support Riddoch et al. (2010) suggestion these patient's extrastriate lesions have served to alter the saliency of stimuli and in turn altered intra-parietal sulcus activity and propose a link between visual selection and regions of the posterior parietal cortex.

Figure ground segmentation

In view of HJA and SA demonstrating impaired segmentation on overlapping figures test and line drawings we identified curve tracing as a useful test of figure ground segmentation in these cases. Curve tracing and segmenting of abstract shapes was selected as a test of figure ground perception and as a test of ability to serially scan attention across relevant curves (Jolicoeur, Roelfsema, Lamme, 2000). It was suggested top down knowledge would have little or no impact on this task. In this task stimuli comprised two intersecting curves and required a discrimination as to whether target beads lay on the same or different lines. SA was highly impaired and demonstrated increased errors on same trials compared with different trials. HJA in comparison performed showed a similar pattern of performance to controls though he was slower. HJA was found to slow in response time as a function of distances between target beads. This pattern (Jolicoeur, Roelfsema, Lamme, 2000) provided evidence that HJA was serially scanning and shifting attention at a normal rate on these tasks. However, HJA did not show this pattern in Chapter 3 and was unavailable for further testing to examine whether he had been serially scanning and shifting attention on these tasks but possibly utilised a different tracing strategy on this occasion.

SA displayed a highly impaired performance when she was required to segment an abstract amoeba-like shape and to determine whether target beads lay inside or outside of the shape. This particular task had been selected to examine whether HJA and SA were able to segment and separate figure from ground using global shape, and closure information alongside minimal local details (Van Selst, 1993). A further task presented HJA and SA with 2 overlapping amoeba-like shapes and asked that they discriminate whether 2 bead appeared on the a single or on different shapes. SA was unable to complete this task finding it too difficult. HJA demonstrated increased errors relative to controls when target beads were furthest apart while response time increased as a function of distance. This was a more taxing task of figure ground segmentation with complex shapes and both HJA and SA demonstrated an impairment. In chapter 3, we further examined figure ground segmentation in curve tracing by adjusting distance between targets and also by presenting stimuli with no overlap. As part of this we ruled out impaired scanning of attention as the cause of her impaired curve tracing performance. However, while able to scan and shift attention it is unclear whether she was in fact serially scanning and shifting attention during these tasks.

We earlier identified SA to have difficulties more global processing whilst HJA showed a bias to more global aspects of shape. We suggest in SA the combination of poor coding of basic aspects of shape alongside a local bias means she was unable to attend to curves as a whole leading to highly impaired segmentation of both overlapping and non-overlapping curves. SA had shown poor grouping by closure when asked to determine whether targets appeared within or outside an abstract but simple amoeba-like shape consistent with her difficulties with coding of shape and global information playing a role here. HJA in comparison was more sensitive to closure on this task where there was little local detail but struggled on the most difficult condition of a task where such figures overlapped and there was more local demands. It is suggested that this task required integration of more global, wholistic aspects as well as attending to local details in order to segment overlapping shapes.

Ullman (1984) has stated that curve tracing requires either sequential or parallel processing. Jolicoeur, Ullman & McKay argued that in curve tracing you trace until you locate the first target and mark that location before continuing to trace until you encounter the second target or another curve. While local processes acting upon an image could locate two dots there would need to be a global grouping process to distinguish same trials. SA struggled to segment and would trace distractor curves on simple tasks suggesting difficulties where there was overlap in determining which lines to follow and local bias interfering with her ability to attend to task-relevant parts of a curve. This is consistent with Vecera & OReilley (1999) argument that collinearity and connectedness principles are required to separate task relevant from non-task relevant areas for successful discrimination of figure from ground.

Roelfsema et al. (2001) has argued that rather than a moving attentional zoom lens to trace a curve as suggested in early studies of curve tracing there is a gradual spread of attention during mental curve tracing until a target curve is activated with attention remaining on an entire relevant curve (Houtkamp, Spekreijse & Roelfsema, 2003); Roelfsema & Spekreijse, 2005; Roelfsema, Lamme Spekreijse, 1998; Scholte, Spekreijse, & Roelfsema, 2001). SA did not appear to be able to distinguish relevant curves in our tests. Curve tracing is described as involving the binding of spatially separate contour segments into a ‘coherent representation’ of the traced curve. Research suggests feedback between higher visual areas (V4) – to lower areas of the primary visual cortex (V 1) is necessary for curve tracing (Roelfsema, 2001). It is of note that HJA’s has damage to such higher processing areas and also has difficulty integrating parts to whole representation particularly in taxing conditions and yet was able to segment curves similar to controls suggesting intact scanning showing some impairment only on the most difficult condition. This suggests HJA may be using intact early visual areas to perform this task or that other areas undamaged regions may be important (Corbetta and Shulman, 2000).

Super and Lamme (2007) have pointed to differential responses in the primary visual cortex when an animal has successfully perceived figure from ground compare to when such recognition is absent and reported impaired figure ground perception in a monkey following removal of dorsal extrastriate areas. They found intact detection of luminance post lesion irrespective of cuing. Super and Lame (2007) provided evidence that feedback from the extrastriate region to the primary visual cortex as crucial to visual recognition. They found monkeys with extrastriate lesions were able to improve figure ground perception on a cued task but remained impaired on an uncued task and described an early stage in figure ground processing where features/ properties are extracted followed by a later response feedback from higher level processes for perceptual grouping and segmentation. The findings following an extrastriate lesion in monkeys supports feedback from dorsal extrastriate lesions to is crucial to figure ground segmentation.

Evidence from SA's dorsal extrastriate lesion compared with HJA's extrastriate lesion and use of top down processing suggests regions are potentially important in mediating top down processing for visual object recognition. Behrmann & Kimchi (2003) and Vashnou & Chatterjee (1999) reported on two patients with integrative agnosia with similar performance on perceptual tasks other than on hierarchical stimuli where one showed a local bias and the other a global bias. Patient DF (Milner et al., 1991) was a form agnostic and demonstrated a local bias on hierarchical stimuli similar to SA. Based on the contrast in SA and HJA's lesions location may be key with more posterior lesions as in HJA making it more difficult to integrate information from parts to form a whole representation and local bias interfering with contour tracing.

The contrast in visual processing evident in SA compared with HJA supports the fractionation of definitions of apperceptive agnosia to include form agnosia alongside integrative agnosia. This suggests object recognition requires coding of both local details and global shape. Davidoff & Warrington (1993) in comparing patients SMK (impaired shape discrimination but intact figure ground perception) and FGP (impaired figure ground perception and intact shape discrimination) suggested shape discrimination and figure ground perception were similarly both required for normal object recognition. Our results throughout this thesis have indicated this to be the case. SA is unable to segment curve tracing even when provided with simplified stimuli where larger curves spaced further apart were presented to aid following target curves. Despite further simplifying stimuli by removing overlap and maintaining targets at a fixed distance, SA demonstrated a highly impaired performance. Athough, SA remained impaired relative to controls she demonstrated an improved performance on these simple non-intersecting curves. It would be interesting to explore this further by varying complexity of this task in a controlled way. This would include examining for an effect of distance on this simpler task where target dots were moved apart. Further experiments on more complex amoeba shapes where concavities could be systematically varied and SA be asked to make determinations as to whether dots lay within a shape. Also to look at base and incremental representations as a priming task to examine if SA shows priming effects from a shape she cannot discriminate by discriminating whether targets appears inside or outside of the shape when it is followed by a task she is able to do where targets are followed through. In a test of orienting attention she was found to be able to orient and shift attention in a pattern comparable with controls and similarly in Chapter 2, she was reported to be able to perform a conjunction search similarly to controls. However, it may that SA is using an ineffective tracing strategy on this task and not scanning spatially as the task demands.

SA showed impaired figure ground segmentation on simple curves as well as complex shapes and was unable to determine spatial relations on abstract shapes. SA's difficulties are not attributable to a failure to scan spatial attention as in Chapter 3 she was demonstrated to be able to scan in a serial search task as well as able to shift attention on Posner attentional cuing task. In Chapter 2, we suggested SA's impaired curve tracing was attributable to poor encoding of global shape and poor segmentation of curves when she was unable to utilise top down information on these irregular shapes to mediate her deficit in coding basic aspects of shape. It may also be that while she is able to scan for attention she is using a different strategy which may locally bias in integrating of parts to whole. It would require further testing to examine this and eye tracking task may provide insight into this strategy.

How much does the dissociations between form and integrative agnosia and functional impact of deficit apply to other cases? Milner et al. (1991) reported on DF who displayed form agnosia and a local bias in response to hierarchical stimuli. Milner et al.(1991) have suggested DF demonstrated a tendency to focus on local aspects of given stimuli to the cost of more global shape perception. The case of SA shows a similar pattern with a deficit in basic coding of shape alongside a local bias as well as severely impaired performance in segmenting simple overlapping and non-overlapping curves as well as overlapping figures. The findings within this thesis support normal object recognition to require coding of both global and local aspects of shape. Baylis and Baylis (1996) reported on a dissociation between poor performance on tests of figure-ground separation and normal visual search and orienting of attention suggesting figure ground is separable from tasks of attention but that both are needed for object recognition.

Future directions for research

I would have liked to have included further tests of figure ground segmentation where we could examine to what extent SA can use local cues to facilitate figure ground segmentation and object recognition. SA was able to use top down information to aid her performance on a name verification task she was otherwise struggling with. Could she similarly make use of explicit local cues? It would also interesting to examine HJA's performance on a task where global shapes are presented with local cues. Would this interfere with his ability to segment? Would he adapt? Also how further testing on how was was distributing attention in curve tracing tasks?

For future study I would be interested in reviewing cases of simultanagnosia as well as form agnosia with a focus on SA and to discussing performance of patients on the Efron shape discrimination test as well as tests of visual attention. SA has bilateral damage with lesions affecting the dorsal extrastriate regions and performs poorly on the Efron test as do patients with simultanagnosia. SA does not however appear to have a problem in shifting attention (a feature of simultanagnosia). SA favoured local shape when tested with hierarchical letters – similar to simultagnosics but shows no difficulty in processing multiple items, I would be keen to explore further this further.

Conclusion

This thesis has examined visual routines in two cases of visual agnosia distinguished by having dorsal and medial, ventral extrastriate lesions. I have described their different perceptual impairments with patient HJA demonstrating impaired local processing interfering with local aspects of visual recognition and name verification and a global bias when presented with hierarchical forms but relatively preserved curve tracing and figure-ground segmentation. In comparison, SA demonstrated a pattern comprising impaired processing of the more global aspects of shape leading to impaired visual recognition and a local bias when presented with hierarchical forms. SA showed improved name verification compared with HJA and showed intact attentional cueing and shifting of attention but was impaired on even simplified curve tracing tasks. Curve tracing has proved to be a useful test of figure-ground segmentation in neuropsychological cases which does not appear to be demanding of top down processes. These findings contribute to the neuropsychological literature on different patterns of perceptual deficits in cases of agnosia.

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