

Global and Local Processing in Object Categorization

by

Mary-Ellen Large

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for the degree of Doctor of Philosophy

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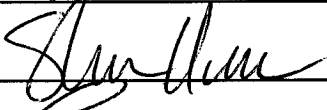
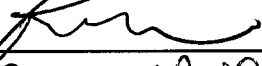
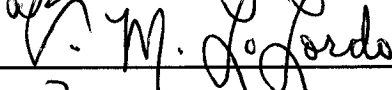
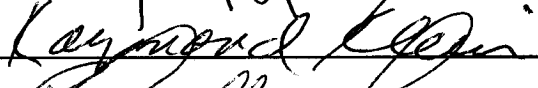

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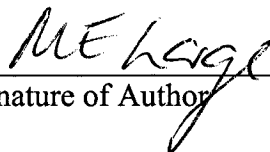
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DEDICATION

I would like to dedicate this thesis to my mother and my father. My father, Ken Large passed away just as I began my graduate career. I wish he'd been around, I know he would have been thrilled to see me complete my PhD. He was so excited when I started on this path although he worried that I might be disappointed. Its OK Dad, I haven't been disappointed. A bit surprised maybe that I've survived so far. My mother, Margaret Large has been incredibly supportive as always. I am so proud of her. Whenever I felt down or burdened, I would think about Mom and all she has gone through over the same time period and the load seems that much lighter.

TABLE OF CONTENTS

INTRODUCTION.....	1
THESIS STATEMENT	1
MOTIVATION.....	1
GOALS / OBJECTIVES	4
CONTRIBUTIONS	7
GLOBAL AND LOCAL PROCESSING.....	11
(I) GLOBAL AND LOCAL PROCESSING AND SPATIAL EXTENT	12
(II) GLOBAL AND LOCAL PROCESSING AND THE 'CATEGORICAL' MODEL OF ATTENTION	14
(III) GLOBAL AND LOCAL PROCESSING AND PERCEPTUAL ORGANIZATION	16
(IV) GLOBAL AND LOCAL PROCESSING AND OBJECT RECOGNITION.....	19
OBJECT CATEGORIZATION	21
(I) LEVELS OF CATEGORIZATION	21
(II) VISUAL SIMILARITY AND CATEGORIZATION.....	25
(II) OBJECT CATEGORIZATIONS AND GLOBAL AND LOCAL PROCESSING.....	30
INVESTIGATIVE METHOD	32
RESEARCH OBJECTIVES	40
(I) GLOBAL AND LOCAL PROCESSING IN OBJECT RECOGNITION	40
(II) SELECTION OF GLOBAL OR LOCAL LEVELS OF PROCESSING	42
(III) FIXED OR FLEXIBLE GLOBAL-TO-LOCAL SEQUENCE IN PROCESSING	44

(IV) EFFECTS OF GLOBAL AND LOCAL PROCESSING ON OBJECT RECOGNITION: ARE THEY
BASED ON THE SPATIAL EXTENT OF ATTENTION OR GROUPING AND PARSING PROCESSES?

49

EXPERIMENT 1	51
METHOD	54
RESULTS	57
DISCUSSION	59
EXPERIMENT 2	65
METHOD	69
RESULTS	73
DISCUSSION	82
EXPERIMENT 3	91
METHOD	93
RESULTS	95
DISCUSSION	104
COMBINED ANALYSIS OF DATA FROM EXPERIMENTS 2 & 3	112
RESULTS	113
DISCUSSION	122
GENERAL DISCUSSION	126
IMPLICATIONS OF FINDINGS FOR THEORIES OF OBJECT RECOGNITION	133
FUTURE RESEARCH	137

CONCLUSION.....	139
REFERENCES.....	140
APPENDIX A.....	149
APPENDIX B	151
APPENDIX C	152
APPENDIX D	154
APPENDIX E	158

LIST OF FIGURES

Figure 1.	Three examples of hierarchical figures. A) A hierarchical figure made of letters in which the local level is made up of the same letters as the global level (consistent). B) A hierarchical figure made up of digits in which the local level is made up of different digits from the global level (inconsistent). C) A hierarchical figure made up of symbols (inconsistent).	13
Figure 2.	Illustration of a parallel processing model for perceptual grouping and local selection in hierarchical analysis (source, Han et al 1999, pg. 1421).	17
Figure 3.	An example of a hierarchical organization of objects belonging to the superordinate category of 'animal'. At the basic level are categories of fish, birds and dogs and at the subordinate level there are categories of finches, swallows, seagulls and pigeons.	22
Figure 4.	Illustrates variations in visual similarity between members of different basic level categories (BASIC) or between members of the same basic level categories (SUBORDINATE). According to Biederman et al's (1999) three types of subordinate categorizations, distinguishing a finch from an ostrich would be Type 1 (large differences in metric properties - short thick neck versus long thin neck); distinguishing a finch from a thrasher would be Type 2 (small scale differences in geon structural descriptions - small curved beak versus elongated beak); distinguishing a finch from a flycatcher would possibly be Type 3 (small differences in metric properties - slightly rounder head and body).	28
Figure 5.	Examples of the hierarchical figures used in the global and local task. The targets were two or five and could appear at the global or local level.	37
Figure 6.	Illustrates a typical sequence of trials in a block with the target object 'finch'. (See text for further details).	38

Figure 7.	Illustrates two mechanisms of global and local processing and how they may act on object images. A) Demonstrates how varying the size of the attentional window captures different scales of visual information. B) Demonstrates how grouping and parsing processes capture different scales of visual information.	50
Figure 8.	Examples of the various stimuli used in the object detection task for Experiment 1. Stimuli associated with each of the categorization conditions in Experiment 2 and Experiment 3. For each subordinate and basic level task the targets and distractors were either visually similar or visually dissimilar (see Appendix A for a list of objects).	55
Figure 9.	Reaction times to the target detection task after priming by a global/local divided attention task. The numbers in brackets are the percentage correct for each condition.	58
Figure 10.	The large and small hierarchical figures used in Experiment 2. The local level of the large hierarchical figure subtends the same visual angle as the global level of the small hierarchical figure. If attentional priming is due to grouping and parsing processes there should be differences in target detection times in relation to the primes. If attentional priming is due to the size of the attentional window there should be no difference in target detection times in relation to the primes.	67
Figure 11.	Hierarchical stimuli for the divided attention task. The approximate visual angles subtended at the global and local levels for each hierarchical figure are listed.	70
Figure 12.	Examples of the stimuli used in the object detection task in Experiment 2 and Experiment 3. For each subordinate and basic level task the targets and distractor were either visually similar or visually dissimilar (see Appendix C for a list of objects).	71
Figure 13.	Reaction times to the target detection task after priming by a global/local divided attention task. The numbers in brackets are the percentage correct for each condition.	75

Figure 14.	Mean reaction times to the target detection task in the context of visually similar and dissimilar distractors. The attention primes were either the global level of the small hierarchical figure or the local level of the large hierarchical figure. Both attention primes subtended the same visual angle. The numbers in brackets are the percentage correct for each condition.	77
Figure 15.	Mean reaction times to basic and subordinate target detections made in the context of visually similar or visually dissimilar distractors after priming by a divided attention task. The attention primes were hierarchical figures at various sizes (Large, Medium and Small). The numbers in brackets are the percentage correct for each condition.	78
Figure 16.	An illustration of how the large, medium and small sized primes may bias the distribution of attention. The differing distribution of attentional resources facilitates the processing of different perceptual attributes and this in turn influences the level at which an object's structural description is activated. The different colour boxes represent different levels in a hierarchical structural description of an object with the top most level representing coarse shape details and the lower levels representing progressively finer shape information.	86
Figure 17.	The digits used in the attention priming task for Experiment 3. The digits subtended the same visual angles as the global (G) and local elements (L) of the hierarchical figures in Experiment 2.	93
Figure 18.	Mean reaction times to the target detection task after priming by variously sized digits. The labels global and local refer to origins of the attention primes. Global element primes were the digits 2 and 5 that subtended the same visual angles as the global levels of the hierarchical primes in Experiment 2. Local element primes were the digits that subtended the same visual angles as the local levels of the hierarchical primes in Experiment 2. The numbers in brackets are the percentage correct for each condition.	96

Figure 19.	Mean reaction times to the target detection task made in the context of visually similar or dissimilar distractors preceded by attention primes. The attention primes were variously sized digits constructed from the hierarchical primes in Experiment2. The numbers in brackets are the percentage correct for each condition and the bars denote +/- 1 standard errors.	98
Figure 20.	Mean reaction times to the target detection task in the context of visually similar and dissimilar distractors. The attention primes consisted of the digits '2' and '5' which subtended the same visual angle and where constructed from the global element of the small hierarchical figure (Global Small) and the local element of the large hierarchical figure (Local Large) used in Experiment 2. The numbers in brackets are the percentage correct for each condition.	100
Figure 21.	Mean reaction times to basic and subordinate target detections made in the context of visually similar or visually dissimilar distractors after priming by single digits that varied in size. The attention primes were the digits '2' and '5' constructed by separating out the global and local elements of the large, medium and small hierarchical figures used in Experiment 2. The numbers in brackets are the percentage correct for each condition	101
Figure 22.	Mean reaction times for basic and subordinate target detections in the context of visually similar and dissimilar distractors. The attention primes were the global elements of the small hierarchical figure/small digit group or the local element of the large hierarchical figure/large digit group. All attention primes subtended the same visual angle.	115
Figure 23.	The percentage of correct responses to subordinate (squares) or basic (circles) target detections after priming by either hierarchical figures (solid lines) or separate digits (dotted lines). All of the attention primes subtended the same visual angles.	117

Figure 24.	Mean reaction times to subordinate and basic target detections made in the context of visually similar or visually dissimilar distractors after priming by either hierarchical figures (solid lines) or separate digits (dotted lines). The attention primes varied in size (Large, Medium and Small).	118
Figure 25.	The percentage of correct responses to target detections made in the context of visually similar or visually dissimilar distractors after priming by either medium sized hierarchical figures (solid lines) or medium sized separate digits (dotted lines).	121
Figure 26.	A model of the relationship between global and local processing, the distribution of attention and the effects of prior knowledge, perceptual demands and priming by hierarchical figures on the recognition of an object (see text for a full explanation).	129

LIST OF TABLES

Table 1.	The level of attention, which primed the target detection task in each of the four conditions as a function of the size of the hierarchical prime for Experiments 1 and 2. Local refers to faster target detections after local level decisions. Global refers to faster target detections after global level decisions. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.	87
Table 2.	The level of attention, which primed the target detection task in each of the four conditions, as a function of the size of the attention primes for Experiments 2 and 3. Local refers to faster target detections after local level decisions or local element decisions. Global refers to faster target detections after global level decisions or global element decisions. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.	107
Table 3.	A comparison of the priming effects of the global level or element of the small hierarchical figure and the local level or element of the large hierarchical figures. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.	124

Abstract

An implicit assumption of cognitive research into the allocation of global and local attention is its importance during the visual recognition of objects and scenes in real world contexts. However, most of the knowledge accumulated about global and local attention is based on effects of the recognition of artificial hierarchical stimuli (Navon figures) that bear little resemblance to naturally occurring objects. To this end, the thesis examined effects of global or local attention (using a divided attention task with hierarchical figures) as they primed subsequent detection of target objects at different levels of category identity (basic and subordinate). Target objects were identified among distractor objects that varied in their degree of visual similarity to the targets. If levels of attention priming affected the level of categorization (basic vs. subordinate) then attention selection is related to conceptual aspects of object recognition. Conversely, if levels of attention priming affected levels of distractor similarity (similar vs. dissimilar) then attention selection is related to earlier perceptual aspects of object recognition.

Evidence was found to support a role for global and local processing in the recognition of real world objects. Global priming was beneficial for basic level target detections when objects were visually dissimilar, and local priming was beneficial for subordinate level target detections when objects were visually similar. Effects of attention priming were sensitive to visual similarity suggesting that global and local attention were strongly influenced by early perceptual processes. Global or local priming occurred in a flexible manner depending on the nature of the recognition task. It was proposed that global and local processing aids the selection of perceptual attributes of the object diagnostic for recognition, and that selection is based on two mechanisms; spatial extent and grouping/parsing operations.

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Introduction

Thesis Statement

The primary purpose of this research was to provide empirical evidence indicating that global and local attention, as conceptualized by Navon (1977), are used in the recognition of more realistic objects. Global and local levels of attention were manipulated prior to the performance of an object detection task. It was postulated that if global and local attention were used in object recognition, then performance on the object detection task should vary depending on the level of attention.

Motivation

Since Navon's (1977) seminal paper "The Forest Before The Trees: The Precedence Of Global Features In Visual Perception" there have been numerous research papers on the topic of global and local processing. An implicit assumption of this cognitive research into global and local processing is its importance during the visual recognition of objects and scenes in real world contexts. It has been argued that the structural organization of objects and scenes is hierarchical such that global levels of structure encompass local structural components (Hoffman, 1980; Kinchla & Wolfe, 1979; Navon, 1977; Paquet & Merikle, 1988; Robertson, 1996; Ward, 1982, amongst many others). For example, the human body has a basic bipedal form at the global level, which contains many details such as arms, legs and torso. These local details can be further broken down into hands, feet, and chest and again into fingers, toes and ribs. However, most of the knowledge accumulated about global and local processing is based on effects of the recognition of artificial hierarchical stimuli (Navon figures) that bear little resemblance to naturally occurring objects.

A number of models have been proposed to account for effects of global and local processing. These can be divided into two broad categories. One set of models considers the spatial extent of attention, in which attention is focused on a region of space that can vary in size (Lamb & Robertson, 1988; Lamb & Yund, 2000; Robertson, Egly, Lamb & Kerth, 1993; Robertson, 1996). The size of the attended region would be relatively larger for global processing than local processing. Other models are based on principles of perceptual organization which propose that visual information is divided into global and local processing streams on the basis of grouping local elements for global identifications or parsing local elements for local identifications (Han, Humphreys & Chen, 1999a,b; Kimchi 1998; 2000). In both models a distinction is made between attending to the coarse structure of an object's visual properties at the global level and attending to fine details at the local level.

This notion of coarse and fine detailed visual information is also relevant to object categorization (Archambault, Gosselin & Schyns, 2001; Morrison & Schyns, 2001; Oliva & Schyns, 1997; Schyns & Oliva, 1999; Snowden & Schyns, 2000). Objects can be categorized at various levels of specificity. At the most general level (superordinate) the object dog could be called an “animal”, at an intermediate level (basic) it could be called a “dog” and at a specific level (subordinate) a “beagle”. It is at the basic level that objects are most likely to be identified and named most quickly (Jolicoeur, Gluck & Kosslyn, 1984; Murphy & Brownell, 1985; Rosch, Mervis, Gray and Boyes-Braem, 1976). One of the reasons that subordinate categorizations may take longer is that perceptual information required to categorize objects at this level is less discriminable than the information required for basic level categorizations (Biederman, Subramaniam, Bar,

Kalocsai & Fiser, 1999; Jolicoeur et al, 1984). In general, it is likely that subordinate categorizations entail visual processing of fine details of an object's structure while basic level categorizations entail processing coarse scale information about an object's structure. Global and local processes may involve allocating attentional resources to facilitate the selection of fine or coarse-scale perceptual cues diagnostic for the recognition or categorization of an object.

However, it is also important to consider effects of visual similarity in visual tasks (Duncan & Humphreys, 1989). It has been shown that the degree of visual similarity or dissimilarity between objects belonging to the same category can affect performance on categorization tasks. For example, responses to atypical category members are quicker at the subordinate level than the basic level (Jolicoeur et al, 1984, Murphy & Brownell, 1985). Of course, atypical exemplars (e.g., ostrich, penguin) are generally more visually distinct from other within-category exemplars. Lloyd-Jones & Humphreys (1997a; 1997b) demonstrated that structurally similar objects (fruits and vegetables) were more difficult to name at the basic level and more difficult to categorize at the superordinate level than structurally dissimilar objects (clothing and furniture). Their results suggested that visual similarity is not just a factor in subordinate category judgements but also a factor in basic level and superordinate level category judgements. Accordingly, discriminations between visually dissimilar objects could rely on coarse scale perceptual information and discriminations between visually similar objects could rely on fine scale perceptual information, independently from the category level of the object. Consequently, global and local processes in object recognition may be more responsive to degrees of visual similarity between objects than to category membership.

In order to investigate the role of global and local processing in object recognition this research made use of a well-known effect in the attention literature, the level repetition effect. Using hierarchical stimuli to manipulate global and local levels of processing, the level repetition procedure involves comparing the performance on a second stimulus presentation when the attention levels for the first and second stimulus presentations are the same versus when they are different. It has been found that the efficiency of detecting targets increased when the level of attention was repeated across consecutive stimulus presentations. The level repetition effect has been shown to be long lasting (Robertson, 1996; Ward, 1982) and robust to changes in target form and target location (Fileteo, Friedrich & Stricker, 2001; Hübner, 2001; Lamb & Yund, 1996; Ward, 1982). Thus, a priming paradigm was chosen similar to that used in studies of level-repetition effects. A global and local divided attention task preceded and primed a subsequent target detection task in which participants indicated the presence of a target or a distractor object at either a basic level or subordinate level of categorization. The degree of visual similarity between the targets and distractors in the target detection task was manipulated.

Goals / Objectives

This research had four main objectives. The first objective was to provide empirical evidence indicating that global and local processing are used in the recognition of more realistic objects. More specifically, the aim was to determine whether global processing influenced the selection of coarse-grained information from the input image and local processing influenced the selection of fine-grained information. Given that the perceptual demands on the visual system may vary depending on the nature of a

recognition task (Morrison & Schyns, 2001; Schyns, 1998) the investigation focused on the role of global and local processing in categorizing objects at basic or subordinate levels.

The second objective was to determine how global and local levels of processing were selected. Was it on the basis of conceptual knowledge of an object or the perceptual demands of the object detection task? Global and local processing are traditionally investigated using hierarchical figures that were developed to measure early perceptual/attentional processes. Effects related to top-down conceptual knowledge are generally not considered. However, with more realistic objects there is the possibility that prior knowledge of the visual properties of the object may influence whether global and local levels of processing are instigated. Recent research has shown that conceptual knowledge can influence perceptual processes (Boucart & Humphreys, 1992; Boucart, Humphreys & Lorenceau, 1995; Gauthier, James, Curby & Tarr, in press; Humphreys & Boucart, 1997; Murray & Jones, 2002) and differences in the way objects are categorized can change how they are perceived (Goldstone, Lippa, & Shiffrin, 2001; Schyns & Rodet, 1997). With more realistic objects it is possible that the allocation of attention at either global or local levels is mediated by prior conceptual knowledge of the visual properties of objects. When stored representations of target objects are activated by the object label, the level of the representation may differ depending on the specificity of the target label. For example, the representation for 'dog' may only include coarse scale shape information, whereas the representation for 'beagles' may incorporate fine scale shape information. These top-down processes may in turn influence the allocation of attentional resources such that a global level of attention is initiated for coarse scale representations

and a local level of attention is initiated for fine scale representations. Alternatively, the level of attention may be modulated by the perceptual requirements of the task.

Discriminating a particular breed of dog amongst other dogs biases attention towards detailed shape information. Discriminating a particular breed of dog amongst a group of man-made objects biases attention towards coarse scale information.

The third objective was to determine whether attentional resources would be allocated flexibly depending on the nature of the recognition task or in fixed global-to-local sequence. Reverse hierarchy theory (Hochstein & Ahissar, 2002), the automatic activation of semantic information from global shape (Boucart & Humphreys, 1992; Boucart et al, 1995; Humphreys & Boucart, 1997) and Sanocki's (1998, 2001) studies suggest that in object recognition, the visual system commences with processing coarse scale information in the input image, and fine scale information is processed at later stages. If this is the case then one might expect that global level priming would enhance performance for all recognition tasks regardless of the level of categorization or the degree of visual similarity between objects. However, if the visual system can process coarse scale and fine scale information interchangeably, as suggested by Schyns and his colleagues (Morrison & Schyns, 2001; Oliva & Schyns, 1999; Schyns, 1998) then one might expect that the priming effects of the global and local task will be sensitive to the nature of the object recognition task.

The fourth and final objective was to determine whether the use of global and local processes in connection with more realistic objects was related to the distribution of attention across a region of space or to parsing/grouping processes occurring during recognition. Investigations examining global and local processing of hierarchical figures

support the involvement of both of these mechanisms. Theoretically, either or both of these mechanisms could be involved in the processing of global and local features of a pictorial image. On the one hand, researchers investigating automatic activation of semantic information associated with the global form of objects speculate that attentional resources are distributed across a region in space (Boucart & Humphreys, 1992; Murray & Jones, 2002). Edelman and Intrator (2003) postulated that access to different levels of object representations is mediated by the spatial extent of attention. On the other hand, global and local processing may play a role in parsing images into a hierarchy of modular parts (Biederman, 1987; Duncan & Humphreys, 1989; Marr, 1982). Global processing could capture visual information relevant for generating input representations that match large scale components of an object's structure. Similarly, local processing could capture visual information relevant for generating input representations that match small-scale components of an object's structure (Han et al, 1999a).

Contributions

Evidence was found to support a role for global and local processing in the recognition of real world objects. Local level priming facilitated subordinate target detections made in the context of visually similar distractors. Global level priming was associated with basic target detections or target detections made in the context of visually dissimilar distractors. Shifts between global and local levels of attention facilitated the selection of coarse or fine-grained information from the stimulus. When categorizing visually similar objects the attentional bias was towards fine-grained information selected at the local level. Conversely, when categorizing visually dissimilar objects the attentional bias was towards coarse-grained information selected at the global level.

Were global and local levels of processing selected on the basis of conceptual knowledge or the perceptual demands of the object detection task? In support of the influence of perceptual demands, for similar sized hierarchical primes and objects it was found that local level decisions facilitated target detections when the distractors were visually similar and global level decisions facilitated target detections when the distractors were visually dissimilar. However, when hierarchical primes were smaller than the objects in the target detection task, subordinate target detections were faster preceded by local level decisions and basic target detections were faster preceded by global level decisions. This result supported the influence of prior knowledge about the attributes of the target objects on the selection of global or local processing streams.

It was proposed that the perceptual attributes of objects are separated into global and local processing streams that operate in parallel and compete with each other to produce a response output. The distribution of attentional resources increases the efficiency in which perceptual information is selected for either the global or local processing stream. The priming action of the hierarchical figures could either complement or conflict with the distribution of attentional resources prescribed by top down processes or bottom-up processes. In support of this claim, when stored knowledge, perceptual demands, and the priming level of the hierarchical figure complemented each other there were consistent priming effects in Experiments 1 and 2. In contrast, when there was a conflict between the distribution of attentional resources initiated by prior knowledge and those initiated by the perceptual demands of the task, effects of attention priming were more variable.

Was there a fixed or flexible global-to-local sequence in the priming effects of the divided attention task on the object detection task? It was suggested that a fixed global-to-local sequence in object recognition would produce global level priming for all the target detection tasks regardless of the level of categorization or the degree of visual similarity between objects. This was demonstrably not the case. The strongest evidence against a fixed global-to-local sequence was found in Experiment 1 where identical objects were primed by local level decisions when the distractor objects were visually similar to the target objects, and primed by global level decisions when the distractors were visually dissimilar to the targets.

Were the priming effects of the divided attention task based on a grouping/parsing mechanism or on the spatial extent of attention? The results of Experiments 2 and 3 indicated that two mechanisms were involved in the global and local priming effects on the object detection task. In support of a grouping/parsing mechanism, different priming effects were observed for stimuli that subtended the same visual angle but occupied different levels in a hierarchical figure. Also in support of a grouping/parsing mechanism, different priming effects were observed for large hierarchical stimuli compared to individual non-hierarchical stimuli subtending the same visual angles as the global and local levels of the large hierarchical figure.

In support of spatial extent, Experiment 3 demonstrated that varying the size of the attentional window had an impact on object detection performance when targets and distractors were visually similar. Priming by the global elements benefited basic target detections for large and small primes and priming by local elements benefited subordinate target detections for medium and small primes. Also in support of spatial

extent, no reliable differences were found between the priming effects of medium and small sized hierarchical figures and the priming effects of individual non-hierarchical stimuli subtending the same visual angles. Furthermore, different patterns of global and local priming were found for the three sizes of the hierarchical stimuli, indicating that size did matter and that some element of priming by the hierarchical figures was related to the size of the attentional window.

This research has demonstrated that global and local processing as understood by researchers using the global/local paradigm does apply to the recognition of real world objects. The mechanisms of spatial extent and grouping/parsing processes, which have been shown to operate for hierarchical figures, also apply to object recognition. As found with hierarchical figures, the importance of global and local information varies as a function of the perceptual demands of a task. However, unlike traditional research into global and local processing it was found that with real objects top-down processes could also influence the distribution of attention.

Global and Local Processing

Navon (1977) originally conceptualized global and local processing as a form of perceptual organization. From this perspective elements or features of visual stimuli, whether objects or scenes, can be grouped together to form a whole. Using the 'forest before the trees' analogy, the global level is the forest and the local elements are trees which are grouped together to make up the forest. The organization is hierarchical in that the global level encompasses the local level.

More recently, research has focused on the nature of the attentional mechanisms that influence global and local processing. One of the mechanisms studied relates to the spatial extent of attention in which attention is focused on a region of space that can vary in size. For example, if the attended region is large, this could benefit global processing and if the attended region is small this could benefit local processing. An alternative mechanism is 'categorical' attention (Robertson, Egly, Lamb & Kerth, 1993; Robertson, 1996) in which attentional resources are divided between global and local categories of features independently from the regions of space they cover. This chapter discusses some of the knowledge accumulated about global and local processes based on effects of the recognition of artificial hierarchical stimuli. In Section (I) and (II) global and local processing will be discussed in relation to attentional models. In section (III) more recent research about global and local processing and principles of perceptual organization will be discussed. Section (IV) will address the underlying assumption that global and local processing are used in recognizing objects and scenes in the real world.

(I) Global and local processing and spatial extent

Traditionally global and local processing have been studied using artificial stimuli called variously 'Navon figures', 'compound figures' or 'hierarchical figures'. They will be referred to as hierarchical figures in the succeeding pages. Figure 1 depicts some common examples of hierarchical figures. These figures consist of a number of small features at the local level that are grouped together to make up a single large feature at the global level. The features in a hierarchical figure can be any kind of symbol, digit or letter. Additionally local and global levels can be consistent or inconsistent with each other. That is, the global level can either be the same symbol as the local level (Figure 1a) or a different symbol (Figure 1b & 1c). In traditional hierarchical figures the local features are all the same kind of symbol.

There are two different models of attention in relation to spatial extent, one in which attention is conceptualized as a 'spotlight' that moves in space (Hillyard & Munte, 1984; LaBerge, 1983; Posner, 1980) and a second which conceptualizes attention as a gradient of heightened activity surrounding a region of interest (LaBerge & Brown, 1986; 1989). The 'spotlight' model of attention assumes that attention acts like a beam projected onto an area of the visual field. This beam can be moved to different locations in the visual field and the diameter of the beam can be adjusted depending on the area of focus. The 'spotlight' model was modified to incorporate a 'zoom lens' so that the 'spotlight' can also be adjusted in terms of its resolution (Eriksen & St.James, 1986, Eriksen & Yeh, 1985; Ward, 1982). At the global level the attentional beam is at a lower resolution compared to a beam focused on the local level. Thus, when the beam is at the global level

the identity of local features will be difficult to distinguish, as the more detailed visual information will be blurred at lower resolutions. When the beam is at a higher resolution both global and local features will be discriminable. Effectively the size of the beam would be a guide to the possible location of a target and the resolution would be adjusted according to whether the target occurred at either the global or local level in a hierarchical figure.

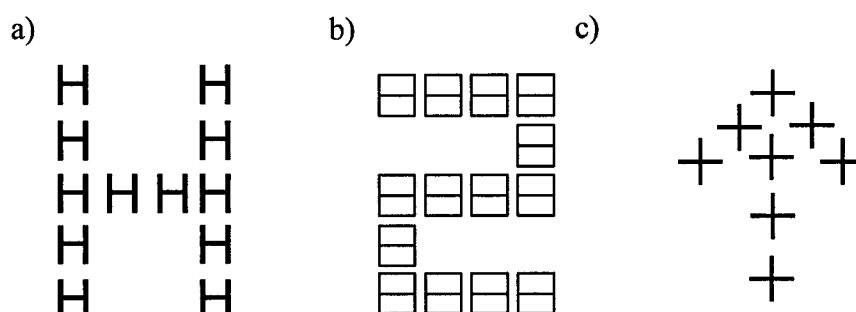


Figure 1. Three examples of hierarchical figures. A) A hierarchical figure made of letters in which the local level is made up of the same letters as the global level (consistent). B) A hierarchical figure made up of digits in which the local level is made up of different digits from the global level (inconsistent). C) A hierarchical figure made up of symbols (inconsistent).

The gradient model of attention is also concerned with the spatial extent of attention. In this model attention is spread across the visual field but the amount of attentional resources varies at different locations within the visual field. LaBerge & Brown (1986) describe the gradient as having a peak centering on the location requiring the most attentional resources and decreasing slopes at either side. According to the gradient model, when processing global and local forms, the total allocation of attentional resources will be the same regardless of the level since the range at which targets will be expected to appear in the visual field will be the same. However those resources will be

spread variably within this range. When attention is focused on the global level attentional resources will be spread more evenly across the stimulus as a whole and when attention is focused on the local level attentional resources will be focused around the location of a local feature.

An investigation into the effects of location uncertainty in the processing of hierarchical figures by Lamb & Robertson (1988) provided support for the role of spatial extent in global and local processing. Hierarchical patterns were presented at varied locations on a display screen or always presented in the center of the screen. When the location of the hierarchical patterns was uncertain then reaction times to central patterns were slower than when the location of the pattern was certain. It appeared that attentional resources were spread over a larger area for trials where the hierarchical figures could appear over a larger area of the visual field. When the location of the hierarchical figure was certain then attentional resources were confined to a smaller area of the visual field.

(II) Global and local processing and the 'categorical' model of attention

A criticism of the attention models based on spatial extent is that they cannot account for all aspects of global and local processing. Robertson et al (1993) and Lamb and Yund (2000) investigated effects of spatially cueing the level at which targets would be presented in hierarchical figures. The cues were rectangles that were approximately the same size as the global level or the local level. Both studies found that identification of global targets was faster when preceded by a global cue compared to a neutral cue (both global and local cues presented simultaneously), no cue at all or an invalid cue.

Similarly, identification of local targets was faster when preceded by a local cue. The enhanced performance provided by the level cues suggested that cues facilitated the processing of information that appeared within the region of space indicated by the cue, supporting the role of spatial extent in global and local processing.

However not all the data could be accounted for by this model. Robertson et al 1993 and Lamb and Yund (2000) also analyzed effects of repeating levels between consecutive trials. They found that global targets preceded by global targets were faster than global targets preceded by local targets and vice versa, local targets preceded by local targets were faster than local targets preceded by global targets. These effects suggested that level-specific information was being carried over from one trial to another, facilitating performance when levels repeated. Furthermore, the effects were independent of the cues. Robertson et al (1993) took this as evidence for a different mechanism they called 'categorical' attention, in which some feature of the level-specific information was sustained from one trial to another.

Robertson et al 1993 proposed that spatial frequency information was the feature that could separate global and local information. Global information would be carried by low frequency bandwidths and local information would be carried by high frequency bandwidths. In effect, attention would be distributed among spatial frequency channels rather than locations in space (see also Robertson, 1996).

Unfortunately, other studies that have manipulated the spatial frequency content of hierarchical figures have not replicated Robertson's (1996) findings (Hübner, 2000; Lamb & Yund, 1993; 1996; 2000; Lamb, Yund & Pond, 1999). Lamb & Yund (1996, 2000) proposed that level repetition priming effects were best explained by level-specific

neural mechanisms. According to the 'level-specific neural mechanism hypothesis' the repetition benefits are due to the fact that one or other level-specific mechanism is activated on trial one and is still active on presentation of a second stimulus. If the target is presented at the same level the processing of the target benefits from this increased level of activation. The major problem with the 'level-specific neural mechanism hypothesis' is that it lacks explanatory power. Knowing that there are level-specific neural mechanisms does not help us understand what characteristics of a hierarchical figure bias processing towards either the global or local level or what kind of attentional mechanisms are involved in separating global and local features in an image.

(III) Global and local processing and perceptual organization

As stated earlier in this section, Navon (1977) conceptualized hierarchical figures as transparent representations of the perceptual organization of visual information in which local features serve as constituents for a global structure. It could be that the division of attentional resources into global and local processing streams is based on gestalt principles of perceptual organization

There is a growing body of researchers investigating how Gestalt grouping principles such as proximity, closure and similarity interact with the processing of hierarchical figures (Han, Humphreys & Chen, 1999a; 1999b; Kimchi 1998; 2000). Han et al (1999a) proposed a parallel processing model for the role of perceptual organization in the processing of hierarchical figures which is reproduced in Figure 2. They argued that there are two processes of perceptual organization; one involves grouping local elements together; and the other selects individual local elements. The

process that groups local elements together produces global identifications and the process that selects individual local elements produces local identifications. These two processes operate in parallel and compete with each other in determining which level of the hierarchical figure dominates visual selection. They proposed that the outcome of the competition depends on the presence of gestalt factors (e.g. similarity and proximity) at the local level and the strength of local element grouping.

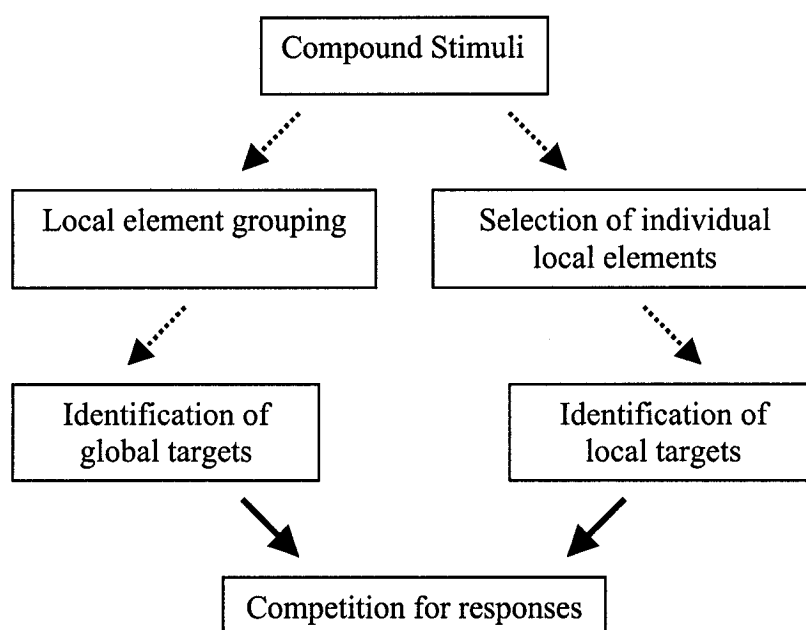


Figure 2. *Illustration of a parallel processing model for perceptual grouping and local selection in hierarchical analysis (source, Han et al 1999, pg. 1421).*

In support of this model, Han et al (1999a) showed that the global advantage could be reduced or eliminated by weakening the grouping processes. They accomplished this by presenting hierarchical figures made up of arrows or triangles presented on a background of 'plus' symbols. The presence of a background made it

difficult to group local elements on the basis of proximity since the local elements (plus signs, arrows and triangles) were all equally spaced. Decreasing the saliency of the global shape biased visual selection in favour of the local elements, producing a local advantage in reaction times. In another experiment, the global advantage was reduced by strengthening the selection of individual elements. This was achieved by using triangles as the local element in a global pattern of an arrow. It appeared that the gestalt factor of closure was a strong cue for visual selection.

According to Han et al's (1999a) model the relative advantage of global or local processing in hierarchical figures can be explained by parallel processing in perceptual organization. Increasing the visual angle of hierarchical stimuli (Kinchla & Wolfe, 1979, Lamb & Robertson, 1990) or reducing the number of local elements in a display (Kimchi 1998; Martin 1979; Navon, 1983) produces a bias in favour of the selection of local elements by weakening the role of proximity in grouping. In contrast, decreasing the visual angle (Kinchla & Wolfe, 1979, Lamb & Robertson, 1990) or presenting hierarchical figures in the periphery of the visual field, (Luna, 1993; Luna, Marcos-Ruiz & Merino, 1995; Navon & Norman, 1983) impedes the selection of local elements.

Han et al's (1999a) parallel model of perceptual organization may well account for level repetition priming effects. It could be that the division of attentional resources is based on grouping processes that select global features of hierarchical figures and parsing processes that select local features of hierarchical figures. Accordingly, level repetition effects could be explained by claiming that preceding trials bias either grouping processes or parsing processes and that this bias benefits target detections when levels are repeated in subsequent trials.

(IV) Global and local processing and object recognition

An underlying assumption of the research discussed in the above sections is that effects of global and local processing observed with hierarchical figures mirror the kind of global and local processing involved in recognizing objects and scenes in the real world. It is true that objects and scenes can be conceptualized as having levels of structure ordered hierarchically, where global levels encompass local structural components (Hoffman, 1980). A forest scene can be broken down into separate trees, bushes and other forest flora and fauna. However, hierarchical figures traditionally employed for research into global and local processing are artificial stimuli, which have no place outside the laboratory. How can we know that observations based on artificially constructed stimuli reflect how the visual and attentional systems operate with more realistic objects and scenes?

Hierarchical figures differ from real objects in a number of ways. For the most part they are made up of two levels. Objects on the other hand, are likely to contain multiple hierarchical levels. For example, one could say that the human body has a basic bipedal form at the global level, which encompasses local details such as arms, legs, torso and head. However, the hierarchy of form does not stop at this point. The local level features can be redefined as global relative to the local details they encompass, such as elbows and hands in the case of arms and so on.

A second major difference is that in hierarchical forms the local level is made up of identical elements. This is not the case for real objects although there may be some repetition in local details. The local details of a human body listed above illustrate this point. Heads, torsos, arms and legs all differ greatly in their overall shapes and sizes.

Furthermore, the local elements in hierarchical figures are independent of each other, whereas in natural objects it is likely that global differences are associated with local differences (Sanocki, 1998).

How might global and local processes affect the recognition of objects? Both in terms of spatial extent and grouping/parsing processes a distinction is made between attending to the coarse details of an object's visual properties at the global level and attending to fine details at the local level. This notion of coarse and fine detailed visual information is also relevant to object categorization. The next chapter discusses how global and local processing may be relevant to the categorization of objects at different levels of specificity.

Object Categorization

It is possible to classify single objects in more than one way. For instance a single object could be called a housefinch, finch, bird, or an animal. This example illustrates a hierarchical structure of categorization involving a sequence of categorizations in which each category includes all the previous ones. For example, the category finch includes all housefinches, bird includes all finches and animal includes all birds. In order to study effects of category hierarchies research has focused on three levels of categorization; superordinate, basic, and subordinate. As one moves down the hierarchy the level of categorization becomes more specific. At the most general level (superordinate) the object bird could be called an “animal”, at an intermediate level (basic) it could be called a “bird” and at a specific level (subordinate) a “finch” (see Figure 3). Research has shown that the semantic and visual processing requirements involved in categorizing objects differ when comparing superordinate and subordinate categorizations to basic categorizations (Jolicoeur et al, 1984; Murphy & Brownell, 1985; Murphy & Lassaline, 1997; Rosch et al, 1976). Section (I) in this chapter describes some of the properties of each the levels of categorization (superordinate, basic and subordinate). Section (II) discusses how visual similarity may effect object categorizations. Section (III) addresses how global and local processing may be involved in object categorizations.

(I) Levels of Categorization

One of the ways of distinguishing between different levels of categorizations is on the basis of informativeness and distinctiveness (Murphy & Lassaline, 1997; Rosch et al, 1976). Informativeness refers to the amount of information associated with a particular category level and distinctiveness refers to how different an object is compared to other members in a category at the same level (e.g., the differences between birds and dogs).

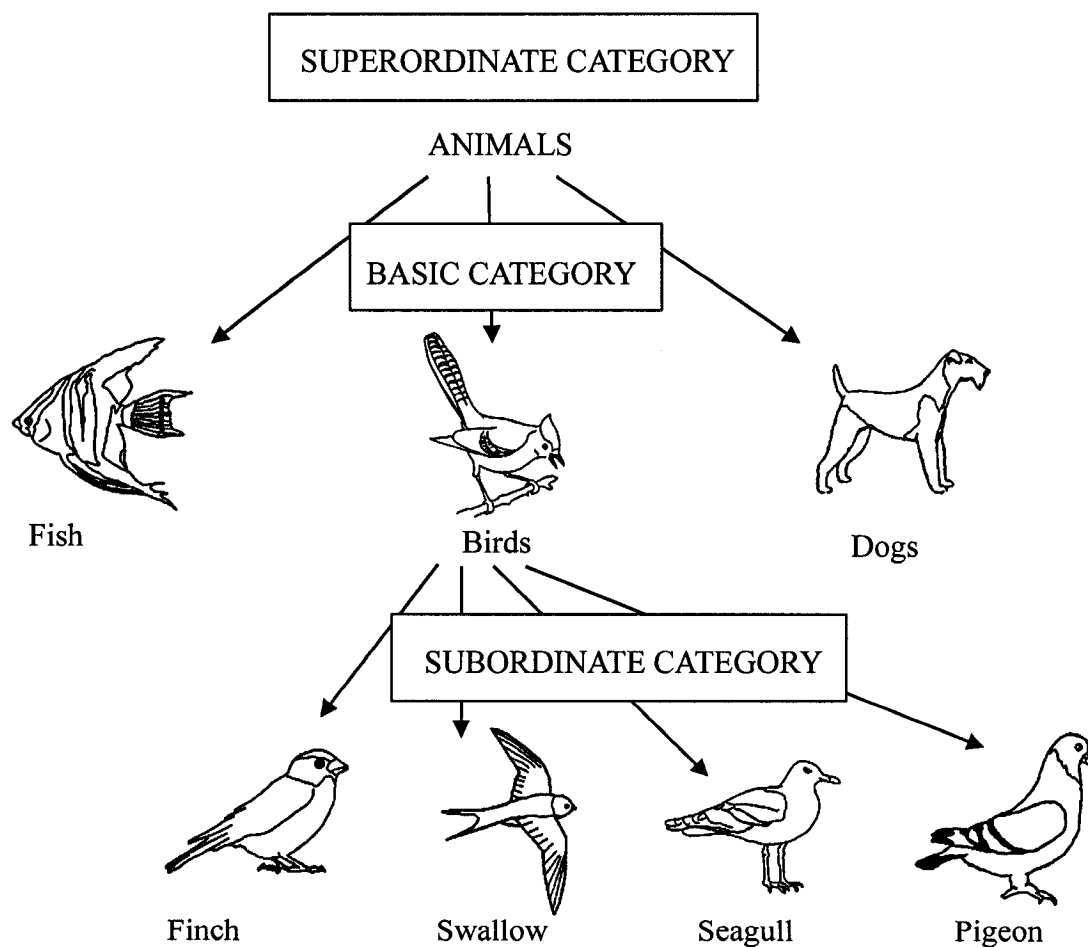


Figure 3. An example of a hierarchical organization of objects belonging to the superordinate category of 'animal'. At the basic level are categories of fish, birds and dogs and at the subordinate level there are categories of finches, swallows, seagulls and pigeons.

Superordinate level of categorization

Superordinate levels of categorization involve grouping objects together that have few features in common. Necessarily, this level of categorization is based on abstract and functional properties of the category members (Murphy & Lassaline, 1997; Rosch et al, 1976). Superordinate categories are very distinctive since category members are not very similar in appearance. For example, vehicles such as cars, airplanes and boats share few attributes in common. However, superordinate categories lack informativeness since little information is associated with an object when it is categorized at the superordinate level. For example, if your friends asked you to help move some furniture this could mean anything from moving a couple of coffee tables to a king-size bed.

Jolicoeur et al (1984) argued that superordinate categorizations proceed via semantic memory. They proposed that superordinate categorizations require the activation of basic (or as Jolicoeur named it 'entry level') level concepts and the activation of superordinate concepts involves searching semantic memory. Therefore naming pictures at a superordinate level would involve activating basic level concepts before retrieving a superordinate label.

Basic Level Categorizations

At the basic level the distinctiveness between classes of objects and the informativeness within a class are maximized. For instance, a “dog” is highly distinct from a “cat” and conveys more information than “animal”. In their seminal paper Rosch and her colleagues (1976) empirically defined basic level categorizations in four experiments. They found that at the basic level objects shared more attributes (visual, semantic and functional) in common than those at the superordinate level. Furthermore,

the number of attributes added for subordinate categorizations was less than the total listed for basic level categorizations.

Researchers have also found that there is a basic level superiority effect. The basic level superiority effect refers to the fact that objects are more likely to be named at the basic level (Rosch et al 1976). People are also faster to verify objects at the basic level or name them more quickly than at other category levels (Jolicoeur et al, 1984; Murphy & Brownell, 1985; Rosch et al, 1976). From the developmental literature it has been shown that the first categories in which children sort objects and name objects are basic level categories (Anglin, 1977; Mervis & Crisafi, 1982). In addition, basic level names are used more frequently and have fewer syllables than subordinate level names (Rosch et al, 1976).

Subordinate level categorizations

Subordinate level categorizations are highly informative because they are more specific and more useful for making fine distinctions between objects. They convey more information about an object than either superordinate or basic categorizations. However, they are much less distinctive. For example, naming an object as a greyhound tells you more about the object than naming it a dog. Not only does 'greyhound' encompass all the attributes of a dog but it also tells you that it is a hunting dog and it runs very fast. On the other hand a greyhound is not very different from other dogs. That is, different kinds of dogs share many attributes in common, which makes it more difficult to distinguish between them than between a cat and a dog. In general, subordinate category members differ from each other in terms of their perceptual properties. A greyhound has long legs,

a pointy muzzle and a deep chest compared to a basset hound, which has short legs and square muzzle.

It has been argued that slower identification speeds at the subordinate level relative to the basic level are due to increased visual processing of the object. Objects belonging to subordinate categories show slower verification times (Hamm & McMullen, 1998; Jolicoeur et al 1984; Murphy & Smith, 1982; Nicholson & Humphrey, 2001). Subordinate classifications are also more vulnerable to degradation in the visual image or changes in viewpoint compared to basic classifications (Archambault et al, 2001; Hamm & McMullen, 1998; Nicholson & Humphrey, 2001).

(II) Visual similarity and categorization

In the section describing basic level categories, it was stated that one of the distinguishing features of this level of categorization is that it is more informative than superordinate categories and more distinctive than subordinate categories. Distinctiveness refers to how dissimilar one category is to other contrast categories. One of the dimensions in which categories can be dissimilar from one another is in their visual attributes.

Rosch et al (1976) investigated the degree of visual similarity of objects belonging to the three category levels. They found that objects belonging to basic and subordinate categories were more visually similar than objects belonging to superordinate categories. This result was determined by computing the ratio of overlap between pairs of objects. The objects either belonged to the same basic category (sports car, sedan car), different basic categories but the same superordinate category (car and airplane) or the

same subordinate category (two different types of sports car). Furthermore, it was found that subjects had great difficulty in categorizing objects when two pictures of superordinate category members (cat and a fish) were averaged together compared to when the averaged picture was based on two basic level category members (MacIntosh and Golden Delicious apples) or two subordinate category members (two Golden Delicious apples). The results of these experiments demonstrated that objects in basic and subordinate categories are more consistent in their shape structure than objects in superordinate categories. For example it is easier to distinguish a bird from a dog than it is to distinguish a 'labrador' from a 'rottweiler' on visual properties alone. Snodgrass and McCullough (1986) demonstrated the importance of controlling for effects of visual similarity in visual categorization tasks. Subjects were asked to classify pictures of fruits, animals and vegetables. They found that fruits were classified more quickly when contrasted with animals than when they were contrasted with vegetables. They argued that performance on a picture categorization task was affected by the degree of visual similarity between objects belonging to a single category and between objects belonging to different categories.

An example of how visual similarity or dissimilarity of objects belonging to the same category can affect people's performances was provided by Jolicoeur et al, (1984). They explored the effects of typicality on object naming. An exemplar within a basic level category can either be typical of that category or atypical of that category ('robin versus 'penguin' in the category 'bird'). Subjects were asked to name a series of pictures of objects. They found that people were more likely and quicker to name typical category members at the basic level and more likely and quicker to name atypical members at the

subordinate level. Atypical exemplars are generally more visually distinct from other within-category exemplars and typical exemplars are generally more visually similar. Jolicoeur et al's results indicate that the basic level superiority effect can be reversed when a basic level category member is visually distinct from other members of the same category.

Murphy and Brownell (1985) replicated Jolicoeur et al's experiment using a category verification task. Subjects were shown a word followed by a picture and had to indicate whether the picture matched or did not match the preceding word. Murphy and Brownell also manipulated the distinctiveness of subordinate categories. In the first experiment, the false trials were made up of objects taken from the same subordinate, basic or superordinate category levels. This meant that verifying the match between a subordinate word and picture would be difficult since it would involve distinguishing the object from other visually similar objects belonging to the same basic category (e.g., dress shirt, t-shirt, polo shirt). In their second experiment Murphy and Brownell (1985) changed false trials so that they came from different basic and superordinate categories (e.g., dress shirt, car, hammer). They found that once the subjects realized that they no longer had to distinguish subordinates ('dress shirts') from amongst other subordinates of the same category (other types of shirts) they were faster at subordinate level verifications than basic level verifications. Murphy and Brownell demonstrated that the cost associated with subordinate level categorizations was dependent on the degree of visual similarity between objects. Lloyd-Jones and Humphreys (1997a; 1997b) demonstrated that structurally similar objects (fruits and vegetables) were more difficult to name at the basic level and categorize at the superordinate level than structurally

dissimilar objects (clothing and furniture). Their results suggested that visual similarity is not just a factor in subordinate category performance but also a factor in basic level and superordinate level category performance.

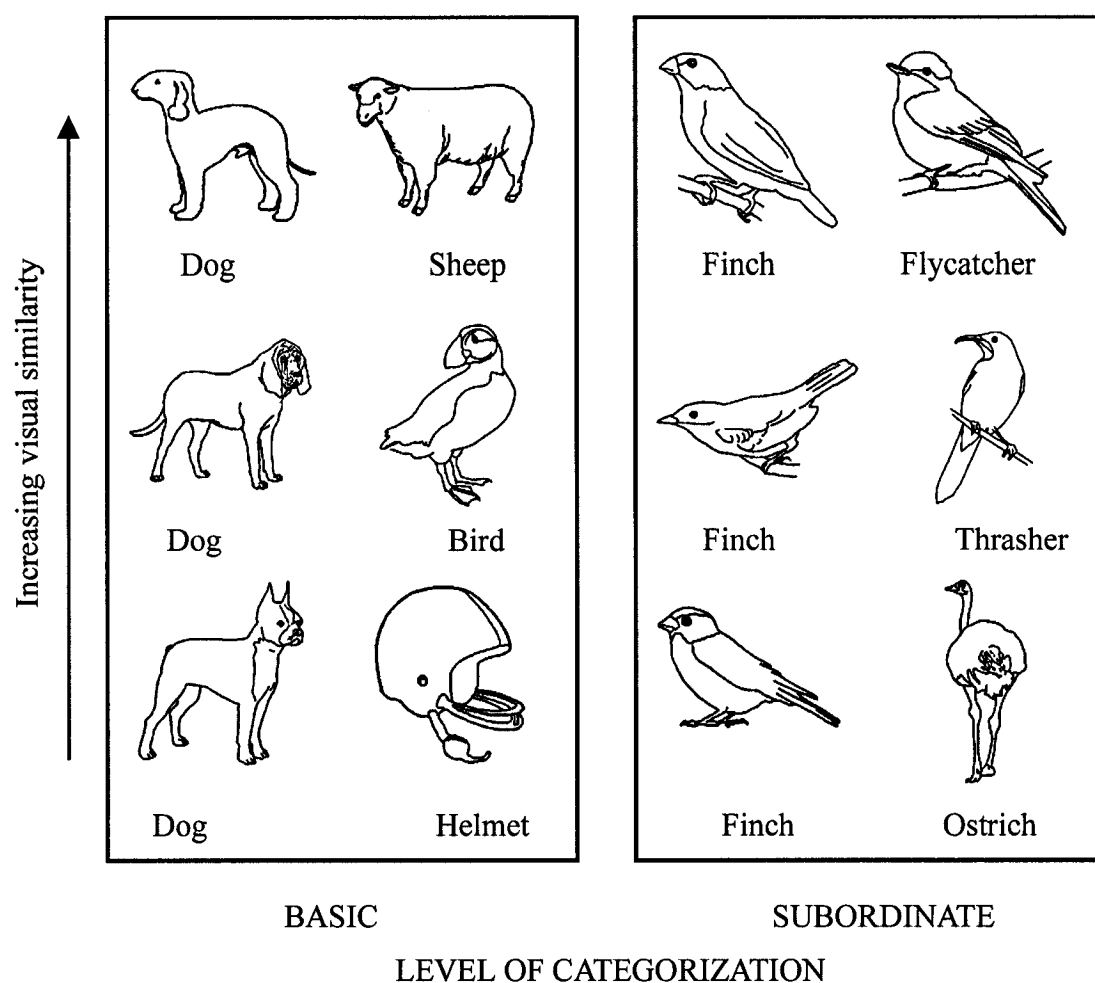


Figure 4. Illustrates variations in visual similarity between members of different basic level categories (BASIC) or between members of the same basic level categories (SUBORDINATE). According to Biederman et al's (1999) three types of subordinate categorizations, distinguishing a finch from an ostrich would be Type 1 (large differences in metric properties - short thick neck versus long thin neck); distinguishing a finch from a thrasher would be Type 2 (small scale differences in geon structural descriptions - small curved beak versus elongated beak); distinguishing a finch from a flycatcher would possibly be Type 3 (small differences in metric properties - slightly rounder head and body).

Biederman et al (1999) expanded on the issue of visual similarity and effects of categorizing objects at the subordinate level. They argued that subordinate categorizations vary in their perceptual demands on the visual system (see Figure 4). For example, distinguishing between various paper clips or faces is quite a different task from distinguishing between a table with a round top and one with a square top, although these tasks are all defined as subordinate categorizations. Biederman et al (1999; see also Biederman, Subramaniam, Kalocsai, & Moshe Bar, 1999) divided subordinate categorizations into three different types based on their perceptual requirements.

Type 1 subordinate categorizations are fast, accurate and viewpoint invariant, similar to basic level categorizations. They occur when geon structural descriptions of objects differ both in parts and relations (e.g., grand piano and upright piano). Type 1 subordinate categorizations also occur when there are large differences in the metric properties of the objects (e.g., thin handled bucket versus a thick handled bucket).

Type 2 subordinate categorizations are more difficult than type 1 categorizations and are likely to take longer. These categorizations are based on small viewpoint invariant differences (e.g., logos on cars) or small scale differences in geon structural descriptions. Biederman et al (1999) argued that in these types of categorizations basic level membership is processed first which guides the search for viewpoint-invariant differences.

Type 3 subordinate categorizations are the most difficult and are most disrupted by changes in viewpoint. Type 3 classifications require metric information since the differences are very small and configurational in nature. A classic example of type 3 subordinate categorizations is face discriminations.

It is possible that basic level categorizations will also vary depending on their demands on the perceptual system. For example, distinguishing the dog from the helmet or from the bird in Figure 4 would likely be a Type 1 categorization since these images vary both in their parts and their part relations. On the other hand distinguishing a dog from mammals may require some Type 2 categorizations. For example, the dog and the sheep in Figure 4 may be distinguished based on the differences in the shape of the ears.

To summarize the degree of visual similarity between members belonging to the same category or between members belonging to different categories can influence the performance of category judgements. Subordinate level judgements may be quicker than basic judgements when objects are visually distinct from each other. Basic level judgements may be similarly affected depending on the degree of visual similarity between objects.

(II) Object categorizations and Global and local processing

Research has demonstrated that humans can recognize any number of objects with or without colour information, surface cues, high or low spatial frequencies and so on (Archambault et al, 2000; Biederman & Cooper, 1991; Nicholson & Humphrey, 2001). Human performance in object recognition tasks suggests that for any given object there are multiple perceptual cues that are diagnostic for its identity at either the basic or subordinate level. Schyns and his colleagues have proposed that the visual system makes use of perceptual cues flexibly, depending on the constraints of the task demands. Within this framework, studies have focused on the usage of spatial frequency information in categorization (Oliva & Schyns, 1997; Schyns & Oliva, 1999; Snowdon & Schyns, 2000;

see Morrison & Schyns, 2001 for a review). It has been demonstrated that high spatial frequency ('fine') information and low spatial frequency ('coarse') information were used interchangeably depending on the nature of the categorization task. For example, when categorizing identical face stimuli, different spatial scales were important depending on whether the categorization of the face was at the level of identity, gender or expression (Schyns & Oliva, 1999).

On this basis, it could be argued that the perceptual cues needed to discriminate between visually distinct objects such as a robin and an ostrich will be different from those needed to discriminate between visually similar objects such as a robin and a sparrow. It could be that global and local processing involves allocating attentional resources to facilitate the selection of perceptual cues that are diagnostic for the recognition or categorization of an object. For example, when coarse scale perceptual cues are most diagnostic recognition performance may benefit from global attentional processes and when fine scale perceptual cues are most diagnostic recognition performance may benefit from local attentional processes.

On the whole, one may find that global processing benefits basic categorizations and local processing benefits subordinate categorizations. However, in cases where basic categorizations involve objects which are visually similar, the requirements for fine scale perceptual cues may favour local processing. On the other hand, if subordinate categorizations involve objects which are visually distinct from one another, the requirements for coarse scale perceptual cues may favour global processing. A method for determining the role of global and local processing in object recognition as a function of category level and visual similarity is described in the following chapter.

Investigative Method

To investigate whether local and global processing is involved in object categorization, the experimental method in this study made use of a well-known effect in the attention literature, the level repetition effect. Using hierarchical stimuli to manipulate global and local levels of processing, the level repetition procedure involves comparing the performance on a second stimulus presentation when the attention levels for the first and second stimulus presentations are the same versus when they are different. It has been found that the efficiency of detecting targets increased when the level of attention was repeated across consecutive stimulus presentations. The level repetition procedure was chosen because it does not require *a priori* assumptions about what the global and local features are in any given object. Additionally, it was reasonable to assume that a task targeting global and local processing could prime an object recognition task because it has been demonstrated that the level repetition effect is independent of target form, location, and response priming and that it is long lasting (Filoteo, Friedrich & Stricker, 2001; Hübner, 2000; Robertson, 1996; Ward, 1982;).

Level repetition effects are independent of target form

The level repetition effect was first reported by Ward (1982). There have been numerous follow-up studies examining level repetition effects (Hübner, 2000; Filoteo et al, 2001; Lamb & Yund, 1996; Robertson, 1996; Robertson et al, 1993). A striking feature of many of these studies is that level repetition effects are always shown to be

independent of the identity of the target. For example, Robertson (1996) used the letters H, S, E and A to make up the hierarchical figures. The target letters were H and S and could appear at either the global or local level. Across all four experiments level repetition priming was shown to be independent of whether the target letter changed or not. This property of level repetition effects is important for this present study as it is predicated on the assumption that level repetition effects will be seen between two very different targets, namely digits and line-drawings of objects.

Level repetition effects are independent of location

In one of his experiments Ward (1982) manipulated the location of the hierarchical stimuli. Across trials the stimuli appeared randomly in one of four quadrants of the display screen such that the stimulus location differed between two consecutive trials. He found that level repetition effects were independent of locations. This finding has been replicated a number of times with stimuli displayed to the left or right of fixation (Hübner, 2000; Robertson, 1996), or with stimuli displayed above and below fixation (Lamb & Yund, 1996). The fact that level repetition priming is independent of location suggests that the priming effects at the local level were not dependent on fixating the spatial location where a local figure would or would not appear. This is important because the arrangement of local features in a hierarchical figure would not be the same as the arrangement of local features in a line drawing.

Level repetition effects are independent of response priming

Filoteo et al (2001) investigated whether perceptual priming or response priming could explain level repetition effects. They presented hierarchical stimuli consisting of the letters H, S, E and A, of which H and S were the targets. Across consecutive trials the target could change from H to S with the level remaining constant across trials or the target could be constant with the level changing from global to local or local to global, or both the form and the level of the target could remain constant across two trials, or finally, both the form and the level could change across consecutive trials. They tested for perceptual priming by excluding data from trials in which the target level changed and they tested for response/identity priming by excluding data from trials in which the target level remained the same. They found evidence for perceptual priming in that subjects were faster to respond to subsequent trials when target form was repeated across two trials. He also found evidence for response priming. In the trials in which the level of the target always changed between trials participants were slower when the target form was the same compared to when the target form changed between trials. However, the important point is that even when perceptual priming and response/identity priming were taken into account level repetition effects were still observed.¹ This demonstrated that a portion of the priming effects involved in level repetition effects was independent of the perceptual similarities between targets and similar response requirements between targets.

¹ Robertson (1996) also found letter repetition effects. Similar to Filoteo (2001) letter repetition priming was faster when the target changed than when target was the same

Further support for the notion that level repetition priming is not due to response priming was reported by Lamb & Yund (1996). Previous research (Bertelson, 1965; Fletcher & Rabbit, 1978; Krueger & Shapiro, 1981; Terry, Valdes, & Neil, 1994 as cited in M.R. Lamb & W.E. Yund, 1996) has shown that subjects have a tendency to select their response based on whether the stimulus presented on trial N matches the stimulus presented on trial N+1 or not. Essentially the research demonstrated that subjects were biased to respond more quickly if the stimulus was repeated. They were also biased to respond more slowly to stimuli that differed from a prior stimulus even if this difference was on an irrelevant dimension. Lamb & Yund termed this the 'bypass rule' since subjects effectively 'bypass' normal processing of the stimulus in favour of response selection processes.

It is possible that level repetition effects could be explained by the 'bypass rule'. For example, if the same target was present on both trials and at the same level then reaction times would be relatively fast. However, if the target was at a different level then the reaction times would be slowed since the change in level would bring about an incorrect tendency to change responses. This pattern mirrors that found for level repetition priming. However, the 'bypass rule' also predicts that when the target changes across two trials but the levels remained the same level repetition priming would harm performance since there would be a tendency to repeat the response incorrectly in the second trial. On the other hand if both the target form and level changed across two trials there would be a correct tendency to change the response to the second trial so reaction

across trials. This suggested that level repetition priming and identity priming were separate processes.

times would be faster in this condition. If level repetition priming is independent of response selection priming, then reaction times should be faster when the level remains the same and reaction times should be slower when the level changes, regardless of changes in target form. Lamb and Yund (1996) found that level repetition priming could not be accounted for by the 'bypass rule' because level repetition facilitated performance independently of changes in target form. Taken together the results of Lamb and Yund's and Filoteo et al's (2001) studies suggest that level repetition effects could occur between targets that differ in their response requirements such as hierarchical figures and line-drawings of objects.

Robust level repetition effects

Finally, level repetition effects have also been shown to be long lasting. Robertson (1996) explored the duration of level repetition effects by presenting hierarchical figures at three different inter-trial intervals (1, 2 or 3 seconds). She found that level repetition effects were virtually the same across all three inter-trial intervals. The fact that level repetition effects have been shown to be long lasting is a useful property for the purposes of this investigation. The combination of two different tasks within a series of trials may be taxing on the participant. Because level repetition effects are long lasting it allows for some flexibility in the timing of inter trial intervals to accommodate task complexity.

General Method

A priming paradigm was chosen similar to that used in studies of level-repetition effects. A global and local divided attention task preceded and primed a subsequent object detection task in which participants indicated the presence of a target or a distractor object at either a basic level or a subordinate level of categorization. The degree of visual similarity between the targets and distractors in the object detection task was also manipulated because performance in category discriminations is linked to the visual similarity of category members.

The hierarchical figures in the global and local task were large 2's and 5's made up of small 8's and large 8's made up of small 2's and 5's as depicted in Figure 5. The global and local task was a divided attention task in which participants indicated the presence a '2' or a '5'. The targets could appear at either the global or local level.

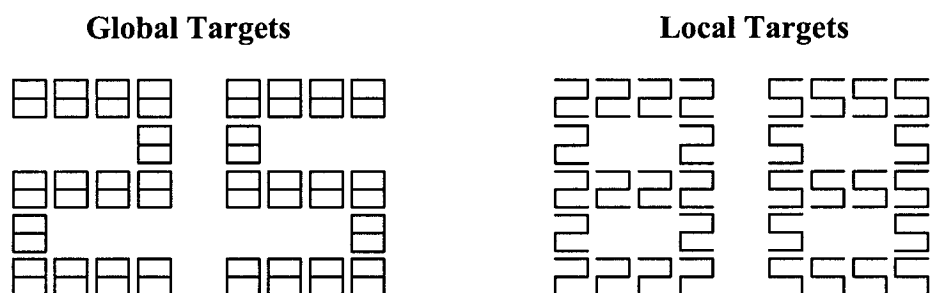


Figure 5. Examples of the hierarchical figures used in the global and local task. The targets were two or five and could appear at the global or local level.

The objects in the object detection task were a variety of line drawings. Some came from the Snodgrass & Vanderwart (1980) set and others were constructed from photographs for the purposes of this experiment. Half of the object detection trials contained target objects and the other half contained distractor objects. At the beginning of each block of trials participants were instructed about which objects were targets. The

participants were required to indicate by a key press whether the line drawing presented on the screen was a member of the target category or not. To manipulate the category level of the object detection task the target labels were either basic level names such as 'dog', or 'fish' or subordinate level names such as 'beagle' or 'finch'. The distractor objects could be visually similar (e.g., beagles and other dogs) or visually dissimilar (e.g., beagles and manmade objects) to the target objects. The experimenter based the judgement of visual similarity on research into category-specific effects where living things are generally found to be more visually similar to each other than non-living things (Forde & Humphreys, 2001; Lloyd-Jones & Humphreys, 1999a, 1999b).

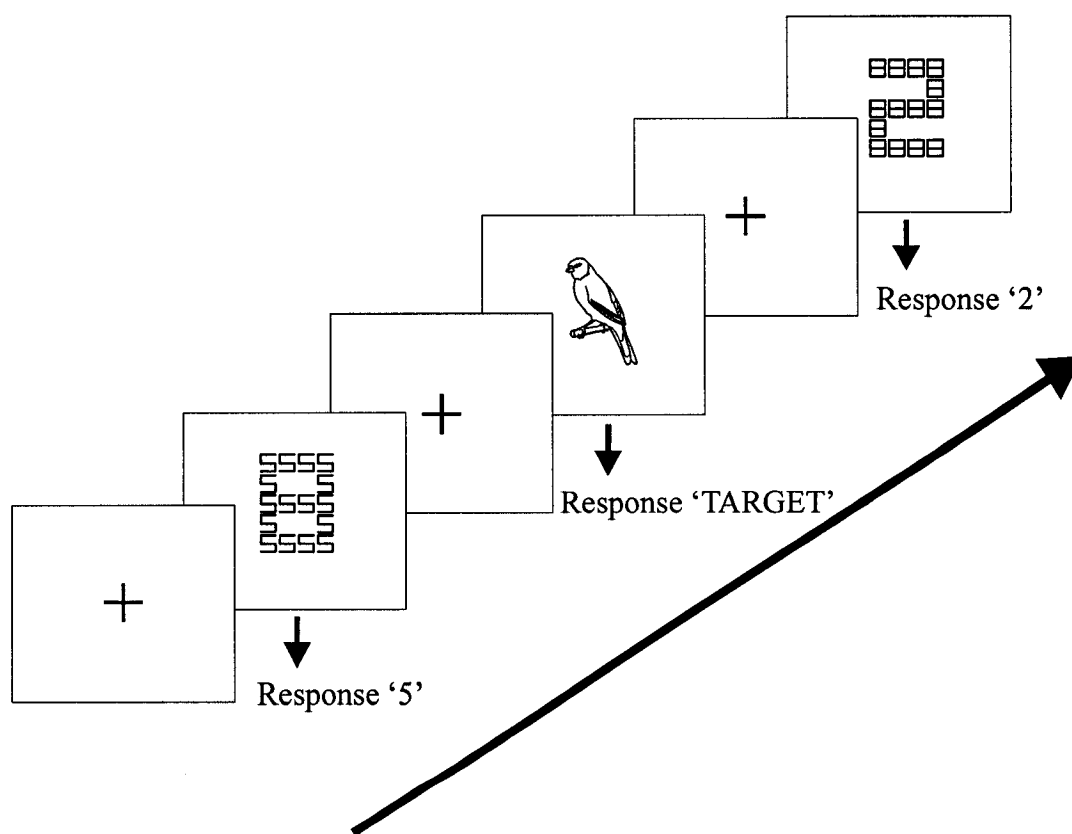


Figure 6. Illustrates a typical sequence of trials in a block with the target object 'finch'. (See text for further details).

Trials alternated between the divided attention task and the object detection task. As shown in Figure 6, participants first saw a fixation cross, followed by a hierarchical figure to which they responded with a key press to identify the presence of a '2' or a '5'. This was followed by a second fixation cross and then an object to which they responded with one key press if the object was a target and another if the object was a distractor (timings varied between experiments). For both the divided attention task and the object detection task, stimuli remained on the screen until the participant made a response or 3s had passed. The target detection task involved detecting the same kind of target in a block of trials, but within this block the targets and distractors were presented in a random order. For example, in one block of trials the target object could be 'beagles' and in a separate block of trials the target object could be 'dogs'. The stimuli in the divided attention task were presented in a random order in each block of trials.

Research Objectives

This research was concerned with four main objectives. The first objective was to investigate whether global and local processing played a role in a more realistic object recognition task. The second objective was to determine how global and local levels of processing were selected. Were the levels selected on the basis of the category label (basic or subordinate) assigned to the target object or the perceptual demands of the object detection task (visually similar or dissimilar distractors)? The third objective was to determine if there was a fixed or flexible global-to-local sequence in the priming effects of the divided attention task on the object detection task. Finally, the fourth objective was to investigate whether the priming effects of the divided attention task were based on the spatial extent of attention or on grouping and parsing processes associated with the perceptual organization of visual information. These four objectives are discussed in more depth below.

(I) Global and local processing in object recognition

It has been claimed that global and local processing are used in real world object recognition and scene perception (Hoffman, 1980; Kimchi, 1982; Navon, 1977, amongst others). However, the majority of the evidence for this claim has been provided by investigations that measure global and local processing effects using hierarchical figures. These figures bear little resemblance to real objects and scenes. Research by Sanocki (1998, 2001) is an exception.

Sanocki investigated global and local processing in natural objects using an integrative priming technique. This technique involves a brief presentation of a shape prime quickly followed by a target briefly presented at the same location as the prime. When prime and target are presented at short durations they are integrated. Integrative priming has been shown to increase the efficiency of later processing (Sanocki, 1991. Sanocki (1998, 2001) chose primes representing global or local features of houses. For global primes he chose coarse scale information related to the outline of the objects and for local primes he chose fine scale information related to the internal structures of the objects. Using this technique he demonstrated that global and local feature priming does improve the efficiency of object identification relative to a control condition.

A potential criticism of Sanocki's research is that he assumed *a priori* what features were global and what features were local. In the study reported here no assumptions were made about which features are global and which are local. Indeed, based on Schyns' (1998) arguments it is likely that what might be considered a global or a local feature will differ depending on the demands of the object recognition task. In using a divided attention task to prime an object recognition task it is assumed that the priming task determines the allocation of attentional resources. Furthermore, there is a performance cost associated with the reallocation of those resources. Thus, if the allocation of attentional resources is suitable for the selection of perceptual cues diagnostic for the recognition task, then performance will benefit in the object detection task. However, if the allocation of attentional resources is not suitable and has to be adjusted, then performance in the object detection task will be impaired.

The role of global and local processing in object categorization has been discussed in a preceding chapter. To recap, it was argued that global processing could facilitate the selection of coarse-grained information from the input image, whereas local processing could facilitate the selection of fine-grained information. On the whole, it is expected that global processing will benefit basic categorizations and local processing will benefit subordinate categorizations. However, in cases where basic categorizations involve objects which are visually similar, the requirements for fine scale perceptual cues may favour local processing. On the other hand, if subordinate categorizations involve objects which are visually distinct from one another, the requirements for coarse scale perceptual cues may favour global processing.

(II) Selection of global or local levels of processing

Global and local processing are traditionally investigated using hierarchical figures. If one is required to identify a target at the local level then local processes are initiated. If one is required to identify a target at the global level then global processes are initiated. Effects related to top-down conceptual knowledge are generally not considered. However, with more realistic objects there is the possibility that prior knowledge of the visual properties of the object may influence whether global and local levels of processing are initiated.

There is evidence that conceptual knowledge of objects influences recognition. In a series of studies Boucart and her colleagues (Boucart & Humphreys, 1992; Boucart et al 1995; Humphreys & Boucart, 1997; see also Murray & Jones, 2002) found that semantic information affected judgements about the physical properties of objects such as

their global shape (oval or round), surface texture, motion, colour and the orientation of embedded lines. It has also been demonstrated that differences in the way objects are categorized can change how they are perceived (Goldstone, Lippa, & Shiffrin, 2001; Schyns & Rodet, 1997). There is some debate about whether the influence of semantics in object recognition is related to a later naming stage rather than the early visual processing stages of object recognition (Dean, Bub & Masson, 2001; Humphreys, Lloyd-Jones & Fias, 1995).

Gauthier et al (in press) wanted to establish whether semantic associations could directly affect perceptual judgements that do not require naming. They used novel objects that had no names and a visual sequential-matching task. They arbitrarily associated semantic information with novel shapes and objects. They predicted that semantically dissimilar information would facilitate the recognition of visually similar novel objects. Indeed, they found that associating the objects with semantically dissimilar concepts did produce better performance than associating them with semantically similar concepts. Their results suggested that conceptual information could influence perceptual processes.

If conceptual knowledge can influence perceptual processes, as demonstrated by Gauthier et al, (in press), then it is possible that the allocation of attentional resources to either the global or local level is mediated by prior knowledge of the visual properties of the target objects. For example, when discriminating a particular breed of dog, prior knowledge suggests that breeds of dogs are highly visually similar and processing fine visual details is more likely to produce accurate detections than processing coarse visual details. Based on stored knowledge, a level of attention may be selected prior to the task

and the effects of the priming attention with the global/local task could facilitate or interfere with this prior selection.

Alternatively, the level of attention may be modulated by the perceptual demands of the task. Discriminating a particular breed of dog amongst other dogs biases attention towards detailed shape information. Discriminating a particular breed of dog amongst a group of man-made objects biases attention towards coarse scale information. In this case attention priming could coincide or conflict with attentional biases set by the perceptual requirements of the task

(III) Fixed or flexible global-to-local sequence in processing

As mentioned previously, a common finding in studies investigating global and local processing is that the global level is identified more quickly. Moreover, the identity of the global level interferes with the identity of the local level (global asymmetry) but the local level does not interfere with the identity of the global level. Navon (1977) explained this finding with the principle of global precedence. He argued that local features could not interfere with global features because by the time the local features were identified global feature identification would already be complete. Thus the identity of local features was irrelevant to the identification of global features. On the other hand global features could interfere with the identification of local features, as they would be available before the processing of local features was complete. It is important to note that the global precedence principle claims that when identifying an object or scene there is a fixed sequence of processing in the direction of global features first followed by local features.

Further research into global and local processing indicated that there were limitations to global precedence. Kinchla & Wolfe (1979) proposed that there was an optimal size for the detection of features in a hierarchical stimulus of 2° of visual angle; anything larger or smaller would be processed more slowly. Other investigators found that under certain circumstances local features could be identified more quickly than global features. Lamb & Robertson (1990) investigated the effects of different sized hierarchical stimuli and found that there was a cross over from global to local precedence at around 6° or 9°, depending on the size range of the stimulus set. Local precedence could also be found if the local level was made up of fewer or larger local features (Martin, 1979). This suggested that the more conspicuous a feature was the more it would stand out from the background and the quicker it would be detected.

Evidence demonstrating limitations to global precedence notwithstanding, the recognition of objects and scenes in the real world may be in a fixed global to local sequence. It has been shown that people are very capable of picking up the conceptual gist of visual material (Potter, 1976; VanRullen & Thorpe, 2001a). Using an RSVP (rapid serial visual presentation) paradigm Potter demonstrated that people can detect basic object types within 100-200ms. Event-related brain potential (ERP) methods have also been used to investigate subjects' ability to locate animals and non-animals in naturalistic scenes (Antal, Keri, Kovacs, Janka and Benedek, 2000; Li, VanRullen, Koch & Perona, 2002; Thorpe, Fize & Marlot, 1996; VanRullen & Thorpe, 2001b). ERP effects associated with this dichotomy were observed within 150ms of stimulus onset. In contrast humans are much slower and more fallible at detecting details in a visual image. This phenomenon has been explored using change detection tasks (Rensink, O'Regan, &

Clark, 1997) in which subjects have to indicate whether or not an image has changed between successive presentations. It turns out that we are relatively blind to quite large differences.

Hochstein & Ahissar (2002) proposed a 'reverse hierarchy' theory to account for the disparity in our abilities to abstract general information from visual material and our blindness to details. The 'reverse hierarchy' theory maintains that visual information is processed by low level perceptual mechanisms that feed forward through a hierarchy of low level processes leading to increasingly complex representations. It is these high level representations that are first available to conscious perception. Awareness of detailed information requires top-down processes that proceed back down through the hierarchy, accessing lower level representations, which encompass more visual details. According to the 'reverse hierarchy', perception does indeed proceed in a fixed global-to-local sequence. The global form is perceived first by accessing high-level representations and the local features become available only after further processing which involves access to lower level representations.

In line with the 'reverse hierarchy' theory, research has shown that semantic information is automatically activated based on the global configuration of an object (Boucart & Humphreys, 1992; Boucart et al 1995; Humphreys & Boucart, 1997). The paradigm involved presenting a reference object followed by two laterally presented objects; a target and a distractor. The task was to indicate which of the two objects matched the reference object in terms of some physical property such as its global shape, global orientation or size. Boucart and her colleagues found semantic facilitation effects when the reference and target objects were semantically related and semantic interference

effects when the reference and distractor objects were semantically related even though semantic information was task-irrelevant. Subsequent research demonstrated that activation of semantic information associated with global form occurred even when the task required judgements of local form (Boucart & Humphreys, 1997). This research suggests that in tasks requiring access to semantic information associated with an object, biasing attention to the global shape would be most efficient.

Sanocki (1998, 2001) provides further support for a fixed global-to-local sequence in perceptual processing. He suggested that large-scale visual information was more effective during the early stages of processing an object and small-scale visual information was more effective during the later stages of processing. As mentioned earlier in this chapter, Sanocki investigated global and local processing using global and local shape primes. To determine whether the contribution of global and local primes would change over time he presented the primes either before or after the target. He argued that the global prime would be more beneficial preceding the target as it would contribute to the construction of a global representation of the object. Conversely, the local prime would be more beneficial following the target as it would help to distinguish between alternative objects. His experiments supported his claim. Global primes were more effective when presented before the target and local primes were more effective when presented after the target. Sanocki's (1998, 2001) results suggest that there is a global-to-local sequence in the development of an object representation.

Moreover, it is also possible that a fixed global-to-local sequence maps onto category level sequence. It has been suggested in the literature that objects are identified initially at the basic level and then further processing is required to make subordinate

level categorizations (Biederman et al, 1999; Jolicoeur et al 1984; Tarr & Bülthoff, 1995, Tarr & Kriegman, 2001). Perhaps global processing is used to select perceptual cues necessary for making basic level identifications and then local processing is used to select perceptual cues necessary for further subordinate categorizations as speculated by Hochstein & Ahissar (2002).

In contrast, research into the effects of spatial scale on object recognition tells a different story. Studies investigating the usage of spatial information in categorization (Morrison & Schyns, 2001; Oliva & Schyns, 1997; Schyns & Oliva, 1999; Snowden & Schyns, 2000) have found that high spatial frequency ('fine') information and low spatial frequency ('coarse') information were used interchangeably depending on the nature of the categorization task. For example, when categorizing identical face stimuli different spatial scales were important depending on whether the categorization of the face was at the level of identity, gender or expression (Schyns & Oliva, 1999). Archambault et al (2001) investigated the effects of viewing distance on categorization. They found that as size decreased (with a corresponding loss of high spatial frequency information) subordinate level categorizations were more impaired than basic level categorizations. This suggests that basic and subordinate level categorizations required information at different spatial scales of the same stimulus. Similarly, Collin and McMullen (2002) found that subordinate level categorizations were vulnerable to the loss of high spatial frequency information compared to basic level categorizations. The coarse-to-fine distinction can also be linked to global and local processing. Whether global and local processing are linked to spatial frequency is in contention (Hübner, 2000; Lamb & Yund, 1993; 1996; 2000; Lamb et al 1999; Robertson 1996). However, they are certainly

analogous in the sense that *global* refers to broad characteristics of the whole stimulus and *local* refers to the fine details of the stimulus.

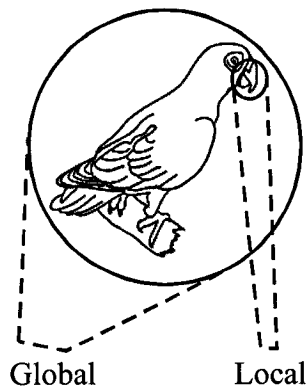
(IV) Effects of global and local processing on object recognition: Are they based on the spatial extent of attention or grouping and parsing processes?

As discussed in Chapter 2, investigations into global and local processes, as they relate to hierarchical figures, suggest that there are two mechanisms involved in global and local processing. One mechanism is related to the spatial extent of the attentional focus and the second mechanism relates to processes of perceptual organization, specifically, grouping and parsing processes. Theoretically either or both of these mechanisms could be involved in the processing of global and local features of a pictorial image.

In terms of the spatial extent of attention, a large window of attention at low resolution may be the optimal spread of attentional resources for capturing coarse scale visual information. In contrast, a smaller window of attention at higher resolutions may be optimal for capturing fine-scale visual information (see Figure 7). Researchers investigating automatic activation of semantic information associated with the global form of objects speculate that attentional resources are distributed across a region in space (Boucart & Humphreys, 1992; Murray & Jones, 2002). Edelman and Intrator (2003) postulated that access to different levels of object representations is mediated by the spatial extent of attention. For example, at the level of a human body one could discriminate a head, torso, arms and legs, but not the facial features. A different level of representation would be required to discriminate facial features.

In terms of perceptual organization global and local processing may play a role in grouping and parsing images into a hierarchy of modular parts (Han et al, 1999a). Han and his colleagues argued that there are two processes of perceptual organization; one involves grouping local elements together (global identifications); and the other selects individual local elements (local identifications). As depicted in Figure 7, when identifying objects, global processing may handle visual information relevant for generating input representations that match to large-scale object parts or object wholes. Local processing may handle visual information relevant for generating input representations that match to small-scale object parts.

A) SPATIAL EXTENT



B) GROUPING AND PARSING

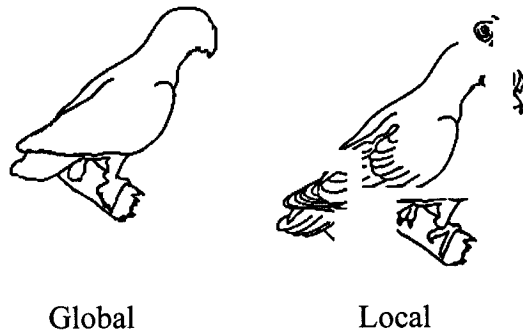


Figure 7. Illustrates two mechanisms of global and local processing and how they may act on object images. A) Demonstrates how varying the size of the attentional window captures different scales of visual information. B) Demonstrates how grouping and parsing processes capture different scales of visual information.

Experiment 1

The main purpose of Experiment 1 was to establish whether the allocation of attention resources at global and local levels differed in an object recognition task. The second objective of Experiment 1 was to determine whether global and local processes in object recognition operated in a fixed global-to-local sequence, as suggested by research conducted by Sanocki (1998, 2001) and the reverse hierarchy theory proposed by Hochstein & Ahissar (2002). The third objective was to determine whether the allocation of attentional resources was based on the perceptual demands of the object recognition task or prior knowledge of the attributes of an object.

Schyns and his colleagues (Morrison & Schyns, 2001; Schyns 1998) have suggested that coarse scale (low spatial frequencies) and fine scale (high spatial frequencies) perceptual cues are diagnostic for different recognition tasks. The same principle may apply to global and local processing. Granting that the allocation of attentional resources assists the processing of perceptual cues present in a stimulus input, then it is possible that variations in the distribution of attentional resources will support the processing of different kinds of perceptual cues. For example, if attention is allocated to the global features of a stimulus this should benefit the selection of coarse scale perceptual cues and if attention is allocated to local features this should benefit the selection of fine scale perceptual cues.

The next question is whether attentional resources will be allocated flexibly depending on the nature of the recognition task or in a fixed global-to-local sequence. Reverse hierarchy theory (Hochstein & Ahissar, 2002), the automatic activation of

semantic information from global shape (Boucart & Humphreys, 1992; 1997; Boucart, Humphreys & Lorenceau, 1995) and Sanocki's (1998, 2001) research suggest that in object recognition the visual system commences with processing coarse scale information in the input image and then processes fine scale information at later stages. If this is the case one might expect that global level priming would enhance performance for all recognition tasks regardless of the level of categorization or the degree of visual similarity between objects. However, if the visual system can process coarse scale and fine scale information interchangeably, as suggested by Schyns and his colleagues (Morrison & Schyns, 2001; Oliva & Schyns, 1999; Schyns, 1998), then one might expect that the priming effects of the global and local task will be sensitive to the nature of the object recognition task.

The final question of interest is what prompts the selection of global or local levels of processing in object recognition, prior knowledge about an object's attributes or the perceptual demands of the task. Research by Gauthier et al (in press) suggests that prior conceptual knowledge about an object can influence perceptual processes. The objects used in Experiment 1 are common objects such as dogs, mammals and various manmade artifacts, familiar to the participants. Before the presentation of trials, participants are given the name of the target they are required to detect. The label given to the target is either at a basic level (dog) or a subordinate level (beagle). The allocation of attentional resources may be driven by the activation of stored representations of the objects and the level of the representation may differ depending on the specificity of the target label. For example, the level of the representation for 'dogs' may only incorporate coarse scale shape information and the level of representation for 'beagles' may only

incorporate fine scale shape information. These top-down processes may in turn influence the allocation of attentional resources such that a global level of attention is initiated for coarse scale representations and a local level of attention is initiated for fine scale representations.

Alternatively, the level of attention may be modulated by the perceptual requirements of the task. Discriminating a particular breed of dog amongst other dogs biases attention towards detailed shape information. Discriminating a particular breed of dog amongst a group of man-made objects biases attention towards coarse scale information. Attention priming could coincide or conflict with attentional biases set by the perceptual requirements of the task

Experiment 1 used the general method described in Chapter 4. A global and local divided attention task preceded and primed a subsequent object detection task in which participants indicated the presence of a target or a distractor object. The target object was labeled at either a basic level ('dog') or a subordinate level of categorization ('beagle'). The degree of visual similarity between the targets and distractors in the object detection task was also manipulated. 'Dog' targets were paired with either 'mammals' in the visually similar condition or various manmade objects in the visually dissimilar condition. 'Beagle' targets were paired with other breeds of dogs as distractors in the visually similar condition and with various manmade objects in the visually dissimilar condition (see Figure 8 for examples and Appendix A for a list of objects)

It was expected that if the priming effects of global and local attention were driven by prior semantic knowledge then global decisions should positively prime basic decisions and local decisions should positively prime subordinate decisions independent

of the degree of visual similarity between the target objects and the distractor objects. If attentional priming effects on object decisions were modulated by the perceptual demands of the object detection task it was expected that global decisions would positively prime object decisions between visually dissimilar items and local decisions should positively prime object decisions between visually similar items, independent of category level.

According to the fixed global-to-local sequence hypothesis the early stages of object recognition involve processing coarse scale shape information. If this is the case it would be expected that global decisions would positively prime object detections regardless of category level and the degree of visual similarity between the targets and the distractors.

Method

Participants

Forty-one undergraduate students from Dalhousie University participated in the experiment to fulfil a course requirement. All had normal or corrected-to-normal vision and provided written, informed consent.

Stimuli and Procedure

The hierarchical stimuli for the divided attention task were large 2's and 5's made up of small 8's and large 8's made up of small 2's and 5's (see Figure 5). The global level digits were 4 cm tall and 3 cm wide subtending a visual angle of approximately 5.7° and the local level digits were 8mm tall and 7mm wide at a visual angle of approximately 1.2°. The lines were 1 pixel thick. In the object detection task there were 80 black and

white line drawings which consisted of 28 drawings of beagles, 28 drawings of other breeds of dog, 28 drawings of mammals and 28 drawings of manmade objects (see Figure 8). The mammals and manmade objects were taken from the Snodgrass and Vanderwart (1980) set. The beagles and dog line drawings were created using Adobe Photoshop from images taken from the web and converted into line drawings or from images taken from children's colouring books. The lines of the drawings varied from 1 to 2 pixels in width. All the objects subtended an approximate visual angle of 7.8° . The stimuli from both tasks were presented using SuperLab 1.75 software on an IMac computer.

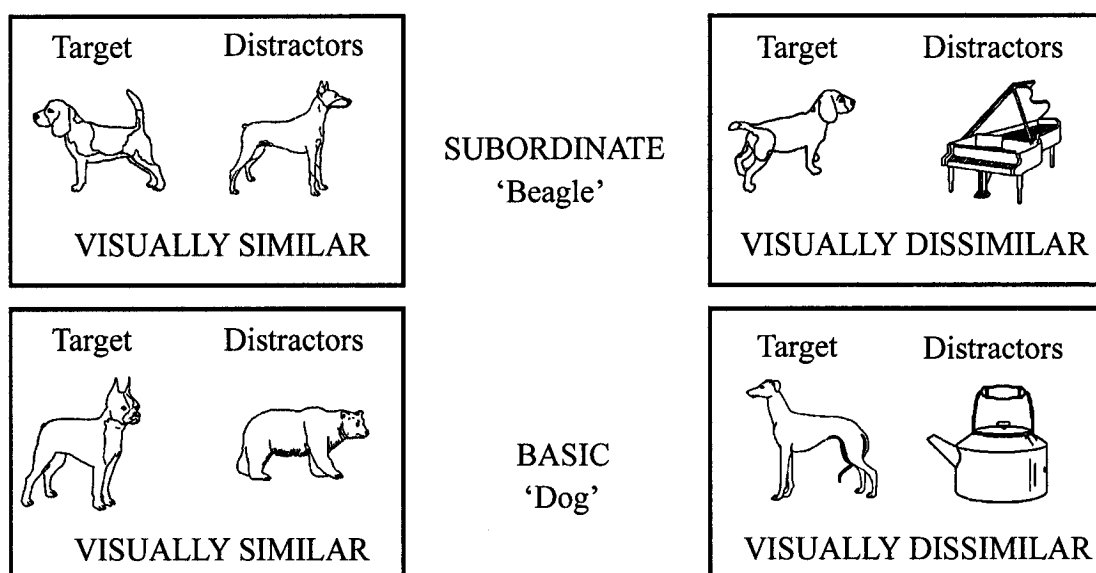


Figure 8. Examples of the various stimuli used in the object detection task for Experiment 1. Stimuli associated with each of the categorization conditions in Experiment 2 and Experiment 3. For each subordinate and basic level task the targets and distractors were either visually similar or visually dissimilar (see Appendix A for a list of objects).

The participants first saw a fixation cross presented for 1000ms followed by an interstimulus interval of 200ms followed by a global/local figure to which they responded with a key press to identify the presence of a '2' or a '5'. This was followed by a second

fixation cross (1000ms), an interstimulus interval of 200ms and an object to which they responded with one key press if the object was a target and another if the object was a distractor. For both tasks stimuli remained on the screen until the participant made a response or 3s had passed. The divided attention task always preceded the object detection task making a trial “couplet”. The experiment consisted of four test blocks each of which was preceded by a practice block. There were 16 trial “couplets” in each practice block and the order of couplets was pseudo-randomized. Half of the couplets in a block had global level targets and half had local level targets. Half of the global level targets required a ‘2’ response and half a ‘5’ response, as did the local level targets. The divided attention task was the same in each block but the object detection task differed. The test blocks consisted of four blocks with 40 trial “couplets” in each block. Half of the couplets in a block had global level targets and half had local level targets. Half of the global level targets required a ‘2’ response and half a ‘5’ response, as did the local level targets. In each block the order of couplets was pseudo-randomized such that no target response in either task was repeated more than three times. The pseudo-random order was identical for each subject due to limitations of the SuperLab program. The divided attention task was the same in each block but the object detection task differed. Instructions preceding each block indicated which set of images were targets. For subordinate categorizations the targets were “beagles” which appeared with visually similar distractors (“dogs”) in one block and visually dissimilar distractors (manmade objects) in another. For basic categorizations the targets were “dogs” which appeared in one block with visually similar distractors (“mammals”) and in another block with

visually dissimilar distractors (manmade objects). Blocks were presented in a Latin square order across all participants.

Results

Reaction times and percentage correct for the target detection task were analyzed using a 2 X 2 X 2 repeated measures Analysis of Variance (ANOVA). The factors were Prime Level (global or local), Distractor Type (visually similar, visually dissimilar) and Category Level (subordinate or basic). Data were included in the RT analysis only if two responses in a couplet were correct. Four subjects were excluded as they achieved less than 30% correct in one cell of the factorial design. In all reported results the significance of effects was evaluated at the level of $p=.05$ and outliers in the reaction time data were excluded based on the method advocated by VanSelst & Jolicoeur (1994) for evaluating outliers in designs with a small number of observations per cell. The analysis of reaction times and percentage correct for the divided attention task is reported in Appendix B.

Reaction Times

Target detections made in the context of dissimilar distractors were faster (mean = 582ms) than target detections made when the distractors were similar (mean = 681ms, $F(1,36) = 41.75$, $MS^e = 18,419$). Figure 9 shows that priming by global or local levels differentially affected target detections times ($F(1,36) = 6.46$, $MS^e = 3,363$). Target detections made when the targets and distractors were visually dissimilar were faster when preceded by global decisions (mean = 577ms) than when they were preceded by local decisions (mean = 587 ms). In contrast target detections made when distractors were similar were faster when preceded by local decisions (mean = 672 ms) than when they were preceded by global decisions (mean = 690 ms). There was no interaction between

Prime Level and Category Level, suggesting that global and local levels did not interact with the category level of the target.

Although there was no interaction between Category Level and Distractor Type, *t*-tests showed that manipulating the degree of visual similarity between the targets and distractors did affect reaction times for both basic and subordinate target detections. Basic target detections were faster with visually dissimilar distractors than visually similar distractors, ($t(1,73) = 5.84$) and subordinate target detections were faster with visually dissimilar distractors than visually similar distractors ($t(1,73)=4.74$).

Percentage Correct

More correct responses were made for target detections when the distractors were dissimilar (93%) than for target detections when the distractors were similar (88%, $F(1,36) = 10.16$, $MS^e = 124$). There were no other significant main effects. These measures failed to support any speed-accuracy trade-offs.

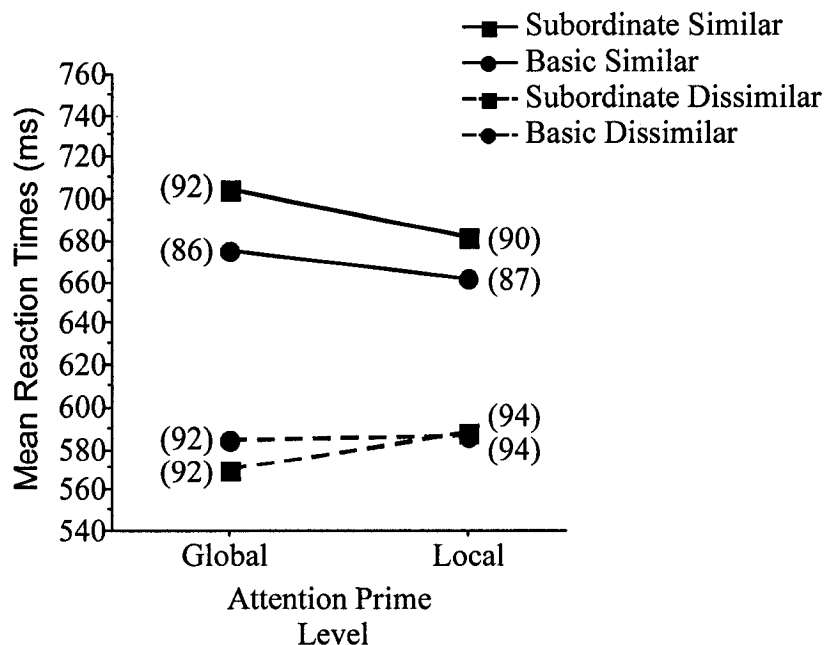


Figure 9. *Reaction times to the target detection task after priming by a global/local divided attention task. The numbers in brackets are the percentage correct for each condition.*

Discussion

The data showed that global and local processing did influence the object detection task depending on the context provided by the visual similarity of the distractors. Object detections within the context of visually dissimilar distractors were faster when preceded by global decisions. On the other hand object detections within the context of visually similar distractors were faster when preceded by local decisions. These attentional priming effects suggest that both global and local attention were used in the visual categorization of objects. Moreover, since the influence of global and local processing on identical targets differed depending on the visual similarity of the distractors, it appeared that global and local attention operated at early perceptual stages of object categorization. Finally, the evidence for local level priming effects on the object detection task suggested that the selection of global and local features that are diagnostic in a recognition task was flexible rather than fixed.

The evidence reported supports the notion that attention was selectively modulated depending on perceptual demands of the recognition task, similar to evidence found with spatial scale (Archambault et al 2001; Schyns & Oliva, 1999). Identical targets differentially benefited from global and local priming depending on the visual similarity or dissimilarity of the distractor objects. This suggests that the requirements of the object detection task determined a bias in the allocation of attentional resources which best supported a category judgement. Global and local processing may operate at the point when visual properties of a distal stimulus are selectively attended to. Shifts

between global and local levels of attention may act to facilitate the selection of coarse or fine-grained information from the stimulus. When categorizing visually similar objects the attentional bias is towards fine-grained information selected at the local level, conversely, when categorizing visually dissimilar objects the attentional bias is towards coarse-grained information selected at the global level.

The alternative hypothesis that prior conceptual knowledge of the target objects would influence the selection of global or local levels of attention was not borne out by the results since the priming effects of the attention task did not vary according to the category level of the target label. However, this hypothesis cannot be dismissed out of hand. It is still possible that the selection of attention level was initially set by the category level and was later modified on the basis of the perceptual demands of the object detection task. For instance, when beginning the task of detecting subordinate targets amongst visually dissimilar objects, attention may have been set at the local level and then, during the course of the task, attentional resources may have been reallocated for the selection of global features. Whether this is the case or not, cannot be determined within the current experimental design. However, the results suggest that even if attentional resources were initially allocated on the basis of conceptual knowledge the perceptual demands of the task had a stronger influence on the distribution of attentional resources.

As regards a fixed or flexible sequence of processing for global and local features, the data suggested that the sequence was flexible. The evidence we have reported supports the notion that the allocation of attention at global and local levels can be selectively modulated depending on task demands, similar to evidence found with spatial

scale (Archambault et al 2001; Schyns & Oliva, 1999). Identical targets differentially benefited from global and local priming depending on the visual similarity or dissimilarity of the distractor objects. This suggests that the requirements of the recognition task determined a bias in global and local attention which best supported recognition judgements.

A strong claim for a fixed global-to-local sequence in processing visual information is that local information is not processed until the processing of global information is completed. An alternative to this is that global and local processing occur in parallel (Han et al, 1999a) and these two processes compete with each other in determining which level dominates in the production of a response. It could be that biases in the allocation of attentional resources produced by the attention task facilitated the processing of global and local information, such that global priming produced faster response times for target detections that required coarse scale information, and local priming produced faster target detections that required fine scale information.

The difference between the results of this experiment and that of Sanocki's (1998, 2001) finding of global primes being more effective during the early stages of processing an object and local primes being more effective during the later stages of processing, may be a consequence of methodological differences. Sanocki selected a set of global features and a set of local features to prime the object recognition task and used an integrative priming technique where primes were presented before or after the presentation of the target. In this experiment, the primes always preceded target detection and the purpose of the priming was to bias the allocation of attentional resources that might benefit the selection of global or local features. This is quite different from supplying global and

local features directly. Perhaps in conditions where there is either equal activation of global features or equal activation of local features the visual system behaves more flexibly.

As regards the reverse hierarchy theory, Hochstein and Ahissar (2002) speculated that the initial conscious perception of objects is at the basic level. However, this may not be the case. The specificity of the initial conscious percept of the object may be variable and dependent on the context of the recognition process. Reverse hierarchy theory was devised to explain the speeded recognition of objects in a scene belied by a lack of awareness of fine details related to that scene. In this experiment, participants were required to detect single objects displayed sequentially. Perhaps the reduction of complexity in this task allowed for more specific identifications without recourse to lower levels of processing for accessing finer details related to the object's visual attributes.

It must be noted however, that not all conditions benefited from global or local priming. A closer examination of the priming effects of the divided attention task indicate that benefits for global priming were not observed for basic target detections in the context of visually dissimilar distractors (see Figure 9). Is this because the manipulation of the degree of visual similarity between target and distractor objects did not have the desired effect? Analysis of the data would not support this argument, because basic and subordinate target detections were faster with visually dissimilar distractors than visually similar distractors. An alternative explanation is that in the condition with basic level targets and visually dissimilar distractors the objects were more varied in their perceptual attributes than in the subordinate target detection task. In the case of the basic target

detection task it is likely that target objects shared few coarse scale or fine scale perceptual cues in common with distractor objects. Thus priming from global or local decisions was equally beneficial. In the case of the subordinate target detection task the target objects were more similar visually than basic target objects. It is conceivable that a similar set of global features was more efficient for discriminating subordinate targets from visually dissimilar distractors compared to more variable local features.

Before concluding this section, some problems associated with the methodology of Experiment 1 need to be addressed. There are two major problems with the design of this experiment that may have had an impact on the results. The first is that the sequence of the trials was determined *a priori* by the experimenter due to limitations with the program used to present the stimuli. The order of trials was produced using the randomizing function in Excel but the same order of trials was presented to each subject. It is possible that the particular sequence of trials was a factor in the pattern of priming shown in the target detection data. Secondly, the basic level targets ('dogs') were also used as the distractor objects in the subordinate target detection task with visually similar distractors. Thus, subjects had to re-map their responses to the 'dog' stimuli during the course of the experiment, which could have slowed down their reaction times to targets in some conditions relative to other conditions. Although the effects would have been spread equally between target detections primed by global or local decisions this unnecessary addition of noise to the data is not ideal.

To summarize, the results of this experiment indicated that global and local attention modulated the usage of perceptual information in the detection of target objects. When discriminating between visually similar objects, perceptual information supported

by local processing was more important than perceptual information supported by global processing. Conversely, when discriminating between visually dissimilar objects, perceptual information supported by global processing was more important than perceptual information supported by local processing. The distribution of attentional resources at global and local levels was based on the perceptual demands of the recognition task and global and local information was used flexibly. However, it is necessary to show some caution in interpreting the results from Experiment 1 given the methodological flaws. The following experiment overcomes the methodological problems of Experiment 1 and investigates whether the attentional priming effects were based on the allocation of attentional resources across a region of space (*attentional window hypothesis*) or based on parsing objects into their global and local constituents (*parsing hypothesis*).

Experiment 2

As discussed previously, there is evidence that there are two mechanisms involved processing hierarchical figures, a mechanism based on the allocation of attention across a region in space (spatial extent) and a mechanism based on grouping and parsing hierarchical figures into their local and global constituents. The purpose of Experiment 2 was to substantiate the findings of Experiment 1 and to investigate whether the priming effects of the hierarchical figures observed in Experiment 1 were due to the spatial extent of attention (*attentional window hypothesis*) or to grouping and parsing processes (*parsing hypothesis*).

In support of the *attentional window hypothesis* Robertson et al (1993) combined a cueing paradigm with a global/local divided attention task. In their Experiment 5, the cues were shaded rectangles that were slightly larger than the global form or slightly larger than the local form. They found that identification of global targets was faster when preceded by a global cue compared to no cue at all and similarly identification of local targets was faster when preceded by a local cue. They proposed a model in which cues facilitated the processing of information that appeared within the region of space indicated by the cue.

However not all the data could be accounted for by this model. They also analyzed effects of repeating levels between consecutive trials and found that global targets preceded by global targets were faster than global targets preceded by local targets and vice versa, local targets preceded by local targets were faster than local targets preceded by global targets. These effects suggested that level-specific information was

being carried over from one trial to another, facilitating performance when levels repeated. Furthermore, the effects were independent of the cues, which Robertson et al took as evidence for a different mechanism, called categorical attention, in which some feature of the level-specific information was sustained from one trial to another. They argued that spatial frequency bandwidths could be a good candidate for level specific information.

Additional evidence supporting the involvement of two separate mechanisms in the processing of hierarchical figures was provided by Lamb and Yund (2000). They also used rectangular cues approximately the same size as global and local forms and found that global and local target identifications were faster preceded by valid cues than invalid cues and neutral cues, even though the cues were not reliable predictors of location. Lamb and Yund postulated that the onset of the stimulus drives attention to the stimulus location, so that if the size of the attentional window is appropriate performance is enhanced, but if the size of the attentional window is not appropriate performance suffers. Similar to Robertson et al 1993, the effect of cues was also independent of level repetition effects, supporting the existence of two independent mechanisms involved in the processing of global and local forms. However, they did not find evidence that spatial frequency bandwidth selection could explain level repetition effects since level repetition effects and cue effects were both present regardless of whether spatial frequency differences were present or absent in the global and local forms.

Given that there is little corroborating evidence for the involvement of spatial frequency information in global and local processing (Hübner, 2000; Lamb & Yund, 1993; 1996; 2000; Lamb et al, 1999), we proposed that the second mechanism is based

on grouping and parsing processes (Han et al, 1999a). Grouping processes would be involved in the selection of global feature information, and parsing processes would be involved in the selection of local feature information. In this case it is the process that guides the allocation of attentional resources, not the nature of the level specific information.

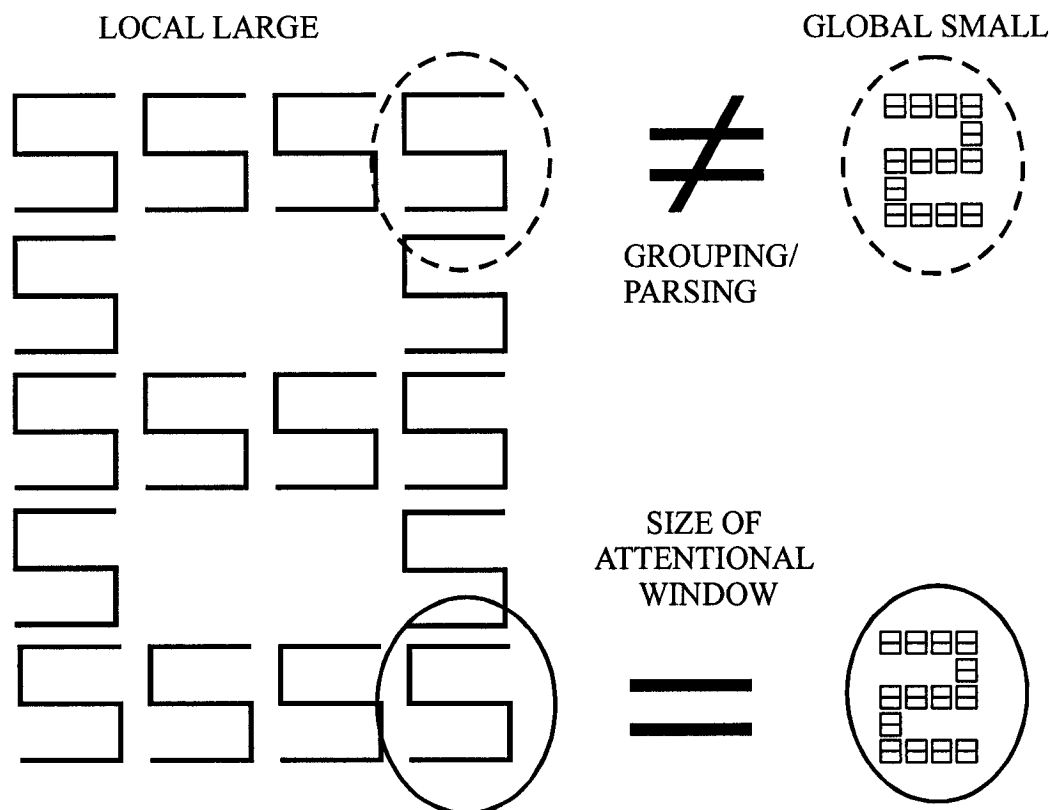


Figure 10. The large and small hierarchical figures used in Experiment 2. The local level of the large hierarchical figure subtends the same visual angle as the global level of the small hierarchical figure. If attentional priming is due to grouping and parsing processes there should be differences in target detection times in relation to the primes. If attentional priming is due to the size of the attentional window there should be no difference in target detection times in relation to the primes.

In order to establish whether the priming effects in Experiment 1 were due to either the spatial extent of attention or grouping/parsing processes, Experiment 2 included three different sized hierarchical stimuli (large, medium and small, see Fig. 11). The sizes

of the large and small hierarchical figures were adjusted so that the local level of the large hierarchical figure subtended the same visual angle as the global level of the small hierarchical figure. Figure 10 depicts the size relationships between the global and local levels of the large and small hierarchical figures. If the priming effects observed in Experiment 1 were due to the allocation of attentional resources based on the size of the attentional window, then there should be no differences in the effects of priming between the local level of the large figure and the global level of the small figure. This is because the size of the attentional window is the same for both levels. However, if the priming effects were due to grouping or parsing images into their global and local constituents, then a different pattern of priming would be expected from the local level of the large figure and the global level of the small figure. This is because priming effects would be related to level specific processes, not spatial extent.

Experiment 2 used the general method described in Chapter 4, however, there were a number of changes incorporated into the design in response to the methodological problems encountered in Experiment 1. First of all, in the condition with subordinate targets and visually similar distractors the targets were changed from 'beagles' to 'finches' and the distractors were changed from 'dogs' to 'other breeds of birds'. In the condition with basic targets and visually dissimilar distractors the target objects were changed from 'dogs' to 'fish' and the distractors remained manmade objects (see Fig.12 and Appendix C for a list of objects). This change was made to avoid response confusions due to the fact that in Experiment 1 'dogs' could be targets in one condition and distractors in another. The second change was that trials were presented in a different random order for each subject.

The *parsing hypothesis* would predict that the local level of the large hierarchical figure would prime target detections when the distractors were visually similar and the global level of the small hierarchical figure would prime target detections when the distractors were visually dissimilar, in line with Experiment 1. If there were no differences in the priming effects of the local level of the large figure and the global level of the small figure, this would support the *attentional window hypothesis*. Furthermore, if the attention mechanisms based on spatial extent and grouping/parsing processes are independent of each other, then it was expected that there would be no difference in the priming patterns on target detection times for each of the different sized hierarchical figures.

Method

Participants

Sixty-one undergraduate students from Dalhousie University participated in the experiment to fulfil a course requirement. All had normal or corrected-to-normal vision, and provided written, informed consent.

Stimuli

The hierarchical stimuli for the divided attention task were 2's and 5's made up of 8's or 8's made up of small 2's and 5's (see Figure 11). There were three sizes of hierarchical stimuli. The large hierarchical stimuli were 8.7 cm tall by 6.2 cm wide at the global level, and 1.7 cm tall by 1.4 cm wide at the local level, subtending visual angles of approximately 8.7° and 1.7° at the global and local levels respectively. The medium hierarchical stimuli were 5.2 cm tall by 3.7 cm wide at the global level and 0.9cm tall by

0.74 cm wide at the local level, subtending visual angles of approximately 5.2° and 0.9° . The small hierarchical stimuli were 1.7 cm tall and 1.4 cm wide at the global level and 0.3cm tall by 0.25 cm wide at the local level, subtending visual angles of approximately 1.7° and 0.3° . The lines for the medium and small hierarchical stimuli were 1 pixel thick, and they were 2 pixels thick for the large hierarchical stimuli.

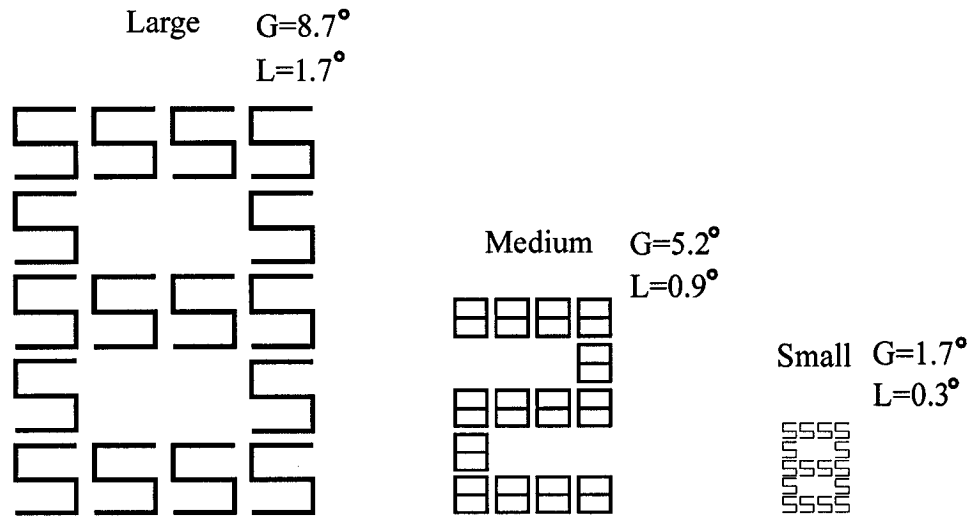


Figure 11. Hierarchical stimuli for the divided attention task. The approximate visual angles subtended at the global and local levels for each hierarchical figure are listed.

In the object detection task there were 176 black and white line drawings which consisted of 22 drawings each of finches, other breeds of birds, beagles, dogs, mammals, fish and 44 drawings of a variety of manmade objects (see Figure 12). From each of the animal categories 6 drawings were used in practice trials and 12 manmade object drawings were also used in practice trials. The line drawings were either taken from the Snodgrass and Vanderwart (1980) set, modified from children's colouring books or created from photographic images using Adobe Photoshop/Illustrator. The lines of the drawings varied from 1 to 2 pixels in width. All the objects subtended an approximate

visual angle of 5.2°. The stimuli from both tasks were presented on a white background using custom programmed software (MacInnes, 2000) on a G3 computer.

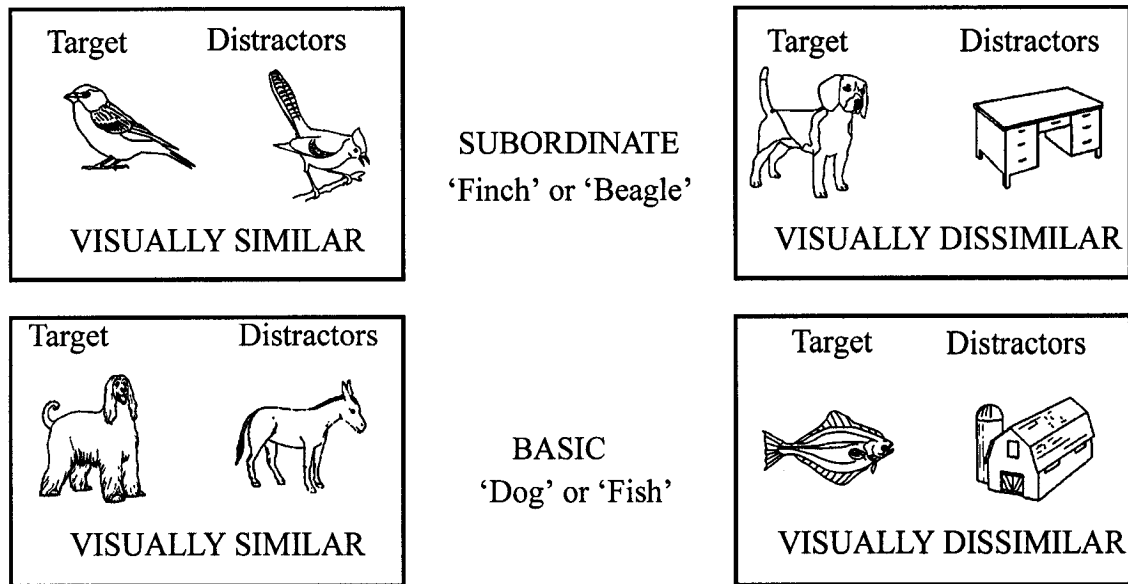


Figure 12. Examples of the stimuli used in the object detection task in Experiment 2 and Experiment 3. For each subordinate and basic level task the targets and distractor were either visually similar or visually dissimilar (see Appendix C for a list of objects).

Procedure

The participants first saw a fixation cross presented for 500ms followed by a global/local figure to which they responded with a key press to identify the presence of a '2' or a '5'. This was followed by an intertrial interval of 1000ms and second fixation cross (500ms), and an object to which they responded with one key press if the object was a target and another if the object was a distractor. For both the divided attention task and the target detection task stimuli remained on the screen until the participant made a response or 3s had passed. Half the participants responded to the divided attention task with their left hand and the object detection task with their right hand, and vice versa for

the remaining participants. The divided attention task always preceded the object detection task making a trial “couplet”. There was a block of trials for each of the object detection tasks. These were further divided into 3 blocks of trials, one for each of the three sizes of the hierarchical stimuli. Thus, there was a total of 12 blocks of test trials each consisting of 32 trial “couplets”. It was decided to block the three sets of different sized hierarchical figures because uncertainty about the size of the hierarchical stimulus might introduce an undesired variable. For example, Lamb & Robertson (1988) demonstrated that when participants were uncertain about the location of hierarchical figures this eliminated local precedence. Random presentation of hierarchical figures varying in size would also introduce location uncertainty since the figures would occupy variable regions of space.

Each test block was preceded by practice trials consisting of 12 trial “couplets”. In each block the order of couplets was randomized. Half of the couplets in a block had global level targets and half had local level targets. Half of the global level targets required a ‘2’ response and half a ‘5’ response, as did the local level targets. The divided attention task was the same in each block but the object detection task differed. Instructions preceding each block indicated which set of images were targets and which were distractors. As depicted in Figure 12 for visually similar subordinate categorizations the targets were “finches” and the distractors were “other breeds of bird”. For visually dissimilar subordinate decisions the targets were “beagles” and the distractors were “manmade objects”. For visually similar basic categorizations the targets were “dogs and the distractors were “mammals” and for visually dissimilar basic categorizations the targets were “fish” and the distractors were “manmade objects”. Participants were shown

pictures of 'beagles' and 'finches' to familiarize themselves with these target objects before proceeding with the experimental trials. These pictures were the same as those that appeared in the practice trials. The presentation order of the four object detection tasks was randomized. For each object detection task the blocks of three different sized hierarchical stimuli were presented in a latin square order.

Results

Multi-factorial repeated measures ANOVAs were performed on the reaction times and percentage correct for the target detection task. The factors were Attention Level (global or local), Size (large, medium and small), Distractor Type (visually similar, visually dissimilar) and Category Level (subordinate or basic). Fourteen subjects were excluded as they achieved less than 50% correct in one or more of the cells in the factorial design. In practice the majority of excluded subjects performed poorly in the condition with subordinate targets and visually dissimilar distractors. The analysis of reaction times and percentage correct for the divided attention task is reported in Appendix D.

Reaction Times for the overall analysis of all factors

As in Experiment 1, target detections were faster when the distractors were dissimilar (mean = 593ms) than when distractors were similar (mean = 711ms, $F(1,46) = 91.53$, $MS^e = 42,406$). This pattern of results occurred in all subsequent analyses for Experiment 2 and will be omitted in the ensuing results sections. There was evidence that the degree of visual similarity between targets and distractors influenced performance on basic and subordinate target detections ($F(1,46) = 4.365$, $MS^e = 40,964$). Subordinate

target decisions were slower (mean = 733ms) than basic target decisions (mean = 688 ms) when the distractors were visually similar ($t(1,281) = 4.13$). However, there was no reliable difference between category levels when the distractors were dissimilar ($t < 1$). There was also a relationship between visual similarity and the size of the hierarchical primes, ($F(2,92) = 4.45$, $MS^e = 11,147$). In the context of visually similar distractors target detections made after responses to the medium sized hierarchical figures (mean = 728ms) were slower than target detections made after the large and small sized hierarchical figures (Large = 697ms, Small = 707ms). When the distractors were visually dissimilar there was little difference in target detection times in terms of the size of the preceding hierarchical figures (Large = 600ms, Medium = 586ms and Small = 594ms).

Most importantly, there were a number of effects associated with global and local priming. Firstly, the effects of global and local priming were sensitive to the category level ($F(1,46) = 8.02$, $MS^e = 3,843$) of the target detections and to the degree of visual similarity between targets and distractors ($F(1,46) = 3.96$, $MS^e = 8,256$). The influence global and local priming on target detections is best understood by examining the combined effects of category level and visual similarity, since all three factors interacted with each other ($F(1,46) = 15.16$, $MS^e = 5,145$). Figure 13 shows that subordinate target detections made in the context of visually similar distractors were faster preceded by local decisions (mean = 720ms) than preceded by global decisions (mean = 750ms, $t(1,140) = 2.75$). In contrast, basic target detections made in the context of visually similar distractors were faster preceded by global decisions (mean = 689ms) than preceded by local decisions (mean = 702ms, $t(1,140) = 2.29$). Similarly, subordinate target detections made in the context of visually dissimilar distractors were faster preceded by global

decisions (mean = 579ms) than preceded by local decisions (mean = 604ms, $t(1,140) = 2.69$, $p = .008$). There was no reliable difference produced by global (mean = 590ms) and local priming (mean = 605ms) on basic target detections made in the context of visually dissimilar distractors ($t(1,140) = 1.59$).

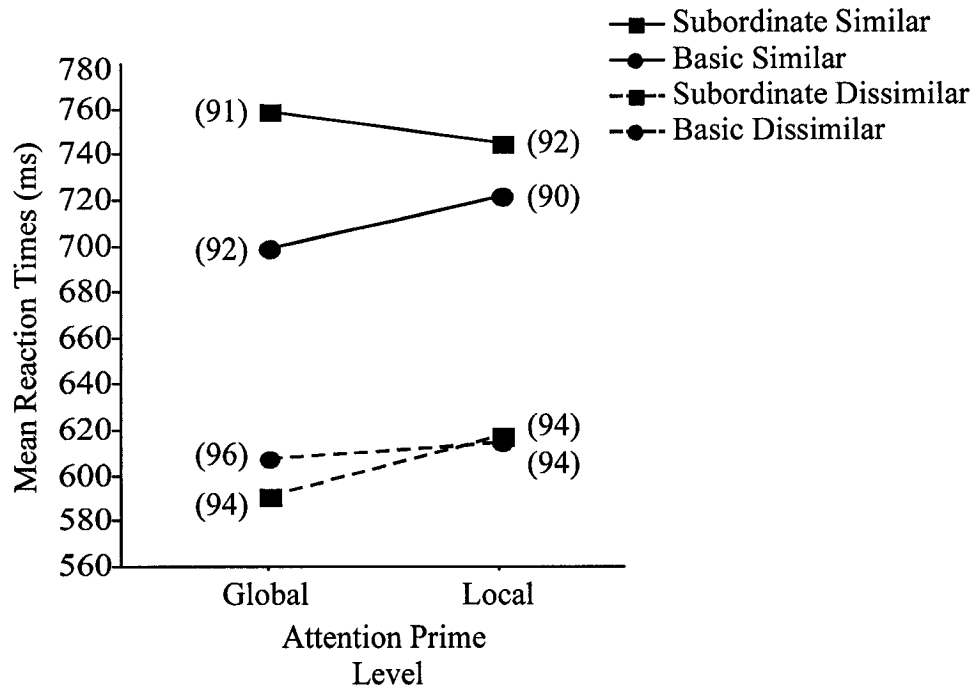


Figure 13. Reaction times to the target detection task after priming by a global/local divided attention task. The numbers in brackets are the percentage correct for each condition.

Percentage Correct for the overall analysis of all factors

More correct responses were made for target detections when the distractors were dissimilar (95%) than for target detections when the distractors were similar (91%, $F(1,46) = 36.08$, $MS^e = 87$). Again this pattern of accuracy was found for all subsequent analyses and will not be reported in the ensuing sections. The size of the hierarchical primes influenced the accuracy of basic and subordinate target detections ($F(2,92) = 4.85$, $MS^e = 64$). Performance was worse on subordinate target detections (92%, basic = 94%)

after priming by small hierarchical figures and worse on basic target detections (92%, subordinate = 94%) after priming by medium hierarchical figures. There was a small difference in percentage of correct responses for basic (92%) and subordinate (93%) target detections after priming by large hierarchical figures. There were no other significant effects. These measures failed to support any speed-accuracy trade-offs.

Reaction times for target detections after priming with Global (Small) and Local (Large) hierarchical figures.

A 2 X 2 X 2 repeated-measures ANOVA was performed with factors of Attention Level (Global Small/Local Large), Category Level (Subordinate/Basic) and Distractor Type (Similar/Dissimilar). In support of the *parsing hypothesis* significant differences were found in the effects of global (small) and local (large) priming on target detection times $F(1,46) = 4.745$, $MS^e = 8,697$). The pattern of means was similar to that found in the overall analysis of the data. As depicted in Figure 14, subordinate targets detected amongst visually similar distractors were faster preceded by local decisions (mean = 707ms) than by global decisions (mean = 741ms) and basic targets detected amongst visually similar distractors were faster preceded by global decisions (mean = 674ms) than local decisions (mean = 690ms). Subordinate targets detected amongst visually dissimilar distractors were also faster preceded by global decisions (mean = 587ms) than local decisions (mean = 628ms). There was little difference in the detection of basic targets when the distractors were visually dissimilar (mean after global priming = 597ms, mean after local priming = 605ms).

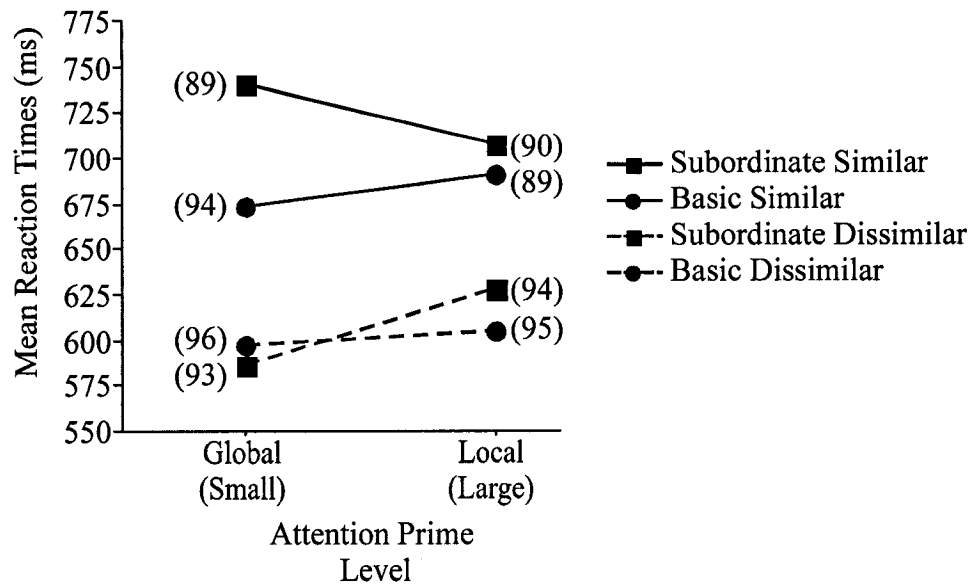


Figure 14. Mean reaction times to the target detection task in the context of visually similar and dissimilar distractors. The attention primes were either the global level of the small hierarchical figure or the local level of the large hierarchical figure. Both attention primes subtended the same visual angle. The numbers in brackets are the percentage correct for each condition.

Percentage correct for target detections after priming with Global Small and Local Large hierarchical figures.

There were more correct responses to basic target detections (94%) compared to subordinate target detections (92%). Effects of global (small) and local (large) priming also differed depending on the category level of the target ($F(1,46) = 4.94$, $MS^e = 67$). There were more correct responses made to basic target detections preceded by global (small) decisions (95%) than preceded by local (large) decisions (92%) and little difference in subordinate target detections after priming by either global (small) or local (large) decisions (91% and 92%, respectively). This interaction provides further support for the *parsing hypothesis* and failed to support any speed-accuracy trade-offs.

Separate analyses of target detections after priming with each of the three different sizes of hierarchical stimuli.

Separate analyses of reaction times and percentage correct were performed on the target detection data after priming by each size of the hierarchical stimuli (large, medium and small). According to the *parsing hypothesis* there should be no differences in the effects of priming between the three sizes of hierarchical stimuli. For each analysis a 2 X 2 X 2 repeated-measures ANOVA was performed with factors of Attention Level (Global/Local), Category Level (Subordinate/Basic) and Distractor Type (Similar/Dissimilar).

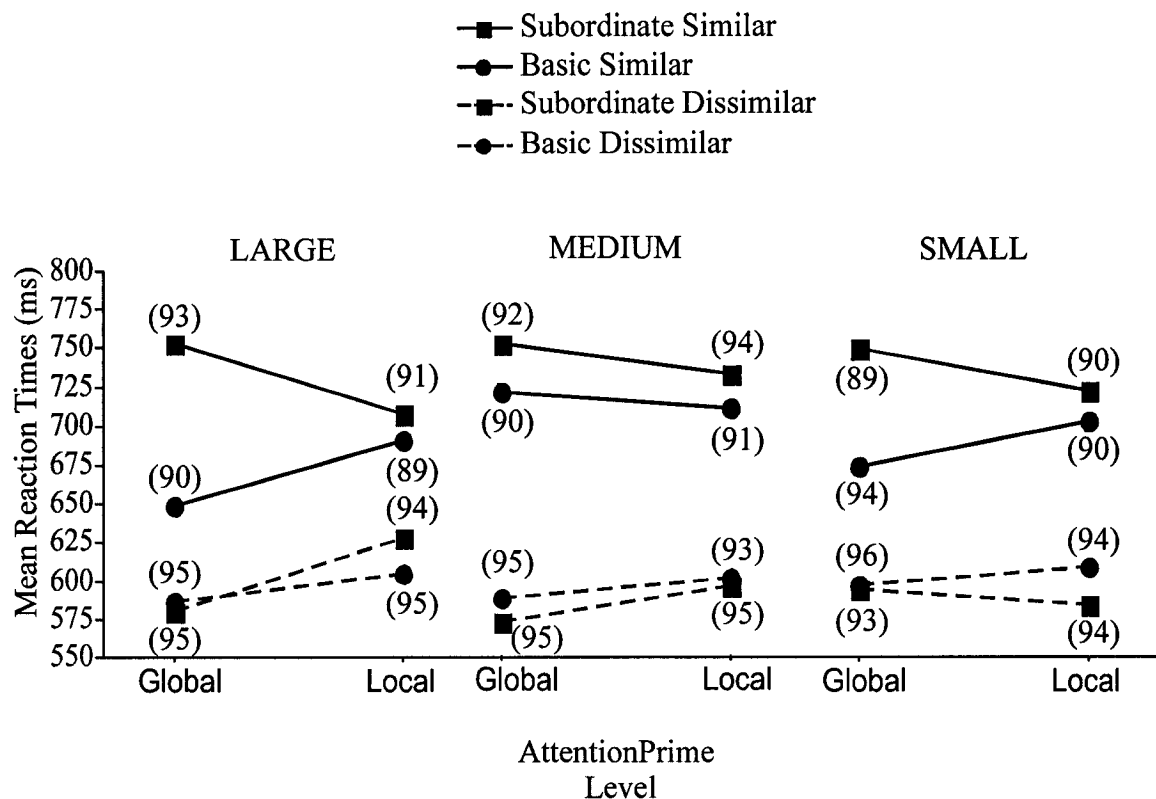


Figure 15. Mean reaction times to basic and subordinate target detections made in the context of visually similar or visually dissimilar distractors after priming by a divided attention task. The attention primes were hierarchical figures at various sizes

(Large, Medium and Small). The numbers in brackets are the percentage correct for each condition.

Reaction times to target detections primed by large hierarchical stimuli

Overall basic target detections (mean = 633ms) were faster than subordinate target detections (mean = 667ms, $F(1,46) = 4.27$, $MS^e = 26,150$) and all target detections were faster preceded by global decisions (mean = 642ms) than preceded by local decisions (mean = 658ms, $F(1,46) = 6.6$, $MS^e = 3,626$). Similar to the overall analysis, effects of global and local priming were sensitive to both the category level of the targets ($F(1,46) = 3.96$, $MS^e = 4,811$) and the degree of visual similarity between targets and distractors ($F(1,46) = 6.37$, $MS^e = 4,700$).

The factors of Category Level and Distractor Type acted in conjunction with global and local priming ($F(1,46) = 6.551$, $MS^e = 12,310$). Figure 15 shows that subordinate target detections made in the context of visually similar distractors were faster preceded by local decisions (mean = 708ms) than preceded by global decisions (mean = 753ms, $t(1,46) = 2.28$). In contrast, basic target detections made in the context of visually similar distractors were faster preceded by global decisions (mean = 649ms) than preceded by local decisions (mean = 691ms, $t(1,46) = 3.18$). Similarly, subordinate target detections made in the context of visually dissimilar distractors were faster preceded by global decisions (mean = 579ms) than preceded by local decisions (mean = 628ms, $t(1,46) = 2.51$). The difference between basic target detections preceded by either global (mean = 586ms) or local decisions (mean = 605ms) when made in the context of visually dissimilar distractors, was not significant.

Percentage correct for target detections primed by large hierarchical stimuli

Target detection accuracy differed depending on the degree of visual similarity between targets and distractors ($F(1,46) = 23.47$, $MS^e = 62$). There were no other significant effects and no evidence for a speed accuracy trade-off.

Reaction times for target detections primed by medium hierarchical stimuli

Similar to Experiment 1, target detections made in the context of visually dissimilar distractors were faster preceded by global decisions (mean = 579 ms) than preceded by local decisions (mean = 593ms). In contrast target detections made in the context of visually similar distractors were faster preceded by local decisions (mean = 721ms) than preceded by global decisions (mean = 736ms). Although the interaction between Attention Level and Distractor Type was marginal ($F(1,46) = 3.41$, $p = .07$, $MS^e = 6,081$) it is believed that the results were real since it is the condition that matches most closely to Experiment 1, in which the objects and the hierarchical attention primes are approximately the same size. A combined analysis of the results from Experiment 1, and priming by medium sized hierarchical figures revealed no reliable differences between the two sets of data ($F(1,82)=1$).

Percentage correct for target detections primed by medium hierarchical stimuli

Target detection accuracy differed depending on the degree of visual similarity between targets and distractors ($F(1,46) = 9.62$, $MS^e = 67$). There were no other significant effects and no evidence for a speed accuracy trade-off.

Reaction times for target detections primed by small hierarchical stimuli

There was evidence that the degree of visual similarity between targets and distractors influenced performance on basic and subordinate target detections ($F(1,46) = 4.59$, $MS^e = 16,595$). Basic target detections (mean = 686ms) were faster than subordinate target detections (mean = 727ms) when made in the context of visually similar distractors but subordinate target detections (mean = 586ms) were faster than basic target detections (mean = 602ms) when made in the context of visually dissimilar distractors. The effects of global and local priming were influenced by the category level of the target ($F(1,46) = 5.428$, $MS^e = 4,420$). Subordinate target detections were faster preceded by local decisions (mean = 650ms) than preceded by global decisions (mean = 664ms) and basic target detections were faster preceded by global decisions (mean = 636ms) than preceded by local decisions (mean = 653ms).

Percentage correct for target detections primed by small hierarchical stimuli

Target detection accuracy differed depending on the category level of the target ($F(1,46) = 4.71$, $MS^e = 79$). There were more correct responses for basic target detections (94%) than subordinate target detections (92%). There was no evidence of a speed accuracy trade off.

Discussion

The main purpose behind Experiment 2 was to discover whether the priming effects of global and local attention depended on a parsing mechanism or were related to the size of the attentional window. Evidence was found that supported the role of a parsing mechanism. A comparison was made between the priming effects of two stimuli that subtended the same visual angle but belonged to different levels of a hierarchical figure; namely the local level of the large hierarchical stimulus versus the global level of the small hierarchical stimulus. Results showed that there was a difference in the priming effects of these two stimuli. Subordinate target detections made in the context of visually similar distractors were faster when preceded by the local level of the large hierarchical stimulus compared to the global level of the small hierarchical stimulus. Subordinate target detections made in the context of visually dissimilar distractors were faster when preceded by the global level of the small hierarchical stimulus compared to the local level of the large hierarchical figure. For both basic target detections reaction times were generally faster after priming by the global level of the small hierarchical stimulus. If the priming effects of global and local attention on the object recognition task were due only to the size of the attentional window then there should have been no difference between the effects of these two attentional primes as they were the same size.

A strong prediction of the *parsing hypothesis* was that the size of the hierarchical figures would not influence global and local priming effects on target detection. Although manipulating the size of the hierarchical stimuli did not give rise to any interactions with attention level, the patterns of priming differed for each of the three sizes of the hierarchical figures. In the case of large hierarchical stimuli, it was found that only

subordinate target detections made in the context of visually similar distractors were faster after priming by local decisions. Both basic target detections and subordinate target detections made in the context of visually dissimilar distractors were faster after priming by global decisions. In the case of small hierarchical stimuli it was found that in general subordinate target detections were faster after local decisions regardless of the visual similarity or dissimilarity of the distractors, whereas basic target detections were faster after global decisions. In contrast, when target detections were preceded by medium sized hierarchical stimuli it was found that subordinate and basic target detections made in the context of visually similar distractors were faster preceded by local decisions and subordinate and basic target detections made in the context of visually dissimilar distractors were faster preceded by global decisions. These differences in patterns of priming for the three different sized hierarchical primes suggest that size did make a difference and that some element of attentional priming was related to the size of the attentional window.

Furthermore, the manipulation of the sizes of the hierarchical stimuli did influence target detections depending on the degree of visual similarity between the targets and the distractors. The difference between target detections made in the context of visually similar and dissimilar distractors was greater when preceded by medium hierarchical stimuli than it was when the target detections were preceded by small or large hierarchical stimuli.

To summarize, the data from Experiment 2 support two separate mechanisms, one involved in parsing objects into their global and local constituents and another associated with resizing the attentional window. This finding is not unprecedented. Other

researchers have also found evidence supporting the involvement of these two mechanisms in the processing of global and local figures (Lamb & Yund, 2000; Robertson et al, 1993). The interesting question is how these two mechanisms contributed to the performance of the object detection task.

Research conducted by Kim, Ivry & Robertson (1999) may shed light on this question. Kim et al were interested in finding out whether parsing objects into their global and local forms was based on the absolute size of the stimulus or was relative to the physical attributes of the stimulus. They presented subjects with different-sized hierarchical stimuli. The global level of the small hierarchical stimulus was the same size as the local level of the large hierarchical stimulus. They examined level repetition effects and size repetition effects and found that level repetition effects were influenced by the overall size of the hierarchical forms. Their results suggested that level repetition effects were not independent of the absolute size of the hierarchical forms. Kim et al argued that their data could be explained by a dual frequency filtering mechanism that first selects the absolute spatial frequency range in a stimulus and then, selects the relative frequencies within the range. Either of these filtering operations could influence target detections on subsequent trials.

A problem with the dual frequency filtering mechanism is that there is little support for spatial frequency information being the basis on which images are broken down into their global and local constituents (Hübner, 2000; Lamb & Yund, 1993; 1996, 2000; Lamb et al, 1999). An alternative to Kim et al's (1999) explanation is that effects related to the size of the hierarchical stimuli were due to adjustments in the size of the attentional window rather than spatial frequency. Effects related to the level at which

targets appeared were due to parsing hierarchical forms into their global and local constituents, possibly based on gestalt principles.

The different pattern of priming found for the large, medium and small sized primes in this experiment might be explained by one mechanism that adjusts the attentional window to the overall sizes of the hierarchical forms and objects, and a second mechanism that parses object features into global and local forms relative to the size of the attentional window. The fact that people are able to recognize objects in many different formats such as black and white or coloured photographs and illustrations, line drawings, cartoons and variously degraded images supports the notion that numerous properties of a visual stimulus are diagnostic for its identity. The hierarchical primes bias the visual system to process one set of perceptual cues instead of another set of perceptual cues. In effect, changing the sizes of the hierarchical figures modulates attentional processes and changes the availability of perceptual cues.

Moreover, Han et al (1999a) proposed that the discrimination of parts or features of objects might occur with respect to hierarchical levels of the representation. For example arms may be represented as parts relative to the body and hands may be represented as parts relative to the arm and fingers may be represented as parts relative to the hand. Large, medium and small hierarchical primes may bias attention towards perceptual cues that activate different levels in a hierarchical representation. Taking the above example, the global level of the large hierarchical prime may facilitate processing of overall body shape information and the local level may facilitate processing of the arm. Conversely, the global level of the medium hierarchical prime may facilitate processing of the hand and the local level may facilitate processing of fingers, and so on.

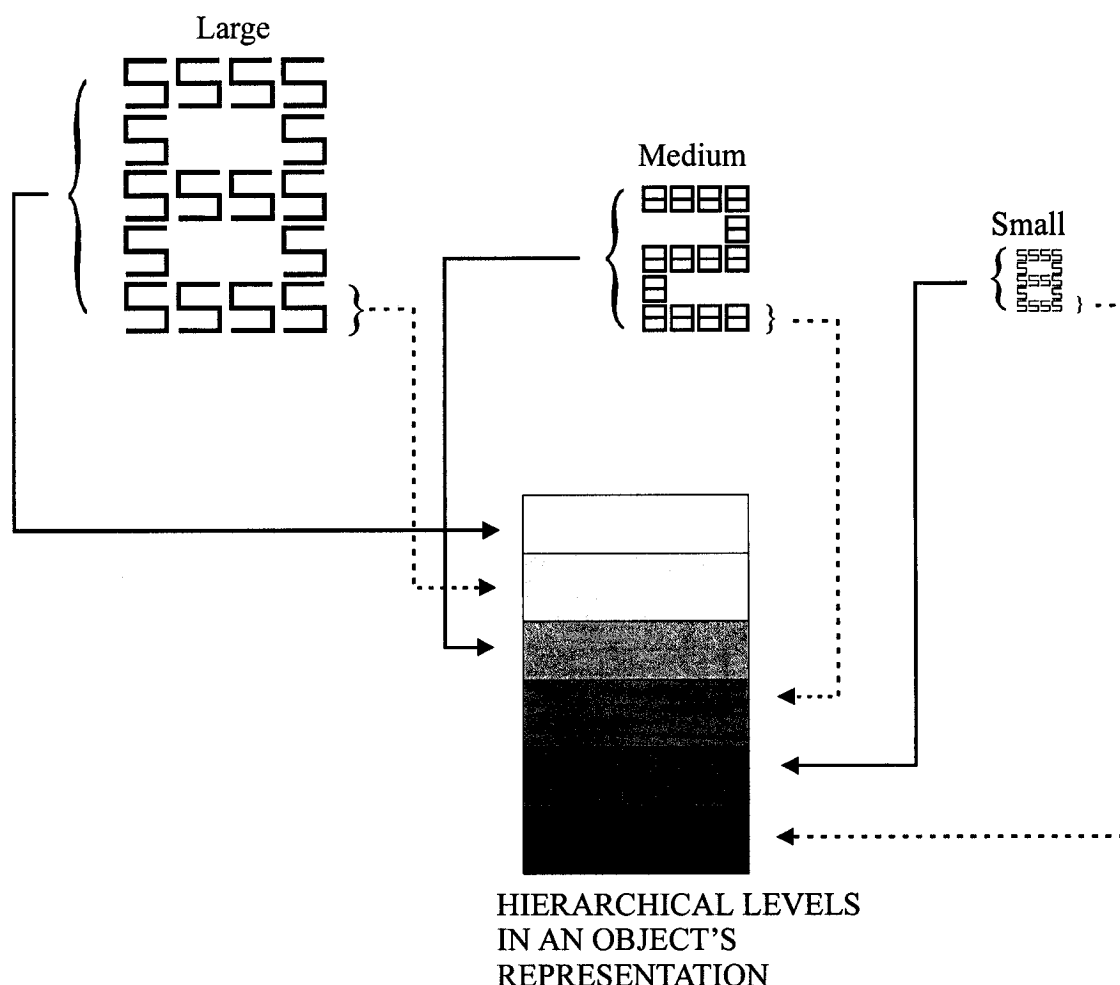


Figure 16. An illustration of how the large, medium and small sized primes may bias the distribution of attention. The differing distribution of attentional resources facilitates the processing of different perceptual attributes and this in turn influences the level at which an object's representation is activated. The different colour boxes represent different levels in a hierarchical representation of an object, with the top most levels representing coarse shape details and the lower levels representing progressively finer shape information.

In this case, the different pattern of priming observed for the three sizes of hierarchical figures may be due to an association between the distribution of attention, the nature of the perceptual attributes benefiting from that distribution, and the level at which a representation is accessed (see Figure 16).

It was predicted that the overall pattern of priming in Experiment 2 would be similar to that observed in Experiment 1. In Experiment 1 subordinate and basic target detections made in the context of visually similar distractors were faster when preceded by local decisions compared to global decisions, whereas in Experiment 2 only subordinate detections in the context of visually similar distractors showed this effect of priming (see Table 1). Furthermore, separate analyses of the variously sized hierarchical stimuli showed different patterns of priming. It was only when the hierarchical figures were similar in size to the objects that the results of Experiment 1 were replicated. The difference in the pattern of priming observed in Experiments 1 and 2 can be explained by the hypothesis that different sized hierarchical figures biased the availability of different perceptual cues. However, in light of the results of Experiment 2 the claims made about the roles of conceptual knowledge and perceptual demands in the selection of a global or local distribution of attention need to be revisited.

Table 1. *The level of attention, which primed the target detection task in each of the four conditions as a function of the size of the hierarchical prime for Experiments 1 and 2. Local refers to faster target detections after local level decisions. Global refers to faster target detections after global level decisions. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.*

<u>Condition</u>	<u>Large</u>	<u>Medium</u>	<u>Small</u>	<u>Exp 1 (Medium)</u>
Subordinate Similar	Local	Local	Local	Local
Subordinate Dissimilar	Global	Global	Local	Global
Basic Similar	Global	Local	Global	Local
Basic Dissimilar	Global	NP	Global	NP

The pattern of priming on the target detection task when preceded by a small hierarchical figure would suggest that conceptual knowledge influenced the selection of

global or local levels of attention. Table 1 shows that subordinate target detections were primed by local decisions and basic target detections were primed by global decisions regardless of the degree of visual similarity between the targets and the distractors. This would suggest that the important variable in the selection of the level of attention was the category level of the target. In Experiment 1 it was hypothesized that attentional priming effects related to the level of category decisions would reflect the influence of prior knowledge on the selection of attention level. How can one reconcile evidence for the influence of both prior knowledge and perceptual demands on the selection of attention level?

It is conceivable that the selection of attention level is initially influenced by prior knowledge of the target object where a global level of attention is selected for basic decisions and the local level is selected for subordinate decisions. However, the preceding divided attention task biases the selection of perceptual attributes of objects, some of which may be more effective for target detection than others. If the perceptual attributes selected on the basis of the initial distribution of attention are effective, then the pattern of priming reflects the category level of the target object. However, if selection of perceptual attributes is not diagnostic, the pattern of priming reflects the results of a competition between the global and local processing streams. When the target detection task is primed by the small hierarchical figure, this selection is effective for subordinate and basic target detections when distractors are visually similar and when they are visually dissimilar. However, for medium and large hierarchical figures the nature of the perceptual cues favoured by local processing were not as effective as those favoured by

global processing. Thus, one observes an advantage for basic target detections made after global decisions.

In Experiment 2 the three sizes of hierarchical primes resulted in different effects. From Table 1 it can be discerned that the same pattern of priming from hierarchical figures was found for subordinate target detections made in the context of visually similar distractors, regardless of size. However, there were different patterns of priming for subordinate target detections made in the context of visually dissimilar distractors and basic target detections made in the context of visually similar or dissimilar distractors, depending on the size of the hierarchical figures.

It was proposed that varying the sizes of the hierarchical figures modulates the distribution of attentional resources and thus biases the availability of perceptual cues. Perhaps for basic level categorizations there are more avenues available for correct identification. Archambault et al (2000) speculated that the reason basic level categorizations were more robust to changes in the size of the stimuli may have been because perceptual cues conveyed by either low or high spatial frequencies were equally diagnostic for basic level identifications. In Experiment 2, the differences in priming effects for basic level target detections could reflect the flexibility of basic level categorization processes in the usage of perceptual cues. For example, detailed information such as the shape of a dog's paws or the shape of deer's hoofs could allow one to distinguish between a dog and a deer equally as well as gross differences in body shape. The same could be said for subordinate target detections when they are made in the context of visually similar distractors. Discriminating a 'beagle' from a gun could be done equally well with detailed information such as the shape of the nose, or from

course-scale information such as body shape. In a model where global and local processes occur in parallel it may be that the selection of perceptual cues in the local processing stream wins out over the selection of perceptual cues in the global processing stream after priming by a hierarchical figures similar in size to the objects. On the other hand, the selection of perceptual cues in the global processing stream may win out when the hierarchical primes differ in size from the objects.

There were also effects that did not involve attention priming. Consistent with Experiment 1, target detections made in the context of visually similar distractors were slower than target detections made in the context of visually dissimilar distractors, demonstrating that it is easier to distinguish between objects that are visually dissimilar than objects that are visually dissimilar. A difference was also found between subordinate target detections and basic target detections made in the context of visually similar distractors compared to subordinate and basic target detections made in the context of visually dissimilar target detections. When distractors were visually similar to the targets basic target detections were faster than subordinate target detections. However, when distractors were visually dissimilar to the targets no reliable difference was found between subordinate and basic target detections. This result suggests that differences between subordinate and basic target detections do depend on the degree of visual similarity between the target object and distractor objects in a visual task.

Experiment 3

In Experiment 2 it was argued that the pattern of attention priming on the object target detection task was due to the action of two separate mechanisms. One mechanism involved resizing the window of attention relative to the overall sizes of the hierarchical figures and the objects. The second mechanism parsed objects and attention primes into their global and local constituents relative to the size of the attentional window. However, there is the possibility that all the priming effects can be explained by the *attentional window hypothesis* in which attentional resources are distributed according to spatial regions of interest. The purpose of Experiment 3 was to test whether resizing the attentional window would influence the performance of object target detections.

It is possible that the pattern of priming by the hierarchical figures observed in Experiment 2 could be explained by the by set size effects. Lamb & Robertson (1990) investigated the effects of visual angle on global and local processing. They presented subjects with hierarchical figures subtending visual angles of 1.5°, 3°, 4.5° or 6° in one experiment (small-stimuli set) and 3°, 6°, 9° and 12° (large-stimuli set) in another experiment. They found that the transition point from faster reaction times to global targets to faster times to local targets differed depending on set of hierarchical figures presented. In the small-stimuli set the transition point was between 1.5° and 3° and in the large-stimuli set the transition point was between 3° and 6°. They proposed that in the large-stimuli set, attention was distributed over a wider area and this benefited global processing over local processing.

Set size effects may underlie the pattern of priming effects observed in Experiment 2 because the divided attention task that primed the target detection task was blocked according to the size of the hierarchical figure. The main evidence for the parsing mechanism in Experiment 2 was the fact that priming by the local level of the large hierarchical figure differed from priming by the global level of the small hierarchical figure even though they both subtended the same visual angle. However, the large and small hierarchical figures subtended different visual angles as a whole. Effectively, the overall distribution of attention would differ for each of these figures. Thus, the different patterns of priming observed for large and small hierarchical figures could have reflected a difference in the distribution of attention based on the overall size of the hierarchical figures.

In Experiment 3 the target detection task was the same as that used in Experiment 2, but the attention priming task was modified. The global and local levels of the hierarchical figures were separated into individual digits (see Figure 17). For example the large hierarchical prime was separated into digits subtending visual angles of 8.7° for the global level and 1.7° for the local level. The task of the participant in the attentional priming condition was to indicate whether the digit was a 2 or a 5. In effect, the digits act in a similar fashion to the rectangular cues used by Robertson et al (1993) and Lamb & Yund (2000) in their investigations into the effects of cueing the region of space covered by global or local targets.

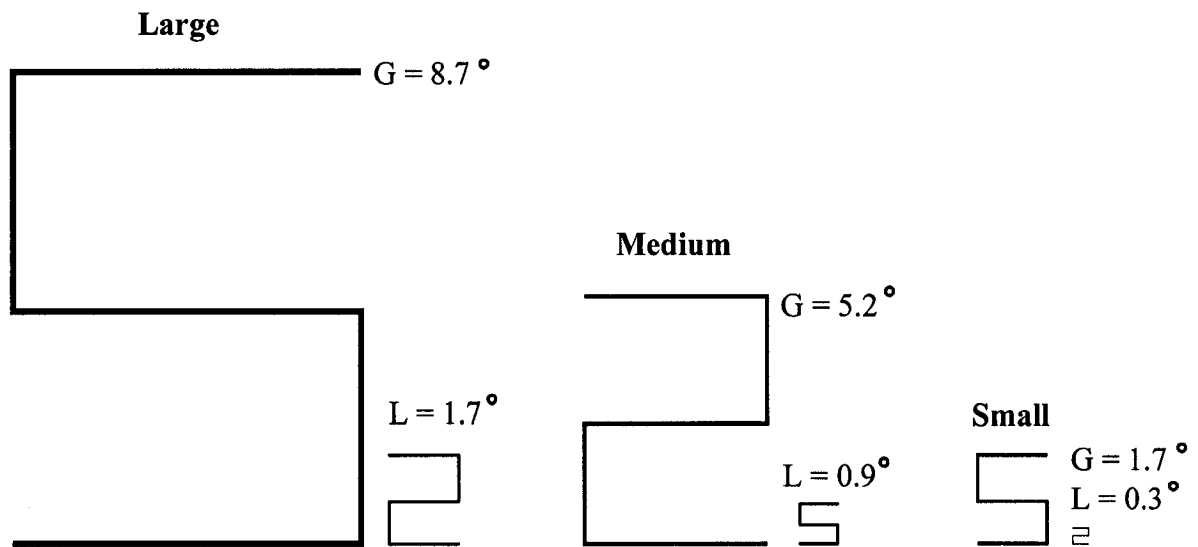
In support of the *attentional window hypothesis*, it was expected that similar priming effects on the target detection task would be observed when primed by separate digits subtending the same visual angles as the global and local levels of the hierarchical

figures. On the other hand, if the *parsing hypothesis* was correct it was expected that there would either be no reliable effects on the target detection task when primed by separate digits, or the patterns of priming would differ markedly from those observed in Experiment 2. In addition, there would be no reliable difference in the priming effects for digits subtending the same visual angle.

Method

Participants

Sixty-five undergraduate students from Dalhousie University participated in the experiment to fulfil a course requirement. All had normal or corrected-to-normal vision, and provided written, informed consent.



Stimuli

Figure 17. *The digits used in the attention priming task for Experiment 3. The digits subtended the same visual angles as the global (G) and local elements (L) of the hierarchical figures in Experiment 2.*

The stimuli for the attention task were the digits 2 and 5. Stimuli were constructed by separating out the global and local levels of the hierarchical figures in Experiment 2 as depicted in Figure 17. The digits corresponded in size to the global and local elements of the hierarchical figures presented in Experiment 2 (see figure 11 for examples). The large group of digits subtended visual angles of approximately 8.7° and 1.7° , corresponding to the sizes of the global and local levels of the hierarchical figures respectively. The medium digits subtended visual angles of approximately 5.2° and 0.9° and the small digits subtended visual angles of approximately 1.7° and 0.3° . The lines for the medium and small hierarchical stimuli were 1 pixel thick and 2 pixels thick for the digits subtending visual angles of 8.7° and 5.2° . The same 176 black and white line drawings from Experiment 2 were used in the target detection task (see Figure 12 and Appendix C). All the objects subtended an approximate visual angle of 5.2° . The stimuli from both tasks were presented on a white background using custom programmed software (MacInnes, 2000) on a G3 computer.

Procedure

The timing of the presentation of the stimuli was the same as that described in Experiment 2. The attention priming task always preceded the target detection task making a trial “couplet”. In the attention priming task single digits were presented on the computer screen and participants responded with either a ‘2’ or ‘5’ key press. The target detection task was the same as Experiment 2.

As in Experiment 2 there was one block of trials for each of the 4 target detection tasks. These blocks were further divided into 3 blocks of trials for each of the three sized digit groups (large, medium, and small). The individual digits corresponding in size to the global and local levels of the hierarchical figures were presented in 3 separate blocks for each of the sizes (large, medium, and small). The total number of test blocks was 12 and each block consisted of 32 trial “couplets”. There were 4 blocks of practice trials, one block for each target detection task. Each practice block consisted of 12 trial "couplets". The order of presentation of the test blocks was the same as Experiment 2. In each block (test or practice) the order of couplets was randomized. Half of the couplets in a block had digits corresponding to the global level targets and half had local level targets. (The individual digits corresponding to the global and local levels of the hierarchical figures will also be referred to as 'global' and 'local'). Half of the global level targets required a ‘2’ response and half a ‘5’ response, as did the local level targets. The attention priming task was the same in each block but the target detection task differed. As in Experiment 2, participants were given instructions preceding each block indicating which set of images were targets and which were distractors. Participants were also shown pictures of 'beagles' and 'finches' to familiarize themselves with these target objects before proceeding with the experimental trials. The pictures were the same as those that appeared in the practice trials.

Results

Multi-factorial repeated measures ANOVAs were performed on the reaction times and percentage correct for the target detection task. The factors were Attention Level (global element or local element), Size (large, medium or small), Distractor Type

(visually similar or visually dissimilar) and Category Level (subordinate or basic). Data were included in the RT analysis only if two consecutive responses in a couplet were correct. Seventeen subjects were excluded as they achieved less than 50% correct in one or more of the cells in the factorial design. The analysis of reaction times and percentage correct for the divided attention task is reported in Appendix E.

Reaction times for the overall analysis of all factors

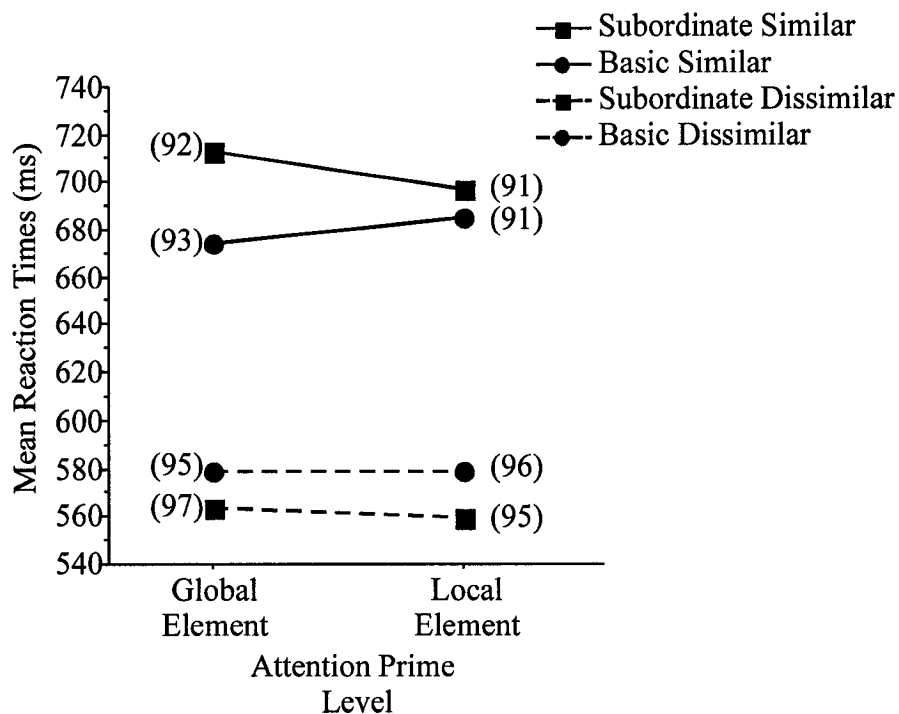


Figure 18. Mean reaction times to the target detection task after priming by variously sized digits. The labels global and local refer to origins of the attention primes. Global element primes were the digits 2 and 5 that subtended the same visual angles as the global levels of the hierarchical primes in Experiment 2. Local element primes were the digits that subtended the same visual angles as the local levels of the hierarchical primes in Experiment 2. The numbers in brackets are the percentage correct for each condition.

As reported previously target detections were faster when the distractors were dissimilar than when distractors were similar ($F(1,47)=197.44$, $MS^e = 21,742$). This pattern of results occurred in all subsequent analyses for Experiment 2 and will be

omitted in the ensuing results sections. There was evidence that the degree of visual similarity between targets and distractors influenced performance on basic and subordinate target detections ($F(1,47) = 8.52$, $MS^e = 15,189$). Basic target detections (mean = 680ms) were faster than subordinate target detections (mean = 705ms, $t(1,293) = 3.01$) when the distractors were visually similar. In the case of visually dissimilar distractors, the opposite pattern was observed; subordinate target detections (mean = 561ms) were faster than basic target detections (mean = 578ms, $t(1,293) = 3.36$).

In support of the *attentional window hypothesis*, priming by global and local elements was influenced by the category level of the targets ($F(1,47) = 4.87$, $MS^e = 3,422$). Subordinate target detections (mean = 628ms) were faster than basic target detections (mean = 632 ms) after local element decisions and basic target detections (mean = 626ms) were faster than subordinate target detections (mean = 638ms) after global element decisions. From Figure 18 it appears that this effect was due to differences in target detection times when the distractors were visually similar¹.

Furthermore, unlike the data from Experiment 2, attention priming was influenced by the size of the digit groups ($F(2,94) = 3.33$, $MS^e = 3,625$). Target detections made after small attention primes were faster preceded by local element decisions (mean = 627ms) than global element decisions (mean 644ms, $t(1,191)=2.14$). There were no reliable differences in target detections times after medium or large attention primes. The influence of size on attention priming was further mediated by the degree of visual

¹ A separate analysis was performed on target detections made in the context of visually similar distractors and those made in the context of visually dissimilar distractors. There were no significant priming effects on target detections made in the context of visually dissimilar distractors.

similarity between targets and distractors ($F(2,94) = 7.99$, $MS^e = 3,305$). As is evident in Figure 19, target detections made in the context of visually similar distractors were faster preceded by large global element primes (mean = 673ms) than preceded by large local element primes (mean = 699ms, $t(1,95) = 2.67$). On the other hand, target detections preceded by small local element primes (mean = 687ms) were faster than target detections preceded by small global element primes (mean 715ms, $t(1,95) = 2.51$). There was no significant difference between target detections made in the context of visually dissimilar distractors preceded by global and local element primes at any of the three sizes.

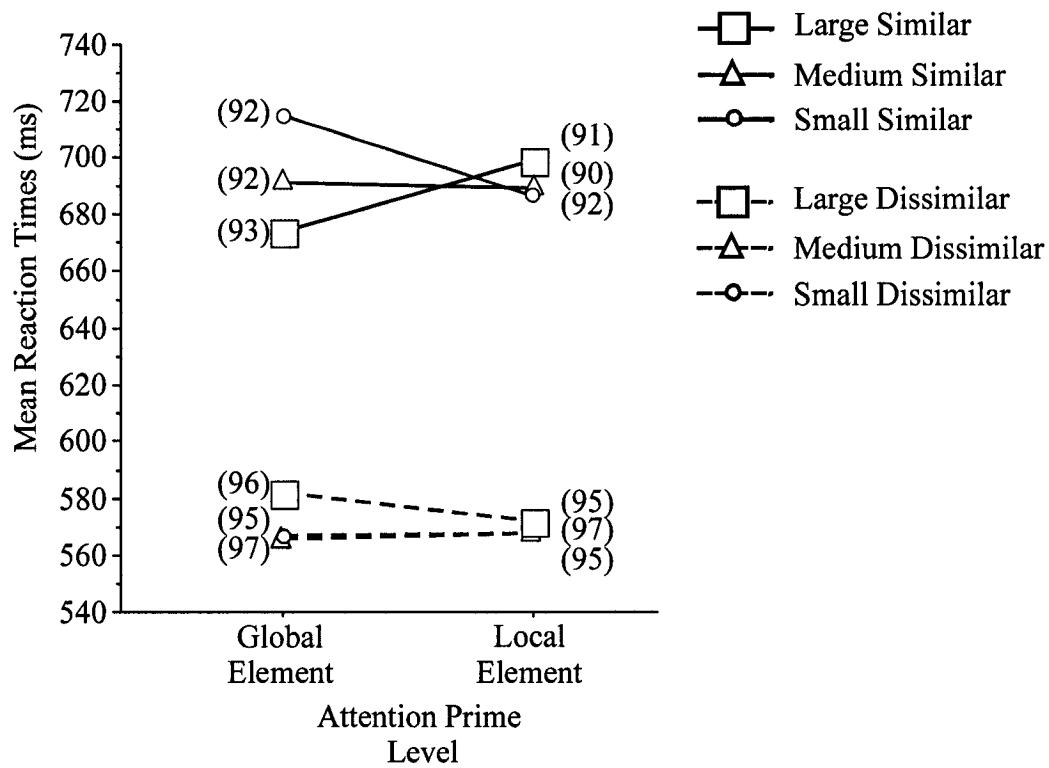


Figure 19. Mean reaction times to the target detection task made in the context of visually similar or dissimilar distractors preceded by attention primes. The attention primes were variously sized digits constructed from the hierarchical primes in Experiment 2. The numbers in brackets are the percentage correct for each condition and the bars denote ± 1 standard errors.

Percentage correct for the overall analysis of all factors

More correct responses were made for target detections when the distractors were dissimilar (96%) than for target detections when the distractors were similar (92%, $F(1,47) = 29.5$, $MS^e = 166$). Again this pattern of accuracy was found for all subsequent analyses and will not be reported in the ensuing sections. Target detection accuracy was also influenced by attention priming ($F(1,47) = 3.94$, $MS^e = 79$) with more correct responses being made for target detections preceded by global element decisions (94%) than for target detections preceded by local element decisions (93%). There were no other significant effects. These measures failed to support any speed-accuracy trade-offs.

Reaction times for target detections after priming by the Global Element of the Small Digit Group and the Local Element of the Large Digit Group.

Reaction times to targets differed depending on the degree of visual similarity between targets and distractors ($F(1,47) = 212.27$, $MS^e = 8,593$). No other effects were significant, suggesting that attention priming by separate digits subtending the same visual angle shared similar priming effects on the target detection tasks (see Figure 20).

Percentage correct for target detections after priming by the Global Element of the Small Digit Group and the Local element of the Large Digit Group.

Target detection accuracy also differed depending on whether the attention prime was a global element or a local element ($F(1,47) = 5.75$, $MS^e = 41$). There were more correct responses to target detections made after priming by the global element of the small group of digits (95%) than after priming by the local element of the large group of digits (93%). These measures failed to support any speed-accuracy trade-offs.

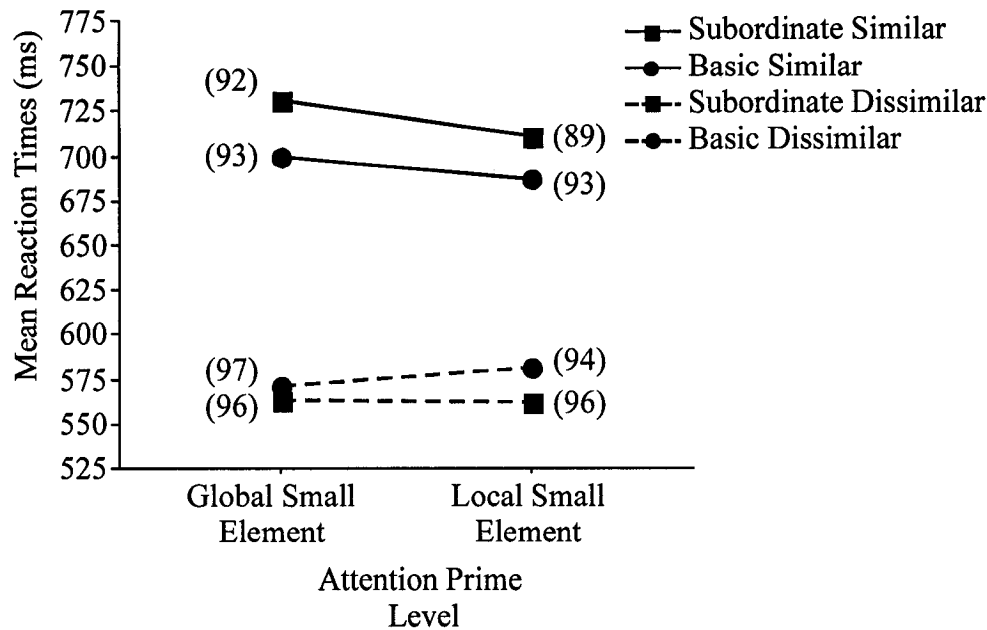


Figure 20. Mean reaction times to the target detection task in the context of visually similar and dissimilar distractors. The attention primes consisted of the digits '2' and '5' which subtended the same visual angle and were constructed from the global element of the small hierarchical figure (Global Small) and the local element of the large hierarchical figure (Local Large) used in Experiment 2. The numbers in brackets are the percentage correct for each condition.

Analyses of target detections after priming with each of the three different digit groups.

Separate analyses of reaction times and percentage correct were performed on the target detection data after priming by each the digit groups (large, medium and small). These analyses were conducted because the *attentional window hypothesis* suggests that there should be differences in the effects of priming between the three sizes of digit groups as each digit subtends a different visual angle (excepting the global element of the small digit group and the local element of the large digit group). For each analysis a 2 X 2 X 2 repeated-measures ANOVA was performed with factors of Attention Level (Global

element/Local element), Category Level (Subordinate/Basic) and Distractor Type (Similar/Dissimilar).

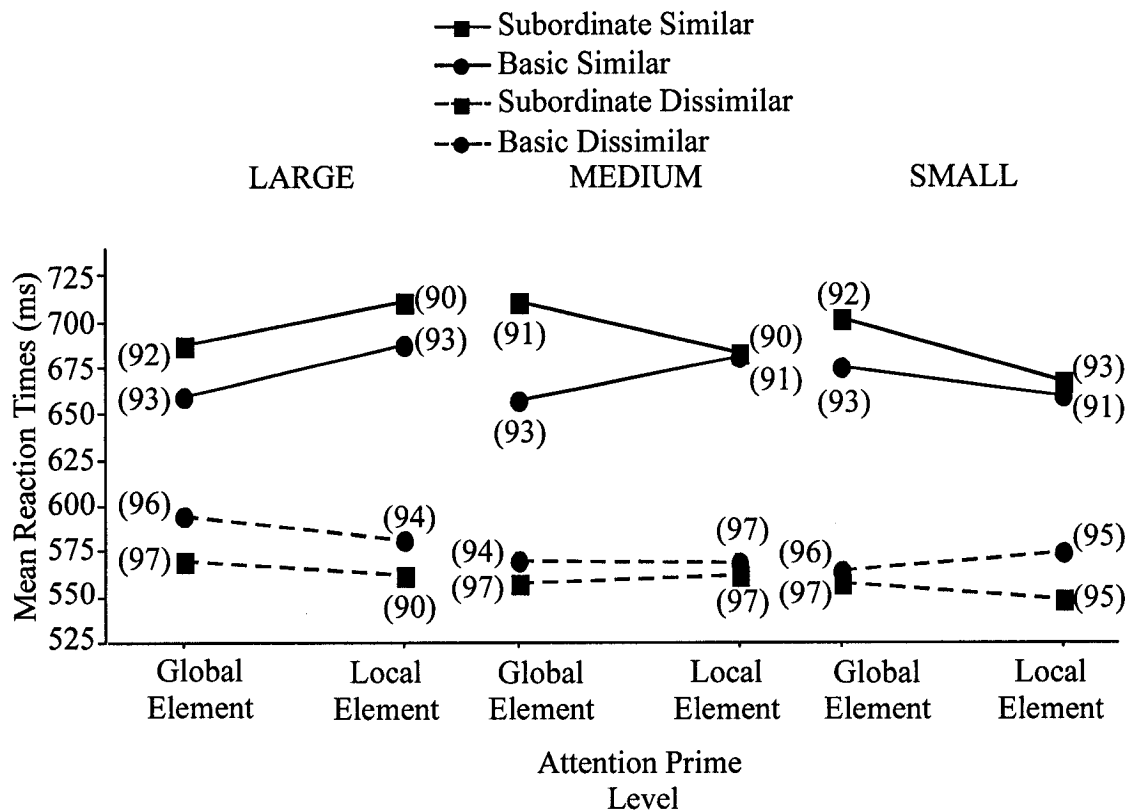


Figure 21. Mean reaction times to basic and subordinate target detections made in the context of visually similar or visually dissimilar distractors after priming by single digits that varied in size. The attention primes were the digits '2' and '5' constructed by separating out the global and local elements of the large, medium and small hierarchical figures used in Experiment 2. The numbers in brackets are the percentage correct for each condition

Reaction times for target detections after priming by the large digit group.

There was evidence that the degree of visual similarity between targets and distractors influenced performance on basic and subordinate target detections ($F(1,47) = 5.50$, $MS^e = 9,912$). Basic target detections (mean = 673ms) were faster than subordinate target detections (mean = 699ms, $t(1,95) = 1.95$) when the distractors were visually similar. In the case of visually dissimilar distractors the opposite pattern of reaction

times was observed; subordinate target detections (mean = 566ms) were faster than basic target detections (mean = 588ms, $t(1,95) = 2.33$).

In support of the *attentional window hypothesis* differences were found in effects of global and local element priming as a function of the degree of visual similarity between the targets and distractors ($F(1,47) = 12.45$, $MS^e = 2,479$). As is evident in Figure 21, target detections made in the context of visually similar distractors were faster preceded by the global element (mean = 673ms) than preceded by the local element (mean = 699ms, $t(1,95) = 2.67$). In contrast there was no significant difference after priming by global (mean = 582ms) or local elements (mean = 572ms) for target detections made in the context of visually dissimilar distractors.

Percentage correct for target detections after priming by the large digit group.

Target detection accuracy differed depending on the degree of visual similarity between targets and distractors ($F(1,47) = 11.18$, $MS^e = 114$). There were no other significant effects and no evidence for a speed accuracy trade-off.

Reaction times for target detections after priming by the medium digit group.

Differences were found in effects of global and local priming as a function of both the category level of the target and the degree of visual similarity between the targets and distractors ($F(1,47) = 5.99$, $MS^e = 3,692$). From Figure 21 it is clear that there was little difference between the priming effects of the global and local elements on either basic or subordinate target detections ($t < 1$) made in the context of visually dissimilar distractors. However, subordinate target detections made in the context of visually similar distractors were faster after priming by the local element (mean = 690ms) compared to the global

element (mean = 719ms, $t(1,47) = 2.02$). Also basic target detections were faster after priming by the global element (mean = 663ms) compared to the local element (mean = 688ms), although this difference was not significant.

Percentage correct for target detections after priming by the medium digit group.

Effects of priming by the global and local elements differed depending on the degree of visual similarity between targets and distractors ($F(1,47) = 4.41$, $MS^e = 53$). There were more correct responses for target detections made in the context of visually similar distractors after priming by the global element (92%) compared to priming by the local element (90%). For target detections made in the context of visually dissimilar distractors there were more correct responses after local priming (97%) compared to global priming (95%). There was no evidence for a speed accuracy trade off.

Reaction times for target detections after priming by the small digit group.

Target detection times differed depending on whether they were primed by the local or global elements ($F(1,47) = 4.06$, $MS^e = 4,835$). Target detections preceded by local element primes (mean = 627ms) were faster than those preceded by global element primes (mean = 641ms). There was evidence that the degree of visual similarity between targets and distractors influenced performance on basic and subordinate target detections ($F(1,47) = 4.243$, $MS^e = 9,088$). Subordinate target detections (mean = 558ms) were faster than basic target detections (mean = 577ms, $t(1,95) = 1.98$) when the distractors were visually dissimilar. In the case of visually similar distractors the opposite pattern of reaction times was observed; basic target detections (mean = 690ms) were faster than

subordinate target detections (mean = 711ms), although this difference was not significant.

In support of the *attentional window hypothesis* attentional priming was influenced by the degree of visual similarity between targets and distractors ($F(1,47) = 5.675$, $MS^e = 3,787$). Target detections made in the context of visually similar distractors were faster preceded by local elements (mean = 686ms) than preceded by global elements (mean = 715ms, $t(1,95) = 2.51$). In contrast, there was no significant difference for target detections made in the context of visually dissimilar distractors after priming by global or local elements ($t < 1$).

Percentage correct for target detections after priming by the small digit group.

Target detection accuracy differed depending on the degree of visual similarity between targets and distractors ($F(1,47) = 11.52$, $MS^e = 119$). There were no other significant effects and no evidence for a speed accuracy trade-off.

Discussion

Experiment 3 investigated whether manipulating the size of the attentional window would influence object target detections. There was evidence that resizing the attentional window influenced object target detections. Subordinate target detections were faster when preceded by local element decisions than by global element decisions for small and medium sized primes. In contrast basic target detections were faster when preceded by global element decisions than local element decisions for large and medium sized primes. However, as shown in Table 2, there were a number of differences in the effects of attention priming between Experiments 2 & 3, suggesting that the *attentional*

window hypothesis could not account for all the priming effects observed using hierarchical figures in Experiment 2.

Firstly, attention priming effects associated with separate digits were only observed when the targets and distractors were visually similar. In the case of visually dissimilar targets and distractors no reliable difference was found between subordinate and basic target detections when primed by separate digits. In Experiment 2 global and local level priming by hierarchical figures were observed on both subordinate and basic target detections made in the context of visually dissimilar distractors, depending on the size of the prime. In those conditions with visually dissimilar distractors the target objects shared few coarse scale or fine scale perceptual cues in common with the distractor objects. Thus smaller or larger attentional windows were equally beneficial for target detections. In those conditions with visually similar distractors distinguishing between coarse scale and fine scale perceptual cues may have been more important, resulting in differences in the pattern of priming depending on the size of the attentional window.

Alternatively, speed of processing may account for the lack of priming effects for target detections with visually dissimilar distractors. In Experiments 1, 2 and 3 target detections made in the context of visually similar distractors were consistently slower than target detections made in the context of visually dissimilar distractors. Perhaps target detections in all conditions benefited from the distribution of attention based on spatial extent but the rapidity of target detections with visually dissimilar distractors obscured the effect.

Second, priming effects of the large digit group were quite different from the priming effects of the large hierarchical figure. In particular, subordinate target detections with visually similar distractors were primed by the large global element in Experiment 3 but by the local level of the large hierarchical figure in Experiment 2. Finally, global and local priming by small hierarchical figures were sensitive to the category level of the target, whereas priming by separate global and local elements of the small digit group were sensitive to the degree of visual similarity between targets and distractors.

In addition, it was proposed that the difference in priming effects of the local level of the large hierarchical figure and the global level of the small hierarchical figure might be explained by differences in the distribution of attentional resources produced by blocking the three sizes of hierarchical figures. This explanation was not borne out by the results of Experiment 3. A comparison of the priming effects of the local element from the large digit group with the global element from the small digit group showed no reliable differences. This would suggest that the difference in priming effects of the local level of the large hierarchical figure and the global level of the small hierarchical figure demonstrated in Experiment 2 are indeed due to the influence of a grouping/parsing mechanism that guides the processing of global and local constituents of a visual stimulus.

Interestingly, target detections made in the context of visually similar distractors were faster when preceded by digits subtending either the smallest or the largest visual angles relative to the visual angle subtended by the objects. Subordinate and basic target detections preceded by the global element of the large digit group (8.7°) were faster than target detections preceded by the local element (1.7°). In contrast subordinate and basic

Table 2. *The level of attention, which primed the target detection task in each of the four conditions, as a function of the size of the attention primes for Experiments 2 and 3. Local refers to faster target detections after local level decisions or local element decisions. Global refers to faster target detections after global level decisions or global element decisions. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.*

<u>Condition</u>	<u>Large</u>		<u>Medium</u>		<u>Small</u>	
	Hierarchical Primes	Separate Digits	Hierarchical Primes	Separate Digits	Hierarchical Primes	Separate Digits
Subordinate Similar	Local	Global	Local	Local	Local	Local
Subordinate Dissimilar	Global	NP	Global	NP	NP	Local
Basic Similar	Global	Global	Local	Global	Global	Local
Basic Dissimilar	Global	Local	NP	NP	Global	NP

target detections preceded by the local element of the small digit group (0.9°) were faster than target detections preceded by the global element (1.7°). These results would suggest that large increases or decreases in the size of the attentional window benefited object detections.

Fiser, Subramaniam and Biederman (2001) investigated the effects of size variation on object detection and found that the visual system was sensitive to these variations and could 'tune into' particular size ranges. They used a RSVP (rapid serial visual presentation) task in which 40 gray level object images were presented. The participants' task was to indicate with a key press the presence of a target object in the sequence. Two types of sequences were used: a 'homogenous' sequence in which all the images were the same size, and a 'heterogeneous' sequence in which one of the images was a different size (half of the time a target) from all the other images. They found that an advantage in correct identifications for large images compared to small images in a single sequential presentation task was eliminated in the 'homogeneous' RSVP task. They proposed that the size of the images preceding and following the target influenced recognition. Their results and the results of this experiment indicate that attention to particular regions in space can facilitate visual processing.

Fiser et al (2001) also found that large targets embedded in a sequence of small images were detected more accurately than small targets embedded in a sequence of large targets. They speculated that this asymmetry in performance was due to adaptation mechanisms that show faster adaptation to abrupt increases than abrupt decreases, similar to that found in light intensity adaptation in sensory cells. A similar finding was observed when priming target detections with separate digits. Target detections were faster

preceded by small local elements relative to small global elements. However, target detections were also faster preceded by large global elements relative to large local elements, arguing against an adaptation mechanism that results in asymmetrical performances. In Experiment 3 target detections benefited from both a large increase and a large decrease in size between the prime and the object.

The difference in results between Fiser et al's study and this experiment may be due to the use of different dependent measures. Fiser et al used accuracy as a measure for their effects and this experiment focused on reaction times. There were also significant methodological differences. The sizes of the stimuli preceding the target in the RSVP task did not vary, whereas the sizes of the stimuli preceding the targets in the object detection task in this experiment switched randomly between two sizes.

Furthermore, it is possible that the effects of the attention priming task on target detections were not due to the actual distribution of attentional resources set by the size of the digits. The majority of the digits in the attention priming task were different in size to the objects. The size of the attentional window set by the attention priming task may not have been optimal for discriminating target objects. This may have necessitated resizing the attentional window to accommodate the overall size of the objects. This process of resizing the attentional window may take a period of time. In this case the effects of the attention priming task may be related to the direction of the adjustment in the size of the attentional window. That is, if the attentional window was resized in a direction that facilitated the selection of perceptual attributes leading to target detection, performance would benefit, and if resizing was in a direction that impaired the selection

of perceptual attributes leading to target detection, performance would show a cost. This account may well explain the pattern of priming observed for the large group of digits.

The priming effects of the large digit group were in the opposite direction to those observed for the other digit groups and those observed for hierarchical figures. Target detections made in the context of visually similar distractors were faster preceded by global level digit decisions than preceded by local level digit decisions. Target detections made in the context of visually dissimilar distractors were faster preceded by local element decisions than preceded by global element decisions. One would expect that target detections requiring detailed visual shape information would benefit from a relatively smaller attentional window and target detections requiring coarse visual shape information would benefit from a relatively larger attentional window. It could be that the effects of attentional window size are not based on the absolute size of the attentional window but on the direction and degree of change needed to resize the attentional window appropriately for detecting fine or coarse shape information in the object image. Using the zoom lens metaphor for attention, zooming in would increase the salience of fine details of the object and zooming out would increase the salience of coarse details of the object. When the attentional window was set at the global level for the large digits the attentional focus may have been adjusted by zooming in as the object in the target detection task was smaller than the global level digit. The action of narrowing the focus of attention may have facilitated the detection of fine details. On the other hand when the attentional window was set at the local level of the large digits the attentional focus may have been adjusted by zooming out, as the object was larger than local level digit. The

action of widening the focus of attention may have facilitated the detection of coarse shape information.

Unfortunately, this explanation cannot account for the pattern of priming observed for medium and small digit groups. For example, subordinate target detections made in the context of visually similar distractors were faster when preceded by the local element of the small group of digits. If effects of the attention priming task were associated with the direction in which the window of attention was adjusted then there should be either no difference in priming by global or local elements, as they are both smaller than the objects, or target detections should be faster after global digits, as they are closer in size to the object. Clearly, more research is required to unravel the connections between object recognition and the distribution of attention across regions of space.

In conclusion, Experiment 3 demonstrated that resizing the attentional window influenced object target detections. In general subordinate target detections were faster when preceded by local elements than by global elements and basic target detections were faster when preceded by global elements than local elements. Additionally, target detections benefited when the attentional window was at the largest or smallest size relative to the target objects. However, the *attentional window hypothesis* could not account entirely for the priming effects of hierarchical figures on object detections. The following chapter attempts to clarify the differences between the results of Experiments 2 and 3.

Combined analysis of data from Experiments 2 & 3

It was postulated in Experiment 2 that the different pattern of priming on object target detection found for the three sizes of hierarchical forms was due to combined actions of the spatial extent of attention and a grouping/parsing processes. The size of the attentional window was adjusted in line with the overall size of the hierarchical figure, and grouping/parsing processes separated out global and local constituents relative to the size of the attentional window. In so doing the availability of perceptual cues diagnostic for detecting a target object varied as a function of the size of the hierarchical figure and gave rise to different patterns of priming.

Alternatively, the different patterns of priming may have been due entirely to adjustments in the size of the attentional window based on the visual angle subtended by the global and local levels of the hierarchical figures. Experiment 3 tested this hypothesis by priming the object detection task with separate digits that subtended the same visual angles as the global and local levels of the hierarchical figures used in Experiment 2. The results of Experiment 3 suggested that some of the effects observed in Experiment 2 were due to resizing the attentional window relative to the visual angles subtended by targets at the global and local level.

However there were a number of important differences in the priming effects for Experiment 2 and Experiment 3. For example, in Experiment 2, different priming effects were observed for stimuli that subtended the same visual angle but belonged to different levels of a hierarchical figure (global vs. local). In Experiment 3, priming effects of the global and local elements subtending the same size did not produce any reliable

differences in target detection times. In addition, global and local priming by small hierarchical figures was sensitive to the category level of the target whereas priming by separate global and local elements of the small digit group was sensitive to the degree of visual similarity between targets and distractors. Finally, priming effects of the large digit group were quite different from the priming effects of the large hierarchical figure, particularly for subordinate target detections with visually similar distractors.

In order to separate out effects that may have been due to the grouping/parsing mechanism from effects that may have been due to adjustments in the size of the attentional window, data from Experiment 2 and 3 were analyzed together. If the priming effects of the hierarchical figures were due to a grouping/parsing mechanism, then the pattern of priming observed for hierarchical figures should differ from the pattern of priming observed for separate digits. If the priming effects of the hierarchical figures were due to adjustments made to the size of the attentional window, then there should be no difference in priming effects for hierarchical figures and separate digits.

Results

Multi-factorial mixed design ANOVAs were performed on the reaction times and percentage correct for the target detection task. The within-subject factors were Attention Level (global or local), Size (large, medium and small), Distractor Type (visually similar/visually dissimilar) and Category Level (subordinate/basic). The between subject factor was Prime Type (hierarchical/digit). Only the results that demonstrated differences in the data from Experiment 2 and 3 are reported below.

Reaction Times for the overall analysis of all factors

There were two interactions involving the between factor of Prime Type; a four-way interaction between Attention Level, Distractor Type, Size and Prime Type, $F(2,186) = 5.752$, $p=.004$, ($MS^e = 4,009$), and a four-way interaction between Attention Level, Category Level, Distractor Type and Prime Type which approached significance, $F(1,93) = 3.678$, $p=.06$, ($MS^e = 4,440$). These interactions will be explored by separate analyses of target detections after priming by each of the three different sizes of attentional primes.

Percentage correct for the overall analysis of all factors

Target detection accuracy in Experiments 2 and 3 differed depending on the category level of the target and the size of the attention prime ($F(2,186) = 3.81$, $MS^e = 61$). There was no difference between basic (93%) and subordinate target detections (93%) when they were preceded by large hierarchical primes. However, when the large group of digit primes preceded targets, there were more correct responses for the basic target detections (95%) than subordinate target detections (93%). In the case of the medium sized attentional primes, there were more correct responses for subordinate target detections (94%) than basic target detections (93%) when the primes were hierarchical figures and there was little difference between basic (94%) and subordinate target detections (94%) when the primes were separate digits. In the case of the small sized attentional primes, there were more correct responses for basic (94%) than subordinate target detections (92%) when the primes were hierarchical figures and once again there was little difference between basic (94%) and subordinate target detections (94%) when the primes were separate digits.

Reaction times for target detections after priming with Global Small and Local Large attentional primes.

There were different patterns of priming for hierarchical figures compared to the separate digits, depending on the degree of visual similarity between targets and distractors, ($F(1,93) = 5.04$, $MS^e = 13,980$). Target detections made in the context of dissimilar distractors were faster when primed by separate digits (mean = 569ms) than by hierarchical figures (mean = 604ms), and there was little difference between target detections made in the context of visually similar distractors (means = 704ms and 707 ms).

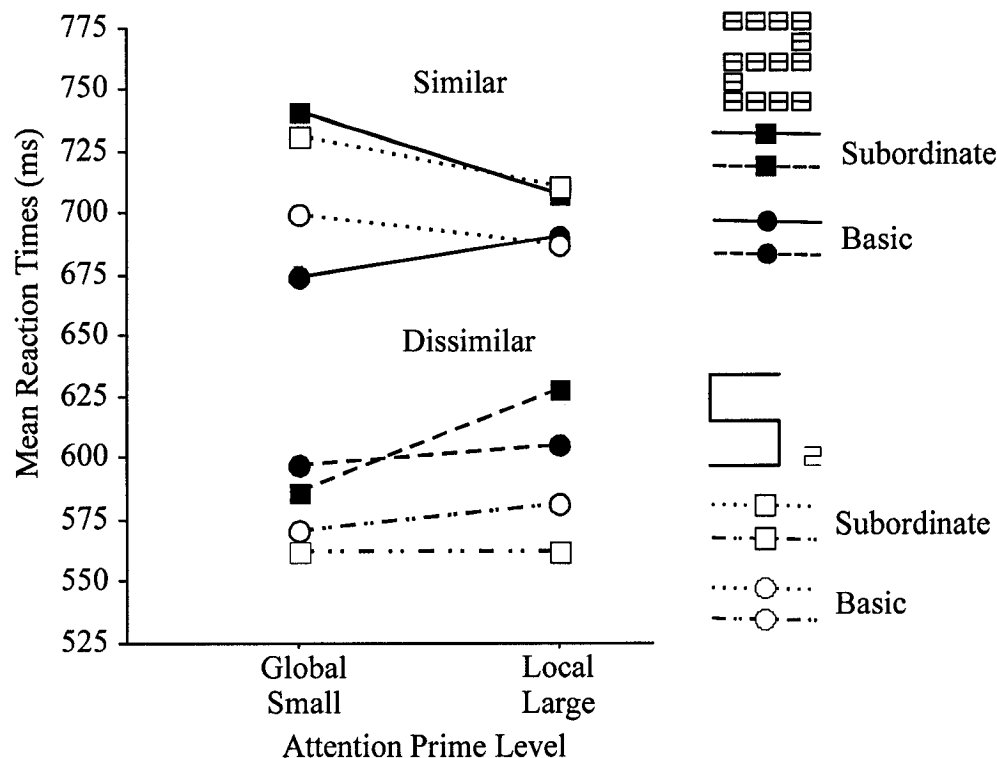


Figure 22. Mean reaction times for basic and subordinate target detections in the context of visually similar and dissimilar distractors. The attention primes were the global elements of the small hierarchical figure/small digit group or the local element of the large hierarchical figure/large digit group. All attention primes subtended the same visual angle.

The priming effects of the hierarchical figures and separate digits differed depending on the category level of the targets and the degree of visual similarity between the targets and the distractors, suggesting that grouping and parsing processes were responsible for the priming effects of the hierarchical figures ($F(1,93) = 2.84$, $MS^e = 7,759$). However, these differences only approached significance ($p=.09$). As shown in Figure 22, the main differences were for basic target detections made in the context of visually similar distractors and subordinate target detections made in the context of visually dissimilar distractors. When primed by hierarchical stimuli the basic target detections were faster when preceded by global decisions (mean = 674ms) than local decisions (mean = 691ms) and subordinate target detections were also faster preceded by global decisions (mean = 587ms) than local decisions (mean = 628ms). When primed by separate digits there was little difference between basic and subordinate target detections when preceded by either global or local decisions.

Percentage correct for target detections after priming with Global Small and Local Large attentional primes.

The priming effects of the hierarchical figures and separate digits differed depending on the category level of the targets, providing further support for the *parsing hypothesis*, ($F(1,93) = 6.71$, $MS^e = 66$). As can be seen in Figure 23, for subordinate target detections there were more correct responses after global decisions (95%) than local decisions (92%) when the primes were separate digits. When the primes were hierarchical figure there was little difference in the percentage of correct responses after global (91%) or local decisions (92%). For basic target detections there were more correct responses after global decisions (95%) than local decisions (92%) when the

primes were hierarchical figures. When the primes were separate digits there was little difference in the percentage of correct responses after global (95%) or local decisions (94%).

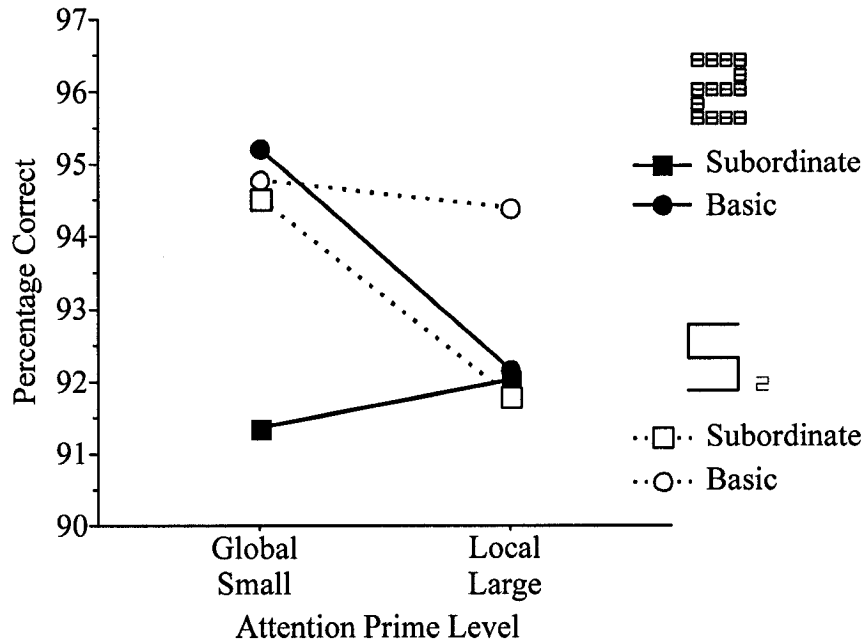


Figure 23. The percentage of correct responses to subordinate (squares) or basic (circles) target detections after priming by either hierarchical figures (solid lines) or separate digits (dotted lines). All of the attention primes subtended the same visual angles.

Separate analyses of target detections after priming with each of the three different sizes attentional stimuli.

Separate analyses of reaction times and percentage correct target detections after priming by each of the three different sizes of attentional primes were conducted. For each analysis a mixed factorial ANOVA was used with 3 within-subject factors of Attention Level (Global /Local), Category Level (Subordinate/Basic) and Distractor Type (Similar/Dissimilar) and a between factor of Prime Type (Hierarchical/Digit).

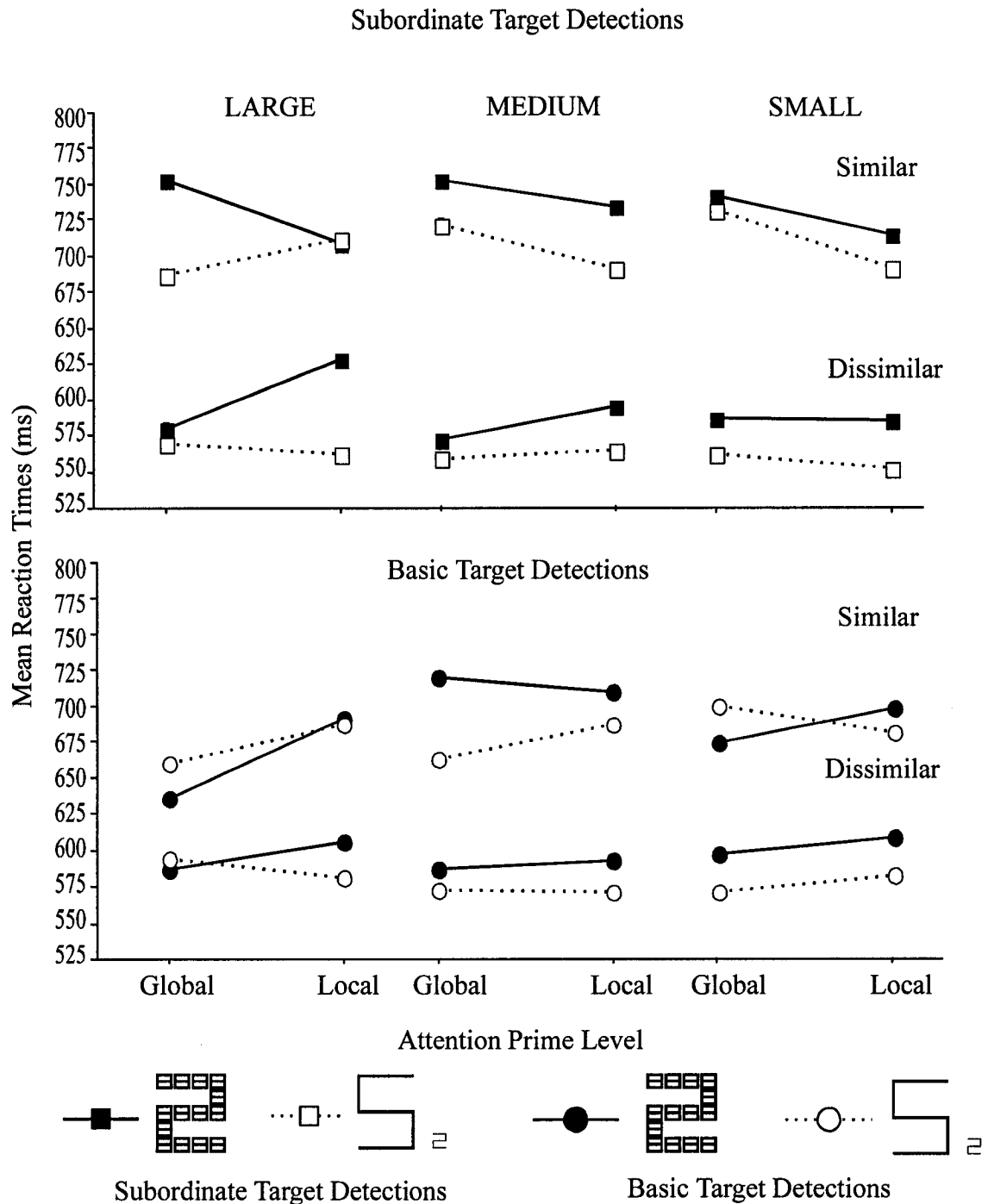


Figure 24. Mean reaction times to subordinate and basic target detections made in the context of visually similar or visually dissimilar distractors after priming by either hierarchical figures (solid lines) or separate digits (dotted lines). The attention primes varied in size (Large, Medium and Small).

Reaction times for the large attentional primes

There were different patterns of global and local priming for large hierarchical figures compared to the large group of digits depending on the degree of visual similarity between targets and distractors ($F(1,93) = 11.16$, $MS^e = 4,409$). Target detections made in the context of visually similar distractors were faster preceded by global element decisions (mean = 673ms) than by local element decisions (mean = 699ms) when the primes were separate digits. When the primes were hierarchical figures there was little difference in the priming effects of global (mean = 694ms) and local decisions (mean = 699ms). Target detections made in the context of visually dissimilar distractors were marginally faster when preceded by local element decisions (mean = 572ms) than by global element decisions (mean = 582ms) when the primes were separate figures. When the primes were hierarchical figures target detections were faster preceded by global decisions (mean = 582ms) than by local decisions (mean = 617ms).

As is evident from Figure 24, there were also different patterns of global and local priming for large hierarchical figures compared to the large group of digits depending on the degree of visual similarity between targets and distractors and the category level of the targets ($F(1,93) = 4.75$, $MS^e = 9,125$). For subordinate target detections made in the context of visually similar distractors, target detections were faster preceded by local decisions than by global decisions when the primes were hierarchical figures. The opposite pattern was true for separate digit primes, where target detections were faster preceded by global element decisions than by local element decisions, although this difference was not statistically reliable. For subordinate target detections made in the context of visually dissimilar distractors, target detections were faster preceded by global

decisions than by local decisions when the primes were hierarchical figures. When the primes were separate digits, target detections preceded by local element decisions were faster than global element decisions. Again, this difference was not significant.

For basic target detections made in the context of visually similar distractors, target detections were faster preceded by global decisions than by local decisions for both hierarchical primes and for separate digit primes. Basic target detections made in the context of visually dissimilar distractors were faster preceded by global decisions than local decisions (this difference was not significant) after priming by hierarchical figures. When the primes were separate digits basic target detections made in the context of visually dissimilar distractors were faster preceded by local element decisions than by global element decisions.

Percentage correct for the large attentional primes

There were no significant interactions involving the between factor of Prime Type.

Reaction times for the medium attentional primes

There were no significant interactions involving the between factor of Prime Type, suggesting the effects of medium sized attentional primes were the same for both hierarchical figures and separate digits.

Percentage correct for the medium attentional primes

The accuracy of target detections preceded by hierarchical attention primes or separate digit primes differed depending on the visual similarity of targets and distractors ($F(1,93) = 3.94$, $MS^e = 67$). There were more correct target detections in the context of

visually similar distractors after priming by hierarchical figures (92%) than after separate digits (91%). On the other hand there were more correct target detections in the context of visually dissimilar distractors after priming by separate digits (96%) than after priming by hierarchical figures (95%).

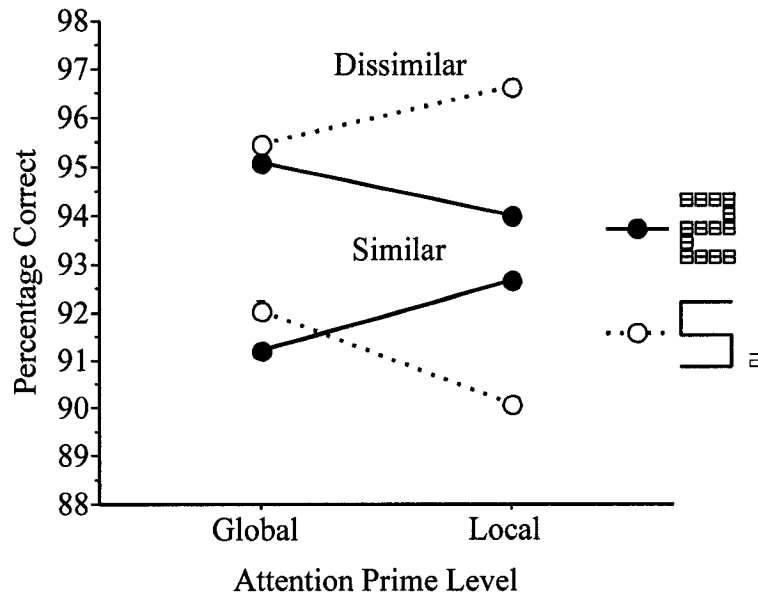


Figure 25. The percentage of correct responses to target detections made in the context of visually similar or visually dissimilar distractors after priming by either medium sized hierarchical figures (solid lines) or medium sized separate digits (dotted lines).

As is evident from Figure 25, target detection accuracy after priming by medium hierarchical figures and the medium group of digits differed depending on whether the primes were global or local and depending on the degree of visual similarity between targets and distractors ($F(1,93) = 6.29$, $MS^e = 60$). There were more correct target detections in the context of visually similar distractors when they were preceded by local decisions for hierarchical primes (93%) than by global decisions (91%), whereas, there were more correct target detections when preceded by the global element of the separate digit prime (92%) than by the local element (90%). For target detections made in the

context of visually dissimilar distractors, there were more correct responses when they were preceded by global decisions with hierarchical primes (95%) than local decisions (94%). Whereas, there were more correct responses when target detections were preceded by the local element of the digit primes (97%) than by the global element (95%).

Reaction times and percentage correct for the small attentional primes

An analysis of the RT data and percentage correct data for the small sized attentional primes did not reveal significant effects involving the between factor of Prime Type. However, a separate analysis of basic target detections made when the distractors were visually dissimilar was performed. In this condition differences in the effects of attention priming by hierarchical figures and separate digits were marginally significant, $F(1,93) = 3.586$, $p = .06$, $MS^e = 6,126$. Basic target detections were faster after global decisions with hierarchical primes. Conversely basic target detections were faster preceded by the local element of the digit primes.

Discussion

It was argued in Experiment 2 that differences in the pattern of priming for large, medium and small sized hierarchical primes were due to two separate mechanisms. It was suggested that these differences could be accounted for by parsing objects into their global and local constituents relative to the size of the attentional window. Support for this conjecture was found, but mainly for large hierarchical primes. The pattern of priming by large hierarchical primes was very different from that found for separated digits subtending the same visual angle as the global and local levels of the hierarchical figure. However, no reliable differences were found in the patterns of priming for

medium and small sized attention primes regardless of whether the primes were hierarchical or separate digits. This would suggest that the size of the attentional window was the underlying factor in effects of priming found for these attentional primes.

The strongest indicator of the involvement of a parsing/grouping mechanism was found when the attention primes were larger than the objects in the target detection task. In three out of the four conditions, priming by the hierarchical figures was in the opposite direction to priming by the separate digits (see Figure 24 and Table 2). When primed by hierarchical figures, subordinate target detections made in the context of visually similar distractors were faster after priming by local level decisions than global level decisions, whereas, basic target detections were faster after priming by global level decisions than local level decisions. Both basic and subordinate target detections were faster after global level decisions when made in the context of visually dissimilar distractors. In contrast, when primed by separate digits, both subordinate and basic target detections, made in the context of visually similar distractors, were faster after global element decisions. Whereas, subordinate and basic target detections were faster after local element decisions when made in the context of visually dissimilar distractors element decisions. These results clearly imply that not all the priming effects observed in Experiment 2 can be explained by the *attentional window hypothesis*.

Further support for the involvement of a grouping/parsing mechanism can be found in the comparison of priming effects for global small and local large attentional primes. In both Experiment 2 and Experiment 3 these attention primes subtended the same visual angle, the only difference being that in Experiment 3 the primes were separate elements of a hierarchical figure. In the reaction time data, a difference in the

pattern of priming approached significance. However, there was a significant difference in the pattern of correct responses on target detections depending on the category level of the target. When primed by hierarchical figures, more correct responses were made to subordinate target detections after local decisions and more correct responses were made to basic target detections after global decisions. When primed by separate digits, there were more correct responses to subordinate target detections after global decisions and little difference for basic target detections. The fact that both the hierarchical primes and the separated digit primes subtended the same visual angle but produced different effects (see Table 3) argues against the hypothesis that attentional priming effects can all be explained by the distribution of attentional resources across regions of space.

Table 3. *A comparison of the priming effects of the global level or element of the small hierarchical figure and the local level or element of the large hierarchical figures. NP stands for no priming, when the difference in target detection times after global or local decisions was less than 10ms.*

<u>Condition</u>	<u>Hierarchical Primes</u>	<u>Separate Digits</u>
Subordinate Similar	Local Large	Local Large
Subordinate Dissimilar	Global Small	NP
Basic Similar	Global Small	Local Large
Basic Dissimilar	NP	Global Small

However, the case for global and local processing involving a grouping/parsing mechanism in object recognition would be much stronger if differences between the results of Experiments 2 and 3 had been found for all three sizes of the attentional primes. Unfortunately, no reliable differences were found between the priming effects of the medium and small sized attentional primes on target object detection times. Figure 24 shows that priming effects in terms of reaction times to medium and small sized attention

primes appeared to differ between Experiments 2 and 3 for basic target detections made when distractors were visually similar. However, this difference only approached significance for the small sized attention primes ($p=.06$). Given these results, it is possible that priming by medium and small sized attention primes in Experiment 2 can be explained by spatial extent, where attentional resources are distributed on the basis of the size of the attentional window.

In conclusion, a comparison of the priming effects of hierarchical figures and separate digits showed evidence supporting the involvement of both the spatial extent of attention and grouping/parsing processes. It may be premature to conclude that the priming effects of Experiment 2 can mostly be explained by spatial extent, until further research has been conducted investigating effects of size of the attentional window on object recognition.

General Discussion

This research was concerned with four main objectives. The first objective was to investigate whether global and local processing played a role in a more realistic object recognition task. Evidence was found to support a role for global and local processing in the recognition of real world objects. Local level priming facilitated subordinate target detections made in the context of visually similar distractors. This condition is most comparable to strict definitions of subordinate categorization. The target objects and distractor objects belonged to the same basic level category and shared many features in common. Effects of global priming were less consistent, but most often associated with basic target detections or target detections made in the context of visually dissimilar distractors. This suggests that shifts between global and local levels of attention facilitate the selection of coarse or fine-grained information from the stimulus. When categorizing visually similar objects the attentional bias is towards fine-grained information selected at the local level, conversely, when categorizing visually dissimilar objects the attentional bias is towards coarse-grained information selected at the global level.

The second objective was to determine how global and local levels of processing were selected. Was it on the basis of the category label given the target object or the perceptual demands of the object detection task? In Experiments 1 & 2, where the hierarchical primes were the same size or close to the same size as the objects in the target detection task, the results supported the notion that global and local levels of processing were selected based on the perceptual demands of the task. The perceptual demands were manipulated by selecting target objects and distractors that varied in the

degree of visual similarity to each other. It was found that local level decisions facilitated target detections when the distractors were visually similar and global level decisions facilitated target detections when the distractors were visually dissimilar. However, it was also found that when hierarchical primes were smaller than the objects in the target detection task the important factor was the category level of the target objects. Subordinate target detections were faster preceded by local level decisions and basic target detections were faster preceded by global level decisions. This result appeared to support the influence of prior knowledge about the attributes of the target objects on the selection of global or local processing streams.

A possible explanation for these contrasting results is that the distribution of attentional resources is initially guided by top down processes initiated by prior knowledge of the visual attributes of a target object. However, this may be a dynamic process and may be modified based on the perceptual demands of the task. It is assumed that the benefits of global and local processing are associated with the selection of perceptual attributes of the object diagnostic for its recognition. The priming action of the hierarchical figures could either complement or conflict with the distribution of attentional resources prescribed by top down processes. However, in these experiments a third factor comes into play. Participants were required to detect objects that were presented with either visually similar or dissimilar distractor objects. Thus, the perceptual attributes, which may have been sufficient for recognizing a dog, may not be sufficient for recognizing a dog when it is presented amongst other four-legged mammals.

According to Han et al (1999a) the perceptual attributes of objects are separated into global and local processing streams that operate in parallel and compete with each other to produce a response output. For example, if the task is to recognize a dog then perceptual attributes related to coarse shape information represented in the global stream are likely to win the competition. On the other hand, if the task is to recognize a particular breed of dog then perceptual attributes related to fine details of the object's shape represented in local stream are likely to win the competition. Furthermore, the distribution of attentional resources may increase the efficiency with which perceptual information is selected for either the global or local processing stream. In these experiments a number of factors may influence the distribution of attentional resources as depicted in Figure 26: prior knowledge of the visual attributes of the object, the perceptual demands of the recognition task, and, of course, the priming action of the hierarchical figures.

The results of Experiments 1 & 2 support the claim that all three of these factors influence the distribution of attention. When stored knowledge, perceptual demands, and the priming level of the hierarchical figure complemented each other the priming effects of the hierarchical figures were consistent. For example, subordinate target detections made in the context of visually similar objects were faster preceded by local decisions in both experiments. In this condition the targets were subordinate level targets (beagles or finches). Based on prior knowledge, distinguishing a subordinate category member would likely require the processing of fine details of the object's shape attributes (Biederman et al, 1999; Murphy & Lassaline, 1997). In terms of the perceptual demands of the task, when targets and distractors were visually similar to each other,

discriminating between them would also require the processing of fine details of an object's shape attributes. When the prime level was local, this would involve processing fine details of the hierarchical figure. Thus, in this particular condition prior knowledge, perceptual demands and prime level were all in accordance with a distribution of attentional resources that maximized the processing of fine details of an object's structure.

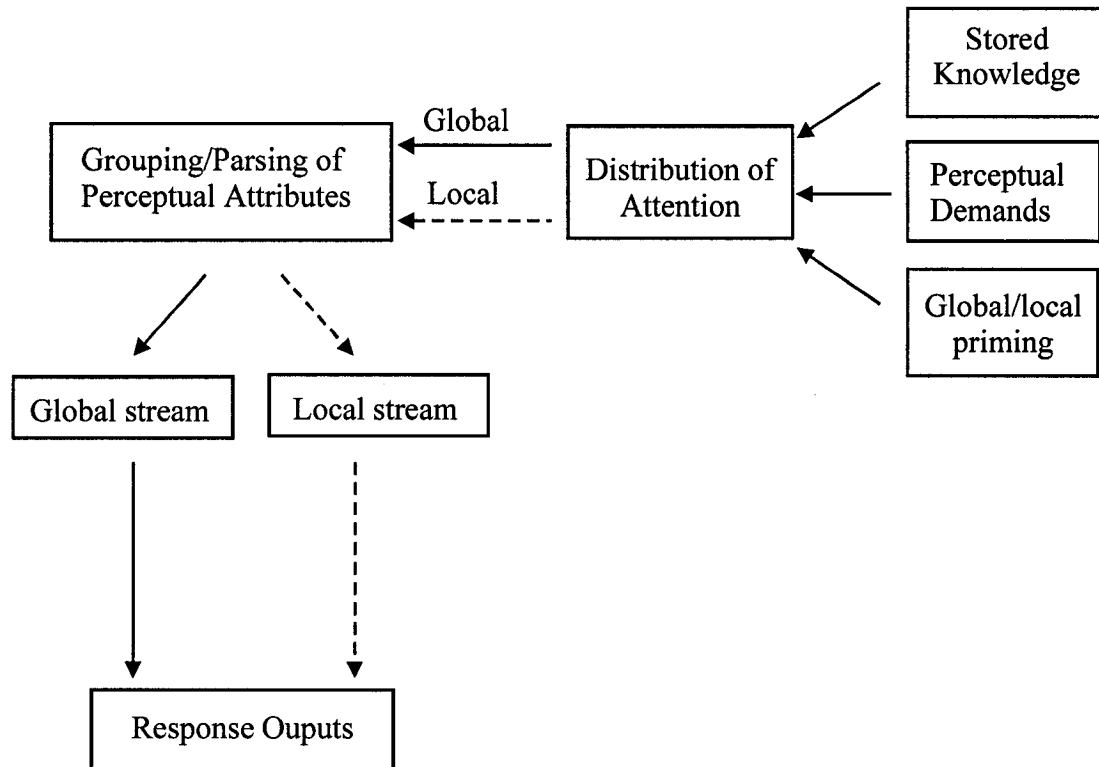


Figure 26. A model of the relationship between global and local processing, the distribution of attention and the effects of prior knowledge, perceptual demands and priming by hierarchical figures on the recognition of an object (see text for a full explanation).

In contrast, in Experiments 1 and 2 global and local priming effects on basic target detections made in the context of visually similar distractors were less consistent. Based on prior knowledge, distinguishing a basic level category member would likely require the processing of coarse details of an object's shape. However, in this condition the targets and distractors were visually similar to each other and discriminating between

them would likely require processing fine details of an object's shape. There is a conflict between a global distribution of attentional resources initiated by prior knowledge and a local distribution of attentional resources based on the perceptual demands of the task. Thus, the results of a competition between global and local processing streams to produce a response were much more variable in this condition. For example, when the hierarchical figures were the same or close to the same size as the objects, target detections were faster after local priming, but when the hierarchical figures were larger or smaller than the objects target detections were faster after global priming.

The third objective was to determine if there was a fixed or flexible global-to-local sequence in the priming effects of the divided attention task on the object detection task. To recap, there is evidence to suggest that in object recognition global level, coarse scale perceptual information occurs in the early stages of processing and later stages involve the processing of local level details (Boucart & Humphreys, 1992; Boucart, et al 1995; Hochstein & Ahissar, 2002; Humphreys & Boucart, 1997; Sanocki, 1999; 2001). However, research conducted by Schyns and his colleagues (1998, Morrison & Schyns, 2001) on the usage of perceptual information at high and low spatial frequencies would suggest that coarse and fine scale information was processed flexibly. It was suggested that a fixed global-to-local sequence in object recognition would produce global level priming for all the target detection tasks regardless of the level of categorization or the degree of visual similarity between objects. This was demonstrably not the case. The strongest evidence against a fixed global-to-local sequence was found in Experiment 1, where identical objects were primed by local level decisions when the distractor objects

were visually similar to the target objects, and primed by global level decisions when the distractors were visually dissimilar to the targets.

A difficulty with this interpretation is that it is possible that global processing did occur and was completed before local processing. It could be that the global prime benefited global processing, but the perceptual information available from the global processing stream was insufficient to identify the object. The production of a response was delayed until local level information became available. The benefits observed from local priming may reflect increased efficiency in the processing of local level information after the completion of global processing.

In support of flexible usage of fine and coarse scale perceptual information in object categorization, converging evidence is provided by studies investigating the usage of spatial scale mentioned previously (Morrison & Schyns, 2001; Oliva & Schyns, 1997; Schyns & Oliva, 1999; Snowden & Schyns, 2000). Schyns and his colleagues have found that the use of high spatial frequency ('fine') information and low spatial frequency ('coarse') information depended on the nature of the categorization task. Moreover, studies investigating differences in orientation effects during categorization (Hamm & McMullen, 1998; Nicholson & Humphrey, 2001) also suggest flexible usage of diagnostic visual object information. These studies found greater effects of orientation when verifying objects at the subordinate level compared to the basic level. Identical stimuli were used in subordinate and basic category conditions, suggesting that object information useful for subordinate categorizations was more sensitive to effects of orientation than object information useful for basic categorizations. Furthermore,

Nicholson & Humphrey (2001) found that surface cues provided by full colour images were more beneficial to subordinate categorizations than basic categorizations.

Finally, the fourth objective was to investigate whether priming effects of the divided attention task were based on the spatial extent of attention or grouping/parsing processes. The results of Experiments 2 and 3 indicated that both were involved in the global and local priming effects on the target detection task. In support of grouping/parsing processes, different priming effects were observed for stimuli that subtended the same visual angle but occupied different levels in a hierarchical figure. Also in support of grouping/parsing processes different priming effects were observed for large hierarchical stimuli compared to priming by individual non-hierarchical stimuli subtending the same visual angles as the global and local levels of the large hierarchical figure.

In support of the spatial extent, Experiment 3 demonstrated that varying the size of the attentional window had an impact on target detection performance when targets and distractors were visually similar. Priming by the global elements benefited basic target detections for large and small primes and priming by local elements benefited subordinate target detections for medium and small primes. Also in support of spatial extent, no reliable differences were found between the priming effects of medium and small sized hierarchical figures and the priming effects of individual digits subtending the same visual angles. Furthermore, different patterns of global and local priming were found for the three sizes of the hierarchical stimuli, indicating that size did matter and that some element of priming by the hierarchical figures was related to the size of the attentional window.

Implications of findings for theories of object recognition

According to the model outlined in Figure 26, global and local processing operate at the point when visual properties of a distal stimulus are selectively attended. Changes in the distribution of attention may act to facilitate the selection of coarse or fine-grained information from the stimulus. When categorizing visually similar objects the attentional bias is towards fine-grained information selected at the local level, conversely, when categorizing visually dissimilar objects the attentional bias is towards coarse-grained information selected at the global level.

Viewpoint-independent theories of object recognition hold that representations of objects are stored in memory as structural descriptions consisting of three-dimensional volumetric components and their configurations (Biederman, 1987; Marr, 1982). Marr (1982) proposed that object representations are hierarchical and modular in their organization. At the top of the hierarchy there is a module that represents the gross properties of an object such as its orientation and size. This module can be further decomposed on the basis of component axes into additional modules, each containing unique shape information that varies in its level of structural detail about an object. Progression through the hierarchy of modular components of the object representation leads to access to more specific information about an object's shape. The further the progression through the hierarchy the more distinctive objects become from each other.

It could be that global and local processing modulate access to the hierarchical levels of an object representation by modulating the selection of coarse or fine scale visual information at the input stage of object recognition. Global processing captures

coarse scale visual information relevant for generating input representations that match to modular components of the structural description at the upper levels of the hierarchy.

Similarly, local processing captures fine scale visual information relevant for generating input representations that match components at the lower levels of the hierarchy.

A major advantage of viewpoint-independent theories of object recognition proposed by Marr and Biederman is their ability to explicitly code for the parts of objects. The importance of object parts has been demonstrated by a number of researchers (Biederman and Cooper, 1991; Hoffman & Richards, 1984; Hoffman & Singh, 1997; Tversky & Hemenway, 1984). It has been argued that part decomposition is an important factor in object categorization (Edelman & Intrator, 2003; Hummel, 2000; Tarr & Bülthoff, 1995; Tarr & Kriegman, 2001). For example, the detection of head and legs may help to identify an object as an animal as opposed to a vehicle. Global and local processing may play a role in decomposing objects into their constituent parts.

It is difficult to conceive of a role for global and local processing in line with view-dependent theories of object recognition. View-dependent theories of object recognition propose that a number of viewpoint specific representations are held in memory. Object recognition is based on computing the similarity between the input representation and the stored view-based representations (Edelman & Bülthoff, 1992; Edelman & Duvdevani-Bar, 1997; Tarr & Bülthoff, 1995; Tarr & Pinker, 1989; Tarr & Pinker, 1990; for a review see Vecera, 1998). The main thrust of view-dependent theories is to account for the recognition of objects when seen from unfamiliar vantage points without recourse to explicitly representing spatially distinct parts. According to Edelman (1998), stored representations are holistic and input representations consist of 'fragmented

patterns of atomic features". These atomic features are mapped into a high-dimensional measurement space. Matching between input representations and stored representations is based on the similarity relationships between patterns of unanalyzed atomic features and stored prototypes (Edelman, 1998). Effectively, these theories make no distinction between coarse and fine scale information as it relates to the visual structure of objects.

Recently however, Edelman & Intrator (2003) have proposed a computational model (the Chorus of Fragments model) that is viewpoint-dependent and incorporates the notion of a hierarchy of structure. The distributed representation of an object's structure in this model allows for discrimination of the learned object at different locations. More importantly it also allows for the discrimination of separate components of an object. This model can distinguish when the same shape appears at the top of one object and the bottom of another object without recourse to an alphabet of all-or-none parts such as geons.

Edelman & Intrator (2003) argued that based on the principle of shallow scope their model could also account for hierarchical levels of representation. The principle of shallow scope states that only one level of a representation can be instantiated at any given time. For example, at the level of human body one could discriminate that it had a head, a body, arms and legs but not that the head had two eyes a nose and a mouth. To make this discrimination one would have to change to another level of representation. Similarly, if one wanted to discriminate the whites of the eyes or the length of the eyelashes another level of representation would have to be instantiated. They proposed that levels of representation would be controlled via attentional processes that can steer attention to specific locations in an image and control the spatial resolution of the

window of attention at that location. In effect, at the global level the spatial extent and low resolution of the window of attention would allow for the discrimination of coarse details of an object. At the local level the spatial extent and high resolution of the window of attention would allow for the discrimination of fine details of an object. Moreover, the structure of the levels of representation would allow links between other entities at the same scales (e.g., the pupils or eyelashes) but not across scales (e.g., the head and the fingers). The model proposed by Edelman & Intrator (2003) would certainly argue for a role for global and local processing based on the spatial extent of attention. However, it is less clear whether there is a role for a grouping/parsing mechanism.

Viewpoint-dependent and viewpoint-independent theories are often presented in opposition to each. However, it has been proposed that both of these representational formats may operate in object recognition. Tarr & Bülthoff (1995) proposed that viewpoint-independent and -dependent theories lie on a continuum. Viewpoint-dependent representations are recruited for specific identifications of objects ('rover' the dog) and viewpoint-independent representations are recruited for categorical identifications (the object is an 'animal' or a 'dog').

More recently Tarr & Kriegman (2001) extended the idea of a dual representational format sub-serving object recognition. They suggested that there are two parallel processing streams. In one stream the configurations of viewpoint independent features are extracted from the input image. In the other processing stream a coarser feature based viewpoint-independent description is extracted, which provides information about category membership. The configurations of features determined by viewpoint-dependent processes are then compared to stored feature configurations in memory. The

viewpoint-independent description may then be used to constrain the search for a match between input feature configurations and stored feature configurations. The combination of viewpoint-dependent and viewpoint-independent representational formats allows for varying levels of specificity in the recognition of objects. It could be that local processing is used to select the features for the creation of viewpoint-dependent representations of an object. In turn global processing is used to select features for the creation of the coarser viewpoint-independent representation.

Future research

One of the difficulties with the methodology described in this research is that spatial extent is confounded with hierarchical structure in hierarchical figures. Experiment 3 was designed so that the data it produced would be comparable to the data produced in Experiment 2. However, this design is not optimal for examining effects of spatial extent. Blocking the attention primes in sets of two different sizes may have obscured some of the effects of the spatial extent of attention on object categorization. For example, attention priming effects associated with separate digits were not observed when the targets and distractors were visually dissimilar. Effects of spatial extent could be investigated independently from hierarchical structure by cueing attention to a region of space prior to performing a categorization task.

There is some doubt as to whether the functional role of local levels of hierarchical figures reflects the role of local levels in real world objects (Kimchi, 1992; Kimchi & Palmer, 1985). There is a body of evidence suggesting that when the global level is composed of many local elements the local elements are treated like texture and are therefore perceptually separable from the global form. In hierarchical figures where

the global level is composed of fewer local elements the local elements are perceived as figural parts of an overall form and the global and local levels are perceptually integrated (Kimchi & Merhav, 1991; Kimchi & Palmer, 1985; Klein & Barresi, 1985). Performance differences observed in tasks involving hierarchical figures are arguably due to the separation of texture from overall form rather than hierarchical processing of form. Given that there is very little texture information in line drawings it seems unlikely that this interpretation of global and local processing can account for the priming effects of local level decisions on subordinate target detections in Experiments 1 and 2. However, it is an important issue and would be worth exploring in future research.

It is possible to modify hierarchical stimuli so that the arrangement and composition of the local elements more closely reflect the hierarchical structure of objects. For example, hierarchical figures could be constructed with unevenly spaced local elements, mixed sizes of local elements, varying forms of local elements. All of these manipulations would reduce the textural format of the local level. Examining the priming effects of traditional hierarchical figures on these modified hierarchical figures may shed some light on assumptions underlying the global/local paradigm.

A further line of research would be to examine the effects of conceptual knowledge versus the effects of perceptual demands on the selection of global and local levels of attention. This could be accomplished by examining global and local priming on novel stimuli that vary in terms of visual similarity. Conceptual knowledge could be manipulated by having participants categorize the stimuli prior to a global and local priming task.

Finally, a logical progression of the research discussed in this thesis would be to investigate global and local processing in face recognition. Face recognition is a special case of subordinate categorization characterized by configural/wholistic processing in contrast to the feature/part processing of objects (Tanaka & Farah, 1993; Tanaka & Sengco 1998; Yin, 1969). Recently an eyewitness recognition study has shown that recognition performance for faces was enhanced following a global processing task compared to a local processing task. (Macrae & Lewis, 2002) suggesting that global and local attention may differentially influence faces and objects.

Conclusion

Evidence was found to support a role for global and local and processing in the recognition of real world objects. Global priming was beneficial for basic level target detections and when objects were visually dissimilar, and local priming was beneficial for subordinate level target detections when objects were visually similar. Global or local priming occurred in a flexible manner depending on the nature of the recognition task. It was proposed that global and local processing aid the selection of perceptual attributes of the object diagnostic for recognition, and that selection is based on two mechanisms; spatial extent and grouping/parsing operations. Further research was recommended to clarify the role of spatial extent in object categorization, the function of the local level in traditional hierarchical figures and the influence of conceptual knowledge in the selection of local and global information in visual stimuli.

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APPENDIX A

List of objects used as targets or distractors in the target detection task.

Test Conditions

	Subordinate Similar	Basic Similar	Subordinate Dissimilar	Basic Dissimilar
Targets	20 beagles	See Subordinate Similar distractors	20 beagles	See Subordinate Similar distractors
Distractors	afghan airedale basset hound bedlington terrier bloodhound borzoi boston terrier bull mastiff bull terrier bulldog chihuahua collie daschund doberman greyhound pekinese pointer retriever sheepdog yorkshire	bear camel cat cow deer donkey elephant goat gorilla horse kangaroo lion monkey mouse pig rabbit raccoon rhinoceros sheep squirrel	baby carriage barn basket bike blouse bus car chair church desk dress gun helicopter helmet iron piano plane telephone truck watercan	See Subordinate Dissimilar distractors

Practice conditions

	Subordinate Similar	Basic Similar	Subordinate Dissimilar	Basic Dissimilar
Targets	8 beagles	See Subordinate Similar distractors	8 beagles	See Subordinate Similar distractors
Distractors	dalmation german shepherd scotty husky great dane spaniel poodle st bernard	beaver giraffe groundhog leopard seal skunk tiger zebra	balloon boot kettle motorcycle roller skates sailboat train van	See Subordinate Dissimilar distractors

Appendix B

Results of the analysis of data from the global/local divided attention task in Experiment 1.

Multi-factorial repeated measures ANOVAs were performed on the reaction times and percentage correct for the global/local task.

Reaction Times

The results of the ANOVA revealed no main effects or interactions.

Percentage correct

More correct responses were made to global and local levels of the hierarchical figures when they were preceded by target detections made in the context of visually dissimilar distractors (93%) than when they were preceded by target detections made in the context of visually dissimilar distractors (88%, $F(1,36) = 14.91$).

Appendix C

List of target and distractor objects used in Experiments 2 and 3.

Test conditions

	Subordinate Similar	Basic Similar	Subordinate Dissimilar	Basic Dissimilar
Targets	16 finches	afghan airedale bedlington terrier bloodhound boston terrier bull mastiff bull terrier chihuahua collie doberman greyhound husky pointer pug retriever saluki	16 beagles	angelfish catfish dogfish dolphin fish fighting fish halibut hammerhead jack lookdown mackerel ray sailfish salmon sturgeon tarpon tuna
Distractors	bluejay canada goose falcon flamingo hummingbird kingfisher mockingbird parrot pelican pigeon puffin seagull swallow swan titmouse woodpecker	bear camel cat cow deer donkey elephant goat gorilla horse lion monkey mouse pig rabbit sheep	ashtray barn bike blouse bottle desk gun hat helicopter helmet iron oven piano roller skates telephone truck	basket bed boot cannon car church coat dress dresser guitar kettle kite motorcycle plane pot water can

Practice Conditions

	Subordinate Similar	Basic Similar	Subordinate Dissimilar	Basic Dissimilar
Targets	6 finches	bulldog cocker german shepherd pekinese sheepdog basset hound	6 beagles	flounder johndory paddlefish shark walleye bluegill
Distractors	cockatoo duck egret meadow lark stork thrasher	kangaroo raccoon rhinoceros squirrel zebra beaver	baby carriage chair hammer lamp record player jet fighter	couch house key sailboat train coffee pot

Appendix D

Results of the analysis of data from the global/local task for hierarchical stimuli in Experiment 2.

Multi-factorial repeated measures ANOVAs were performed on the reaction times and percentage correct for the global/local task. The factors were Attention Level (global or local), Size (large, medium and small), Distractor Type (visually similar, visually dissimilar) and Category Level (subordinate or basic). Data were included in the RT analysis only if two consecutive responses in a couplet were correct. Fourteen subjects were excluded as they achieved 50% or less correct responses in one or more of the cells in the factorial design.

Reaction Times for the overall analysis of all factors

The speed of detecting targets at global and local levels depended on the size of the hierarchical figures ($F(2,92) = 3.11$). For large hierarchical figures local level targets (mean = 611 ms) were identified more quickly than global level targets (mean = 617ms). For medium hierarchical figures there was little difference between the identification times for global and local targets. For the small hierarchical figures global level targets (mean = 616ms) were identified more quickly than local level targets (mean = 638ms). There were no other significant interactions.

Percentage correct for the overall analysis of all factors

There were more correct responses made to global and local levels of the hierarchical figures when they were preceded by target detections made in the context of visually dissimilar distractors (95%) than preceded by target detections made in the context of visually dissimilar distractors (91%, $F(1,46) = 38.92$). There was evidence that

the degree of visual similarity between targets and distractors influenced performance on global and local decisions, $F(1,46) = 6.86$. More correct responses were made for global decisions (92%) than local decisions (90%) when preceded by target detections made in the context of visually similar distractors. But more correct responses were made for local decisions (95%) than global decisions (94%) when preceded by target detections made in the context of visually dissimilar distractors. This pattern of correct responses is opposite to what would be expected. In the case of global/local responses made after target detections in the visually dissimilar condition the results may be due to a speed accuracy trade off since overall reaction times to global levels (mean = 615ms) were faster than reaction times to local levels (mean = 621ms). However, for correct responses made after target detections in the context of visually similar distractors the picture is less clear. The pattern of correct responses in relation to Attention Level and Distractor Type suggest that the influence of the object recognition task was not related to global and local processing but to the level of difficulty. It is more difficult to detect targets amongst visually similar distractors than amongst visually dissimilar distractors (see analysis of target detections). It is also generally more difficult to identify local level targets than global level targets (Navon, 1977; etc).

Performance on the global/local divided attention task was also influenced by the size of the hierarchical figures and the category level of the target objects, $F(2,92) = 6.657$. More correct responses were made to large and medium sized hierarchical figures when preceded by subordinate target detections and more correct responses to small hierarchical figures when preceded by basic target detections.

Separate analyses of reaction times for each of the three different sizes of hierarchical stimuli.

A repeated measures ANOVA with factors of Attention Level (global element/local element), Category Level (subordinate/basic) and Distractor Type (visually similar/visually dissimilar) showed no significant main effects or interactions for the large and medium sized hierarchical figures. However, in the analysis of the small hierarchical figures global targets were identified more quickly than local targets, $F(1,46) = 6.137$.

Separate analyses of percentage correct for each of the three different sizes of hierarchical stimuli.

For the large hierarchical stimuli there were more correct global and local decisions when they were preceded by target detections made in the context of visually dissimilar distractors (95%) than when they were preceded by target detections made in the context of visually similar distractors (90%, $F(1,46) = 20.39$).

For the medium hierarchical stimuli there were more correct global and local decisions when they were preceded by target detections made in the context of visually dissimilar distractors (95%) than when they were preceded by target detections made in the context of visually similar distractors (92%, $F(1,46) = 6.47$).

For the small hierarchical stimuli there were more correct global and local decisions when they were preceded by target detections made in the context of visually dissimilar distractors (95%) than when they were preceded by target detections made in the context of visually similar distractors (92%, $F(1,46) = 25.8$). Furthermore, there were more correct global decisions (92%) than local decisions (88%) when the target

detections were made in the context of visually similar distractors, but little difference in the percentage of correct global decisions (95%) and local decisions (95%) when the distractors were visually dissimilar ($F(1,46) = 4.52$).

Appendix E

Results of the analysis on performance of the global local task

Multi-factorial repeated measures ANOVAs were performed on the reaction times (RT) and percentage correct for the target detection task. The factors were Attention Level (global element or local element), Size (large, medium and small), Distractor Type (visually similar, visually dissimilar) and Category Level (subordinate or basic). Data were included in the RT analysis only if two consecutive responses in a couplet were correct.

Reaction Times for the overall analysis of all factors

The speed of detecting targets at global and local levels depended on the size group that the digits belonged to, ($F(2,94) = 4.78$). For the large digit group, local elements (mean = 565 ms) were identified marginally faster than global level elements (mean = 569ms). For the medium digit group there was no reliable difference between the identification times for global and local elements ($t < 1$). For the small digit group, global elements (mean = 560ms) were identified more quickly than local elements (mean = 578ms). There were no other significant interactions. The biggest cost in reaction times was found for the smallest element. This was likely due to the fact that the difference between the size of the digit and the size of the objects was largest for the small local element.

Percentage correct for the overall analysis

More correct responses made to global and local digits when they were preceded by target detections made in the context of visually dissimilar distractors (95%) than

$F(1,47) = 26.47$). Performance on the attention priming task was sensitive to the category level of the preceding target object and the degree of visual similarity between the targets and distractors, $F(1,47) = 5.03$. There were more correct responses to digits preceded by a basic target detection (93%) than preceded by subordinate target detections (91%) when those target detections were made in the context of visually similar distractors. When the target detections were made in the context of visually dissimilar distractors there was little difference in the number of correct responses to digits after basic target detections (95%) and subordinate target detections (95%).

The percentage of correct responses to global and local elements also differed depending on the category level of the preceding target object, $F(1,47) = 4.36$. There were more correct responses to local element decisions preceded by basic target detections (95%) than subordinate target detections (93%) and no difference between global element decisions preceded by either basic target detections (93%) or subordinate target detections (93%). In the case of the local elements the pattern of errors suggest that it was easier to identify digits after basic target detections than after subordinate target detections. According to the attentional window hypothesis there should be more correct responses after a subordinate target detections since the size of the attentional window should to at a size closer to the local digit than the global digit. It could be that the pattern of correct responses has more to do with the level of difficulty experienced in preceding object detection trials. The fact that the degree of visually similarity between the targets and distractors in the target detection task had a consistent effect on the number of correct responses to digits supports this argument.

Separate analyses for digit responses for each of the three different digit groups.

Reaction times in digit responses for each of the three different digit groups

A repeated measures ANOVA with factors of Attention Level (global element/local element), Category Level (subordinate/basic) and Distractor Type (visually similar/visually dissimilar) showed no main effects or interactions in the attention priming task for the large and medium group of digits. For the small digit group, global element decisions were made more quickly than local element decisions, $F(1,47) = 14.99$.

Percentage correct in digit responses for each of the three different digit groups.

In the large digit more correct responses were made to digits preceded by target detections made in the context of visually dissimilar distractors (91%) than preceded by target detections made in the context of visually similar distractors (95%, $F(1,47) = 10.22$). This was also the case for the medium digit group, $F(1,47) = 20.10$ and the small digit group, $F(1,47) = 14.24$.

In the medium digit group there was also evidence that the degree of visual similarity between targets and distractors influenced performance on global and local element decisions, $F(1,47) = 8.80$. More correct responses were made to the medium group of digits when they were preceded by basic target detections (93%) made in the context of visually similar distractors than preceded by subordinate target detections (90%). But more correct responses were made to medium sized digits preceded by subordinate target detections (97%) made in the context of visually dissimilar distractors than preceded by basic target detections (95%). Performance on global and local element decisions was also differentially affected by the category level of preceding target

objects, $F(1,47) = 4.91$. There were more correct responses made to global elements (94%) than local elements (92%) preceded by subordinate decisions and more correct responses made to local elements (95%) than global elements (93%) when preceded by basic decisions. This pattern of correct responses is similar to that found in the overall analysis and is most likely due to the level of difficulty experienced in making the target detections influencing subsequent digit decisions. A significant three-way interaction between Attention Level, Category Level and Distractor Type, $F(1,47) = 5.47$, supports this argument. Differences in the number of correct responses to medium sized digits diverge when they are preceded by subordinate and basic target detections made in the context of visually similar distractors. These target detections are more difficult compared to those made the context of visually dissimilar target detections.