

SEEING TREES OR SEEING FORESTS IN SIMULTANAGNOSIA:
ATTENTIONAL CAPTURE CAN BE LOCAL OR GLOBAL

by

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B.ScH., Queen's University, 2004

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES

(Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA

August, 2006

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Abstract

Patients with simultanagnosia often demonstrate 'local capture', meaning that they identify only the local elements of stimuli that contain a hierarchy of both local and global structures. Recent studies, however, have found that these patients may implicitly process the global form. We examined the general applicability of the concept of local capture, and specifically whether the global level of stimuli can be explicitly reported by patients with simultanagnosia. We tested a patient with simultanagnosia with globally biased stimuli such as hierarchical Arcimboldo faces and small, dense Navon letters. With Arcimboldo faces our patient often reported only the face and not the local elements -- the first demonstration of global rather than local capture. With Navon letters, the patient's ability to report the global letter varied with stimulus density and inversely with stimulus size, so that local capture was found only with large and sparse stimuli. With both faces and letters, the likelihood of global capture by the patient was related to the ease of global reporting in controls, as indexed by their reaction times. This suggests that the patient's global perception is influenced by the same factors operating in healthy individuals. We conclude that attentional capture in simultanagnosia can be either global or local. Capture likely occurs because of a pathological restriction and/or rigidity of attention, but the type of capture depends upon the competitive balance between global and local salience.

TABLE OF CONTENTS

Abstract	ii
Table of Contents.....	iii
List of Tables	iv
List of Figures	v
Acknowledgements	vi
Co-Authorship Statement	vii
CHAPTER 1: INTRODUCTION	1
References	4
CHAPTER 2: EXPERIMENTS	6
Method	6
Experiment 1	7
Experiment 2.....	8
Results	9
Experiment 1	9
Experiment 2.....	10
CHAPTER 3: DISCUSSION.....	14
References	18
APPENDIX: Copy of UBC Research Ethics Board Certificate of Approval	19

LIST OF TABLES

Table 2.1. Reaction times for healthy participants classifying Arcimboldo images	10
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LIST OF FIGURES

Figure 1.1. Typical Navon hierarchical letter	1
Figure 1.2. Typical Arcimboldo painting	3
Figure 2.1. MRI scans of patient SL	6
Figure 2.2. Patient accuracy - Local letters	11
Figure 2.3. Patient accuracy - Global letters	11
Figure 2.4. Patient accuracy (Global letters) as a function of inter-element spacing	13
Figure 2.5. Patient accuracy (Gobal letters) as a function of control reaction time	13

Acknowledgments

First and foremost, I would like to thank my supervisors, Dr. Alan Kingstone and Dr. Jason Barton for their guidance, patience, and wisdom, and for their personal and academic support. Next, I would like to thank my MA Committee members, Dr. Jim Enns and Dr. Todd Handy, for challenging me, while at the same time offering advice and encouragement. I would like to express my heart-felt appreciation to SL for her enthusiastic and dedicated participation in these experiments, as well as for her inspirational attitude towards life and its challenges. Thank you to members of the BAR and BAR-TON labs for their help along the way and a very special thank you to my family and friends, for I could not have done this without them.

This work was supported by the University of British Columbia, the Natural Sciences and Engineering Research Council of Canada, and the Michael Smith Foundation for Health Research.

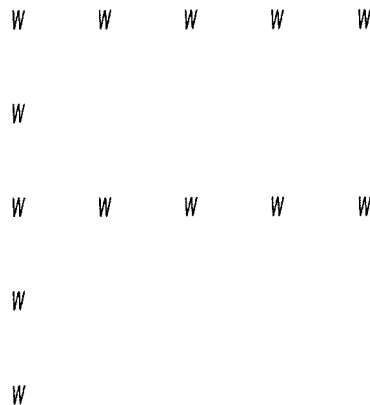
Co-Authorship Statement

I am the primary author on all of the MA work presented in this thesis, including experimental design, implementation, data analyses, and manuscript preparation. The work benefited from discussions with my supervisors, Dr. Alan Kingstone and Dr. Jason Barton.

CHAPTER 1:
Introduction¹

Simultanagnosia is a restriction of visual attention such that the patient is only aware of a single object at one time (Moreaud, 2003; Rafal, 2003; Rizzo & Vecera, 2002). This results in a “gross incapacity to combine the elements of the perceptual display into a coherent and integrated whole.” (Luria, 1959). There are also reports of an abnormal direction of attention towards smaller, local elements at the expense of the larger, global level, a phenomenon called ‘local capture’ (Karnath, Ferber, Rorden, & Driver, 2000). Karnath et al. (2000) reported that a simultanagnosic patient could not identify global letters, naming only local letters of hierarchical Navon stimuli (Navon, 1977) e.g. Figure 1.1. This suggested that attention was captured by local elements, preventing explicit processing of the global form, a finding consistent with other reports that simultanagnosics lock onto local elements at the expense of the global whole (Jackson, Swainson, Mort, Masud, & Jackson, 2004; Rafal, 1997).

Figure 1.1. Typical Navon hierarchical letter



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An important question is whether there are conditions under which global report can become explicit in simultanagnosia. Recent studies reveal a competitive balance between local and global processing that depends upon stimulus factors such as size and density (Kimchi, 1988; Kinchla & Wolfe, 1979; Martin, 1979; Yovel, Yovel, & Levy, 2001). Large, sparse Navon stimuli like those used by Karnath et al. (2000) bias even healthy subjects towards local processing. The combination of a normal local bias with pathologic limitations of attention may generate an appearance of local capture in simultanagnosia. Compelling evidence of local capture as a generalizable phenomenon would be provided if local capture occurred even with globally-biased stimuli. However, if the use of locally-biased stimuli was critical to generating the appearance of local capture in prior reports, then simultanagnosics may perceive the global level of globally-biased stimuli. Testing these alternatives was our primary goal. Our secondary goal was to determine how the level of capture in simultanagnosics relates to the balance of local and global processing in healthy control participants.

Experiment 1 used Arcimboldo images: faces made up of a collage of local objects, such as fruit (Figure 1.2). There is evidence that faces are processed holistically, making them globally-biased (Farah, Wilson, Drain, & Tanaka, 1998; Moscovitch, Winocur, & Behrmann, 1997). Experiment 2 used hierarchical Navon letters, first to replicate previous local capture results (e.g. Karnath et al., 2000), and then to explore the effects on capture of stimulus size and density, factors that influence the global/local balance (Enns & Kingstone, 1995).

Figure 1.2. *Typical Arcimboldo painting*



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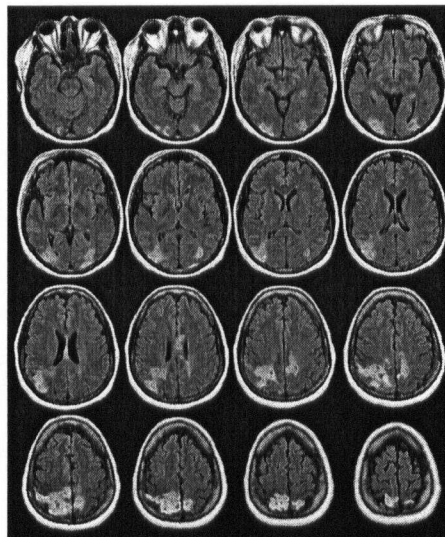
CHAPTER 2:

Experiments¹

Method

Participants. SL, a 48 year-old woman with bilateral parietal and lateral occipital infarcts (Figure 2.1), presented with a left inferior quadrantanopia and Balint's syndrome, including ocular motor apraxia, optic ataxia and simultanagnosia, manifested as piecemeal interpretation of complex scenes (e.g. Boston Cookie Theft picture). SL showed impairments of attention, with subnormal performance on backwards Digit Span and tasks of letter and number sequencing. She had left hemineglect as assessed with the Sunnybrook Neglect Assessment Battery. Testing was done between 8 and 22 weeks after stroke. By the first testing session, she no longer had neglect or quadrantanopia, optic ataxia was limited to the left hand, but she still experienced simultanagnosia.

Figure 2.1. *MRI scans of patient SL*



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Control participants (n = 14) ranged in age from 21 to 49 years (mean = 29.6), with normal acuity. Participants gave informed consent prior to the experiments, which were performed in accordance with the Declaration of Helsinki.

Experiment 1

Stimuli and Apparatus: There were three image sets. The first was 12 Arcimboldo pictures. A second contained 19 images of objects not arranged in the configuration of a face (local controls). A third set of 8 images contained faces not made up of objects (face controls). Arcimboldo pictures spanned 7.5-15.8° (width) by 10-22° (height). Control images spanned 7.0-24.5° by 5.5-22.8°. For controls each image was presented twice (upright, inverted), in one session. SL had repeated sessions over 3 months.

Procedure: Participants (SL, 3 controls) were seated 57 cm from the monitor. Their task was to verbally report what they saw. After a 300 ms visual mask, a picture appeared centre-screen for an unlimited time. We asked SL for an initial free response. In later sessions questions followed if the information was lacking from the free response: 1) Is the picture right side up, or upside down? 2) How do you know that? 3) Describe some of the local elements of the picture. 4) What would you name this picture? An experimenter keypress initiated the next picture. All 3 image sets were randomly mixed in 2 blocks. Responses were recorded, transcribed, and coded for the presence of a global response and the content of local responses, both for free report and experimenter queries.

Control subject experiment: This tested whether the Arcimboldo pictures that SL always saw as faces (10 of 24 pictures) were identified as faces most quickly by controls. Control and Arcimboldo images were shown in random order, after a 300 ms mask, with unlimited duration. In two sessions 10 healthy participants responded with a two-alternative keypress as quickly as possible, indicating whether they saw a face. Key assignment was counterbalanced across sessions.

Experiment 2

Stimuli and Apparatus: Global letters were created in Adobe Photoshop, using local letters from the same list used for global letters. Each global letter was paired with one incongruent local letter to create 11 stimuli. Local letters were uppercase, Arial font. Global letters were constructed from a 17x17-item grid. Letters were black on a white screen. Three Sizes and three Densities generated 9 stimulus configurations. Each block had 11 trials of the same configuration and was performed twice, once for global report, once for local report (total 198 trials). Trials within each block and block order were randomized.

Procedure: Subjects (SL, 5 controls) were seated 57 cm from the monitor. They verbally identified letters at the specified level (Local or Global). Each trial consisted of a 300 ms visual mask, followed by a hierarchical letter, visible until the participant's response. The response was entered by experimenter keypress, initiating the next trial.

Analysis: A 3-way between-trials ANOVA assessed the influence of stimulus Size and Density on SL's accuracy. This included main factors of stimulus Size (Small, Medium,

Large), Density (Sparse, Medium Density, Dense) and Task (Global, Local). To further investigate interactions involving Task, we performed two secondary 2-way ANOVAs (Global Task and Local Task), with main factors of Size and Density. A Fisher's LSD comparison of means followed any main effects. Alpha levels were $p < 0.05$.

Control subject experiment: This experiment assessed how Size and Density affected the balance between local and global processing in controls, determining if this balance correlated with SL's global reporting. Participants ($n = 4$) performed a reaction time (RT) study with hierarchical letters of the same configurations seen by SL. Participants reported the letter at the instructed level by keypress. Global and Local sessions consisted of 9 blocks each, one per stimulus configuration, in random order. Each block had 40 randomly ordered trials. Letters were presented after a 300 ms visual mask, remained on-screen for 100 ms, followed by a blank screen. The difference between mean Global and mean Local RTs was calculated. SL's Global accuracy score was linearly regressed against these difference scores.

Results

Experiment 1

SL described correctly 100% of Local control pictures and reported image orientation correctly in 95% of trials. She was 100% accurate at identifying and reporting orientation of Upright and Inverted face controls.

SL reported that the Arcimboldo images were faces or contained face elements (e.g. "I can see the nose", not "I can see a pear") on 68% of Upright and 50% of Inverted trials. In 55% of Upright and 46% of Inverted trials she identified the picture in its whole context,

(e.g. a face, person, etc). There was no significant difference between number of Upright and Inverted images identified as faces, $t(61) = 0.541, p = 0.590$. Her reports of local components were revealing. At times (25% Upright, 13% Inverted) local elements external to the face were reported in relation to the global percept of the face (e.g. “I see a flower on the head”). There were no instances where she reported faces made up of a theme of local elements, which controls did (e.g. “It’s like a bowl of vegetables that looks like a face”).

Control experiment: Healthy participants were faster at responding to Arcimboldo pictures that SL always identified as faces than to those for which she sometimes identified local objects instead of faces, in Upright, $t(90) = -3.63, p < 0.001$, and Inverted orientations, $t(101) = -3.17, p = 0.002$ (Table 2.1).

Table 2.1. Reaction times for healthy participants classifying Arcimboldo images

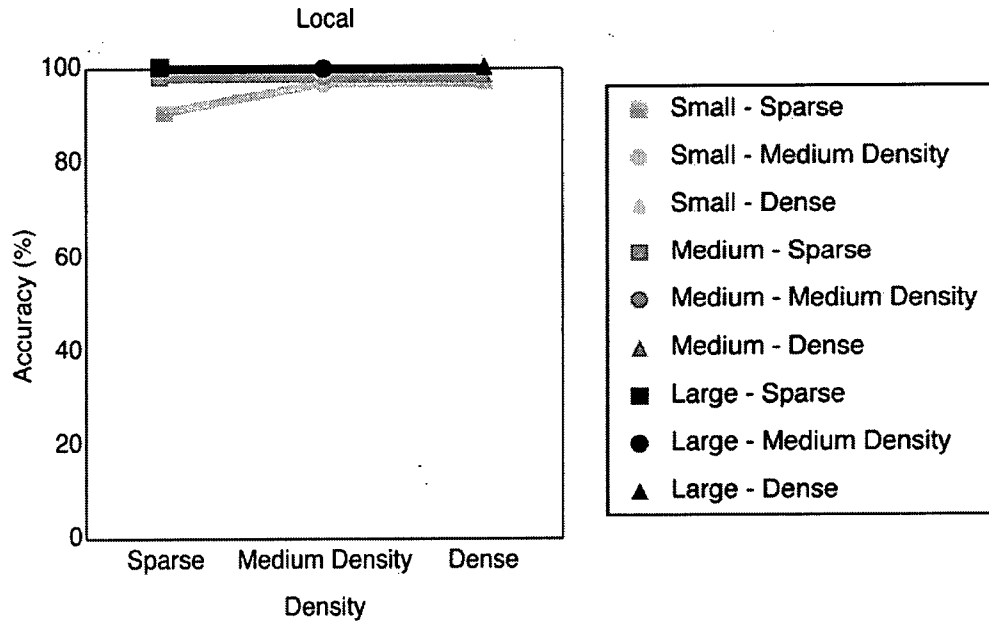
	SL Always saw face	SL did not always see a face
Upright	622.94 (23.49)	804.85 (44.21)
Inverted	688.03 (32.31)	829.99 (30.94)

Mean reaction time (ms) of healthy controls for categorizing Upright and Inverted Arcimboldo pictures that SL either always identified as faces or did not always identify as faces. Standard errors are in parentheses.

Experiment 2

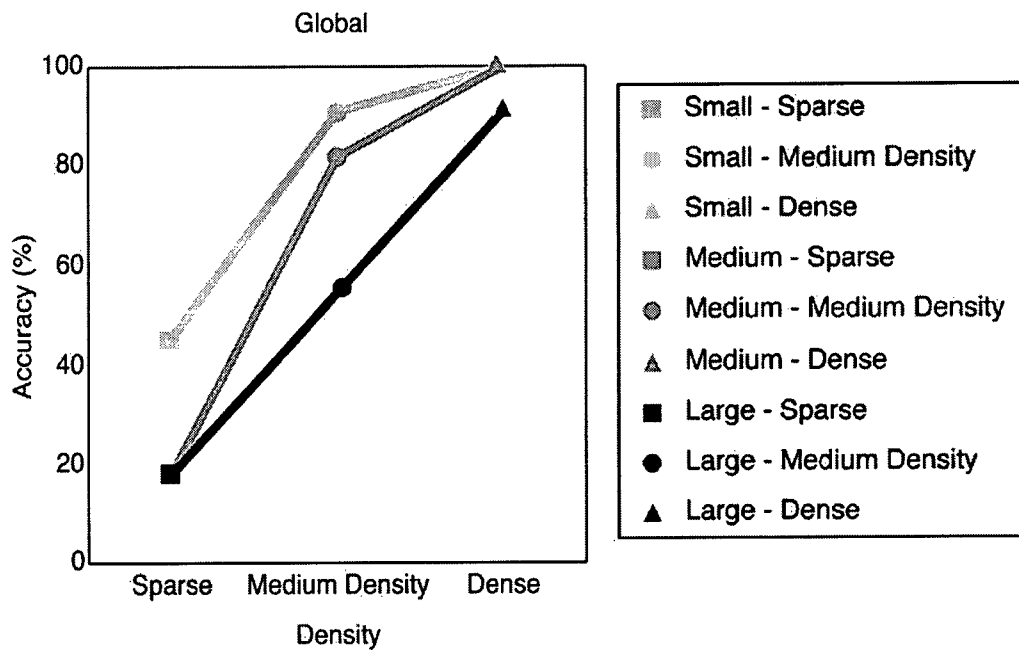
Control subjects achieved near-perfect accuracy in all letter conditions, Global or Local. SL accurately named Local letters in all conditions, making only one mistake (Figure 2.2). She did less well with Global letters, reflected by a significant main effect of Task, $F(1,180) = 71.11, p < 0.001$ (Figure 2.3).

Figure 2.2. Patient accuracy – Local letters



Patient accuracy (out of 100%) for naming local Navon letters. Symbols represent the different Size and Density conditions.

Figure 2.3. Patient accuracy – Global letters



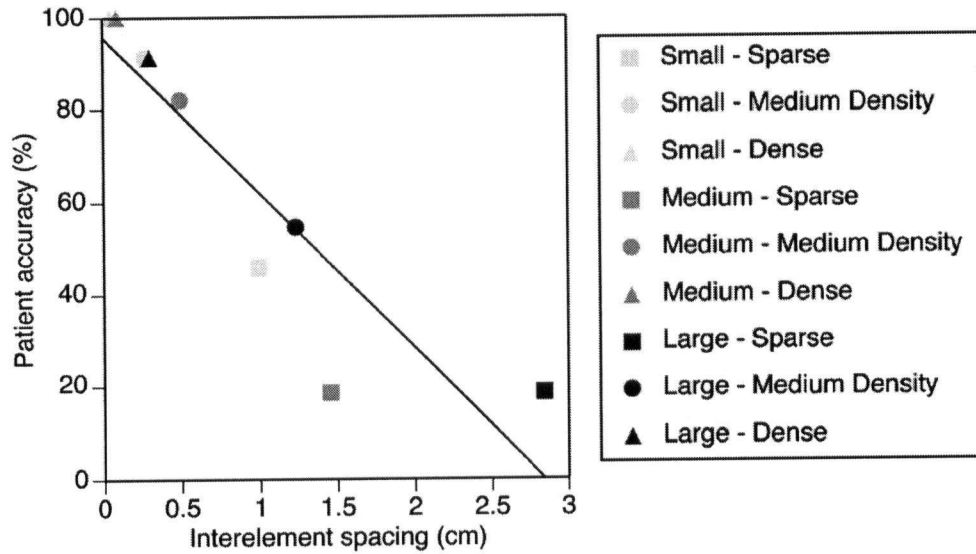
Patient accuracy (out of 100%) for naming global Navon letters. Symbols represent the different Size and Density conditions.

Her performance also varied with stimulus parameters. Although there was no Task x Size x Density interaction, $F(4,180) = 1.01, p = 0.41$, or Size x Density interaction, $F(4,180) = 0.590, p = 0.67$, there was a significant Size x Task interaction, $F(2,180) = 4.24, p = 0.016$, and a significant Density x Task interaction, $F(2,180) = 26.32, p < 0.001$. These interactions were investigated in a 2-way ANOVA for Global Task.

Global task analysis - Naming the Global letter depended significantly on both Size and Density. There was a significant main effect of Density, $F(2,90) = 31.12, p < 0.001$, and Size, $F(2,90) = 3.58, p = 0.032$ (Figure 2.3). All densities differed from each other, (Sparse vs Medium Density, $p < 0.001$; Sparse vs Dense, $p < 0.001$; Medium Density vs Dense, $p = 0.021$). As local elements became more densely packed, Global naming improved. There was a significant difference between Small and Large letters, $p = 0.009$, but not between Small and Medium, $p = 0.184$, or Medium and Large letters, $p = 0.184$. The Size x Density interaction was not significant, $F(4,90) = 0.78, p = 0.54$.

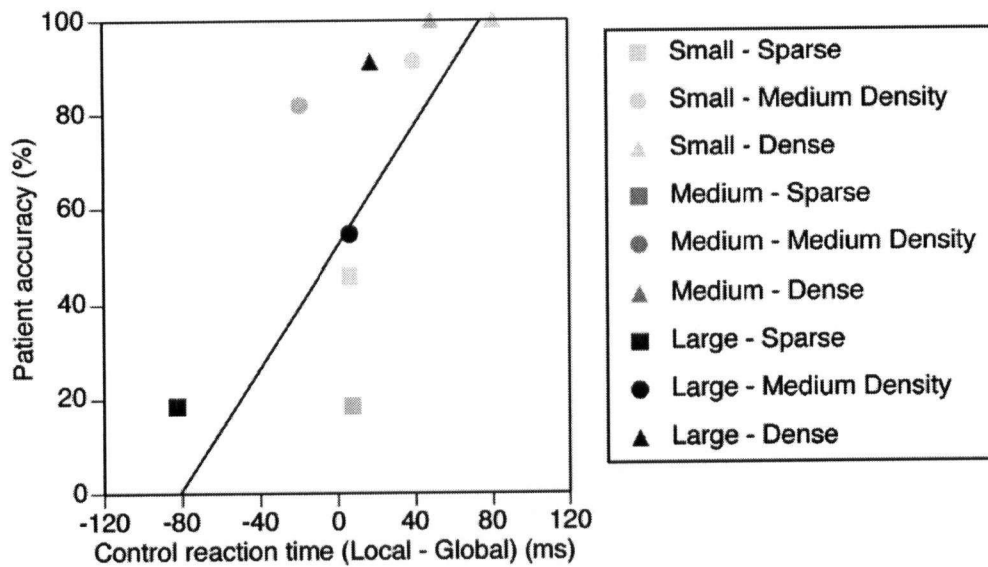
Correlations - SL's global reporting negatively correlated with the separation between local elements, $r = -0.91, p < 0.05$ (Figure 2.4). Her global reporting also correlated with the Global/Local RT difference in control subjects: as controls became faster at naming Global letters, SL's Global naming accuracy improved, $r = 0.71, p < 0.05$ (Figure 2.5).

Figure 2.4. Patient accuracy (Global letters) as a function of inter-element spacing



Patient accuracy (out of 100%) for identifying global letters as a function of distance between local elements, measured from adjacent edges of neighbouring local elements (cm). Line represents correlation between patient accuracy and distance between local elements. Symbols represent the different Size and Density conditions.

Figure 2.5. Patient accuracy (Global letters) as a function of control reaction time



Patient accuracy (out of 100%) for naming global letters of various sizes and densities as a function of level precedence experienced by healthy controls (ms). A positive reaction time (RT) indicates a faster response for naming the global letters compared to the local letters. A negative RT indicates a faster response for naming local letters compared to global letters. Symbols represent the different Size and Density conditions.

CHAPTER 3:

Discussion¹

These results demonstrate that local capture is not a general phenomenon in simultanagnosia; “global capture” can even occur: with Arcimboldo faces SL often reported only the global percept.

This global capture is not likely due to experimenter questioning, priming of the face aspect of the Arcimboldo images, or to a guessing strategy employed by SL. First, questions were designed to avoid leading SL and were posed for both Arcimboldo and control images. Second, Arcimboldo images were mixed with control images of non-face objects, reducing priming effects from previous face stimuli. Third, SL did not report seeing faces in non-face control stimuli, providing further evidence against a guessing strategy.

To determine whether SL was simply failing to report that she saw local objects in the Arcimboldo images, the experimenter specifically asked for descriptions of the local elements of the picture. Though one might question whether SL understood what was meant by ‘local elements’, the fact that she responded to the instructions by reporting the local elements of the face (facial features), and in some trials did report the local objects in Arcimboldo paintings, suggests that she did understand what was being asked.

While we replicated previous findings of local capture with large, sparse Navon stimuli (Karnath, Ferber, Rorden, & Driver, 2000), we also showed that local capture was a function of stimulus size and density, with more global letters reported (less local capture) for smaller

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and more dense stimuli. For both faces and letters, SL was more likely to report the global percept with stimuli for which control subjects were faster to identify the global level, suggesting that her perception is influenced by the same factors that balance local versus global perception in healthy subjects. SL shows a narrowing of attention that can exclude either the local or global frame of reference from awareness, depending on the stimulus.

Previous experiments have shown behaviourally (Karnath et al., 2000) and electrophysiologically (Jackson, Swainson, Mort, Masud, & Jackson, 2004), that simultanagnosic patients with local capture exhibit implicit global processing. We extend these results by demonstrating that global processing can emerge explicitly with appropriate stimulus conditions. This is consistent with a recent report that simultanagnosic patients reported the global identity of Navon stimuli more frequently as stimulus density increased (Huberle & Karnath, 2005). We show that global report also improves with decreasing size. Our combined size-density data (Figure 2.4.) show that the critical aspect for explicit global report may be absolute distance between local elements rather than density or size.

We further show that conditions facilitating explicit global report in simultanagnosia are similar to those favouring global processing in normal subjects. Reducing inter-element spacing of global configurations decreases latency to a global target, a finding attributed to decreases in attentional global processing demands (Enns & Kingstone, 1995). The expression of defective visuospatial attention in simultanagnosia is thus influenced by the attentional requirements of the stimulus. Figures 2.4 and 2.5 confirm that SL's global report is correlated with separation between local elements, as is the relative efficiency of global reporting in normal controls.

Despite SL's variable identification of global letters, she is consistently accurate at naming local letters. Enns and Kingstone (1995) found that decreasing size and inter-element spacing of hierarchical stimuli influenced the search slope for global targets, but not for local targets. Since visual search reaction-time slopes reflect attentional demands (Enns & Kingstone, 1995), this suggests that stimulus size and density affect the attentional demands of detecting a global target but not a local one. This may explain why SL, who is likely operating with limited attentional resources (consistent with her subnormal attention in digit span, letter and number sequencing), did not show an influence of these parameters on local letter report, but identified global letters less for stimuli with sizes and densities that increased attentional demand.

Faces may be a particularly strong stimulus requiring minimal attentional resources for global processing. For example, the 'composite effect', often cited as evidence for holistic face processing, occurs with full or divided attention (Boutet, Gentes-Hawn, & Chaudhuri, 2002). With Arcimboldo pictures this global advantage for faces, combined with the high density of local elements, may have promoted the global facial percept over the local elements. With reduced attentional resources, SL may perceive only the least attentionally demanding of two competing percepts. The importance of saliency in determining which level SL saw is supported by the finding that images SL did not consistently report as faces are more difficult for healthy subjects to group into a coherent whole.

Our results suggest that, in contrast to previous reports of simultanagnosia, SL is not being captured by the local stimulus level, but is instead being captured by the least attentionally demanding stimulus level. Possibly also implicit in the concept of capture is a

difficulty in shifting attention between the stimulus levels, so that after being drawn to the most salient level, the patient has trouble shifting to the less salient one. This would suggest a rigidity as well as a restriction of attention. This rigidity is not likely a complete failure, though: when SL was unable to report the global letters, she did not mistakenly report the local letters, but instead made an error that was a perceptual approximation of the global letter (e.g. reporting 'P' for a global letter 'F'), suggesting degraded access to the global level.

The present findings suggest that lesions of the parietal-occipital cortices, regions that form part of an attentional network in the brain, likely lead to a restriction and/or rigidity of visual attention, such that a patient preferentially attends to one stimulus level at the expense of another. In contrast to implications from previous concepts of local capture, the parietal lobes are likely not responsible for directing attention to the global stimulus level. Rather, it is likely that they facilitate fluidity of attention between both global and local elements, and when dysfunctional, reduced attentional resources are directed to the least attentionally demanding stimulus level. This results in an interaction of limited attention with the saliency of local and global percepts that are in competitive balance with each other, so that either local or global capture can occur.

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