Categorisation in Infants and Adults: Perceptual Saliency as a Function of Timing

Janine V. Spencer

Thesis submitted for the degree of Doctor of Philosophy

MRC Cognitive Development Unit
&
University College London

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

Abstract

Concepts mentally represent categories of entities in the world. They are thought to be fundamental to thinking. Of primary concern is whether conceptual information is at the core of infants' representations of categories, or if infants first learn to classify on a purely perceptual basis. The relationship between perceptual and conceptual categorisation has been conceived of in terms of a dichotomy. I argue, however, that both perceptual and conceptual information are constrained by the amount of time the cognitive system has to process information. In this thesis, I investigate the relative weighting of perceptual information under time pressure at the beginning of conceptual development, in infants, and when conceptual development is complete, in adults.

The effects of timing on categorisation were investigated in 16 experiments with infants and adults. Experiments 1 to 3 utilised the familiarisation/novelty preference procedure with 4-month-old infants. The experiments demonstrated that when processing time is limited, infants show a marked preference for the highly-diagnostic information. With increased looking time, less diagnostic information is incorporated into the object representation. Experiments 4 to 16 revealed that the properties adults use in rapid categorisation tasks correspond to those of infants, and are therefore not a function of age. Rather, how subjects perceive, process and assign relative weighting to different properties in categorising objects is dependent on timing constraints.

Acknowledgements

I am grateful to many people, without whom this thesis would not exist, including Annette Karmiloff-Smith for her advice, support and friendship, Mark Johnson, Paul Quinn, Bradley Franks, John Morton, Greg Murphy, Rob Goldstone, Clive Rosenthal, Kristina Scheuffgen, and Jean Mandler. I am very grateful to everyone at the CDU baby lab for their assistance over the past 3 years, and of course the infants and adults who made the experimental testing possible.

I would also like to thank my parents for their love and continued support over the years, Darcey for being himself, and above all Justin, for everything.

Table of Contents

Table of Figures

Figures for chapter 2

Figures for chapter 3

Figures for Chapter 4

Figures for Chapter 5

Chapter 1

Introduction

Concepts are integral to thinking. For a child to learn that fire can burn, she must use her concepts of *fire* and *burn*. Without making this assumption it is difficult to say why a child's experience with one kind of *fire* and one particular experience of *burn* would be related to a different kind of *fire* and a different kind of *burn*. It is not that the child is simply using association to generalise from one type of fire to another type. Rather, her thoughts concerning *fire* and *burn* are structured. For example, the concepts of John, Mary, and Lucy, and having the concept *John loves Mary* makes it is possible to entertain the concept *Lucy loves John*. Evans (1980) has called this the Generality Constraint. The idea is that to have a concept permits one to think about infinite states of affairs that involve that concept. It is only by treating events, entities, or situations, as different, but related instances are we able to form concepts. Concepts represent our knowledge of the world, be it personal, social or physical. Knowledge is divided up into concepts, and concepts represent or encode categories of things in the world. In other words, concepts classify things into categories. They reflect the way in which we divide the world into classes. On this account, concepts mentally represent categories of entities in the world.

Concepts then are mental representations of categories. A primary function of concepts is the promotion of cognitive economy (Rosch, 1978, but see Pinker, 1997 for an alternative view). The basic premise is that the human cognitive system partitions the large number of objects and information in the world into a manageable number of categories. This process serves to both (1) decrease the amount of information the cognitive system must store in memory and, (2) allow for generalisation and inferencing, i.e., the recognition of novel instances as members of a familiar category. Without the ability to categorise every novel entity encountered would require a new mental representation denoted by a different word.

A further function of concepts is that they enable us to go beyond the information given (Bruner, Goodnow, & Austin, 1956). When encountering an entity, for example a dog, the only direct knowledge of the dog is given by its appearance. It is essential that we can go beyond the basic appearance of the dog and draw upon other related knowledge that we have, such as that even if a dog looks furry and has a wagging tail, not all dogs are friendly and some may even inflict injury. On this account, to have a concept is to have the ability to link perceptual and non-perceptual information (Rips, & Collins, 1993).

In this chapter I aim to address the following issues. Firstly, since concepts have functions, then it is probable that these functions impose constraints on the content of concepts in much the same way that the function of an object, say a chair, imposes constraints on its structure. A chair that does not have a seat of any kind does not fulfil its function as a chair. If it is the case that the content of a concept is constrained by its function, then it is important to know what the nature of the conceptual representation is.

Secondly, people frequently apply their knowledge about categories in a flexible way, giving greater weighting to some aspects of an entity depending on the processing involved or the context (Barsalou, 1987). For example, it is possible to classify a chair as a chair at one time and as a ladder at another. This suggests that conceptual content is context dependent. Given the flexibility people demonstrate in categorisation, how can we provide a psychologically plausible account of the processes involved in categorisation? To classify an entity may require making adjustments to our conceptual content so as to reconcile it with the interpretation required by the context. To classify a chair as a chair in one context - say when sitting on it - and as a ladder in another - when climbing on it to reach a book - requires paying more attention to some properties of the object than to others. A similar idea to this has been put forward by Lamberts (1995) who suggests that because categorisation must often be carried out rapidly people adjust the way in which they weight stimulus dimensions, with perceptual salience dominating the category decision when processing time is limited. One method of ascertaining the relative weighting people assign to objects when making category decisions is by looking at what happens during time-dependent categorisation.

Plan

This chapter is organised as follows. I will firstly consider what the content of concepts is. If concepts are mental representations that allow for the forming of classes of entities into categories, then we need to know what it is that is being represented. Are the contents of concepts restricted to the diagnosticity of perceptual properties, which are used as the building blocks for complex object representations? Or, are the contents of concepts made up of our underlying beliefs about what something is? This issue will be explored in the light of different theories of classification and representation. In section two I will discuss the issues concerning whether infants first learn to classify things in the world on a purely perceptual basis, or whether non-perceptual information is at the core of their representations of categories. This will naturally lead onto looking at the exact relationship between perception and categorisation and will be discussed in section three. Finally, in section four I argue that because much of everyday categorisation is carried out quickly, the relative weighting of perceptual and non-perceptual information is constrained by the amount of time the cognitive system has to process information and make a category decision (Lamberts, 1995).

– oOo –

1.1 Conceptual Content

It has generally been assumed that a concept is a stable mental representation in long-term memory and that people use this representation when thinking and making inferences. It is also believed that people use concepts as a means of classification whereby some kind of feature-detection mechanism is employed so as to compare the content of a concept with the properties of an object, and so decide whether or not an object falls under the denotation of that concept (Franks, 1995). In this section I review some of the basic theories of how people compare the content of their concepts with the properties of an object when making category decisions.

1.1.1 The Classical View

The classical view of categorisation can be traced back to Aristotle. He believed that every concept possesses a defining essence, the attributes of which are singly necessary and jointly sufficient conditions for category membership. Aristotle reasoned that the essences of things are simply a part of an individual's knowledge of the world. We know what a dog is, what it is that defines a dog as a dog, and we know this by inferring it from the examples that we encounter in the world. On this Aristotelian view, membership in a category is defined as being all-or-none. Either an entity fulfils all of the conditions of being a dog in which case it is a member of the category of dogs, or it fails to fulfil at least one of the conditions of being a dog, in which case it is not a member of the category of dogs.

The psychological plausibility of the classical view of concepts has not been without its challengers. Objects are defined as members of a category only if they are in possession of singly necessary and jointly sufficient properties. For example a "Bachelor" would be defined as an "unmarried adult male ". These three attributes are both necessary and sufficient simply because the defeat of any one of them would result in the entity no longer being a "Bachelor". So, for instance, if "male" was changed to "female", the person might be classified as a "Spinster" rather than a "Bachelor"; and similarly if "unmarried" was changed to "married", the person would no longer be classified as a "Bachelor". The problem, however, is how to reconcile the list of definitions with other, perhaps non-defining attributes of our concepts. For example, a Bachelor has the defining attributes of being [unmarried] [adult] and [male]. A Catholic priest has all of these attributes, yet he does not fit the concept of *bachelor* very well. One would be very surprised to find a Catholic priest on a list of eligible bachelors. It is apparent then that people's concepts are far richer than simply the core definitional features (Cohen & Murphy, 1984; Rosch, 1975). For the purposes of this discussion the assumptions of individually necessary and jointly sufficient attributes made by the classical view have one central problematic implication. If an object has the necessary and sufficient attributes then it can be classified as a member; if it does not, then it cannot be classified as a member. However, as I noted earlier, in the course of everyday categorisation, there is often a divergence between the set of properties that an object has, the amount of time needed to check those properties, and the amount of time a person has for making a category decision. In my view, for a person to make a decision on category membership in such cases implies that there are some features of a concept which are defeasible. This defeasibility of features is not accounted for in the classical view. Given this, theorists such as Rosch (1978) and Rosch and Mervis (1975) developed a theory claiming that concepts are organised around prototypes, a view to which we turn next.

1.1.2 Prototype View of Concepts

A particular difficulty with the classical view of concepts is that it is unclear what the defining properties of natural kinds such as *water* or *gold* are. Quine (1969) argued that natural kinds share a similarity relation and it is this similarity relation which explains their belonging to the same kind. Similarity can be defined in terms of surface characteristics, that is perceptual, or conceptual ones (i.e., due to being the same kind). Within prototype theories similarity comparisons are made on the basis of perceptual properties. With respect to more abstract concepts, it was Wittgenstein (1953) who first remarked upon the difficulty of defining necessary and sufficient properties for something to be a *game*. His argument was that there is no set of properties that will separate *all games and only games* from all other things. The apparently necessary properties, such as, *being played*, are not of themselves sufficient. And, the apparently sufficient properties, for example the characteristics of *cricket,* are also not all necessary. Wittgenstein's claim was that different members share a *family resemblance.* Some resemblances overlap more than others, e.g., *{A, B, C, D}*, *{A, D, E}*, *{E, F, G, H}*, *{A, H, K}*. These similarities can be likened to family resemblances. A child may look like her father with respect to her nose, and like her mother with respect to her mannerisms. Although Wittgenstein's observation of finding appropriate necessary and sufficient properties for defining something as a *game* highlights the shortcomings of the classical view of concepts, it still does not capture the nature of the conceptual phenomena when subjects are assigning category membership.

Based on Wittgenstein's notion of family resemblance, Rosch (1978) carried out a number of experiments to see how concepts could be structured according to this view. It was proposed that conceptual representations have a *prototypical* structure. The prototype view of concepts holds that there is no necessity for an entity to have all of the necessary and sufficient properties for picking out sub-parts of an entity in a given context and establishing category membership. Rather, all that is required is for the entity to be in possession of a sufficient number of attributes that other members of the category have. This view argues that concepts are made up of diagnostic attributes (e.g., the shape and colour of an apple are the diagnostic properties of an apple) weighted across category members. The greater the weighting (i.e., the more commonly occurring diagnostic attributes an entity has), the more likely that entity is of being classified as a typical member of that category. For a concept such as lemon the attributes of *taste* and *colour* might be included in the concept. However, *taste* (e.g., sour, bitter, sweet) might be more highly weighted than shape. So the attributes yellow and sour for lemons would have a greater weighting than say yellow and oval, and so an object that was yellow, sour, and juicy would, according to this view, be more prototypical of a lemon than an object that was yellow, *sweet* and juicy. The flexibility of conceptual content is accounted for by assuming that all of the possible weighting for attributes is represented in the concept itself and according to the context the relevant values are chosen.

This view of concepts often holds that classification is accomplished using an idealised abstraction over the cases of the individuals in the category - the average member. Features in the concept are *matched for similarity* against the properties of the object classified: if similarity exceeds the threshold level, then it is classified as a member (Smith & Osherson 1984). Every *match* adds to similarity and every *mismatch* reduces similarity. The extent to which matches/mismatches change similarity depends on the *diagnosticity weighting* of the attributes, their role in identifying members, and the *salience* of attributes. Higher weighting or salience will increase change in similarity. Similarity, typicality and category membership are all measured on the same scale. Context dependency of classification is thought to vary by either lowering the similarity threshold, that is, letting more things into the category, or by increasing the weighting on one or more attributes (narrowing the category).

Several theories are based on similarity relations. The *exemplar theory* (Medin & Schaffer, 1978; Brooks, 1987; Nosofsky, 1991), for example, is comparable to the prototype theory in that it is similarity-based. Here, however, it assumed that sets of instances determine categorisation, not single instances. A concept is represented as the *most typical instances*/members of a category, or a set of such instances. For example, a Labrador, Alsatian, and Collie may be the set of best exemplars, or most typical members of the concept *dog*.

Another recent similarity-based proposal is the *probabilistic theory* (Hampton, 1993). Within this theory a concept is represented as a set of *characteristic attributes* - which are *normally sufficient* for membership. The attributes have different weights indicating their importance in identifying category members. The representation reflects *typicality structure/gradient* for the concept. There are differences between probabilistic and exemplar theories. Within the exemplar theory if the most typical dogs are brown, then they represent the most typical dogs; whereas within the probabilistic theory *brown* would be the most typical/diagnostic value of one attribute of dogs - the *colour* attribute. Regardless, however, of whether the representation of a concept is seen as being *probabilistic,* an *exemplar,* or a *prototype,* all of these theories have in common the notion of good instances or average instances as being crucial to determining the set of entities that fall under the denotation of the concept as well as determining which term(s) associated with the concept truly relate.

The representations of concepts within prototypicality theories are thought to form hierarchies in which successive levels refer to increasingly more abstract concepts. The structure of such hierarchies goes from a single instance *my dog Darcey* to progressively more abstract concepts. In the hierarchical taxonomy of animals, for example, the *Subordinate* level might include *Black Labradors,* the *Basic* level *dogs,* and *Superordinate* level would include the concept *mammal.* Rosch, Mervis, Gray, Johnson, and Boyes-Braehm (1976) argued that it is the basic-level that has the most psychological significance. The basic-level terms are thought to represent the first grouping which children use to refer to objects in the world, and adults are also thought to primarily assign names to groups of objects using basic-level names (Atran, 1996). Children's initial basic-level categories, however, do not always map directly onto adult basic-level categories denoted by the same word. Such differences are to be expected given that children do not possess the same knowledge or expertise as adults. Objects that fall under the extension of basic-level terms are seen as sharing coarse perceptual and/or functional properties in common. These perceptual properties do not vary orthogonally with the world. Rather, they come in causally related clusters (Rosch, 1975). Objects with dog-like feet tend to have dog-like heads. Birds with webbed feet tend to have bills. The basic-level is thought to maximise between-category dissimilarity and maximise within-category similarity, and as such is seen as representing a level of object categorisation that is psychologically fundamental.

In a number of typicality rating experiments[1] Rosch (1975) asked subjects to rate how typical or representative certain objects were as members of the category of vegetable. The findings revealed that there were typicality gradients ranging from highly typical members (e.g., *carrot*) through borderline members (e.g., *tomato*) to non-members (e.g., *cod*). These findings were replicated for many other categories, (e.g., colour categories, natural kinds, artefacts, and social categories). In a further study McCloskey & Glucksberg (1978) asked subjects to say whether objects were or were not category members. Subjects were re-tested a week later. Within this study subjects additionally had to rate the typicality of instances. The findings showed that subjects assigned intermediate ratings to borderline cases like *olive* (as a *fruit*) or *amoeba* (as an *animal*). Additional support for the gradedness of category membership comes from a study by Smith, Shoben & Rips (1974). Here subjects had to verify category membership statements as

---

[1] In typicality rating experiments subjects have to judge how typical a particular object is as a member of a given category. For example, a subject may be asked to say how typical a car seat is as an item of furniture.

quickly as possible: e.g., A tomato is a fruit. It was found that both high typicality and low typicality produced rapid verification times; whereas subjects' reaction times were slower for borderline cases. Hence, the empirical support for categories having some members which are more or less prototypical, appears to be supported.

1.1.2.1 Problems with Prototype Theories

As mentioned previously, all prototype theories are similarity-based. However, similarity may be the consequence of classification rather than the cause. The notion of similarity presupposes a constraint on the specification of the attributes for comparison. To say that things are similar because they fall into the same category emphasises the circularity of similarity, where the notion of similarity is in need of a supplementary explanation. This point was made by Goodman (1972) who argued that for this reason prototype theory itself is only descriptive. Furthermore, people do not always classify solely on the basis of (surface) similarity. For example Rips (1989) found that although a 3-inch disk is more similar to a coin in size than to a pizza, subjects were more likely to categorise it as a pizza. Thus, for some objects *central* attributes appear to be more important. Prototype theory expresses degrees of diagnosticity of attributes (surface appearances), and has no way of representing central attributes. Furthermore, judging the typicality of objects does not imply that they are represented in terms of typicality. Typicality ratings are off-line and so could reflect processing effects subsequent to concept access.

Recent evidence also suggests that typicality ratings vary both across contexts and as a function of the perspective subjects are asked to adopt. For instance, subjects asked to adopt the perspective of an American tend to rate eagles as more typical birds than peacocks, whereas subjects adopting the perspective of a Chinese person will rate peacocks as more typical birds than eagles. As a result of such findings, it has been argued that prototypes may not be stable (Barsalou, 1987), or iterable (Barsalou & Sewell, 1985). And, since classification is not stable, it might be argued that representations are not stable either (see Smith & Jones, 1993 who have argued that there are no such things as stable mental representations since mental activity is essentially dynamic.). This intraperson instability is dependent on contextual effects. So, those attributes that are important in one context may be less so in another. If the prototypical view of concepts is adhered to, this would suggest that the content of people's concepts is comprised of all the possible sets of attributes associated with an object. Categorisation, however, is usually performed in real-time, the mind having to constantly adapt to accommodate sensory input from an ever-changing world, thus it seems unlikely that the brain, as a finite organ, is able to store all of the infinity of unique senses in the content of the concept - just waiting for the right context to occur for them to be retrieved.

1.1.3 Theory-Based Views Of Conceptual Representation

As mentioned previously, in the course of everyday categorisation, there is often a divergence between the set of properties that an object has, the amount of time needed to check those properties, and the time a person has for deciding whether the object is a member of a particular category. In the previous two sections I have argued that neither the classical nor the prototypical view of concepts can adequately handle the context-dependent flexibility of categorisation. The classical approach is inadequate simply because it does not allow for the defeasibility of features. The prototype theory of concepts holds that all of the possible weightings for attributes are represented in the concept itself and, according to the context, the relevant values are chosen. This theory might allow for the defeasibility of features. However, the efficiency of categorising objects in the world indicates that we need to have very simple representations and not an idealised abstraction of the individuals in the category, since an idealisation might involve a great deal of processing to see if enough of the properties of an entity can be mapped on to features in the conceptual representation (Franks, 1995). Consequently we need a theory of concepts which can account for the flexibility of categorisation whilst at the same time overcoming the problems evident in prototype theories.[2] Thus, in this section I consider how a theory-based view of conceptual knowledge could account for the flexibility of categorisation.

The basic premise of the theory-based view of concepts is that people's theories about the world embody knowledge. A theory is a complex set of causal relations between concepts (Murphy & Medin, 1985). Concepts and general knowledge are interwoven. There are no separate representations of concepts. Concepts are simply subparts of information drawn from general knowledge in context.

The representation of concepts within the Theory-theory is coherent to the extent that category membership is explained by a plausible commonsense theory of the domain. It is the commonsense theory that specifies the critical attributes for similarity judgements. Attributes can be more or less deeply embedded in the theory; deeper ones have more (and more critical) explanatory links. There are surface or diagnostic attributes that relate to the perceptual properties of an entity, central/highly frequent attributes, and essence placeholders. Murphy and Medin (1985) argue that observable diagnostic properties are the basis for inferring the presence of usually non-observable central properties. For example, lions have some essence of lionhood, which, although unobservable, is how one can look at a lion and classify it as a member of the category of lions. On this account, if a commonsense theory posits a strong, often causal link between a property and the

---

[2] It should be noted however, that exemplar-based processing permits a great deal of flexibility in the categorisation process simply because it is based on similarity and similarity can vary between representations (Lamberts, 1994).

classification of the object, then that property is central. These central attributes are thought to be immutable (Kahneman & Miller, 1986).

Immutability suggests that people believe central attributes are essential to category membership. Medin and Ortony (1989) label this belief psychological essentialism - the belief that natural kinds have essences. It is not important whether natural kinds really do have essences but that people believe that they do and make category judgements accordingly. On this view, the central features of a concept are those properties that a subject will not allow to be defeated if the entity is to remain a member of the category. If centrality is critical to category membership, then it should help explain differentiating within the basic-level as well as across superordinates.

The Theory-theory proposes that classification will vary according to the task. Quick identification will be based on perceptual similarity, but for analytic categorisation, i.e., when there is no limit on the time given for making a category decision, classification will be explanation/essence-based.

It has been argued that categorising a diverse entity as an instance of the same kind requires stable mental representations (Keil, 1994). However, given the efficiency of categorisation the content of a concept may be made up of a relatively few features with little causal information rather than representing a complex array of idealised attributes of an entity. Whenever we attempt to assign category membership we just access these simple representations. Only when there is not enough information in the perceptual array will deeper theories concerning the entity be accessed (Franks, op. cit.). Hence, within the theory-based theories, classification could be fuzzy or clearly binary, according to the task.

The advantage of theory-based theories over prototype theories is that they provide an explanation for conceptual content and classification varying between contexts, depending on which attributes of an entity are relevant to the task. By contrast, a disadvantage of theory-based theories is that they are prone to circularity in that concepts comprise theoretically structured information, and theories themselves are composed of concepts.

– oOo –

Interim Summary 1:

In the previous section I argued that since concepts have functions, these functions impose constraints on the content of concepts. Therefore, in order to understand the implications of such constraints requires knowledge of the nature of conceptual representations. Secondly, I have argued that our knowledge of categories is often applied in a flexible way, with greater weighting being assigned to some aspects of an entity depending on the processing demands or the context. This suggests that people's conceptual representations are flexible, and perhaps assembled in real-time.

Both the classical theory and the prototype theory are insufficient at explaining the nature of conceptual representations. The theory-based approach to concepts argues that people's theories about the world have a predictive value (Carey, 1985). In explaining how it is that people are able to make category decisions about an entity when some of its surface properties have been defeated, it was argued that people make use of their world knowledge and so are able to access more profound theories (Franks, 1995). However, it was also argued that a conflict may arise between the extent to which attributes of an object have been defeated and the amount of time a person has for deciding whether the object is a member of a particular category. Assigning category membership is a relatively simple task even when timing constraints reduce the amount of perceptual information available to the perceiver. I would argue that this apparent flexibility in categorisation is a result of people having theories about what attributes of a concept can or cannot be defeated. This suggests that there is a trade-off between the importance of perceptual information and conceptual/theory-based information as a function of timing constraints. Rapid categorisation will be similarity/perceptual appearance-based, and when there is no time limit categorisation will be explanation-based. For categorisation to be explanation-based suggests that learning has occurred. However, even categorising on a perceptual basis may involve learning (see Franks, 1995; Medin & Schaffer, 1978). Since the ultimate aim of this thesis is to investigate the relative weighting of perceptual information under time pressure at both the beginning of conceptual development (infants) and in the end-state of conceptual development (adults), it is necessary to establish the role of both perception and conception in the development of conceptual knowledge. Thus, in the following section, I will discuss whether infants first learn to classify entities on a purely perceptual basis, later re-describing it into conceptual knowledge, or whether perceptual information remains intrinsic to categorisation throughout the continuum of concept acquisition.

– oOo –

1.2. The Development of Concepts

In recent years, there has been extensive interest in the origins and development of conceptual representations (e.g., Cohen & Strauss, 1979; Mandler & McDonough, 1993; Jones & Smith, 1993; Quinn & Eimas 1986). It has been suggested that the capacity to form perceptual representations early in life is an essential prerequisite for the acquisition of higher-level cognitive abilities later in development (Quinn, Eimas & Rosenkrantz, 1993). These authors argue that the processes of inference involved in problem solving, successful communication, going beyond the information given, depend on a cognitive system being able to categorise things in the world (for a similar view, see Pinker, 1997). A recent focus of research has been on *what* categories infants learn and *when* they come to learn them. In answer to these questions it has been shown that from 3 to 4-months, and possibly even earlier, infants can categorise objects from within a basic-level, and do so on a perceptual basis (e.g., Quinn & Eimas, 1996; Colombo, O'Brien, Mitchell, Roberts, & Horowitz, 1987; Mervis, 1987; Slater, 1995; Cohen & Younger, 1983). The nature of *how* early categorical representations develop beyond the purely perceptual has been the focus of extensive debate. Just as there is no single theory of concepts in the adult literature, similarly in the developmental literature there is no single theory of how children develop concepts. Thus, in the next section I will explore how different theorists rate the relative importance of perceptual information in the formation of conceptual development. I will begin by giving an overview of what perceptual categorisation is thought to be, prior to comparing it with conceptual categorisation. I will then give the arguments for and against the importance of perceptual categorisation in the formation of concepts.

1.2.1 The Development Of Perceptual and Conceptual Categorisation

Within developmental theory on concepts and categorisation, perceptual and conceptual information have been contrasted. As mentioned previously, concepts are thought to be meaningful in that they support higher-level cognitive functions such as reasoning and inference. Perceptual representations, on the other hand, are determined solely on the basis of perceptual experience. Although perceptual representations are important to cognition, it has been argued that conceptually based representations are richer in that they necessitate a relationship between perceptual aspects of an object and a persons beliefs concerning that object (Neisser, 1987). The idea is that over developmental time children are able to go beyond perceptually-bound representations to form concepts. This conceptual versus perceptual debate is necessarily addressed in terms of basic-level versus superordinate or global categorisation, simply because objects in the basic-level are perceptually similar (or functionally similar in the case of artefacts), whereas objects in the superordinate level need not be.

A compelling set of findings related to the conceptual versus perceptual distinction is that infants' categorical distinctions are a function of perceptual similarity. For example, Quinn, Eimas, and Rosenkrantz (1993) using a familiarisation / novelty-preference looking technique found that infants can form basic-level categorical distinctions chosen from the same superordinate category from as early as 3-4-months of age. However, the reliability of the infants making such categorical distinctions depended on the degree of perceptual similarity or dissimilarity of the objects from within a particular superordinate category. In the Quinn et al study infants were presented with a series of photographic images of either cats or dogs and subsequently tested with a pair of novel photographic exemplars: one a novel exemplar from the familiar category and the other from a novel category. Within this paradigm, categorisation is thought to have occurred if the infant looks significantly longer at the novel out-of-category exemplar than at the novel within-category exemplar. Quinn et al found that infants could form a categorical representation for cats that excluded dogs. However, their categorical representation for dogs did not exclude cats. In other words, when infants were familiarised with dogs they treated a novel cat as if it were a familiar dog. Interestingly, when adult subjects were asked to rate the variability of the cats and dogs, they rated dogs as being far more variable than the cats. Thus, Quinn et al, ran a supplementary experiment in which the perceptual variability of the dogs was reduced to that of the cats. With the variability levels reduced they found that infants could form a categorical representation for dogs that excluded cats. These results highlight the importance of contextual effects when formulating a theory of how children develop categorical representations. The familiarisation study with cats indicated that like adults, infants too use a basic-level distinction when forming representations of categories. However, the results of the familiarisation study with dogs could be taken as demonstrating that infants categorise dogs and cats using a more global or superordinate categorical representation. These findings suggest that whether basic-level or global representations of categories are formed is a function of the level of within-category perceptual similarity.

Using a sequential-touching task, Bauer, Dow, and Hertsgaard (1995) found a similar pattern of results. A sequential-touching task involves presenting infants with a number of stimuli and observing their touching of those stimuli. Categorisation is thought to be present when infants touch multiple objects from one category in succession. These authors presented 13- to 28-month old infants with plastic toy replicas of superordinate category contrasts such as animals versus vehicles as well as basic-level category contrasts such as dogs versus fish. When prototypical basic-level objects were presented to the infants, Bauer, et al established that infants performed sequential-touching behaviour at an earlier age than when non-prototypical objects were presented. As mentioned in section 1.2, prototypicality implies a similarity relation between the prototypical entity and other members of that category. Prototypical members of a category are, however, usually at the basic-level and are thought to maximise between-category dissimilarity and maximise within-category similarity. Given the findings of Bauer et al that infants make category distinctions at an earlier age as a function of whether or not the stimuli are prototypical suggests that the ability to use perceptual similarity when forming representations of categories begins very early in development. If this is the case, then perceptual similarity is an important cue for infants forming representations of categories in the first year of life.

That infants can form categories based on perceptual similarity is evident (e.g., Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). The issue, however, is how infants are able to go beyond perceptually-bound categories to form concepts. By the time infants begin to talk and name objects, they often recognise the function of objects. As mentioned previously, the relationship between conceptual and perceptual categorisation is conceived as a dichotomy. On the one hand Mandler (1988, 1992) argues that perceptual and conceptual categorisation are basically independent and, on the other hand, Smith (1993) argues that perception is the grounding force for conceptual categorisation. In the following section I present both sides of this perception versus conception debate in the development of concepts.

The idea that infants' conceptual categories are basically unrelated to their perceptual ones results from studies focusing on the basic-level versus the superordinate/global level. Basic-level objects within the same category are perceptually similar, whereas superordinate objects within a category do not necessarily share perceptually similar properties. Mandler and McDonough (1993) argued that if perceptual similarity is the basis for developing conceptual categories, then infants should categorise objects together that are perceptually more similar. However, these authors found that 9-month-old infants made a categorical distinction between superordinate categories (i.e., animals versus vehicles, and birds versus aeroplanes) but not between basic-level categories (i.e., dog versus rabbits, and dogs versus fish). In other words, perceptual similarity was not the main basis for the infants' categorical distinctions. Rather, superordinate categorisation took precedence over basic-level categorisation. It is the ability to disregard perceptual similarity in making categorical distinctions that Mandler and McDonough (1993) believe indicates that the infants have formed conceptually-based representations. Concepts are meaningful representations that support higher-level reasoning, thought, and inference and, unlike perceptually-based representations, are not determined solely by immediate perceptual experience. Mandler and Bauer (1988; Mandler & McDonough, 1993) argue that perceptually-based categorisation is based on what things look like, whilst conceptually-based categorisation captures what babies think things are. So, even though birds and aeroplanes look alike, 9-month-old infants can distinguish between them because they know that they are conceptually different. According to this view, 3- to 4-month old infants' representations of categories are based on perceptual information with little or no conceptual content.

Although Mandler et al agree that the information about objects that forms the basis of concepts enters the mind in the first instance via the perceptual system, they argue that from early on in infancy perceptual information is continually being transformed into a form of knowledge that is more properly called conceptual. They suggest that some early conceptual representations formed in infancy are based on animacy (Mandler, 1992). Conceptual representations develop by observing how objects move and interact with one another. Perceptual categories are, according to this view, simply patterns that by themselves do not have meaning. A pattern is turned into a concept by a process of perceptual analysis - a means of analysing which kinds of perceptual information are useful for conceptualising what objects do (Mandler, 1997).

However, Mandler and McDonough's (1993) conclusion that the infants tested during their experiments were not forming categories solely on the basis of perceptual information may be unfounded on at least two counts. Firstly, they did not say how perceptually variable their stimuli were. And secondly, there may be more perceptual variability between global categories than within them. For example, cars and cats would seem to be more perceptually variable than cats and giraffes or cars and trains. Both cats and giraffes have faces and legs, and are texturally distinct from vehicles. In fact, Rakison and Butterworth (1998) have demonstrated with 14- to 22-month old infants that there is actually a <u>perceptual</u> basis for forming superordinate categories. Although a lot changes developmentally during the second year of life, such findings illustrate that global categories can be formed purely on perceptual similarity. Furthermore, the surface geometry of artefacts, such as vehicles, is perceptually very distinct from naturally occurring kinds such as animals[3]. It may be that infants do begin to form primitive concepts of animacy and inanimacy, and they may begin to do so by picking out the perceptual commonalties within and across global / superordinate kinds. Thus, infants arrive at superordinate categories via a perceptual route rather than a conceptual one. This does not imply, however, that the eventual conceptual categories that babies come to form are distinct from their perceptual ones as Mandler suggests.

Quinn and Eimas (1996) have offered an alternative account of the development of concepts. They suggest that both perceptual and conceptual information is involved in categorisation. Early on in life the majority of information to which infants are exposed is via their perceptual system, and so any categorical distinctions that young infants make should be on the basis of perceptual similarity. Quinn and Eimas (1996) found that infants can form perceptually-based representations of categories for cats that excludes dogs and birds, and for dogs that excludes cats and birds. These results indicate that by 3- to 4-months of age infants are able to form some basic-level representations of categories that exclude exemplars from other basic-level categories from the same superordinate category. Over developmental time, the infants gain more information concerning objects in the world, and as a result their categorisation becomes more conceptual in nature. These early categorical distinctions, although perceptually-based, are not arbitrary. Rather, infants' categorisation for animals maps directly onto the basic-level category distinctions that adults make. Additionally, Behl-Chadha (1996) has shown that young infants can make

---

[3] See section 3 for a further discussion of the differences in surface geometry between natural kinds and artefacts.

perceptually-driven basic and superordinate representations of categories for artefacts as well as for the more ecologically driven natural kinds, and that they parallel the conceptual categories that adults make. It has been suggested, therefore (Quinn & Eimas, 1996), that conceptual categories are based on the perceptually-driven categories that young infants make.

Given that concepts are thought to be founded on perceptual distinctions made early on in development, infants should employ perceptual similarity and dissimilarity in different ways as a function of age. Oakes, Coppage, and Dingel (1997) found that age does play a role in whether infants attend to basic-level or superordinate distinctions. More specifically, their study shows that infants attend to basic-level categories when they are familiarised with perceptually dissimilar stimuli, and to superordinate categories when they are familiarised with perceptually similar stimuli. Furthermore, Mervis, Johnson, and Scott (1993) demonstrated with adults the importance of perceptual information on the structure of concepts using natural kinds. In their experiments both novices and experts relied on perceptual similarity when making categorisation judgements, but which perceptual cues were used differed as a function of their level of expertise[4]. This evidence indicates that perceptual representations are not simply replaced by conceptually-based representations as a child's conceptual abilities develop. Rather, perception in the first instance may direct one towards those properties of an entity that can subsequently be used as a relatively reliable indicator of category membership. As knowledge or expertise develops, however, it is the knowledge that directs perception towards other relevant perceptual properties, thus allowing for more fine-grained categorisation.

---

[4] Similar results between experts and novices have been found in problem-solving tasks.

Further support for the importance of perception in the development of concepts comes from Smith and Heise (1992). They suggest that infants are sensitive to surface gradient differences between naturally occurring objects and manufactured objects. Natural kinds tend to have complex and irregular surface gradients. Smith and Heise determined that 12-month old infants are sensitive to textural information in distinguishing animals from vehicles. Additionally, Vidic, Haaf, and Loboschefski (1996) argue that prolonged exposure to an object may lead to infants paying more attention to less obvious properties of an object. These results provide a useful starting point for thinking about the relation between perceptual and conceptual structure, with surface gradient and other perceptual properties being an important force in linking conceptual structure to the real world.

The idea that perception is a guiding force in detecting cognitively significant information in the environment is not a new one. Gibson (1966, 1977) proposed that the perceptual system is functional in that it has evolved to detect significant properties in the environment (affordances). Consider an example from colour perception. One can learn that a red fruit signifies that it is ripe, whereas when that same fruit is green it may cause illness. Here, picking up on the perceptual cue of colour makes a functional difference. Hamlyn (1961) claims that the way in which individuals stay in contact with the properties of the environment which are, epistemically speaking, functionally significant is via perceptual processes. With respect to the example above, it is not the colour per se of an object which is informative. Rather, it is that certain objects have a particular colour in certain contexts and it is this which is functionally important. Perceptual processes permit the detection of functionally significant environmental properties. On this view, knowledge directs perception and perception recruits existing object knowledge.

One possible way forward in the perceptual versus conceptual debate in the development of concepts is to take a quasi Gibsonian stance and interpret both sides of the debate from within this position. For example, Mandler (1992) suggests that when forming a broad 'perceptual' category, such as biological motion, it is the perceptual system that brings together information from the environment concerning motion parameters. On the other hand, Smith (1993) claims that through experience (knowledge) with relations in the environment attention is directed to pick up on perceptual similarity. Combining these two positions it would seem that there is no strict distinction between perception and conception in the development of concepts. If there is no strict distinction, then one could posit that perceptual and conceptual representations are also not distinct. Moreover, given that all studies of cognitive phenomena take sensory input as the basis for cognitive processing, then any theory of concepts must take perception as playing a fundamental role in conceptual formation. The relationship between perception and concepts which will be discussed in the following section.

– oOo –

Interim Summary 2:

The recent literature on perception and concepts has provided considerable support for the idea that higher-level perception in adults is directly linked to higher-level cognitive processes (Goldstone & Barsalou, 1998). This is not to imply that there are no fundamental distinctions to be made. For example, lower-level perception is considered to be a fast, modular process, which is mandatory and cognitively impenetrable. At this lower-level of processing beliefs can not affect the perceptual system (Fodor, 1983). The output of perception is thought to be basic, with more complex representations following as a result of higher-level computation (ibid.). Conception, on the other hand, develops slowly. It is a higher-level cognitive process which gathers information from the outputs of processing sensory input. This input can be perceptual. The conceptual system stores information in long-term memory, combines it with other information and subsequently uses it for making generalisations, inferences, and communication. These two modalities work independently. Such independence, however, has often been taken as suggesting that perception has no role to play in categorisation. Quine (1977) argued that theoretical concepts not based on perceptual input is evidence of an advanced science. Theory-based views of concepts regard them as systems of beliefs originating in knowledge structures, not in perceptual properties (Murphy & Medin, 1985). Even within the developmental literature the strict perceptual/conceptual distinction is often made. Children have been shown to categorise animals on the basis of their internal structure (Carey, 1985), their names (Gelman, 1986), and even their genealogy (Keil, 1989). This ignores perceptual properties. However, many authors claim that children initially categorise objects at the basic-level. Objects within the basic-level are usually perceptually similar. Over developmental time, children make finer-level category distinctions as well as becoming more flexible in their categorisation judgements (Clark, 1983). The latter are processes that incorporate non-perceptual information.

The relationship between perception and conception has a number of consequences for a theory of concepts. Of relevance to this thesis is how a dissociation between perception and conception could account for flexibility. For example, when processing time is limited, highly diagnostic perceptual information determines classification (Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997; Spencer, 1997). It follows that if there is no connection between perception and concepts, perceptually-based categorisation has no input from conceptual content. However, which perceptual properties of an entity are used for making category decisions may depend on contextual effects, timing factors, and learning (Goldstone, 1998). Secondly, categorising on the basis of theoretical knowledge (concepts) implies that perceptual information is unnecessary and therefore not used. Evidence with children and adults would show that this is not the case (Mervis, 1987). In the remainder of this chapter I will explain the interaction between perception and concepts as demonstrated by experimental evidence. I will show that this interaction is vital in the development of concepts.

– oOo –

1.3 The Relationship Between Perception and Concepts

For perception and conception to interact suggests a degree of flexibility within each system. If perception were not flexible, then it could not adapt to differing demands made by the cognitive system. Secondly, if conception were not flexible, then it could not use perception when making inferences and analogies. There is considerable evidence demonstrating the flexibility of the conceptual system (Barsalou, 1987; Kahneman & Miller, 1986). It is often assumed, however, that the perceptual system is not flexible in the way that the conceptual system is. According to Fodor (1983) perception is an input system. Input systems are modular, and among other things, cognitively impenetrable. In other words beliefs cannot effect the operation of the perceptual module. Only when input systems are inflexible can they provide dependable input to the conceptual system (Fodor, 1983). I argue, however, that it is only the low-level perceptual processes, such as edge detection which are wholly modular. Top-down processes can not influence edge detection. Higher-up in the visual system the processes employed are more flexible. Categorisation on the basis of perceptual information is a higher-level perceptual process. Although perception is modular in that it is not a top-down process - perceiving an object as a cup is a fast automatic process - categorisation involves a process of learning, and as such is a higher-level perceptual process. The same system that is used for categorising dogs needs to be flexible so that it can accommodate other categories. A system that is flexible must be able to learn. In this section I suggest that just as conception must be flexible, there must be some degree of flexibility in the higher-level perceptual processes. Flexibility facilitates conception by adjusting the input relative to its demands and requirements. This will go some way to establishing the interaction between perception and conception.

1.3.1 Perceptual Learning

For perception to be flexible implies that it can learn. On this account, what is perceived depends on an individual's experience, knowledge, and psychophysical constraints (E. Gibson, 1969). The notion of perception being flexible or adaptive affords an advantage to the cognitive system. A fixed perceptual system suggests that there is a fixed set of perceptual primitives. However, as Schyns, Goldstone, and Thibaut (1998) have pointed out there is an inherent difficulty with a system of this kind. With a small set of primitives the combinations of them may not be sufficient for distinguishing all of the entities encountered. A set of primitives large enough to construct all combinations necessary for distinguishing all and any of the entities met, may result in a system that is largely unused (ibid.). Thus, it would seem necessary that different primitives are developed as a result of learning. A mechanism of this kind explains how a system can achieve greater generality

Goldstone (1998) has proposed four mechanisms of perceptual learning: attention weighting, imprinting, differentiation, and unitisation. Attention weighting concerns perception changing its focus relative to task and environmental demands. Imprinting involves changes to the lower-level perceptual system by developing receptors specialised for processing parts of stimuli. During the process of differentiation, the perceptual system can psychologically distinguish stimuli that were once undifferentiated. Finally, via unitisation the perceptual system learns to detect a single constructed entity that was originally perceived by detecting several of its component parts. Although all four mechanisms are important for a theory of perceptual learning, attention weighting and imprinting are most relevant for understanding the interaction between perception and conception.

1.3.2 Perceptual Learning and Attention

Which dimensions of a stimulus are perceived can vary by increasing and/or decreasing attention. Paying attention to a particular aspect of an entity suppresses activity outside the visual attention field. Perceptual attention is believed to employ an attention/suppression mechanism (Tsal & Lavie, 1993). One aspect of visual attention is to move the eyes in a series of saccades from one part of the visual field to other regions of interest. Once the eye fixates a region of interest, there may be benefits from shifting attention to another region without saccades (Reeves & Sperling, 1986).

Attention is also important for relating independent attributes such as shape and colour. The flexibility of perception is evident from research suggesting that attention can be selectively shifted to different aspects of a stimulus during information processing (Nosofsky, 1986). When subjects are asked to learn a new category they de-emphasise some aspects of the stimuli which were pre-experimentally salient, and emphasise other aspects which are relevant for learning the experimental category (Livingston & Andrews, 1995). With respect to this thesis, such findings lend weight to the argument that which properties of an entity are used for making category decisions is a function of task demands.

1.3.3 Perceptual Learning via Stimulus Imprinting

According to Goldstone (1998), during stimulus imprinting, perception becomes adapted by developing receptors for stimuli that are seen repeatedly (Nosofsky, 1986, Logan, 1988). These detectors augment the speed and precision of stimulus processing. Either parts of stimuli or whole stimuli can be imprinted.

Exemplar (Nosofsky, 1986) or instance-based (Logan, 1988) models are ones in which whole stimuli are imprinted. Logan's model proposes that every time a stimulus is perceived, a memory trace is formed for that stimulus. Results from perceptual tasks reveal performance increases, and recognition time decreases as a function of the amount of instances that are stored in memory. In other words, as familiarisation with a stimulus increases, so does the ease of retrieving an exemplar of it from memory. Evidence of this was shown by Brooks, Norman, and Allen, (1991). They found that doctors could diagnose skin disorders more accurately when they had had experience with similar cases. This facilitation occurs regardless of whether or not the similarity is based on attributes relevant to the present diagnosis. Furthermore, when unclear or quickly presented stimuli are shown, subjects identify them more accurately when they have had a number of previous exposures to them (Schacter, 1987). Such findings are normally discussed in terms of implicit memory for exposed entities. However, Goldstone (1998) argues that these effects are good examples of perceptual learning.

Imprinting is not restricted to entire stimuli. There is substantial evidence to suggest that people also imprint parts of a stimulus. Specialised detectors often develop to perceive those parts of an entity that are important for recognition purposes. Detectors also develop for frequently seen parts, as well as parts that vary independently from other parts of an entity (Weinberger, 1993). This is a valuable process in that it results in developing new building blocks for characterising the stimuli (Schyns, Goldstone, & Thibaut, 1998; Schyns & Murphy, 1994). The cognitive evidence demonstrates that during learning the perceptual system is flexible in that it can become adapted to the environment. Two questions arise as a result of the notion of perceptual learning. Firstly, how does perceptual learning interact with the conceptual system? And secondly, once perceptual learning has occurred either through selective attention or developing new receptors, can those parts of an entity that are no longer attended to still be perceived? In other words, is information not selected for by the detectors now inaccessible? Or, is the information still available, but the perceptual system has adapted so that it uses the most informative aspects of an entity for the least processing costs? I shall call this the accessibility versus availability problem.[5] These two issues will be addressed and developed in the final part of this section, and the experimental chapters to follow, by showing how task constraints influence perception when making category judgements.

1.3.4 Task Constraints on Categorisation Processes

At the beginning of section 3, I argued that if perception always operated independently of the conceptual system, then task constraints should have no effect on perceptual processes. Categorisation, however, must often be carried out quickly. According to the theory-theory, when processing time is limited, categorisation is carried out on a perceptual basis. In other words, timing constraints affect the way in which people make category judgements. So, when time is limited, categorisation is made on a perceptual basis, otherwise conceptual knowledge is employed. This is not to say that perceptual categorisation is unrelated to a higher-level categorisation process. If it were, then it is difficult to understand how categorisation could be carried out by the perceptual system since categorisation involves making generalisations and inferences. Rather, I would argue that through an interaction with perceptual input systems, the conceptual system learns to pick out those properties that can facilitate rapid categorisation.

Perceptual categorisation is thought to be based on similarity (e.g., Hampton, 1993; Jones & Smith, 1993; Medin & Schaffer, 1978). Smith (1989)

---

[5] This terminology is also used in the memory literature.

presents a theory to explain the apparent dissociation between perceptual and conceptual processes in rapid categorisation. Her theory is based on Nosofsky's (1986) generalised context model (GCM). The GCM is a similarity exemplar-based model. According to the model categorisation occurs by comparing the entity in the visual field to exemplars stored in memory.[6] Additionally, both representations of entities and stored exemplars can be characterised by a number of dimensions. Nosofsky argues that making a category judgement involves comparing the similarity of an entity to the exemplars stored in memory. According to this model, categorising an entity involves considering a number of different categories (K) of which it could be a member. The probability that the entity is classified as being a member of a particular category is denoted (by Lamberts, 1995) by:

$$P(c_k|i) = (1-g)\frac{\sum_{j \in C_k} S_{ij}}{\sum_{m=1}^{m} S_{im}} + \frac{g}{K},$$

Equation 1. g is the guessing rate($0 \leq g \leq 1$), s_{ij} is the similarity between the stimulus i and the stored exemplar j, m is the number of exemplars, and the index $j \in C_j$ is "all j such that the category label of stored instances j is C_k." (Lamberts, 1995)

For the purposes of this discussion the most important component of this equation is the generalisation parameter c. The rate at which similarity decreases as a function of the discrepancies between representations is determined by c (Lamberts, 1995).

---

[6] Although categorisation within the exemplar theory suggests that an object is compared with many exemplars stored in memory, this does not imply that it is possible to recall or retrieve every exemplar from memory. Rather, each object encountered is thought to leave a trace in memory. It is the traces that are accessed during categorisation, not the individual exemplars.

Smith (1989), using Nosofsky's model has argued that adults are able to use different procedures for processing the information during categorisation tasks. The normal mode of categorisation involves similarity estimations. All of the attributes of the entity are weighted equally, any generalisations that are made are relatively superficial. Smith argues that this is the procedure that children normally apply. For adults, however, this procedure is only applied when processing capacities are restricted, such as when there are timing constraints. When there are no processing restrictions, adults have the ability to employ a more sophisticated procedure for categorisation. This may involve more conceptual processes, and as such the capacity for making generalisations is greater. I would argue, however, that via perceptual learning, attributes that are distinctive of category membership, are given greater weighting. This would promote attention to those properties. Such a process would help ensure that categorisation is relatively reliable even when there are constraints on processing capacities.

In extending the GCM Lamberts (1995, 1997, in press) has obtained further evidence concerning the effect of timing constraints in categorisation tasks. Lamberts' claim is that when categorisation is carried out quickly, the perceptual system does not have very much time to process all of the properties of an entity. In particular, his extended generalised context model (EGCM) makes the assumptions that categories are determined by storing exemplars in memory. Within the EGCM the probability that a subject will assign a particular object to a particular category is given by the following equation.

$$P(R_j \mid O_i) = (1-g)\frac{b_j \sum_{j \in C_j} s_{ij}}{\sum_{k=1}^{m}\left(b_k \sum_{k \in C_k} s_{ik}\right)} + \frac{g}{m}$$

Equation 2. "g is the guess rate ($0 \le g \le 1$), s_{ij} is the similarity between the stimulus i and the stored exemplar j, m is the number of categories, b_j represents the bias for making responses J ($\sum b = 1$), and the index $j \in C_j$ refers to all stored exemplars that belong to category J." (Lamberts & Freeman, in press. P5).

Similarity between an object and the stored exemplar is given by:

$$S_{ij}(t) = \exp\left[-c\left(\sum_{p=1}^{P} inc_p(t)u_p\left|x_{ip} - x_{jp}\right|^r\right)^{q/r}\right],$$

Equation 3. "Similarity in the EGCM is assumed as being a function of the distance between stimuli: s_{ij} (t) is the similarity between stimulus i and the stored exemplar j at time t, c is a generalisation value, inc_p (t) is a binary value that indicates whether dimension p has been included (1) or not (0) at time t, u_p is the utility value of dimension p($0 \le u \le 1$, $\sum u = 1$), and x_{ip} and x_{jp} are the values of the stimulus and the stored exemplars on dimension p. This similarity definition extends the similarity notion of the GCM into the time domain, by assuming that similarity depends on the features that have been processed at a given time after stimulus presentation. The type of distance metric is defined by r (city-block if $r = 1$, Euclidean if $r = 2$) and q determines the relation between distance and similarity." (Lamberts & Freeman, in press. P6). r and q were always set to 1 in the experiments reported in Lamberts and Freeman (ibid.).

Lamberts and Brockdorff's (1997) definition of similarity extends that of the GCM by speculating that similarity relies on the attributes that have been processed at a particular time following the presentation of a stimulus.

In a series of experiments the processing assumptions of the EGCM have been tested (Lamberts, 1995; Lamberts & Brockdorff, 1997; Lamberts & Freeman, in press). Within the EGCM a perceptual object representation is built up through a process of stochastic feature sampling (Lamberts & Freeman, ibid.). This suggests that constructing a complete stimulus representation depends on processing time. When processing time is limited, category decisions are made on incomplete representations of the object. Lamberts et al have found that subjects can, and do make category decisions on incomplete object representations. This means that when processing time is limited, category decisions are often made using only certain parts of an object.

– oOo –

1.4 Conclusions

In this chapter I have argued that concepts mentally represent our knowledge of the world. They are mental representations of categories. Concepts have functions, and are constrained by these functions. Accordingly, in the first section I considered different theories explicating the nature of conceptual representations. In section two I considered whether the development of categorisation and conceptual knowledge is based on perceptual or non-perceptual information. This naturally resulted in examining the relationship between the perceptual and the conceptual systems. In the final section I argued that whether perceptual or conceptual information is employed when making category decisions is often a function of task constraints. In the remainder of this thesis I will show experimentally how perceptual information is used during categorisation. Furthermore, I will argue that forming perceptual representations is essential for the development of conceptual knowledge, an ability that is preserved over developmental time.

I will demonstrate that infants show a preference for perceptually diagnostic properties of an entity when presentation time is brief. When presentation time is longer, less perceptually diagnostic properties receive a correspondingly greater perceptual weighting. It can be considered that in the first instance it is the most diagnostic properties of an entity that are processed or perceived, and these are used when rapid categorisation is necessary. Highly diagnostic information is useful for making basic-level, or between-category distinctions, but less useful for making subordinate level, or within-category distinctions. As mentioned previously, objects within the same basic-level share perceptually diagnostic similarities. Diagnostic perceptual information such as global shape can readily distinguish cats from dogs, and chairs from tables, but not Siamese cats from Burmese cats, or Chippendale chairs from Regency chairs. Encoding less diagnostic perceptual information may aid the developing infant to build up detailed representations of entities. Perception is a continuous process that can constantly provide the conceptual system with information that can be used for making more fine-grained distinctions. Evidence of this can be seen in the categorisation differences between experts and novices (Bringham, 1986). The interaction between the perceptual and conceptual systems might be viewed in terms of a feedback system in which perceptual environmental affordances are fed forward to the cognitive system. The more abstract cognitive system may develop a partial or basic-level conceptual representation which contributes to a feedback system that determines the redirection of perceptual focus. Eventually, where appropriate, a more detailed conceptual representation of an entity is formed. When processing time is limited the categorisation weightings will necessarily be highest on the highly-diagnostic pictorial elements of the stimulus. When processing time is not so constrained categorisation weightings will be higher on less diagnostic properties of the stimulus. Which properties have the highest weighting will of course depend on the task demand.

– oOo –

Chapter 2

Introduction

The ability to form basic representations of environmental experiences is thought to be essential for developing higher-level cognitive processes. Without this ability, every object or event encountered would be experienced as new (Quinn, Eimas, & Rosenkrantz, 1993). It is important, therefore, to understand how young infants develop the ability to form categories of complex natural kinds (Roberts & Cuff, 1989). Research suggests that by four-months of age infants can use a basic-level distinction when forming representations of categories (Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997). Additionally, Behl-Chadha (1996) has shown that 3- to 4-month-old infants can form a representation that includes mammals such as dogs, horses, and tigers, but excludes furniture, birds and fish. In other words, young infants are able to form representations for categories at both the basic-level (e.g., cats, dogs) and at the superordinate-level (e.g., mammals, furniture). These findings, among others, raise several important questions. Of particular relevance to this thesis is how the categories that infants form map onto those of adults, and how children establish hierarchically-organised superordinate categories that eventually incorporate subordinate representations. It has been argued that the representations of infants below 15-months of age are perceptual in nature (Mervis, 1987; cf. discussion in Mandler, 1992). The representations of adults, on the other hand, are argued to be conceptual. However, given that perception is thought to be directly linked to higher-level cognitive processes (Goldstone & Barsalou, 1998), the formation of perceptually-based representations in infancy is probably an essential precursor to forming conceptual representations (Behl-Chadha, Quinn, & Eimas, 1995). If this is the case, then it is important to understand the perceptual cues that facilitate this process. Focusing on perceptual aspects of an entity prior to building up a fully-functional conceptual representation may help the infant notice correlations within one basic-level category that are absent across a different basic-level category. Such a process may aid in forming hierarchically-organised categories that incorporate subordinate members. This raises the question of what perceptual cues of an entity permit infants to make such fine-grained categorical distinctions.

As mentioned previously, Quinn, Eimas, and Rosenkrantz (1993) have found that 3- to 4-month-old infants can differentiate relatively similar basic-level category members such as cats from dogs. Both species resemble each other in global shape, specific attributes (e.g., the presence of head, four legs, tail, and some facial features), as well as in the proportional spatial correlation between attributes (i.e., the presence of the same set of attributes consistently detected from each member of both categories). Theory and data on categorisation in adults suggests that basic-level categories may in some instances be distinguished on such a basis (e.g., Marr, 1982; Murphy, 1991; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Tversky & Hemenway, 1984). This suggests that infants may be using fine-grained perceptual cues for making categorical distinctions between two similar species.

The perceptual cues that young infants may use to categorically distinguish perceptually similar animal species such as cats and dogs was tested by Quinn & Eimas (1996). Infants in the experiment were randomly assigned to one of three experimental groups: *Whole Animal*, *Face Only* or *Body Only*.[7] The *Whole Animal* group was familiarised with 12 cats and then given a preference test that paired a

---

[7] Even though the head / face is similar in cats and dogs it may be the most perceptually distinct, or dissimilar attribute for differentiating between them. The rationale behind this derives from the fact that such information is used by a number of species to recognise conspecifics (Johnson & Morton, 1991).

novel cat with a novel dog. The *Face Only* and *Body Only* groups were familiarised and preference tested with the same cats as the *Whole Animal* group. However, in this condition either the bodies (*Face Only* group) or faces (*Body Only* group) of the stimuli were occluded. Reliable preferences for the novel dog stimuli were observed in the *Whole Animal* and *Face Only* groups, but not the *Body Only* group. These preferences were found neither to be a consequence of an inability to distinguish between the cat stimuli nor the result of an a priori preference for the dog stimuli.

The results of the Quinn & Eimas (1996) study indicated that information from the head and face region of the cats was both necessary and sufficient for infants to form a categorical representation for cats that excludes dogs. Also of interest were results showing that (1) infants were able to use body-only information to discriminate individual animal stimuli from within the same category, and (2) adult subjects were able to categorically identify the body-only stimuli as cats or dogs. These additional findings suggest that infants were processing at least some information from the animal bodies, although this information may have been represented less robustly than the head / face and may not have been of sufficient detail to allow for making the categorical differentiation of cats and dogs. That adults can use body information to separate cats and dogs suggests that at some point during development, body information comes to be represented more distinctly in the categorical structures that define animal species.

More generally, the findings demonstrating that young infants rely more on head / face information than on body information to categorically differentiate among animal species have important implications for theories of category development. They indicate that young infants might begin the process of forming categorical representations by attending to and processing information from a perceptually-differentiated attribute that is consistently detected across a category of exemplars.[8] During development, these representations may gradually come to incorporate additional information consisting of attributes that are more broadly distributed across the entire surface of the stimulus. Evidence consistent with this suggestion includes findings that older infants are sensitive to correlations among attributes when processing information from various animal species (Younger, 1990) as well as results showing that adults rely on correlated attribute information when categorising objects from a variety of natural categories (Rosch et al., 1976). The ability to process highly differentiated perceptual information would seem to be an efficient process for developing basic-level categories.

However, attributes that are highly discriminable across categories may not be sufficient for easily differentiating between members of a subordinate category. For example, if head / facial attributes are perceptually similar enough within a category to form a general representation of category members, such as cats, and dissimilar enough across a category to differentiate members of one category from another, e.g., cats from dogs, it follows that head / face attributes are not dissimilar enough for differentiating members within a category, e.g., Labradors from Golden Retrievers. In order to establish hierarchical categories that include subordinate categories, subtle perceptual differences within members of a category need to be incorporated into the representation. Marr's (1982) model of visual cognition suggests such a process. According to Marr, recognising an object involves a general-to-specific process. Firstly the overall shape is processed followed by more specific details. This mode of representation may be an essential prerequisite for young infants learning to categorise. Over successive encounters with an entity, infants become more likely to examine its specific properties. Vidic, Haaf, and Loboschefski (1996) found this to be the case. They re-examined the role different

---

[8] When basic-level categories are globally similar in shape and size, the head / facial region may be the attribute that is the most perceptually distinct. Neurological evidence shows that cells in the inferior temporal cortex are highly selective for faces (Perrett, Smith, Potter, Mistlin, Head, &

body parts, specifically the torso, play in 4-month-olds categorisation. Their findings, in contrast to those of Quinn and Eimas (1996), suggest that the torso is equally as important as the facial region in the categorisation process. One possible explanation for the disparate findings can be related to the length of presentation time infants were exposed to stimuli during familiarisation. As mentioned previously, perception is directed towards perceptually-differentiated properties when processing time is limited (Lamberts, 1997; Smith, 1993). Over an extended period, more perceptual information is blended into a single, unified representation (Adler, 1997). The infants in the Vidic et al study were familiarised to the cat stimuli for 15-seconds per trial. This may have been enough time for them to attend to the perceptually differentiated attributes of the stimuli, i.e., the faces, and subsequently begin to attend to the less differentiated attributes, i.e., the torso of the animals. Although Quinn and Eimas also familiarised infants in 15-second blocks when testing the role of body information, the head and neck region of their stimuli was occluded, suggesting that infants were possibly forming a headless animal category, rather than a cat category.

The series of experiments reported in this chapter represents a further investigation into the perceptual cues used to differentiate between animal species. Specifically, I sought to determine more precisely the relative roles of head / face and body information in the categorical separation of cats and dogs. The experiments with infants aim to provide evidence to suggest that when processing time is limited, infants show a preference for the face/head area of these species when categorically distinguishing between them. With increased looking time, however, categorisation can be determined by less differentiated properties of the stimuli. Such a process may explain how infants learn to form subordinate categories. Two further experiments aim to show that to some extent, the processes

---

Jeeves, 1984). However, this is not to say that faces will always be the most distinct attribute when differentiating between two basic-level animal categories.

adults use in rapid categorisation tasks can be thought of as corresponding to those of infants. Rapid categorisation tasks encourage higher weighting to be assigned to the head/body information. For tasks that require longer processing time, the less differentiated body information may also be used in the categorisation decision. These findings suggest that timing plays an important role in the categorisation abilities of both adults and infants. Five experiments were carried out on infants and adults. All infants in the studies were recruited from the Cognitive Development Unit's subject pool through advertising, local health authorities or birth lists. Parents were not paid for participation but received travelling expenses, as is customary in the Cognitive Development Unit's laboratory.

2.1 Experiment 1 (10-sec familiarisation time).

Experiment 1 is an extension of the work of Quinn and Eimas (1996). In their experiment, the ability to form categorical representations based on face and body information alone using the familiarisation / preference procedure was tested with 4-month-old infants. Preferences were elicited by occluding different parts of the animal. It has been argued, however, that this procedure disrupted the processes by which infants usually form representations for categories (Vidic, Haaf, & Loboschefski, 1996). The present study re-examined the role that head and body information plays in infants categorisation of animals. The exclusive use of cats and dogs as stimuli resulted from the following considerations: i) both cats and dogs have a large number of correlated attributes, ii) they are extremely common as domestic animals, and iii) they appear frequently in children's literature and media.

In order to make any assumptions concerning what information in the stimuli infants use when forming categorical representations of cats and dogs, it is essential to know whether each infant that is tested can discriminate between these two animal species. Therefore, in each of the three infancy experiments reported in this chapter, the infants were always presented with 12 cats or dogs, and then tested with two sets of test trials that paired a novel cat with a novel dog (Whole Animal test). This was to test each infant's ability to form a category for either cats or dogs that excludes the other, as well as novel *hybrids* of cats and dogs (Hybrid test), i.e., a novel cat head attached to a novel dog body versus a novel dog head attached to a novel cat body. Examples of Whole animals are given in Figure 1 and Hybrid test stimuli are given in Figure 2. Thus, in contrast to previous studies (op. cit.,) in the Hybrid condition the cat and dog stimuli were manipulated so that neither the head nor body regions of the target animals were occluded. Instead, the head of the cat stimuli, in a CAT / DOG pair, was replaced with the head of a dog, and vice versa. In essence, this meant that instead of presenting subjects with occluded head and body parts of the target animals, natural-looking transformations of cat and dog stimuli were used. Moreover, because in both the Quinn and Eimas and Vidic et al studies familiarisation time was 15-seconds, this prolonged exposure duration may have been enough time for the infants to incorporate body information into their representations. In contrast to body information Quinn and Eimas suggest that infants focus on the head first when exposed to cat and dog stimuli. Thus, in the present experiment familiarisation time was reduced to 10-seconds to determine if the shorter exposure duration would restrict infants to perceive and process the head and face area of the stimuli first and so incorporate this information more robustly into their representation. In theory, the reduction of exposure duration during familiarisation time, together with the use of the hybrid stimuli, should elicit the same preferences for facial properties as found in the original Quinn and Eimas study (1996), while surmounting the problem of infants forming a headless animal category. Given the Quinn, Eimas, and Rosenkrantz (1993) findings, it was hypothesised that in the Whole Animals condition, infants familiarised to cats would show a preference for the dog stimulus, whereas infants familiarised to dogs would prefer the cat stimulus. Furthermore, on the basis of the Quinn and Eimas (1996) findings, it was hypothesised that infants familiarised to cats would prefer a novel dog head attached to a novel cat body, whereas infants familiarised to dogs would prefer a novel cat-head attached to a novel dog-body. The latter hypothesis was, however, tentative inasmuch as the infants would now be presented with a competing source of novelty from the body. The hybrid test can thus be thought of as a stronger measure of the hypothesis that head / face information is critical for the categorical differentiation of cats and dogs.

A related, further emphasis of this series of experiments is the role of presentation time in the formation of categories. As mentioned at the beginning of this chapter, the properties that will be used in the categorisation process may depend on stimulus exposure duration. Goldstone (1994) has argued that perceptual similarities may be more important when initially grouping objects together into categories, prior to discovering other, less obvious similarities. The first categories that young infants form are thought to be at the basic-level (Mervis, 1987; Slater, 1995). Basic-level objects usually share several surface / perceptual similarity relations. Members of a superordinate category do not necessarily have perceptually similar properties. However, the similarity relations within a subordinate category may be numerous and it may be difficult to discriminate between subordinate category members on the basis of perceptual similarity. Highly distinguishable attributes help to differentiate between categories when presentation time is limited, whereas more homogeneous attributes across category members permit the formation of fine-grained classifications (e.g., at the subordinate level). If this is the case, then it would seem that highly differentiated perceptual similarities may be the initial basis for forming categories, and only once these categories are formed will other, more abstract considerations for the category develop. I hypothesise, therefore, that those object properties given greater weighting when differentiating between categories will be dependent on timing.

Because selective attention to faces is considered to be the way in which young infants learn to differentiate cats from dogs (Quinn & Eimas, 1996), it may be that the head and facial information is more differentiated than the body information in the cat and dog experiments reported. The fact that infants anchor their representations to a few perceptually differentiated attributes may ease the formation of basic-level categories. If timing considerations alter the information being used when forming representations of categories, then a relatively short exposure time may increase reliance on the facial information. The detailed processing of less differentiated information (the body area in the case of cats and dogs) would presumably begin *following* the processing of the highly differentiated perceptual information (head / face region). Limited exposure time per stimulus item should impede the infants from perceiving and processing the less differentiated perceptual information of the familiar category.

2.1.1 Method

2.1.1.1 Subjects

Subjects were 12 4-month old infants (mean age: 4 months 5 days, *SD* = 12 days). There were 8 males, and 4 females. None of the infants had taken part in any other experiment connected with this thesis.

2.1.1.2 Design and Stimuli

The stimuli were 36 colour pictures of cats and dogs (18 cats, 18 dogs). All the stimuli were taken from colour photographs of cats and dogs, and digitised using high quality computer software. The stimuli were printed on photographic paper, thus making them indistinguishable from real photographs. The average height and length of the stimuli was 11 x 11cm. The stimuli were mounted onto white 17.7 x 17.7cm cards for presentation to the subjects. Examples of the CAT and DOG stimuli are shown in Figure 1, and examples of the Hybrid stimuli in Figure 2.

All the infants were tested using a replica of the basic Fagan apparatus (Fagan, 1970). In the domain of vision, the categorisation abilities of young infants has been demonstrated largely through the use of a familiarisation / novelty preference procedure. This procedure relies on the preference that infants exhibit for novel stimuli (Fantz, 1964). The standard procedure involves showing infants a number of exemplars from one category, followed by a preference test that pairs a novel exemplar from the familiar category with an exemplar from a different unfamiliar category. If the infant shows a preference, as evinced through extended looking-time, for the exemplar from the novel category that can not be attributed to an a priori preference or a failure to discriminate among the familiar category members, then this indicates that the infant has formed a representation of the familiar category. The apparatus was a portable visual-preference viewing box. It had a hinged grey display stage (85cm long and 29cm high), with two compartments to hold the stimulus cards. The stage was illuminated using a fluorescent lamp out of the infant's view. The centre-to-centre distance between the compartments was 30.5cm, and on all trials the display stage was situated approximately 30.5cm above the infant's head. In the centre of the stage was a peephole 0.625cm in diameter, through which the experimenter could see the visual fixations of the infant. Figure 3 shows the basic Fagan apparatus.

An initial preference study was conducted to evaluate the possibility of an *a priori* preference between the cat versus dog stimuli, and between the cat head/dog body versus dog head/cat body stimuli. Twelve 4-month-old infants, (mean age: 4 months 4 days, SD = 6 days), 6 males and 6 females, different from those that took part in Experiments 1, 2, and 3, received four 10-second trials during which a dog was paired with a cat on two trials, and a cat head/dog body stimulus was paired with a dog head/cat body stimulus on the other two trials. The test stimuli used in this control study were the same as those selected for use in Experiment 1 (and in Experiments 2 and 3). The order of the two tests was counterbalanced across infants and the first set of two trials was completed before the second set was administered. The left-right positioning of the stimuli was counterbalanced across infants on the first trial of each set of trials, and reversed on the second trial. This preliminary control study to assess possible spontaneous preferences among test stimuli was thus identical to the test phase of Experiment 1 (and Experiments 2 and 3) with the exception that infants did not receive a familiarisation experience. A preference for the dog over cat stimulus (and for the dog head/cat body over cat head/dog body) was calculated for each infant in the control study by dividing the time that the stimuli was observed by the total looking time to both stimuli. The mean preference scores for the dog and dog head/cat body stimuli were 48.86 (SD

= 15.73) and 52.96 (SD = 17.60), neither of which was reliably different from the chance value of 50%, $p>0.20$, two-tailed, in each instance. These results show that infants do not exhibit any systematic preference for the test stimuli to be used in Experiment 1 (and Experiments 2 and 3), and that any reliable novel category preferences observed in Experiment 1 (and Experiments 2 and 3) cannot be attributed to *a priori* preferences.

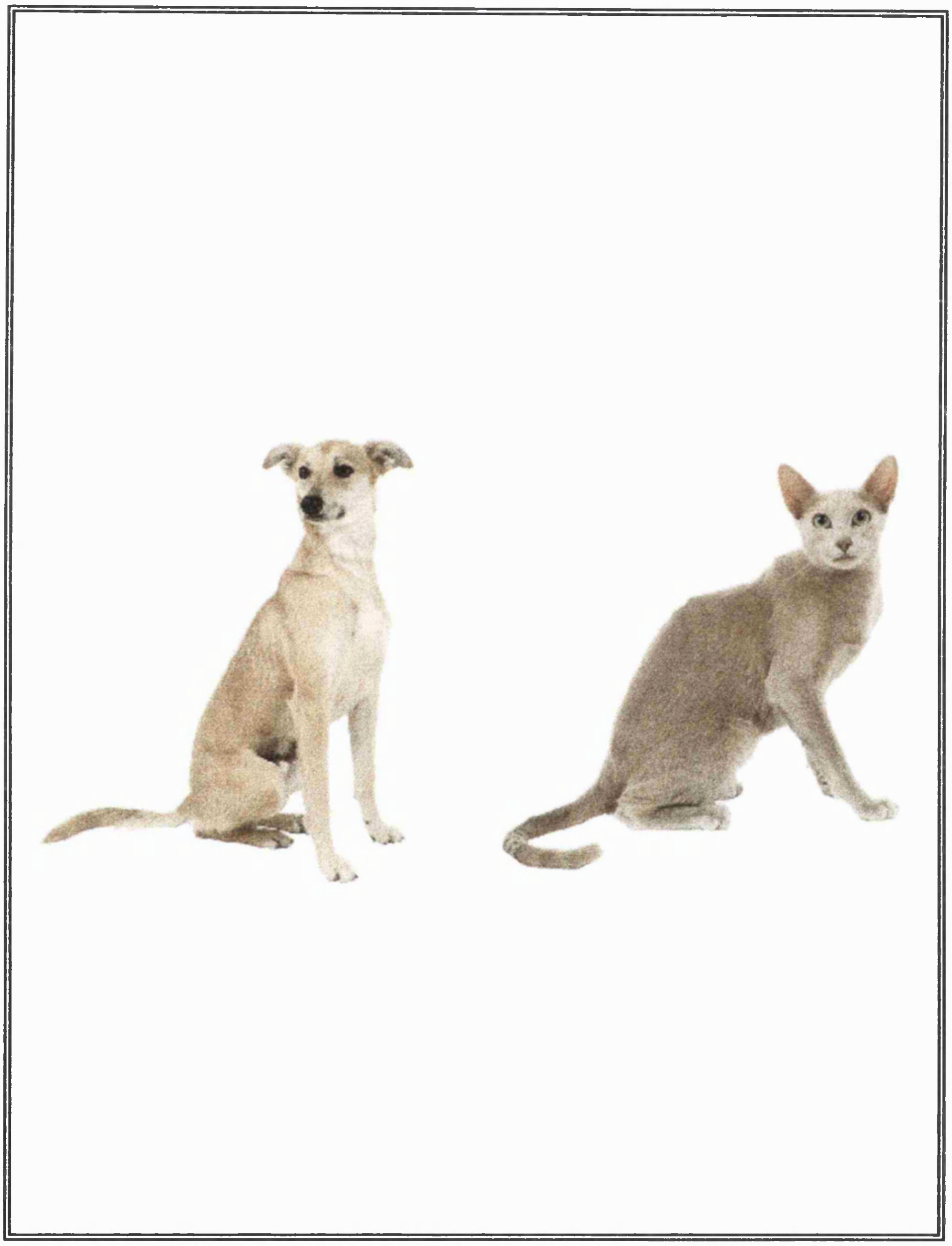


Figure 1. Example of normal CAT and DOG stimuli.

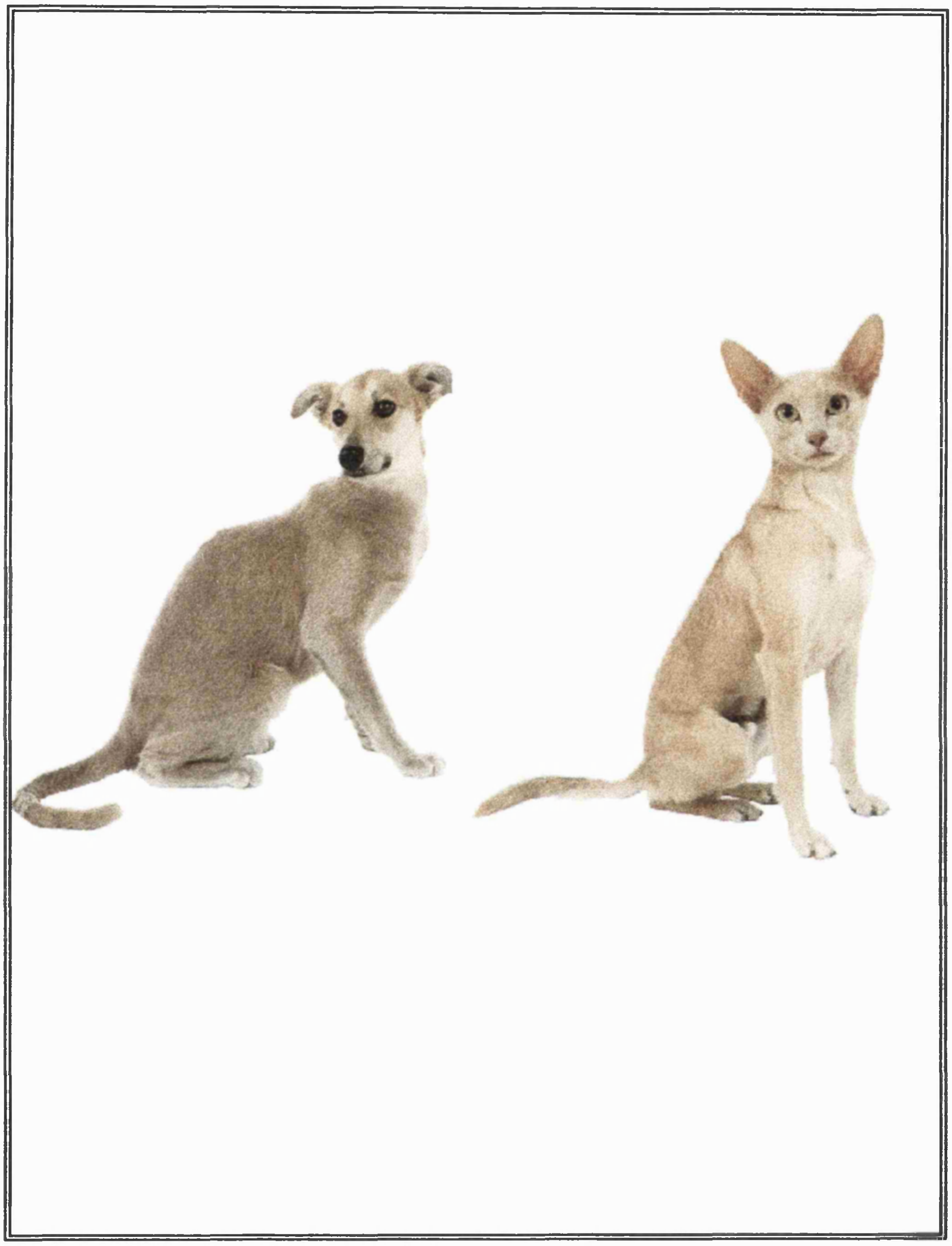


Figure 2. Example of a cat-dog hybrid pair.

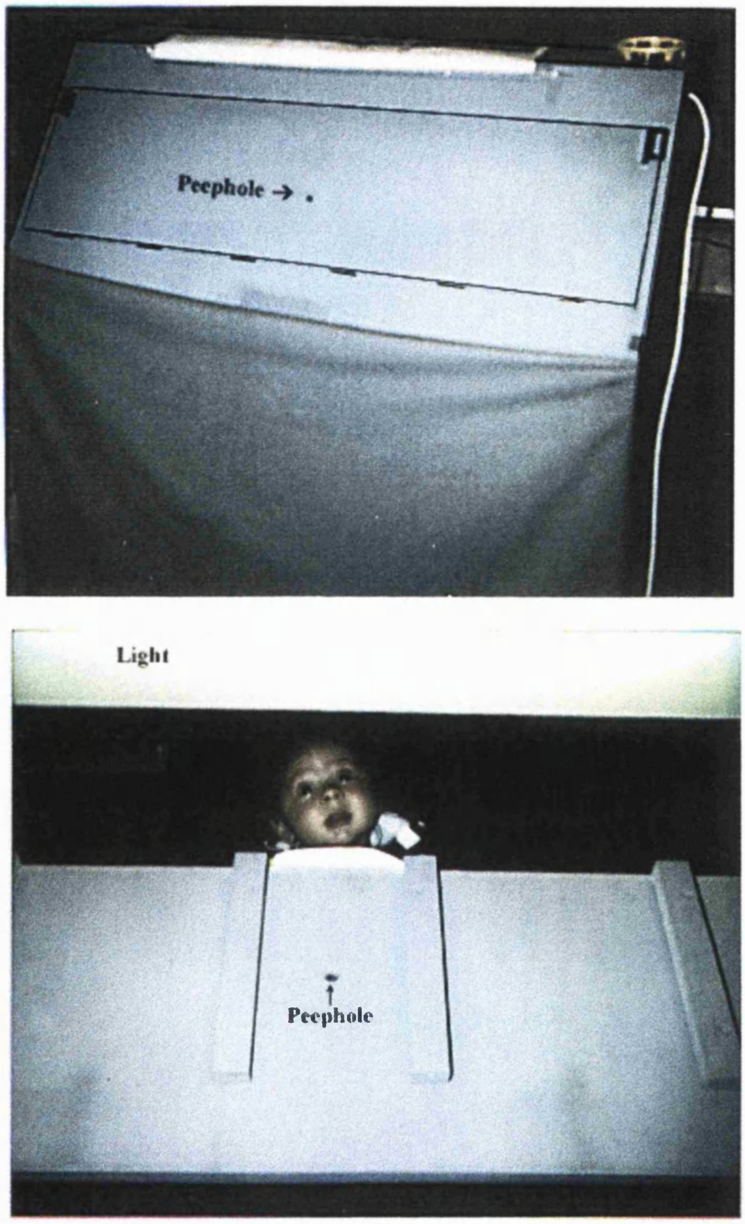


Figure 3. Fagan Box apparatus.

2.1.2 Procedure

Each infant was tested reclining on the lap of its parent, who sat on a low seat. When parent and infant were comfortable the apparatus was wheeled into position. The display stage of the Fagan box was centred directly over the infant. At this stage the infant could no longer see the parent. The stimuli were then placed into the two compartments. Once the infant's attention was attained by talking to her or shaking a rattle, the familiarisation trials began. At no point could the parents see the stimulus items. During a trial, one experimenter looked through the peephole and, with a stopwatch in each hand, timed the infant's looking to the left vs. right stimulus item. This was measured by observing the corneal reflection of each stimulus in the infant's pupil. Four experimenters acted as observers in total[9]. Interobserver reliability of this procedure has been shown to be high (Haaf, Brewster, deSaint Victor, & Smith, 1989; O'Neill, Jacobson, & Jacobson, 1994). The interobserver reliability was measured by checking that there was no variability between the experimenters scores. There was no difference in the mean novelty preference for those infants tested by Experimenter 1 and those tested by Experimenter 2 in each type of preference test (Whole Animal and Hybrid), $p >$ .20, two-tailed, in both cases. A third experimenter timed the fixed length of the familiarisation trials and signalled when a trial was to end (10 seconds in Experiment 1). Between familiarisation trials, the first experimenter opened the display stage away from the infant's view, recorded the data, changed the stimuli, obtained the infant's attention, centred her gaze, and finally closed the stage re-exposing the new stimuli to the infant. Experimenter 1 presented the stimuli in a random order. Experimenter 2 was always blind to the position of the stimuli. For the preference test trials, the first and second experimenter changed places. The

---

[9] Paul Quinn, who has extensive experience using the Fagan Box, trained all of the experimenters.

experimenter who presented stimuli and measured the infant's fixations during familiarisation now measured trial duration and signalled the end of the test trials. The second experimenter now presented the test stimuli and measured fixations. The two experimenters changed roles across infants.

Infants were presented with 12 stimuli, either cats or dogs, during 6 10-second familiarisation trials (2 animals per trial). Half of the infants were familiarised with cats, the other half with dogs. The familiarisation stimuli were randomly selected for each infant, from the pool of 18 available. Immediately after familiarisation and without interrupting the procedure, a set of two 10-second preference test trials was presented. The stimuli for these trials paired a novel cat with a novel dog in the Whole Animal test and one hybrid (cat head, dog body) with the other hybrid (dog head, cat body) in the Hybrid test. The test stimuli were also randomly selected for each infant. The order in which the two sets of test trials were presented was counterbalanced across infants, and the first set of two test trials was completed before the second set was administered. The left-right positioning of the test trial stimuli was counterbalanced across infants on the first test trial of each set of trials and reversed on the second test trial.

In Experiment 1 (and Experiments 2 and 3) all of the infants were tested in the same air-conditioned room at the MRC Cognitive Development Unit. The walls and ceiling were painted grey, and the positioning of the Fagan Box apparatus in the room was kept constant across infants and experiments. All of the testing with the infants was conducted at the same time of day, i.e., in the morning between 10.00 a.m., and 11.30 a.m., after a short feed so that they were alert but satiated. All of the experiments took place in the morning because infants have been shown to exhibit signs of tiredness in the afternoons.

2.1.3 Results

2.1.3.1 Familiarisation Trials

The mean length of each individual looking time for each trial was summed over both stimuli on each trial. Then an average was taken for the first block of three familiarisation trials, and the last three. An analysis of variance was performed to ascertain whether there was an overall difference in looking time between the first three sets of stimuli presented and the last three sets. This ANOVA, first three trial blocks versus second three, performed on the individual scores, revealed no significant effects, $F_{(1,11)}= 0.14$, $p > .10$. Infants thus failed to display a decrement in looking time from the first to last half of familiarisation (first three trials = 5.39, *SD* = 1.14; last three trials = 5.56, *SD* = 1.45). The fact that infants did not habituate is consistent with results obtained with similar stimuli presented over the same number and duration of trials (Eimas, Quinn, & Cowan, 1994; Quinn et al., 1993). This is arguably a consequence of presenting a number of complex stimuli that changed across trials, and probably points to infants' sustained interest in such stimuli, rather than a failure to process them, as is evidenced by the preference data below.

2.1.3.2 Preference Test Trials

For the preference tests trials, the total looking time of each infant across the two test trials to the novel stimulus from the novel category (i.e., in the case of the Hybrid test, this was taken to be the stimulus with the novel category head / familiar category body) was divided by the total looking time to both test stimuli and converted into a percentage score. The mean novel category preference scores for each test condition were first analysed to determine if there were performance differences for infants familiarised with cats and infants familiarised with dogs. No differences were found, $t_{(11)} = 0.44$, $p > 0.10$. The mean novel category preference scores were thus collapsed across the two familiar categories and are displayed in Table 1.

Table 1. Mean novel category preference scores in percentages for the Whole Animal and Hybrid test conditions. Standard deviations are shown in parenthesis.

Whole Animal	Hybrids
Mean preference for novel category (% of looking time)	Mean preference for novel category head (% of looking time)
60.75 (15.37)	66.36 (17.09)
$t_{(11)} = 2.32, p < 0.05$	$t_{(11)} = 3.17, p < 0.01$

In the Whole Animal conditions infants displayed a reliable preference for the novel category animal. The results of the hybrid condition showed that the infants looked significantly longer at the hybrid stimuli with the novel head and familiar body.

2.1.4 Discussion

The result of the Whole Animal test replicates the findings of Quinn and Eimas (1996) and indicates that even with reduced familiarisation experience 3- and 4-month-olds can form categorical representations for cats and dogs, each of which excludes instances of the other. In addition, in the Hybrid test condition, the preference for the novel category head / familiar category body stimuli was reliable. The preference results provide new and stronger support for the claim that information from the head and face region is critical for the categorical differentiation of cats and dogs (Quinn & Eimas, 1996). The preference result from the Hybrid test condition is more convincing than that obtained in the Face Only condition of the Quinn and Eimas (1996) study because, in the present study there was a competing source of novelty from the body. Furthermore, the preference results from the Hybrid condition are consistent with the view that during a short exposure period information from the animals' head and face region is extracted from the stimuli (see discussion of the CONSPEC mechanism in the general discussion of this chapter, Johnson and Morton, 1991).

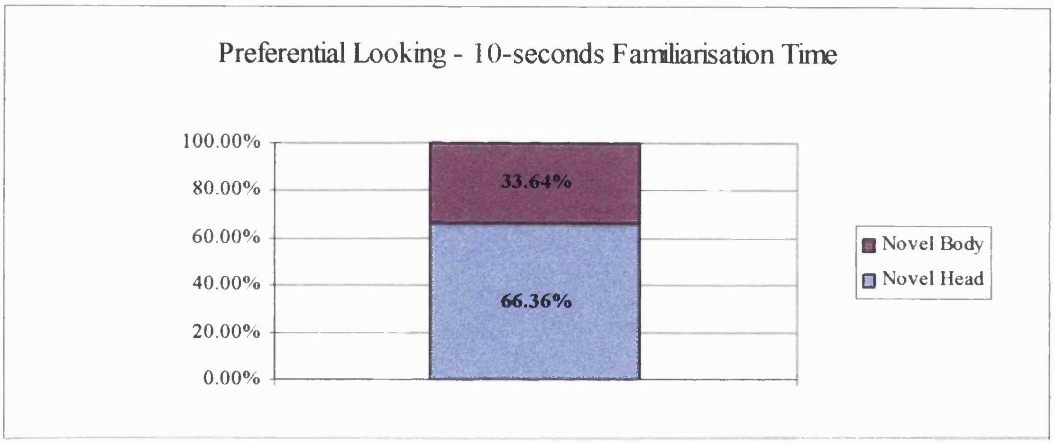


Figure 4. Experiment 1: When infants are familiarised to cats or dogs for a short duration period, they show a significant preference for the stimuli with the face/ head from the novel category in the Hybrid condition, and a significant preference for the novel category stimulus in the Whole Animal condition.

2.2 Experiment 2

In Experiment 2, I sought further evidence for the hypothesis that the information infants use when forming representations of categories is a function of processing time. In a partial replication of the Eimas and Quinn (1994) study, Vidic et al (1996) demonstrated that body / torso information of cats and dogs as well as head / facial information is salient to infants when engaging in categorisation. A problem with the Quinn and Eimas study was the occlusion of either the head or the body. Therefore, their conclusions concerning the importance of the head / face area are open to challenge. However, the results from Experiment 1 in this thesis have demonstrated that infants do show a marked preference for the head / facial area of the animal when familiarisation time is 10-seconds. The discrepancy between these results and those of Vidic et al suggests that timing constraints are an important part of what is perceived and processed first in the categorisation process. In both the Vidic et al and the Quinn and Eimas study, infants were familiarised to the CAT or DOG stimuli in 15-second blocks. It may be that 15-seconds is sufficient time for the infant to perceive and process body information when differentiating between categories. In Experiment 1, infants were familiarised for 10-seconds. This elicited a strong preference for the stimuli with the novel heads in the Hybrid condition. One possibility for this preference is that the head and face area of cats and dogs is perceptually highly differentiated and is perceived and processed first. If this is the case, then when familiarisation time is short, infants may have insufficient time to form a stable representation for the other parts of the animal. On this assumption, infants will have a better memory trace, and perhaps a stronger and more stable mental representation, for the head / face area of the cats or dogs, and will use this information for distinguishing between these two species. The idea that infants extract different kinds of information under varied amounts of familiarisation is not a new one. For example, Freeseman, Colombo, and Coldren (1993) found that whether or not 4-month-old infants extract global or local information from visual patterns depended on the length of experimental familiarisation time. Therefore, in the present experiment, the time to which infants are familiarised to either the cat or dog stimuli was increased to 15-seconds, as was the case in the Vidic et al and Quinn and Eimas studies. If, with more exposure time, infants are able to perceive and process more information other than the most distinctive (heads / faces) the infants should show an equal preference for both the body information and the head / facial information.

2.2.1 Method

2.2.1.1 Subjects

Subjects were 12 4-month-old infants (mean age: 4 months 7 days, SD =10 days). There were 7 males, and 5 females. Two additional infants were tested, but were excluded from the final analysis, one because of fussiness, and the other due to experimenter error. None of the infants had taken part in any other experiment connected with this thesis.

2.2.1.2 Design and Stimuli

The stimuli and procedure were exactly the same as in Experiment 1 with the exception that the presentation of stimuli in the familiarisation trials was 15 seconds instead of 10-seconds. All of the infants in this experiment were tested in the same air-conditioned room at the MRC Cognitive Development Unit as the infants in Experiment 1.The Fagan Box apparatus was positioned in the centre of the room, as in Experiment 1. Infants were always tested in the morning, between 10.00 a.m., and 11.30 a.m.

2.2.2 Results

2.2.2.1 Familiarisation Trials

As in Experiment 1, individual looking times were summed over both stimuli on each trial and then averaged over the first three and last three trials of familiarisation. Once again an analysis of variance was performed to see if there was a difference in looking time between the first three sets of stimuli presented and the last three. The analysis of variance, first three trial blocks versus second three, performed on the individual scores, revealed no significant effects, $F_{(1,11)}= 0.79$, $p > .10$. Infants thus failed to display a decrement in looking time from the first to last half of familiarisation, something that typically occurs in studies of this nature (Bomba & Siqueland, 1983), (first three trials = 7.97, *SD* = 2.45; last three trials = 8.55, *SD* = 2.78).

2.2.2.1 Preference Test Trials

For each preference test, the mean novel category preference scores were analysed to verify that there were no performance differences between infants familiarised with cats and infants familiarised with dogs. Once again, no differences were found, $t_{(11)} = 0.99, p>0.10$. The mean novel category preference scores for each test were thus collapsed across the familiar category and are shown in Table 2.

Table 2. Mean novel category preference scores in percentages for the Whole Animal and Hybrid test conditions. Standard deviations are shown in parenthesis.

Whole Animal	Hybrids
Mean preference for novel category (% of looking time)	Mean preference for novel category head (% of looking time)
63.78 (19.47)	54.39 (19.36)
$t_{(11)} = 2.35, p<0.05$	$t_{(11)} = 1.08$, not significant

This table illustrates that the mean novel category preference for the Whole Animal test was reliably above chance, replicating the results obtained by Quinn et al (1993) and Quinn and Eimas (1996). The mean novel category preference score for the Hybrid test was not reliably above chance.

2.2.3 Discussion

One reason why the results of the hybrid condition may have failed to reach significance is that the 15-second familiarisation trials provided enough time for infants to process both face *and* body information. This suggestion is not inconsistent with the results of the Quinn and Eimas (1996a) and Vidic et al (1996) study in which 3- and 4-month-olds presented with similar stimuli over the same time course of familiarisation processed both face and body information. In the present experiment, information from the novel category body may have competed with information from the novel category head sufficiently to interfere with the preference for the novel category. Moreover, Colombo, Mitchell, Coldren, and Freeseman (1991) have found that the information that infants extract varies as a function of the information they receive. This is consistent with the idea that when infants are exposed to the stimuli during the familiarisation stage for 15-seconds, they perceive equally both the highly differentiated perceptual information (head / facial region), and the less differentiated information (body / torso area). A word of caution should be noted however. These conclusions are not directly supported by the data because the interpretation relies on a statistical null effect. Further experimentation is therefore required to test these speculations. This was addressed in Experiment 3. If it is the case that processing time has an effect on which dimension(s) of the stimuli are perceived and processed, then increasing processing time further may cause the less differentiated perceptual information (i.e., the body in the case of the hybrid stimuli) to be incorporated into the infants' representations more robustly. Consequently, in Experiment 3 familiarisation time was lengthened to 20 seconds.

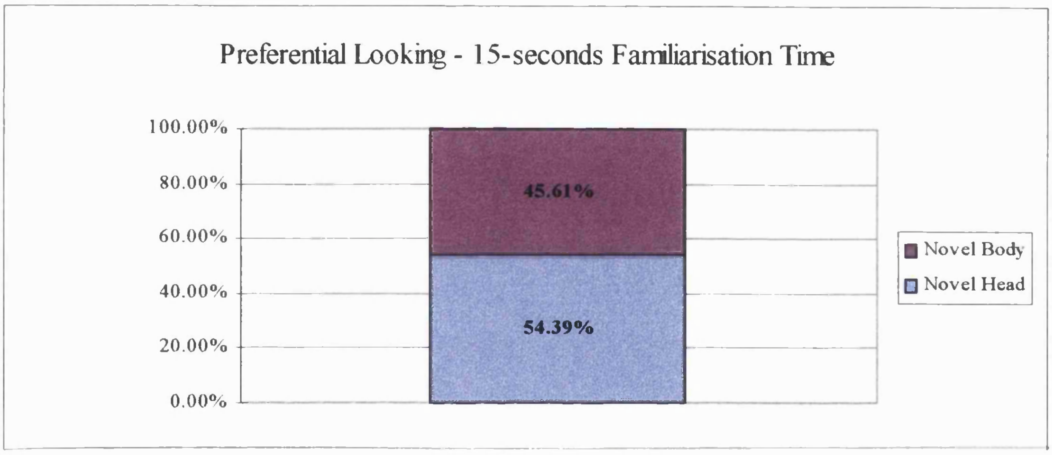


Figure 5. Experiment 2: When familiarisation time is increased from 10-seconds to 15-seconds, there is no significant difference in preferential looking between the stimuli with the novel head and the stimuli with the novel body in the Hybrid condition. In the Whole Animal condition infants showed a significant preference for the novel stimuli from the novel category.

2.3 Experiment 3

To establish the relationship between processing time and perceptual similarity, the exposure time to each member of the familiar category was increased. If abstract structural properties are more influential on perceptual similarity with increased looking time (Goldstone & Medin, 1994) then such a manipulation would be expected to increase reliance on body information. Detailed processing of body information takes longer than processing of face information. With an increase in exposure time there would be more time for the infant's processing to spread from the head / facial region and become more broadly distributed across the entire bodily surface of the stimuli. In an attempt to increase the importance of body information in the representation of the familiar category, Experiment 3 was performed as a replication of Experiments 1 and 2, but with the change that the familiarisation trials were increased to 20-seconds. The expectation was that, contrary to Experiment 1 where infants focused on the head, and Experiment 2 where infants' preferences were divided equally between the head and the body of the stimuli, here they would display reliable novel category preferences for the body of the stimuli in the Hybrid condition.

2.3.1 Method

2.3.1.1 Subjects

Subjects were 12 4-month old infants (mean age: 4 months 6 days, *SD* = 9 days). There were 6 males, and 6 females. The infants had not taken part in any other experiment connected with this thesis.

2.3.2 Design and Stimuli

The stimuli and procedure were exactly the same as in Experiments 1 and 2, with the exception that the presentation of stimuli in the familiarisation trials was increased to 20 seconds. Once again, each infant was tested in the same air-conditioned room at the MRC Cognitive Development Unit as the infants in Experiments 1 and 2. The positioning of the Fagan Box apparatus was the same as before. The testing sessions always took place between 10.00 a.m., and 11.30 a.m.

2.3.3 Results

2.3.3.1 Familiarisation Trials

The mean length of each individual looking time for each trial was summed over both stimuli on each trial, and then an average was taken for the first block of three familiarisation trials, and the last three. Again there was no apparent decrement in looking time, $F_{(1,11)} = 2.14$, $p > .10$ (first three trials = 10.79, SD = 2.85; last three trials = 9.66, SD = 2.54).

2.3.3.2 Preference Test Trials

The mean novel category preference scores for each preference test were analysed to verify that there was no performance difference between infants familiarised to cats and infants familiarised to dogs. No differences were found, $t_{(11)} = 1.41$, $p > 0.10$. Once again, the mean looking time of each infant across the two test trials to the novel category (in the Hybrid test this was taken to be the stimulus with the novel category body and the familiar category head) was divided by the total looking time, and then converted into a percentage. The mean novel category preference scores were then collapsed across the familiar category in the Whole Animal condition and the category with the familiar head / novel body in the Hybrid condition and are shown in Table 3. As in the previous two experiments, the mean novel category preference score for the Whole Animal test was found to be reliably above chance. The mean novel category preference score for the Hybrid test for the hybrid stimulus with the novel body was also reliably above chance. Figure 6 displays infants preferential looking when familiarisation time is increased to 20 seconds. Figure 7 shows the preferential looking for the different infants in each of the three experiments.

Table 3. Mean novel category preference scores in percentages for the Whole Animal and Hybrid test conditions. Standard deviations are shown in parenthesis.

Whole Animal	Hybrids
Mean preference for novel category (% of looking time)	Mean preference for novel category body (% of looking time)
72.5 (9.30)	70.83 (14.14)
$t_{(11)} = 8.38, p<0.001$	$t_{(11)} = 4.89, p<0.001$

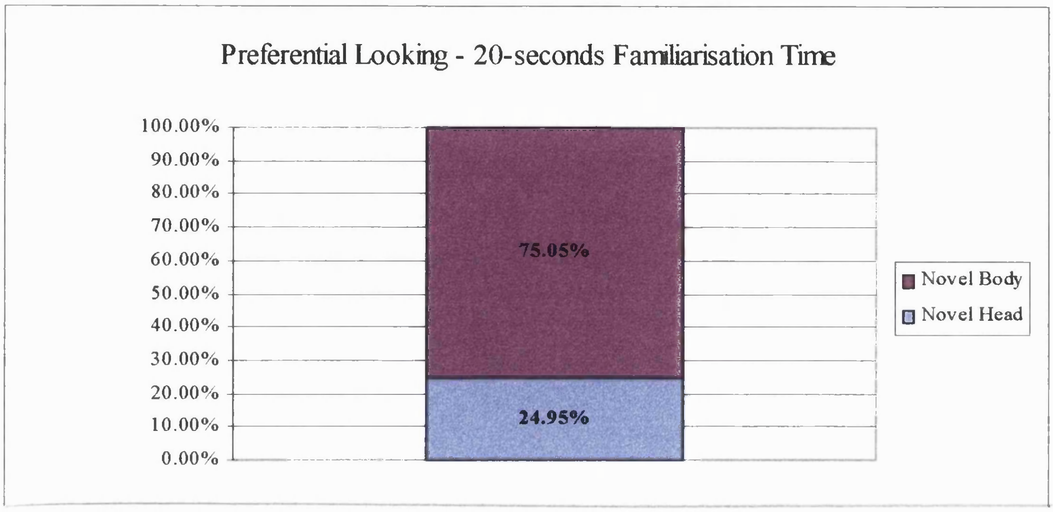


Figure 6. Experiment 3: When familiarisation time is 20-seconds, infants show a marked preference for the stimuli with the novel body in the Hybrid test trials. In the Whole Animal condition infants show a significant preference for the novel stimulus from the novel category.

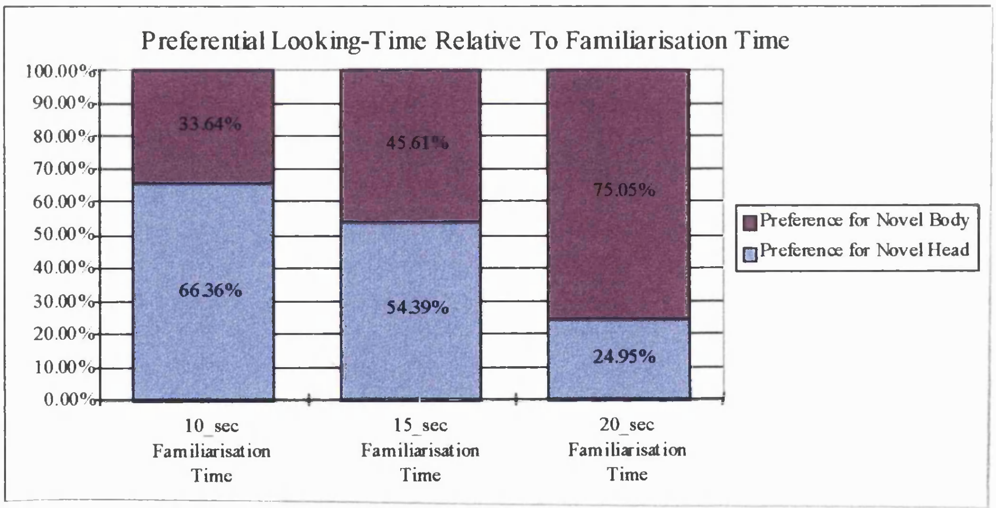


Figure 7. Preference for highly differentiated perceptual dimensions of the stimuli may be influenced by familiarisation trial duration. When processing time is limited due to short exposure time, infants focus on the most perceptually differentiated parts of the stimuli. When infants are exposed for a longer duration, a strong preference emerges for the less perceptually differentiated parts of the stimuli.

2.3.4 Discussion

Experiments 1, 2, and 3 examined the perceptual information that 4-month-old infants use in making categorical distinctions between animal species. Although the results of the Hybrid condition in Experiment 1 seemed to uphold the claim (Quinn & Eimas, 1996) that infants rely on face and head information to distinguish between the two animal species of cats and dogs, the results from the Hybrid condition in Experiment 2 appeared not to support this claim. Moreover, the findings from the Hybrid condition in Experiment 3 suggested that exposure time plays a crucial role and the preferences obtained may be a function of familiarisation trial duration. One possibility is that when processing time is limited, infants first perceive and process highly differentiated perceptual information (head / face for the stimuli used in these experiments) for distinguishing between different categories. However, with longer processing time, other, less differentiated properties become incorporated into the representation. In other words, various stimulus attributes are given differential weightings at different times in the on-line categorisation process (see Smith, 1989). If this is the case, then highly differentiated perceptual similarity relations may be a rich source of information in categorisation when processing time is limited. Of course, such conclusions are tenuous from the present findings since the comparisons made to support these claims rely on cross-experimental comparisons. In principle, there is a problem with exposure duration being analysed across experiments rather than within a single experiment, since it means that exposure duration is confounded with order of study. For example, it is not possible to totally exclude the notion that the effect was influenced by experimenters being more experienced at running studies in the final experiment than in the first, or that infants in the later study were born at different times of the year. Of course, ideally one could now set up an experiment and run a few infants in a single experiment varying the exposure duration to show you get identical results. Unfortunately this is not necessarily feasible for the following reasons. First, there are differences between infant and adult studies. Whereas a large number of adults can be tested in one week in order to run the whole of the experiments in one block design, for infants this is impossible. It is only possible to hold an infants' attention for a few minutes. A block design experiment takes time run. Infants get tired and hungry and will not concentrate for long periods of time. With limited facilities, which are shared by a number of people, only a small number of infants can be brought in for testing in any one week. Recruiting parents to bring in their infants takes time. Once parents agree to bring in their children they expect to be welcomed and provided with refreshments. Before the experiment begins the infants are given a short feed. Following the study the parents are debriefed about the experiment. All of this can take a considerable amount of time. In addition, some babies fail to complete the task due to fussiness before or during the testing. On occasion, infants become ill on the day of testing and consequently can not be tested. Therefore, necessarily babies have to be brought in at different times of the year. Nevertheless, the bulk of infancy research has shown that cross-experimental considerations are not crucial in explaining results (Spelke, 1995; Baillargeon, 1994). Thus, although it is highly unlikely that any of these factors were causing the preferential looking effect rather than familiarisation duration per se, (all experimenters were given rigorous training by Paul Quinn prior to any of the experiments, and the experimental conditions were kept very constant across all three studies), further empirical testing would be needed to entirely rule out all such provisos.

In order to further interpret the infant data from Experiments 1, 2, and 3, categorical decisions for the same stimuli were obtained from adults in Experiments 4 and 5. Obviously, infants and adults are very different subject populations. However, to create relatively comparable experimental conditions, I made the assumption that during familiarisation time infants form some kind of representation for a category. Although these representations differ from the stored representations of adults, when adults are asked to make a category judgement they have to access stored representations, and it is possible that the representations that are accessed are those that have been most recently processed. In this way, the ordering of processing by infants forming a category representation can be compared to the real-time order of processing by adults.

– oOo –

2.4 Experiment 4

The purpose of this experiment was to determine whether adult subjects would place priority on information from the head and face region when judging the category membership of the CAT, DOG and CAT-DOG HYBRID stimuli. The expectation, based on the results obtained with infants, was that head / face information would be more important than body information in determining category identity of cats versus dogs. Specifically, adults were asked to judge the category typicality (Experiment 4) and engage in a 2-alternative forced-choice identification task (Experiment 5) of the same stimuli as those presented to the infants. In asking adults for such judgements, I recognise that there are obvious differences in the way that adults will approach such tasks relative to the perceptual preference behaviour of infants in Experiments 1, 2, and 3. As mentioned above, adults are likely to be responding on the basis of previously-formed category representations. In contrast to young infants, adults also use language to support their categorisations. Nevertheless, I submit that in order to compare the initial state of category representations in infants with such representations in the steady state in adults, and to provide informed speculation on the process of development, it is essential to gather data from both infants and adults with respect to a common set of category exemplars.

Judgements were obtained on the various stimuli. In a standard typicality rating task, subjects are asked to rate how typical a stimulus is as a member of one particular category. For example, subjects may be asked to rate how typical a Labrador is of a dog. However, employing a paradigm of this nature would have defeated the purpose of the experiment with the set of stimuli used throughout this thesis. For example, if subjects had been presented with a hybrid stimulus that had the head of a cat and the body of a dog and asked to rate how typical it was of a cat, then subjects would have already been directed to the head of the stimulus as the more important for determining category membership of this particular stimulus.

Thus, in the present study a bipolar scale was used, with subjects being asked to rate whether a given stimulus was more typical of a cat or a dog (see Rosch & Mervis, 1975). In other words, rather than using a standard typicality task, here subjects were asked to rate their confidence in category membership. In the current study, subjects were asked to rate whether each stimulus item was more typical of a cat or a dog with a 1 representing a respondent's judgement that a given stimulus was very typical of a cat and a rating of 9 representing a judgement that a stimulus item was very typical of a dog. There is evidence to suggest that results from confidence rating tasks are very similar to those obtained in standard typicality tasks. Tversky and Hemenway (1984) have argued that when subjects are asked to list attributes for an object, they do so by contrasting it with other objects. For example, when asked to generate a list of attributes subjects will mention *trunk* for *tree* but not for *Oak tree* because, according to Tversky and Hemenway, tree contrasts with grass or bush, and *trunk* is a property of trees and not one of the contrasting categories. However, since the implicit contrast set for *Oak tree* includes other trees, listing *trunk* as an attribute is less informative as all trees have trunks, whereas listing *Acorns* is informative. Although subjects in the present experiments were not asked to generate lists of attributes, Rosch and Mervis (1975) found that there is a correlation between the attributes subjects list for objects and entities on the one hand, and the typicality ratings subjects assign to these objects depending on whether or not they have these attributes. Therefore, if attributes for objects are generated in terms of implicit contrast categories, and if there is a correspondence between attribute list generation and typicality ratings, it follows that using a bipolar or contrast scale in the present study should elicit similar responses to those which would have been obtained had a standard typicality task been used, but the latter was unsuitable for using the same stimuli for adults as for infants.

As a consequence of using the bipolar ratings tasks, it was predicted that the CATS and CAT HEAD / DOG BODY HYBRIDS would elicit low ratings and the DOGS and DOG HEAD / CAT BODY HYBRIDS high ratings. However, this expectation was tentative for two reasons. First, Quinn and Eimas (1996) provided evidence that adults could identify cats and dogs on the basis of the body alone, and second, a preference for the head and face of the stimuli in Experiments 1-to-3 was only found with infants when presentation time during the familiarisation stage was rapid. With prolonged exposure, infants displayed a preference for looking at the body of the stimuli. In the present experiment, although adult subjects were instructed to make a category decision as quickly as possible, there was no actual manipulation of exposure duration of the stimuli. Therefore, direct statistical comparisons with the infant data will not be possible with the results of this experiment alone.

2.4.1 Method

2.4.1.1 Subjects

Subjects were 20 undergraduate students: 10 male and 10 female, from University College London. All had English as the first language. Subjects were paid £2.00 for their participation.

2.4.1.2 Stimuli

The stimuli were 24 colour pictures of cats and dogs (12 cats, 12 dogs), plus 20 CAT and DOG transformations depicting the head of a cat on the body of a dog (10), and the head of a dog on the body of a cat (10). There were 44 stimuli used in total. They were identical to those used in Experiments 1, 2, and 3 with the exception that they were now presented on a computer screen rather than on cards.

2.4.2 Procedure

Subjects were seated in front of a computer screen that displayed instructions for a bipolar typicality response study. The viewing distance was approximately 45cm. For each stimulus item, subjects had to indicate whether it was more typical of a cat or a dog by pressing the numbers between 1 and 9 on a keypad. A '1' indicated that the stimulus item was very typical of a CAT, and a '9' indicated that it was very typical of a DOG. Subjects were instructed to use the other numbers on the keypad to indicate varying degrees of typicality. The order of stimulus presentation was random, with two different stimuli orders to control for order effects. A typicality response had to have been made in order to go on to the next stimulus item. Although there was no time limit on how long subjects took to make a response, they were instructed to make their decisions as quickly and as accurately as they could.

2.4.3 Results

The typicality ratings for individual stimuli within each of the four conditions were averaged across subjects. The mean typicality ratings for the four general categories of, CATS, DOGS, CAT HEAD / DOG BODY (CD's), and DOG HEAD / CAT BODY (DC's) are illustrated in Figure 8. Table 4. shows the mean typicality ratings for the four category types.

Table 4. Experiment 4: mean typicality ratings for the CAT, DOG, and CAT-DOG HYBRID stimuli. Standard deviations are shown in parenthesis.

WHOLE ANIMALS		HYBRIDS	
CATS	DOGS	CAT HEAD / DOG BODY	DOG HEAD / CAT BODY
1.73 (0.56)	8.47 (0.65)	4.33 (1.06)	6.01 (1.13)

A single factor repeated measures ANOVA revealed a reliable effect of stimulus category, $F_{(3,57)}$= 173.64 $P < 0.001$. Post-hoc tests (using Tukey's HSD) indicated that the mean typicality rating for the CAT stimuli was significantly lower than for the DOG stimuli, $P = 0.000159$, as would be expected given that lower ratings reflect subjects' judgements that a stimulus is more typical of a cat and higher ratings that a stimulus is more typical of a dog. Additionally, the mean typicality rating for the CAT HEAD / DOG BODY stimuli was reliably lower than that for the DOG HEAD / CAT BODY stimuli as measured using Tukey's HSD, $P < 0.001$. Furthermore, the mean typicality rating for the CAT HEAD / DOG BODY stimuli was reliably higher than that for the CAT stimuli, Tukey's HSD, $P < 0.001$, and the mean typicality rating for the DOG HEAD / CAT BODY stimuli was reliably lower than that for the DOG stimuli, Tukey's HSD, $P < 0.001$

2.4.4 Discussion

The findings from this experiment are important as they indicate that when subjects judged the typicality of an item as a member of its category, the highly differentiated head / facial information was relied on to a greater extent than the less differentiated body information. The results also suggest, however, that the less differentiated body information did have some influence on the typicality ratings as evinced by the typicality ratings of the HYBRID stimuli regressing toward the midline of the rating scale (i.e., the category boundary between cats and dogs). This pattern of findings corresponds well with the novel category preferences obtained with infants in Experiment 1. It is also consistent with infant and adult category identity judgements of similar cat and dog stimuli based on body-only information in the Quinn and Eimas (1996) study. In other words, both adults and infants may incorporate body information into their representations for cats and dogs, but the head / face are the initial attributes to be represented, and are either represented more robustly, or are simply a more valid cue for membership in the basic-level categories of cats versus dogs. In addition, the body information may be represented in more detail in the categorical representations of adults, given that adults, but not infants, can classify on the basis of body-only information (see

Quinn & Eimas, 1996). A possible rejoinder, however, is that typicality ratings are prone to inducing borderline cases (see McCloskey & Glucksberg, 1978). Thus, the results may have differed had subjects not been able to make such judgements. Moreover, the manipulation of familiarisation time in Experiments 1, 2, and 3 demonstrates that in infant categorical processing, exposure duration may play an important role in influencing which attributes are taken into account, whereas in the current study, presentation time was not directly manipulated. However, I hypothesise that the infant and adult processes of categorisation are in fact similar. When reaction times are measured with adults during a forced choice categorisation task, they should reflect which attributes are taken into account first in the categorisation process, even though there is clearly no direct relationship between exposure duration in infant studies and reaction time in adult studies (see chapter 6 for further discussion of these issues). In a 2-alternative-forced-choice task, subjects can only respond, for example, 'cat' or 'dog'. If reaction times for all types of stimuli are the same, it would be indicative that only information sufficient for making a category decision is considered. If, however, reaction times are longer for certain types of stimuli (such as hybrids), this would be indicative that more properties have to be considered in order to make (or more properties influence) a category response. To test this prediction, in Experiment 5 a 2-alternative forced-choice categorisation task was employed.

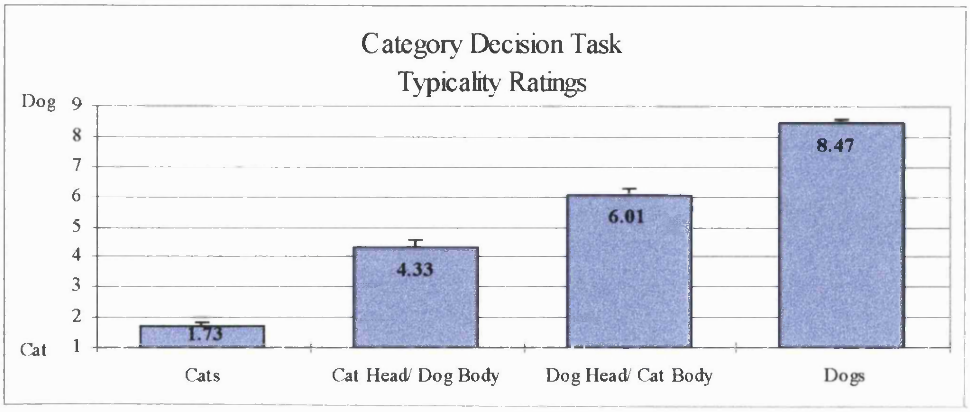


Figure 8. Experiment 4: Mean typicality ratings for the four categories.

2.5 Experiment 5

This is a speed-of-classification task. It predicts that subjects are faster at classifying the normal cat and dog stimuli than the hybrid stimuli. A further aim is to assess whether classification of the hybrid stimuli will also be based on the head / face information. In other words, the purpose of Experiment 5 was to determine whether adult subjects would also place priority on the highly differentiated head / facial information when judging the category membership of the CAT, DOG, and CAT-DOG HYBRID stimuli. A 2-alternative forced-choice categorisation task was used. Subjects were presented with photographic representations of CATS, DOGS, and CAT / DOG, DOG / CAT HYBRIDS and asked to indicate whether the stimulus was a cat or a dog. This experiment was carried out on a computer, allowing for reaction times to be recorded. Analysis of reaction times will give some indication of the properties which are assessed when adults make categorisation judgements. Broad comparisons with the infant data may then be possible. Although exposure time is not manipulated in this experiment subjects were instructed to make their category decisions as quickly as possible. Therefore, if head/facial information is perceived and processed early on in the categorisation process, the prediction is that subjects will have shorter reaction times when the stimuli are categorised on the basis of the head/face information than on the body information.

2.5.1 Method

2.5.1.1 Subjects

Subjects were 20 undergraduate students from University College London, the first language of all of whom was English: 10 males and 10 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

2.5.1.2 Stimuli

The same set of stimuli were employed as in Experiment 4: 12 CATS, 12 DOGS, 10 CAT HEAD / DOG BODY transformations and 10 DOG HEAD / CAT BODY transformations.

2.5.2 Procedure

Subjects were seated in front of a computer screen that displayed instructions for a 2-alternative forced-choice task, based on those employed by McCloskey & Glucksberg (1978). The viewing distance was approximately 45cm. For each stimulus item subjects had to decide whether it was a cat or a dog by pressing on a standard button box, either the left button for CAT or the right button for DOG. The left and right buttons on the button box were marked with the words CAT and DOG accordingly. Subjects had to make either a CAT or DOG response in order to go onto the next stimulus item. The order of stimulus presentation was random, with two different stimuli orders to control for order effects. The length of presentation of each stimulus item depended on the speed of the subject's response. However, all subjects were instructed to make a decision as quickly and as accurately as they could. All reaction times were recorded.

2.5.3 Results

The stimulus types were collapsed into four general categories, CATS, DOGS, CAT HEAD / DOG BODY (CD's), and DOG HEAD / CAT BODY (DC's). Figure 9 illustrates the percentage of CAT and DOG responses by category type.

A Cochran *Q* test indicates that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 422.1, P < 0.001$. A secondary analysis on the two hybrid conditions determined that there was a significant difference in the frequencies of CAT and DOG responses depending on whether the head of the stimulus item was from a cat or a dog: $\chi^2_{(1)} = 99.01$, $P < 0.001$.

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (CATS, DOGS, CAT HEAD / DOG BODY (DC's) and DOG HEAD / CAT BODY (DC's)) were entered into a repeated measures ANOVA. There was a main effect of category: $F_{(3,57)} = 7.89$, $P < 0.001$. On a subsequent post hoc analysis it was revealed that there were no differences in the mean reaction times between the categories CAT and DOG, nor between the two HYBRID categories CD's and DC's as shown in Figure 10. Given that there were no significant differences in reaction times between CATS and DOGS, and the two HYBRID categories, the four variables were collapsed into two new variables: CATS & DOGS, and HYBRIDS (see figure 11.).

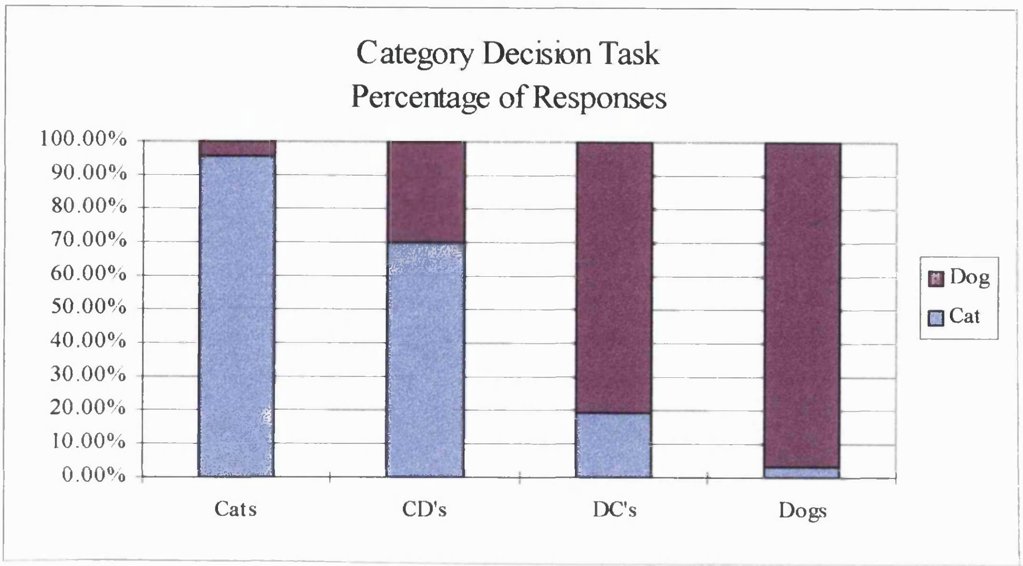


Figure 9. Experiment 5: Percentage of CAT and DOG responses given by subjects on the 2-alternative forced-choice categorisation task.

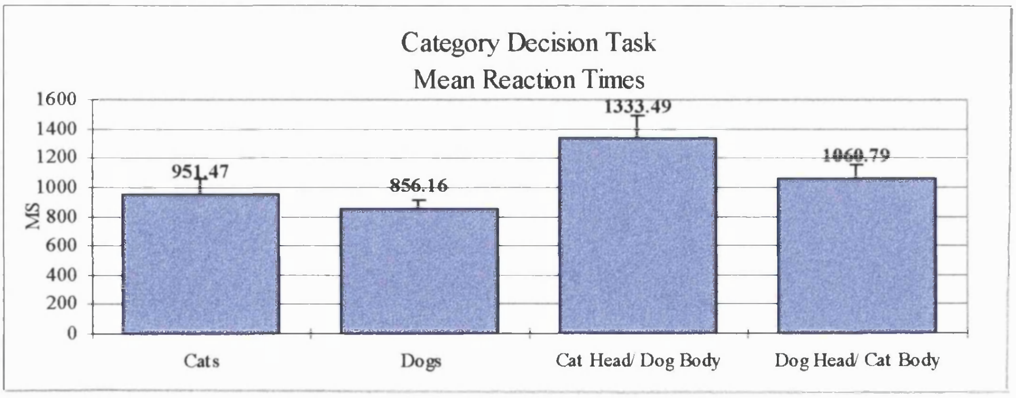


Figure 10. Experiment 5: Mean reaction times for the four category types. A Tukey's HSD revealed that there was no difference in the mean reaction times between the normal CAT and DOG stimuli, nor between the two HYBRID category types.

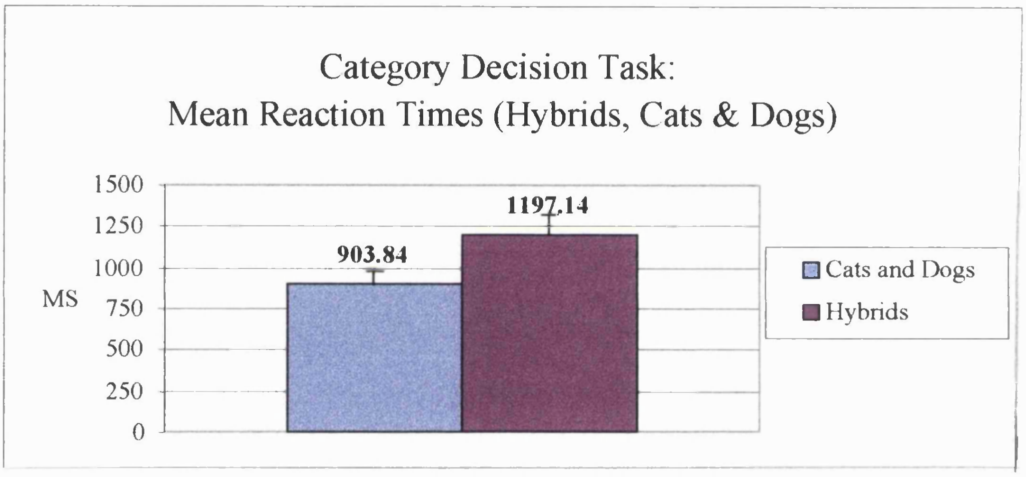


Figure 11. Mean reaction times in MS collapsed over the CAT and DOG stimuli and the HYBRID stimuli. Subjects were significantly faster in their reaction times for assigning category membership to the normal CAT and DOG stimuli than they were to the HYBRID stimuli.

The mean reaction times for the four category-variables, plus the mean reaction times for the two collapsed variables, are presented in Table 5.

Table 5. Experiment 5: Mean reaction times for the 2-alternative forced-choice task.

	CATS	DOGS	CAT HEAD / DOG BODY	DOG HEAD / CAT BODY	CATS & DOGS	HYBRIDS
Mean	951.47	856.16	1333.49	1060.79	903.84	1197.1
SE	104.08	53.48	156.58	98.31	71.7	123.31
SD	465.46	239.18	700.26	439.66	320.67	551.44

A subsequent repeated measures ANOVA established that there was a significant difference in the mean reaction times between the HYBRID stimuli and the normal CATS and DOGS: $F_{(3,57)} = 9.558, P = 0.006$.

2.5.4 Discussion

The discrepancy in reaction times between the two category types (normal CATS and DOGS, and HYBRIDS) suggests that although subjects were using the head and facial properties of the stimuli when making category decisions, body information was also being processed. If subjects had been attending solely to the head area of the hybrid stimuli, then there should have been no difference in reaction times between the two category types. It should be noted that inspection time was not manipulated in the present experiment. The stimulus remained on the screen until the subject made a response. However, subjects were asked to respond as quickly as possible. As such, the direction of causality can not be determined. Given there were significant differences, it is possible to speculate from the response times that although head / facial information is used to categorise early on in the process, increased reaction times for the hybrid stimuli may be due to subjects going on to inspect the rest of each stimulus item (i.e., the body) and not just the head. In other words, it can be contended that the entire stimulus is perceived and processed when making category decisions, but, category decisions are made on the basis of the most highly differentiated properties, the head and face for the present set of stimuli.

There are other interpretations of the reaction time data presented here. One such account comes from the work of Nosofsky and Palmeri (1997). Their Exemplar-Based Random Walk Model (EBRW) is a dynamic theory of categorisation which, they claim, can account for categorisation response times in a number of different tasks. The EBRW is *exemplar-based* because of its assumption that instances are placed in memory during category learning, and that subsequent category decisions rely on retrieving these stored exemplars. When an item is presented, all exemplars are activated. This activation is a function of the recency and presentation frequency of the exemplar, as well as its similarity to the stimulus. Similarity is defined (Palmeri 1997) as the weighted distance in psychological space between the values of the properties of the test item and those of the exemplar. The process of categorisation is characterised by a series of successive "races" between exemplars. The exemplar that wins a "race" is that which is retrieved first, because of its high activation (there is an exponentially distributed random variable to ensure that the race is not identical in outcome with the same parameters). The *random walk* component of the model refers to the way in which one exemplar is eventually categorised. When an exemplar (X) wins a race, a pointer moves towards its categorisation threshold. When another exemplar (Y) wins a race, the pointer moves away from X, and towards (Y). Only when the pointer has passed the categorisation threshold for a particular exemplar, is the stimulus categorised. The details of the categorisation thresholds and step sizes at the end of each race are considered in detail by Nosofsky & Palmeri (1997) and Palmeri (1997).

Thus, response times for categorisation depend on how many "races" are run before one exemplar has sufficient "wins" to breach its categorisation threshold. The length of each "race" is determined by how quickly an exemplar can be retrieved, which is a function of it distance from the stimulus in similarity space. The number of races which have to be run depends on how many different exemplars win races – the larger the number of different exemplars winning races, the longer it will take for one to reach its threshold. Reaction times will therefore be fast if the there are a small number of exemplars which are very similar to the stimulus, and slow if there are a large number of exemplars, all an (equally) large distance from the stimulus in similarity space. Because Nosofsky and Palmeri include recency and presentation frequency in the exemplar activation function, categorisation reaction times must also become faster with practice.

It should be pointed out, however, that the EBRW is only a model of the decision-making component of a perceptual categorisation task. It does not take account of the time course of the perceptual processes involved. It has therefore only been possible to test the model on stimuli with integral dimensions, those that can only be processed in a single step. For example, Palmeri (1997) reports data on classifying a set of twelve colours that varied in saturation and brightness.

If it were the case that the perceptual properties of the stimuli used in Experiment 5 reported above were processed in a single step, after which a decision making process in the style of the EBRW model occurred, it would be possible to interpret the data in terms of the predictions of that model. The fact that reaction times are higher for (images of) hybrids than for whole cats or whole dogs could be interpreted in terms of more competition between exemplars for hybrids than wholes. If more different exemplars "win" races, it will take longer for any one exemplar to reach threshold. However, this model is limited.

Lamberts (in press) has presented a model which overcomes such limitations. The Extended Generalized Context Model (EGCM-RT) allows for different perceptual processing time for different stimulus dimensions. The process of category decision starts as soon as there is any perceptual information on which to make a decision, and as perceptual elements are processed, the similarity of the stimulus representation to the exemplars in memory starts to contribute to the category decision process. When an element is processed, the system decides if enough information about the stimulus has now been gathered to stop sampling and initiate a response, or if more information is required. The decision to stop gathering information is based on the confidence in the category membership of the stimulus. In other words, if there is a high confidence measure for a stimulus belonging to a particular category, there is a correspondingly high probability that sampling will cease.

Lamberts presents data for the recognition of artificial objects with just a few, well-defined dimensions. The EGCM-RT model predicts reaction times in a variety of experiments with a high degree of accuracy, by assuming that differences in reaction time are a function of the duration of perceptual processing. Lamberts, however, cautions against a direct generalisation from these data with artificial objects to the identification of natural kinds. This is because there is no clear consensus as to the nature of the information elements sampled in the principle stages of natural object categorisation. Lamberts' EGCM-RT model is consistent with perceptual processing based on a set of invariant primitives (e.g., Biederman's geons (1987)). But in Lamberts view not only is this not generally accepted, it is also not clear how parts-based representations are translated into dimension-based representations.

From the data reported in Experiment 5 it is not clear whether the entire stimulus is perceived and processed, with category decisions being made on the basis of highly differentiated properties, as suggested above, or category decisions are being made as intrinsic function of the perceptual time series, following Lamberts. Certainly more needs to be known about the perceptual processing of many different natural kinds before these results can be generalised.

– oOo –

2.6 General Discussion

The series of experiments reported in this chapter examined the perceptual information that infants and adults use in making categorical distinctions between animal species and the role of timing in the categorisation process. Experiments 1 to 3 provided evidence that infants rely on face and head information when processing time is short, but that other, less differentiated properties are incorporated into the representation over time. These findings suggest that when processing time is limited highly differentiated perceptual similarity relations may be a rich source of information in the categorisation process.

Experiments 4 and 5 provided evidence that adults also rely more on head / facial information when assigning category membership. The reaction time data indicated, however, that the less differentiated body information (and therefore perhaps the more similar properties) was not ignored. Such findings lend support to the argument that the greater the similarity between items the more confusable they will be (Goldstone & Medin, 1994). For example, it is more difficult to differentiate between a Tonkinese cat and a Burmese cat than between a Burmese cat and a Labrador dog. Cats and dogs differ from each other on a number of attributes, whereas the differences between Tonkinese and Burmese cats are more subtle (i.e., small distinctions in the length of legs, width of tail, and spacing of ears). Furthermore, Lamberts (1994) suggests that the properties that are processed the fastest are those that are critical for identification and subsequent classification purposes. If body information is less perceptually differentiated, then when processing time is short the cognitive system attends to those properties that can provide the most information for the least processing costs (see Sperber & Wilson, 1995). In other words, various stimulus attributes are given differential weighting at different times in on-line categorisation processes (see also Smith, 1989).

These experiments are crucial for understanding concept acquisition. In particular, the results suggest that in rapid categorisation, the similarity space used by both infants and adults to represent cats and dogs is confined to the head and face information. There are two reasons for this supposition. The head and facial region may simply be the more distinguishing attribute of category membership.[10] Secondly, infants (and perhaps adults as well) may possess an innate mechanism that drives attention towards facial information i.e., the CONSPEC mechanism hypothesised by Johnson and Morton (1991) which draws attention automatically to face-like stimuli during the first couple of months of life. This is argued to be a largely sub-cortical perceptual process present at birth. Over time, between 2 and 4 months of age, a cortical process, CONLERN (Johnson & Morton, 1991) becomes operative and allows the infant to take account of the fine-grained details of faces in particular and of visual stimuli in general. Either way, when categorically discriminating between basic-level mammals that have an overall similar shape, the results of the experiments point to a "face first" model of categorisation. This may have an evolutionary advantage for rapid discrimination and explain why it is already so prevalent in early infancy. However, if infants can use head / face

---

[10] Within-category similarity and between-category dissimilarity may be greater for the cat and dog heads than it is for the cat and dog bodies.

information for rapid categorisation, why do they go on to take into account body information when both are available, as suggested by Experiment 3? In other words, why do young infants go beyond their successful categorisation strategies if head / facial information is sufficient to form distinctive representations of categories? What advantages are derived from incorporating less distinguishable properties into the representation over time? It may be that rapid processing of head / face information by infants allows for efficient between-category discrimination. The less differentiated, more fine-grained within-category discrimination of individual exemplars, however, may require processing of both head / face and body information (see Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997; Spencer, 1997). Both between-category and within-category discrimination are essential for children to develop fully-fledged categorisation skills.

– oOo –

Chapter 3

Introduction

In Chapter 2 it was argued that both infants and adults give greater weighting to highly-differentiated perceptual information when making rapid category judgements.[11] Usually, objects within a basic-level share properties that are thought to be "perceptually-salient": categorisation at the basic-level is argued to be faster than at either the superordinate or subordinate levels. The rationale being that the basic-level is the level that has the most psychological significance (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). If this is correct, then it is important to understand the organisation of entities within this level. A possible way forward is to determine the informational requirements for categorisation at the basic-level. Such a discovery may explain why basic-level entities invoke faster categorisation responses. However, saliency is a circular notion. It is often defined as that which subjects categorise or determine as being most salient (e.g., Thompson, 1994; Eiser, 1971). So, the implicit definition of saliency in these contexts may not be distinct from that of diagnosticity. For example, within social psychology, Eiser (1971) defines a salient property or attribute of a stimulus as that which "elicits a response most intensely or emphatically. In the context of a judgement task it is commonly assumed that individuals will discriminate more between different objects of judgement in terms of attributes that they consider salient than in terms of those they consider non-salient, and hence a given dimension can be said to be particularly salient for an individual if she gives particularly extreme or polarised judgements along it." Eiser, p444 (1971). Likewise, within the developmental literature, children are thought to classify

---

[11] Such findings are also predicted by theory-laden accounts of concepts (Medin & Ortony, 1989).

objects on the basis of perceptually-salient dimensions (e.g., Cook & Odom, 1992; Thompson, 1994; Wilkening & Lange, 1987). A dimension is considered perceptually-salient when an individual names a particular dimension first. Dimension salience is argued to "operate at the level of perception, and is automatic and unconscious" (Cook, & Odom, 1992, p. 216). Stimulus dimensions are, according to Cook and Odom (1992), arranged into a salience hierarchy via direct perception (Gibson, 1979). The basic premise of their theory is that dimensions to which individuals are very sensitive reside near the top of the hierarchy, whereas dimensions to which those individuals are less sensitive are nearer the bottom of the hierarchy. So, a dimension is salient if the perceptual system is more sensitive to it than to other dimensions. This would suggest that picking up on perceptual saliency is a bottom-up process. However, Cook and Odom (1992) only measure this sensitivity using a non-speeded classification trial. Thus, the time-delay between being presented with the stimulus and the decision-making procedure may reflect higher-level top-down perceptual processes being employed. As such, it is not clear that perceptual saliency is being measured at all. Therefore, those properties that Cook and Odom report as being salient may in fact simply be diagnostic of their stimuli without necessarily being perceptually salient. In other words, the notion of saliency, with respect to categorisation, is itself an ill-defined term. Therefore, given that the majority of studies conducted throughout this thesis are judgement tasks, involving top-down as well as bottom-up processing, I will use the term 'diagnostic' instead of 'salient' when and if categorisation is made on the basis of certain properties more frequently than others. It is important, however, for categorisation purposes, to distinguish between properties that are differentiable and properties that are diagnostic. Diagnostic properties are those which enable a diagnosis (or decision) about category membership to be made. The shape of a car's radiator grill may be highly diagnostic of the brand of manufacture (for example, Rolls Royce versus Ford). Differentiable properties are those which demonstrate a difference between objects, but which do not necessarily allow a category judgement to be made. The shape of two cars' headlamps may be visually very dissimilar and hence be highly differentiable, but this property is not *necessarily* diagnostic of the brand of manufacture.

Schyns (1998) contends that what is attended to and learned in a categorisation task is a function of what is necessary to visually discriminate the objects. At the basic-level it is the perceptually differentiated parts which play this role. This does not imply that less differentiated attributes are ignored, however. If they were, then only basic-level categories would ever be learned.[12] It is simply that rapid categorisation may rely more heavily on a perceptual process and therefore necessitate that greater weighting be given to highly-differentiated perceptual information. Learning about superordinate and subordinate categories is a slower developmental process and may require higher-level processing, for which other, less obvious information needs to be taken into account.[13]

Members of a basic-level category are often similar in terms of their shape. Having a common shape often entails having common part structures. Tanaka and Gauthier (in press) specify parts as those properties that are "*divisible, local components of an object that are segmented at points of discontinuity*, [and] *are*

---

[12] For example, observing that lions have sharp teeth and strong claws, properties that are not immediately obvious, can help in learning the superordinate category of animals that hunt.

[13] One suggestion of how this might occur comes from Mandler (1989). She argues that higher-level conceptual categories are formed via an analysis of the different trajectories that objects follow, in conjunction with the way they begin to move, and how they interact with other objects. These analyses depend upon perceptual categorisation. For example, animate things move in a biological fashion. However, Mandler's argument is that more is needed than categorising on a purely perceptual basis. For example, when learning about superordinate and subordinate categories. Mandler's idea is that via a process of *perceptual analysis*, perceptual information is redescribed into a conceptual format. In the process some of the perceptual information is lost, involving a reduction and redescription of the huge amount of information provided by the sensory receptors. The results of this kind of redescription is a description of animals as the kinds of things that are self propelled, move irregularly and interact with objects.

perceptually salient [italics added]" (p.5). For example, the properties "has mattress", "has legs" and "has headboard" are parts of the basic-level category bed. Tversky and Hemenway (1984) found that when asked to list attributes of entities, many parts were given for basic-level objects, but few were listed at either the superordinate or subordinate levels. From this they concluded that basic-level category members can be distinguished on the basis of parts. Members of superordinate categories, on the other hand, have few parts in common, whereas members of subordinate categories share a number of parts and are not easily distinguishable on that basis (ibid.). Consequently, Tversky and Hemenway suggested that "the natural breaks among basic-level categories are between clusters of parts, but the natural breaks between subordinate or superordinate level categories are not based on parts." (1984, p. 186).

One issue related to such findings concerns whether parts are the most diagnostic object cues for the perceptual system to attend to during rapid categorisation, and if so, which parts in particular. The experiments in this chapter aim to provide evidence that faces and heads are the most diagnostic perceptual attributes of the stimuli used throughout most of this thesis. I argue, however, that although faces are given greater weighting during rapid categorisation tasks, other, less diagnostic information is incorporated into the representation. It is possible that less diagnostic information is used for learning about hierarchies of categories.

Of course, there is a large body of research in the area of face perception (for review see e.g., Bruce, 1988), but it is important to delineate that which pertains to object categorisation. It is generally believed that there is a specific "face processing" system in the ventral stream of visual processing, the fusiform face area in humans, which may be analogous to a corresponding area in the superior temporal sulcus of macaques (Bruce, Desimone, & Gross, 1981; Caan, Perrett, & Rolls, 1984; Perrett, Smith, Potter, Mistlin, Head, & Jeeves, 1984). A body of experiments provides compelling evidence that observers perceive faces and facial expressions rapidly and accurately in a wide variety of viewing conditions.

Nevertheless, it is important, however, not to conclude a priori that face stimuli will be processed faster than other object properties simply because there is evidence for a greater cortical area devoted to processing faces, than, say, body configurations. There are a number of reasons why faces may require more processing: facial configurations may be difficult to process because of their complexity; or it may be that the sheer number of socially important facial expressions requires greater resources. A greater cortical area devoted to processing faces also does not imply that a face property will necessarily have a greater weighting in an object categorisation decision. Similarly, an ability to make fine discriminations between faces and between facial expressions does not imply anything about the weight of such a property in a specific categorisation task.

It is not the purpose of the experiments in this chapter to determine the speed at which face or any other object property information is perceived. Rather, the aim is to determine what object property subjects use in different types of categorisation tasks, where object property is defined in the widest sense. I hypothesise that head and facial information is important in the categorisation of the cat and dog stimuli used in the experiments reported in this thesis, but that other information is also incorporated into an object representation over time. The rapidity of category decisions and the nature of typicality judgements with different types of cat and dog stimuli will be used to test this.

–oOo–

3.1 Experiment 6

The early ontogeny of face processing skills provides evidence that faces are special. Work on filial imprinting[14] indicates that baby chicks show a preference for attending to stimuli that resemble conspecifics (Johnson, 1992). Furthermore, the distinguishing factor for recognising conspecifics in chicks is that the head region of the target object be intact. Johnson and Morton (1991) suggest that an analogous process may be at work for face recognition with newborn infants. Infants within the first hour of life preferentially attend to face-like stimuli over other stimuli. The particular details of the parts of the face-like stimuli appear not to be important other than they are arranged so as to correspond with eyes and mouth. Between 4 and 6 weeks following birth, however, the preferential tracking of faces decreases rapidly, only becoming reinstated during the 3rd month of life. This suggests that face processing in the newborn is served by different neural circuitry than for the later preference, indicating maturation in the cortical circuitry by 3-months of age. Johnson (1992) proposes that the tendency to attend to faces found in the newborn "may be sufficient to ensure that developing cortical circuitry is exposed more towards this vitally important class of stimuli than towards other objects of less importance" (p, 55). Although the experiments in this chapter were conducted with adult subjects and not with infants, the findings from Experiments 1, 2, and 3 with 4-month olds in Chapter 2 have established that faces are the highly-diagnostic parts of the stimuli used in the studies connected with this thesis when presentation time is limited. Thus, the purpose of Experiment 6 is to establish that information from the head / face area is also a highly-diagnostic perceptual cue in adults and thus should induce faster reaction times during categorisation tasks. If less diagnostic information is also processed, then subjects should also be able to assign category membership to the less perceptually diagnostic parts of animals, as

---

[14] Filial imprinting refers to the process by which young precocial birds learn to recognise the first perceptible object they notice after hatching.

predicted by the Quinn and Eimas (1996) findings that adult subjects could categorically identify bodies presented alone as belonging to either cats or dogs.[15] However, this should be a slower process than assigning category membership to the perceptually-diagnostic parts. To test this prediction a 2-alternative forced-choice categorisation task was employed. Subjects were presented with photographic representations of heads of cats and dogs (the perceptually-diagnostic attributes), and bodies of cats and dogs (the less perceptually-diagnostic attributes) and asked to indicate whether each stimulus was a CAT or a DOG.

3.1.1 Method

3.1.1.1 Subjects

Subjects were 15 undergraduate students from University College London: 6 male and 9 female. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any previous experiments.

3.1.1.2 Design and Stimuli

The stimuli were 40 colour pictures of CAT HEADS and DOG HEADS, CAT BODIES and DOG BODIES (10 CATS HEADS, 10 DOG HEADS, 10 CAT BODIES, 10 DOG BODIES). All of the stimuli were taken from colour photographs of cats and dogs, and scanned and digitised using high quality computer software as in the previous experiments. Figure 12 provides an example of each of the stimulus categories. The order of stimulus presentation was random, with two different stimuli orders to control for order effects.

---

[15] Such information may be one way of establishing hierarchical category representations that include both subordinate and superordinate categories.

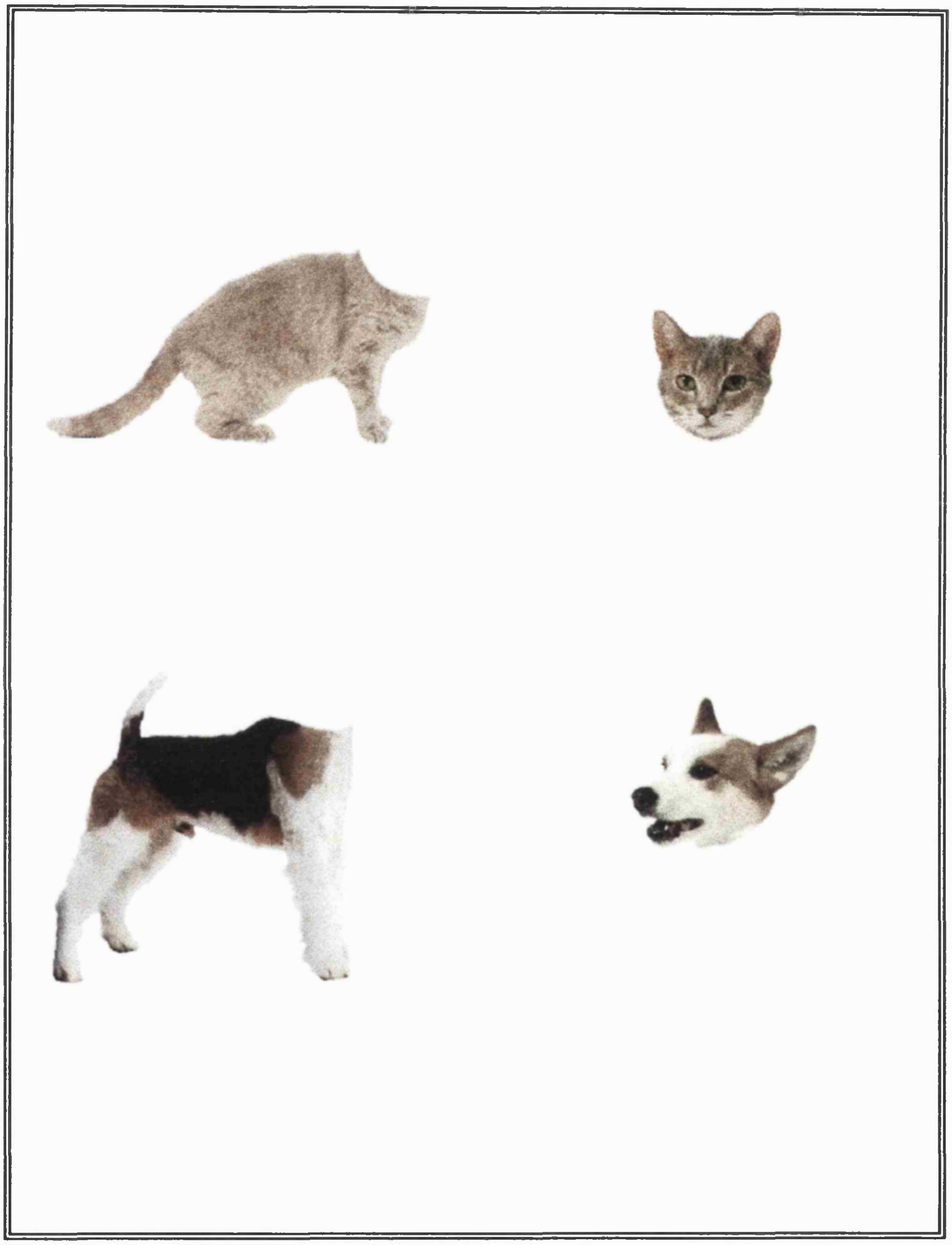


Figure 12. Examples of the head and body stimuli.

3.1.2 Procedure

A 2-alternative forced-choice task was used. The procedure was identical to that in Experiment 5. For each stimulus item subjects had to decide whether the head or body displayed on the screen belonged to either a CAT or a DOG and press a button marked "CAT" or a button marked "DOG" accordingly. The experiment was carried out on a computer allowing for reaction times to be recorded.

3.1.3 Results

The various stimulus types were collapsed into four general categories, CAT HEADS, DOG HEADS, CAT BODIES, DOG BODIES. The frequencies of CAT and DOG responses are given in Table 6. Figure 13 illustrates the percentage of CAT and DOG responses by category type. A Cochran *Q* test indicates that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 332.80$, $p < 0.001$. A subsequent analysis of the individual variables determined that there was a significant difference in the CAT and DOG responses for each of the four different conditions. The individual chi-square values are given in Table 7. Thus, subjects accurately assigned the correct category membership to both the heads and bodies of the various CATS and DOGS. This finding corresponds well with those of the Quinn and Eimas study (1996).

Table 6. **Experiment 6: frequencies of responses by category type.**

	CAT	DOG
CAT HEAD	146	4
CAT BODY	122	28
DOG HEAD	12	138
DOG BODY	4	146

Table 7. **Experiment 7: Individual Chi-Square values and associated significance levels for the four category variables.**

	CAT_HEAD	CAT_BODY	DOG_HEAD	DOG_BODY
Chi-Square	134.4	58.9	134.4	105.8
df	1	1	1	1
Sig.	<0.001	<0.001	<0.001	<0.001

3.1.3.1 Data Analysis of Reaction Times

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (CAT HEAD, CAT BODY, DOG HEAD, DOG BODY) were entered into a repeated measures ANOVA. There was a main effect of category: $F_{(3,42)} = 9.34$, $P < 0.001$. On a subsequent post hoc analysis it was revealed that there were no differences in the mean reaction times between the categories CAT HEAD and DOG HEAD, nor between the two categories CAT BODY and DOG BODY. Therefore the data for the CAT BODIES and DOG BODIES were combined and the data for the CAT HEADS and DOG HEADS were combined. This manipulation showed that there was a significant effect of whether the stimuli were heads or bodies, with heads inducing significantly shorter reaction times than bodies $F_{(1,15)} = 18.62$ $P = 0.000712$ (see Figure 14).

3.1.4 Discussion

It is clear that when subjects are presented with the heads of the cat or dog stimuli alone, they are significantly faster at assigning category membership than they are when presented with the bodies of the cat or dog stimuli alone. This would suggest that the heads of the two animal species are more diagnostic of category membership than the bodies. It may be that the heads contain highly differentiated information in the eyes, nose, and mouth, which in this case is diagnostic of category membership, whereas the perceptual information contained in the bodies of these two species is not so highly differentiated and, as such, take longer to identify. Thus, although the bodies alone contain sufficient information for discriminating between the two categories with a high degree of accuracy, this information takes longer to process.

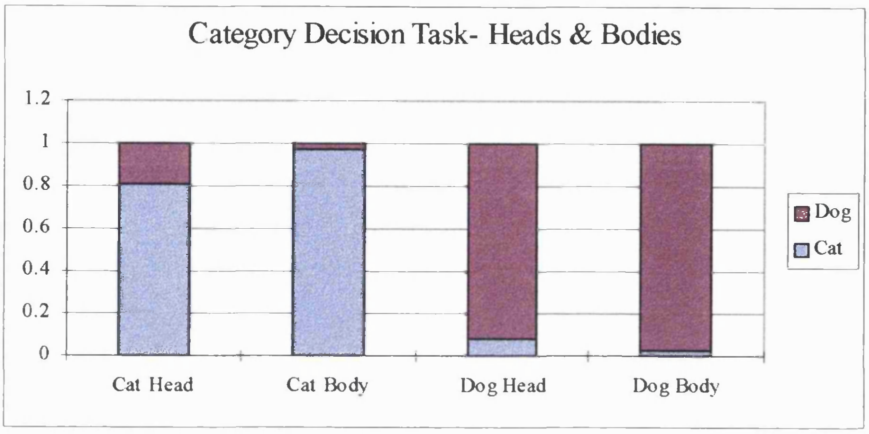


Figure 13. Experiment 6: Percentage of CAT and DOG responses by stimulus type.

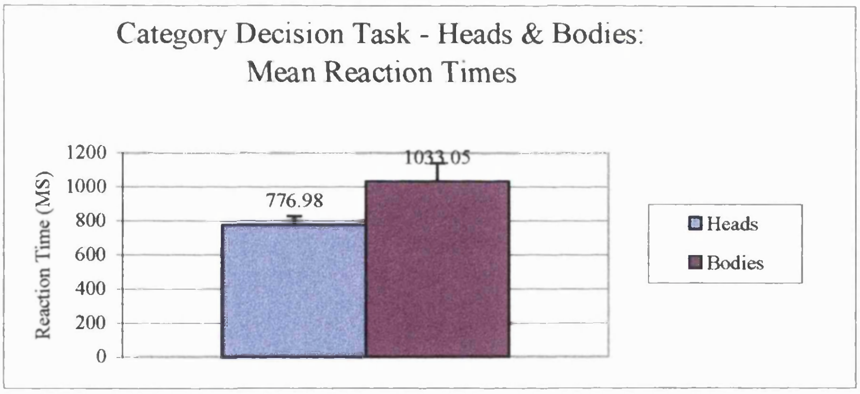


Figure 14. Experiment 6: Mean reaction times in MS collapsed over the CAT HEADS and DOG HEADS and the CAT BODIES and DOG BODIES. Subjects were significantly faster at assigning category membership to the head stimuli than to the body stimuli.

3.2 Experiment 7

It would be easy to conclude from the results of the previous experiments that discrimination is made primarily on the basis of head/face information supported by a large body of evidence for specific cortical face processing regions. It is essential, however, to consider the confounding factor that in the previous experiments the head/face element of the stimuli were always in the same relative position. That is, were subjects to scan the stimulus from top to bottom, facial elements would be perceived and processed first. Studies with non-human subjects, however, have shown that relative position of the face in not necessarily an obstacle in recognising an object. In studies with chicks it has been known that they show a general predisposition to respond to specific classes of stimuli in certain ways. For example, Bolhuis, Johnson, and Horn (1985) found that after 24 hours, dark-reared chicks having only been exposed to two hours of dim overhead light whilst placed in running wheels, displayed a significant preference for a stuffed jungle fowl over a red box. Wanting to discover why the stuffed jungle fowl was preferred, Johnson and Horn (1988) hypothesised that the fowl was visually more complex with respect to its texture and overall shape. In a series of experiments they tested this hypothesis. They found that when the whole jungle fowl was compared with a partially disarticulated jungle fowl displayed in an anatomically unusual way, or to a jungle fowl which had several of its parts separated from the trunk, the dark-reared chicks did not display a preference for the intact jungle fowl. From these experiments Johnson and Horn (1988) concluded that neither the overall outline, nor the texture of the jungle fowl was a dominant factor in the chicks preference behaviour. Rather, they argued that the chicks could be responding to particular configurations of features. They tested this by cutting up the trunk and pelt of a stuffed jungle fowl, jumbling it up with other parts of the fowl and sticking it to the sides of a rotating box. The chicks now showed a strong preference for the intact jungle fowl. They therefore concluded that this test stimulus did not contain the essential characteristics that is attractive to the chicks. Given that the stimulus did, however, contain the same textural complexity as the intact jungle fowl, Johnson and Horn suggested that it is the correct configuration of features which are critical for attracting the chicks. Although the eyes, beak and neck of the cut-up fowl were also stuck onto the box, they were separated from each other. Thus, it may be the presence of clusters of features which is the essential factor for the chicks' preferences. However, to be sure of this hypothesis, Johnson and Horn tested whether it was the greater complexity of the intact jungle fowl over the box outline rather than the absence of correct configurations of features in the latter stimulus which attracted the chicks. For this experiment they cut up another stuffed jungle fowl into parts and stuck it to the side of a rotating box. This stimulus now contained the clusters of features which were absent in the previous test stimulus. When compared with the intact jungle fowl the chicks did not show a preference for either stimulus item. As a result of this series of experiments, Johnson and Horn concluded that it is the cluster of features which are the most important property, especially when the cluster of features are from the head region. i.e., the eyes and beak, and are in their correct configuration. Furthermore, this preference for head and facial configurations does not seem to be species specific; Johnson and Horn demonstrated in other experiments when an intact jungle fowl was not preferred over a variety of similar sized intact mammals. Therefore, the configuration of features associated with the head may be more meaningful than the details of the features themselves, or where they are placed in relation to the parts of the body.

Therefore, in Experiment 7 the relationship between category judgement and stimulus configuration was tested. In the present experiment the same stimuli as used in the previous Whole Animal and Hybrid experiments were separated into parts and spread randomly over the test area. If the faces of cats and dogs are particularly diagnostic, then the results should show that subjects' typicality ratings are based more on the face / head of the animal regardless of where it is positioned. If this is the case, then category decisions will initially be made on the basis of the face / head information. Typicality judgements were obtained for the various stimuli.

3.2.1 Method

3.2.1.1 Subjects

Subjects were 15 undergraduate students from University College London, 7 males and 8 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any previous experiments.

3.2.1.2 Stimuli

The stimuli were 14 colour pictures of cats and dogs (7 CATS, 7 DOGS), plus 14 CAT and DOG HYBRID transformations, 7 with the head of a DOG and the body parts of a CAT, and 7 with the head of a CAT and the body parts of a DOG. There were 28 stimuli used in total. All of the stimuli were taken from colour photographs of cats and dogs, and scanned and digitised using high quality computer software, as in previous experiments. The stimuli were then separated into their constituent parts using Adobe Photoshop™. For example, a dog was split up into legs, tail, body, and head. The HYBRID transformations were constructed from the same HYBRID stimuli as used in the previous experiments and split up in the same way as the normal CATS and DOGS. All of the stimuli were on a white background and were randomly assigned positions on the computer screen. Out of the 28 stimuli, only 2 showed the head of the animal at the top section on the background. Figure 15 shows a normal split CAT stimulus and a normal split DOG stimulus, and Figure 16 two HYBRID stimuli, one with the head of a CAT and the body of a DOG split into various parts, and the other with the head of a DOG and the body of a CAT split into parts.

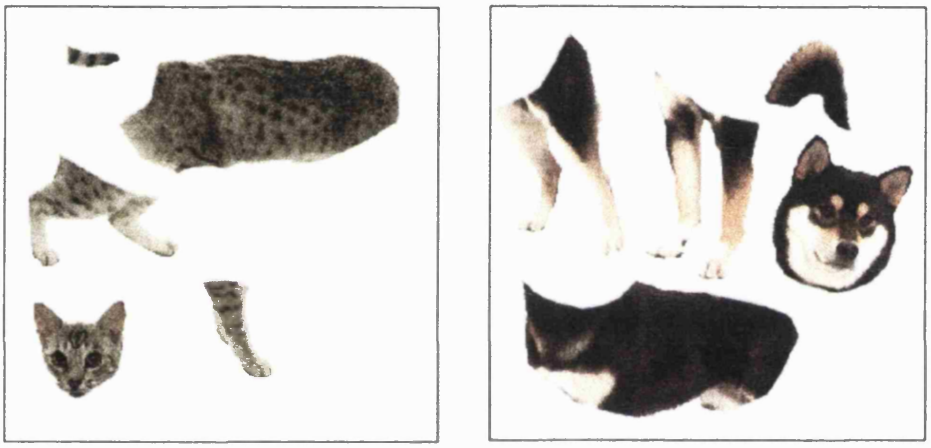


Figure 15. Examples of a normal CAT and DOG split up into parts.

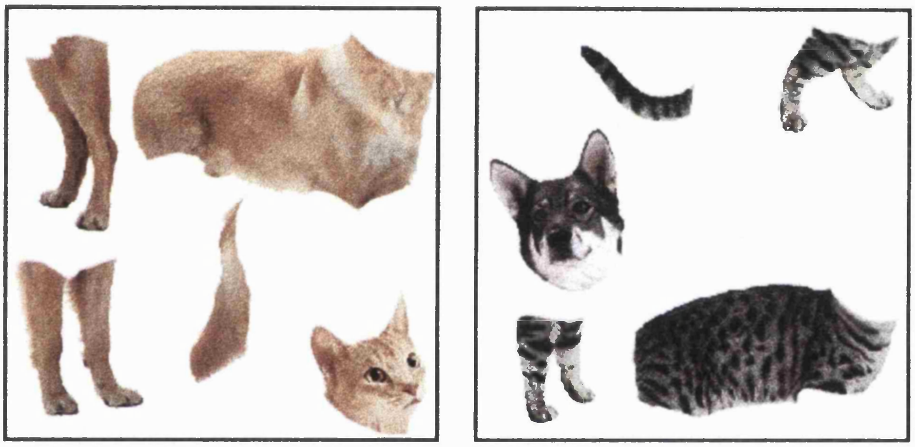


Figure 16. Examples of HYBRID CAT HEAD / DOG BODY PARTS **and** DOG HEAD / CAT BODY PARTS.

3.2.2 Procedure

Subjects were seated in front of a computer screen which displayed instructions for a standard bipolar typicality response study (e.g., Rosch & Mervis, 1975). The viewing distance was approximately 45cm. For each stimulus item subjects had to indicate whether it was more typical of a cat or a dog by pressing the numbers between 1 and 9 on a keypad. A '1' indicated that the stimulus item was very typical of a cat, and a '9' indicated that it was very typical of a dog. Subjects were instructed to use the other numbers on the keypad to indicate varying degrees of typicality. The order of stimulus presentation was random, with two different stimuli orders to control for order effects. A typicality response had to be made in order to go on to the next stimulus item. Although there was no time limit of how long a subject took to make a response, they were instructed to make their decisions as quickly and as accurately as they could.

3.2.3 Results

The typicality ratings for individual stimuli within each of the four conditions were averaged together across subjects. The mean typicality ratings for the four general categories of, CATS, DOGS, CAT HEAD / DOG BODY (CD's), and DOG HEAD / CAT BODY (DC's) are illustrated in Figure 17. A single factor repeated measures ANOVA revealed a reliable effect of stimulus category, $F_{(3,42)} = 138.14$, $P < 0.0001$. Post-hoc tests (using Tukey's HSD) indicated that the mean typicality rating for the CAT stimuli was significantly lower than for the DOG stimuli, $P < 0.0002$, as would be expected given that lower ratings reflect subjects' judgements that a stimulus is more typical of a cat and higher ratings that a stimulus is more typical of a dog. Additionally, the mean typicality rating for the CAT HEAD / DOG BODY stimuli was reliably lower than that for the DOG HEAD / CAT BODY stimuli as measured using Tukey's HSD, $P < 0.0002$. It is clear, then, that the less diagnostic body information did influence the typicality ratings because the mean rating for the CAT HEAD / DOG BODY stimuli was also reliably higher than that for the CAT stimuli as measured using Tukey's HSD, $P < 0.0002$; and the mean typicality rating for the DOG HEAD / CAT BODY stimuli was reliably lower than for the DOG stimuli, $P < 0.0002$.

2.2.4 Discussion

It could have been predicted from the findings of Experiment 6 that body information would also be used in making category decisions, given that subjects were able to identify the cat and dog stimuli on the basis of the body information alone, albeit more slowly. Nevertheless, regardless of the conflicting body information, or the positioning of the head on the screen in relation to the other body parts in the current experiment, subjects did give significantly greater weighting to the head information of the hybrid stimuli than to the other body parts. One possibility for these findings may be due to the fact that the heads of the stimuli were the only body parts which preserved an appropriate configuration of sub-features, i.e., the eyes, nose, mouth, and ears. A comparison can be made here with the findings of Johnson and Horn (1988) in that it might be the presence of these clusters of features presented in their correct configuration which make them the more diagnostic properties, and as such subjects give a greater weighting to this information when making category decisions.

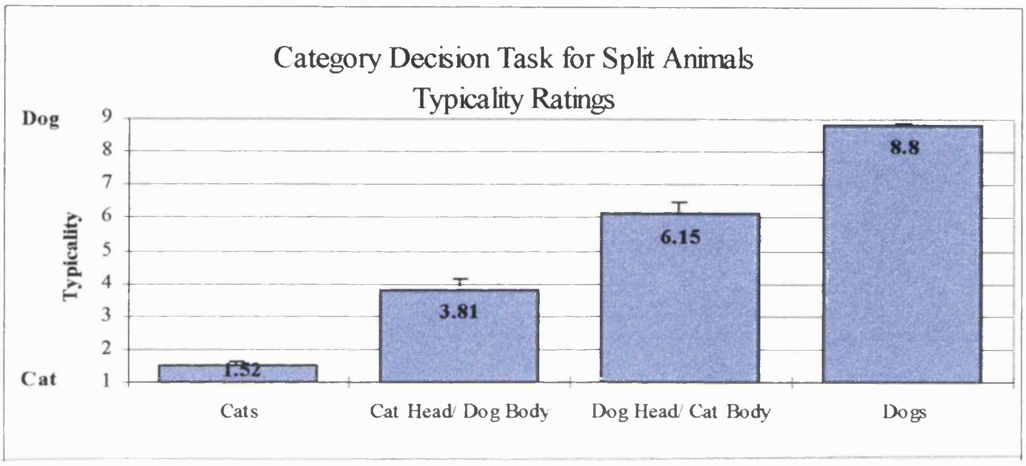


Figure 17. Experiment 7: Mean typicality ratings for the four categories of split animals.

3.3 Experiment 8

In Experiment 7, subjects were asked to indicate how typical the various stimuli were of cats and dogs. Typicality judgements measure the similarity between a number of target objects. How similar one object is to another can vary depending on the knowledge, purposes, and goals of the task. Both knowledge and purposes, however, impose constraints on which properties of an object will be used for making similarity comparisons. Therefore, typicality judgements may involve more analytic categorisation as well as perceptual similarity, and as such higher-level reasoning may also be influencing the category judgements. In other words, in the typicality experiment it is possible that the subjects were using all of the available information, including the less perceptually-diagnostic information. In order to elicit faster responses, a 2-alternative forced-choice method was employed in the present experiment. A 2-alternative forced-choice task can be considered to permit faster responses simply because subjects now have a reduced range of response choices available to them. The typicality rating scale used previously gave subjects a choice of 9 possible responses, whereas a 2-alternative forced-choice task only gives subjects a choice of two. With a 2- alternative forced-choice task subjects are required to make a response as quickly as possible as to whether an object is a cat or dog. In contrast to the typicality judgement task where subjects were judging how cat-like or how dog-like an object was, the 2- alternative forced-choice task does not require that a subject use any more than the most diagnostic properties of the stimuli, rather than having to assess all the appropriate properties which contribute to a stimulus' "catness" or "dogness". Subjects were presented with photographic representations of CATS, DOGS, and CAT/DOG, DOG/CAT HYBRIDS split into their constituent parts.

3.3.1 Method

3.3.1.1 Subjects

Subjects were 15 undergraduate students from University College London, 8 males and 7 females. All subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

3.3.1.2 Design and Stimuli

The same stimuli were used as in Experiment 7: 7 CATS, 7 DOGS, 7 CAT HEAD / DOG BODY PARTS and 7 DOG HEAD / CAT BODY PARTS transformations.

3.3.2 Procedure

The general procedure was a 2-alternative forced-choice task and was the same as that employed in Experiment 6, the only differences being in respect to the stimuli.

3.3.3 Results

The various stimulus types were collapsed into four general categories of CATS, DOGS, CAT HEAD / DOG BODY (CD's), and DOG HEAD / CAT BODY (DC's). Figure 18 illustrates the percentage of CAT and DOG responses by category type.

A Cochran *Q* test indicated that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 270.76$ $P < 0.0001$. A secondary analysis on the two hybrid conditions determined that there was a significant difference in the frequencies of CAT and DOG responses depending on whether the head of the stimulus item was from a CAT or a DOG: $\chi^2 = 12.67$, $P < 0.0004$. In other words, regardless of whether the body parts of the stimuli were from cats or dogs, subjects assigned category membership on the basis of which category the face / head came from.

3.3.3.1 Data Analysis of Reaction Times

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (CATS, DOGS, CD's and DC's) were entered into a repeated measures ANOVA. There was no main effect of category (see Figure 19).

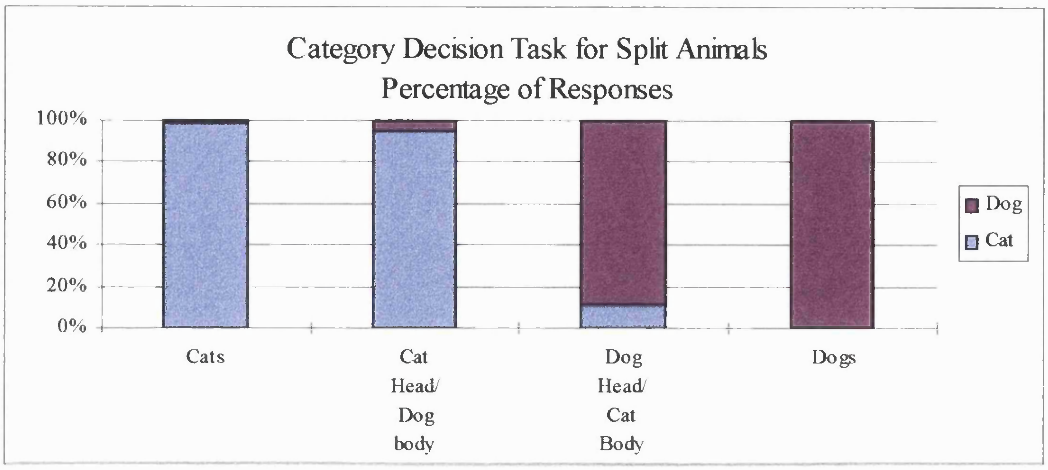


Figure 18. Experiment 8: Percentage of CAT and DOG responses given by subjects on the 2-alternative forced-choice categorisation task for the animals split up into their constituent parts.

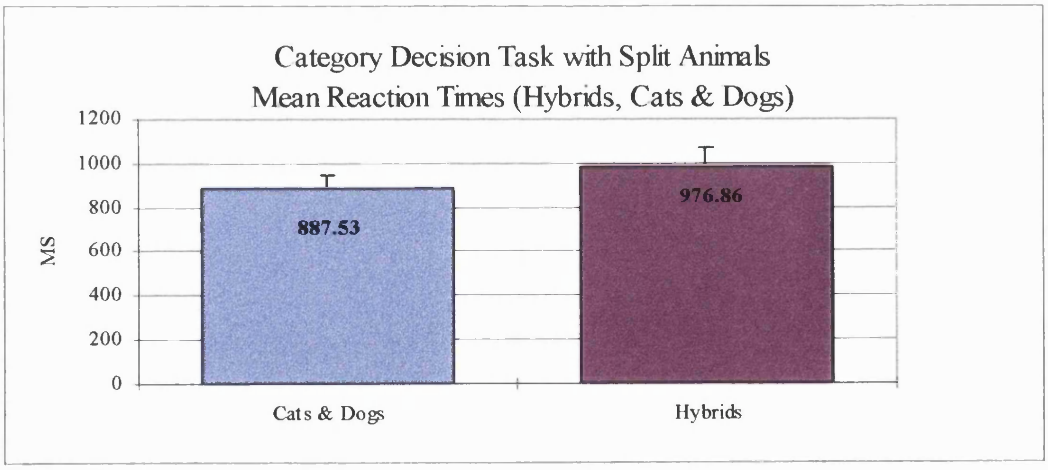


Figure 19. Experiment 8: Mean reaction times in MS collapsed over the CAT and DOG stimuli and the HYBRID stimuli. There was no significant difference in reaction times between the normal CATS and DOGS and the HYBRID stimuli.

3.3.4 Discussion

Employing a 2-alternative forced-choice task it was found that subjects were no slower at assigning category membership to the hybrid stimuli on the basis of the head and facial information than to the normal cat and dog stimuli. Although it is not possible to interpret a statistical null effect, it is conceivable that the lack of effect may have been due to subjects giving the head and facial information more weighting in the categorisation decision process. In addition, the lack of effect of category in response times may also have been to do with the nature of both the stimuli and the task. The characteristics of a forced-choice categorisation task require that subjects make a category decision between two possible alternatives. If processing category information at the basic-level is usually a perceptual process, then making a forced-choice decision under time pressure may involve a threshold response based purely on physical attributes. Given the findings of Johnson and Horn (1988), it could be hypothesised that a stimulus with a cluster of features in their correct configuration will capture the attention of the subjects. Therefore, if a stimulus has a cluster of features associated with a CAT in their correct configuration, then it will be categorised as a CAT, and if a stimulus has a cluster of features associated with a DOG in their correct configuration, then it will be categorised as a DOG. In the present stimuli the only coherent clusters of features in their correct configurations were the heads of the stimuli. Furthermore, since the subjects were aware of the time constraints, and if the heads of the stimuli were processed first, then this might be one explanation for the lack of timing differences between the hybrid stimuli and the normal cat and dog stimuli. What is clear, however, is that this experiment provides no evidence that stimuli are scanned from top-to-bottom with greater weighting given to head/face properties simply because they are scanned first.

3.4 Experiment 9

In the previous experiments I have shown that subjects tend to give a higher weighting to head/face information when asked to make category judgements of cats and dogs, and that this does not depend on a scanning from top-to-bottom process. However, these results were not conclusive as to whether it is the internal facial configuration or the outline of the head shape that is highly-diagnostic. It has been suggested that the principal stage of visual processing is edge extraction / detection (Marr, 1982). Edges are the most diagnostic properties in the visual field. Cells in the retina and the primary visual cortex respond best to edges in the visual field, that is, abrupt changes in luminance, which usually correspond to boundaries between objects (ibid.). Line drawing sketches of objects are recognised just as rapidly as photographic representations of them (see Marr, 1982). It is therefore important to determine the diagnosticity of the outline of the cats and dogs compared to the head information that subjects drew upon in the previous experiments.

3.4.1 Method

3.4.1.1 Subjects

Subjects were 15 undergraduate students from University College London, 7 males and 8 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

3.4.1.2 Design and Stimuli

The stimuli were 16 pictures of cat and dog outlines (8 CATS, 8 DOGS), plus 16 CAT and DOG OUTLINE transformations depicting the head of a cat on the body of a dog (8), and the head of a dog on the body of a cat (8). There were 32 stimuli used in total. All of the stimuli were taken from colour photographs of cats and dogs, and scanned and digitised using high quality computer software. They were then reduced to outlines using Adobe Photoshop™. The 16 CAT / DOG HYBRID transformation outlines were also manipulated using Adobe Photoshop™. All of the stimuli were on a white background. The average height and length of the finished CAT OUTLINES, DOG OUTLINES, and the CAT-DOG HYBRID outlines were 17.7cm by 17.7cm. Figure 20 shows examples of a normal CAT and DOG OUTLINE and a CAT HEAD / DOG BODY OUTLINE and a DOG BODY / CAT BODY OUTLINE respectively.

3.4.2 Procedure

This was a 2-alternative forced-choice task. The procedure was exactly the same as in Experiments 5 and 6.

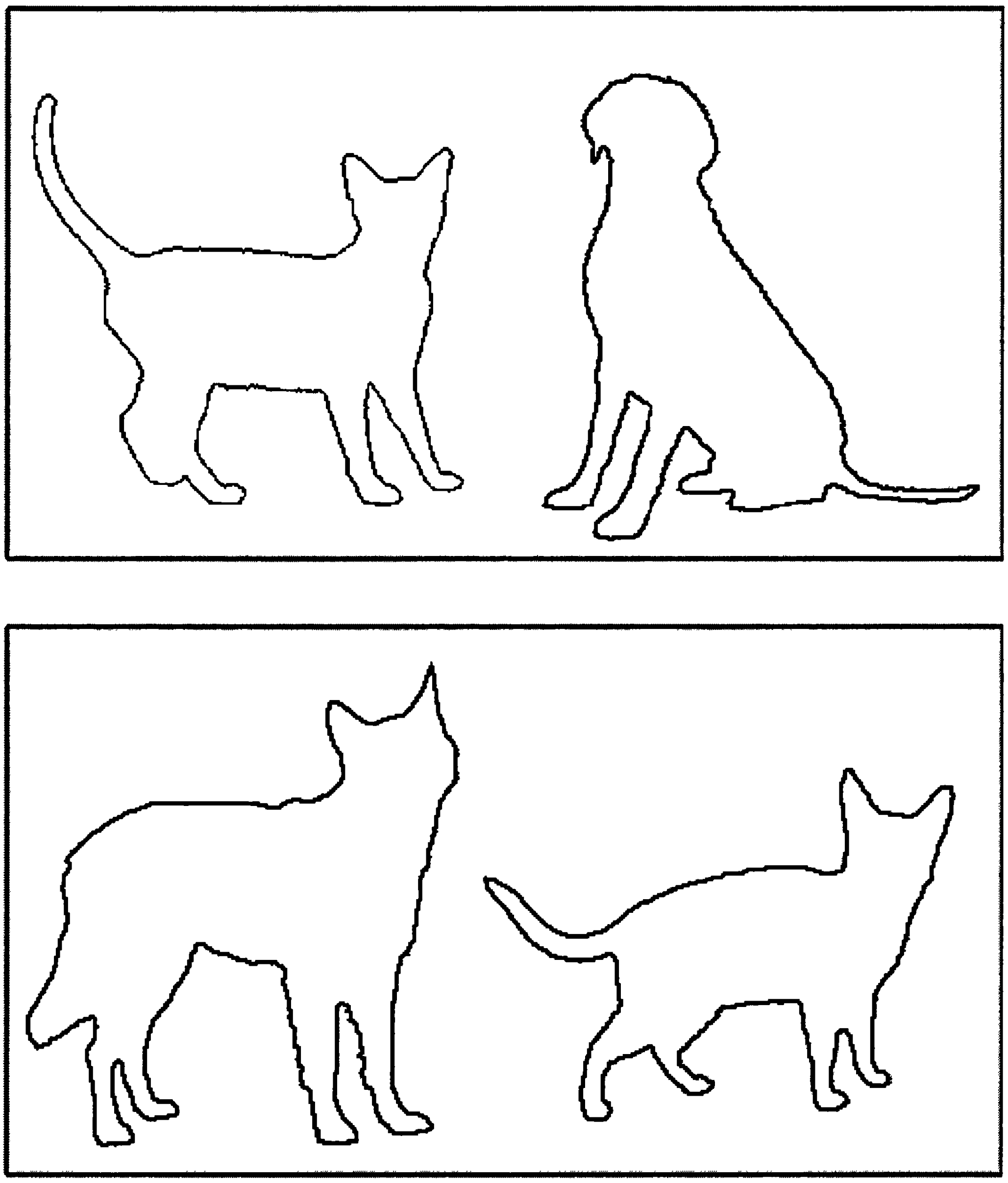


Figure 20. The top box shows an example of normal outline CAT and DOG stimuli. The lower box shows examples of HYBRID outlines of a cat head/ dog body stimulus and a dog head / cat body stimulus.

3.4.3 Results

The various stimulus types were collapsed into four general categories, CAT OUTLINES, DOG OUTLINES, CAT HEAD / DOG BODY OUTLINES (CD's), and DOG HEAD / CAT BODY OUTLINES (DC's). Figure 21 illustrates the percentage of CAT and DOG responses by category type. Frequencies are shown in Table 8.

Table 8 **Experiment 9: frequencies of responses by category type.**

	CAT	DOG
CAT OUTLINE	112	8
CD OUTLINE	68	52
DOG OUTLINE	45	75
DC OUTLINE	1	119

A Cochran *Q* test showed that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 220.7$, $P < 0.001$. A further analysis on the two hybrid conditions determined that there was a significant difference in the frequencies of CAT and DOG responses depending on whether the head of the stimulus item was from a CAT or a DOG: $\chi^2 = 109.01$, $P < 0.001$. However, when individual Chi Square analyses was applied to the CAT HEAD / DOG BODY stimuli and the DOG HEAD / CAT BODY stimuli, it was only in the case of the DOG HEAD / CAT BODY stimuli that subjects made significant more category judgements on the basis of the head than on the body: $\chi^2 = 7.07$, $P < 0.01$. One explanation for this finding is that there is less variability between the shapes of cats' heads than there is between the heads of dogs (Quinn, Eimas, & Rosenkrantz, 1993).

3.4.3.1 Data Analysis for Reaction Times

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (CATS, DOGS, CD's and DC's) were entered into a repeated measures ANOVA. There was a main effect of category: $F_{(3,42)} = 8.13$, $P < 0.001$. On a subsequent post hoc analysis (Tukey's HSD) it was revealed that there were no differences in the mean reaction times between the categories CAT and DOG, nor between the two hybrid categories CD's and DC's (see Figure 22). Given that there were no significant differences in reaction times between normal CAT and DOG stimuli, and the two hybrid categories, the four variables were collapsed into two new variables: CATS & DOGS, and HYBRIDS (see Figure 23). The mean reaction times for the four category variables, plus the mean reaction times for the two collapsed variables, are presented in Table 9.

Table 9. **Experiment 9. Mean reaction times for the 2-alternative forced-choice task**

	CAT OUTLINES	DOG OUTLINES	CAT HEAD/ DOG BODY OUTLINES	DOG HEAD/ CAT BODY OUTLINES	CAT & DOG OUTLINES	HYBRID OUTLINES
Mean	1035	1068.46	1587.11	1532.48	1051.83	1559.79
SE	85.02	82.92	176.92	158.21	64.1	142.35
SD	329.29	321.16	685.22	612.73	248.26	551.31

A subsequent repeated measures ANOVA established that there was a significant difference in the mean reaction times between the HYBRID stimuli and the normal CATS and DOGS: $F_{(3,42)} = 25.06$, $P < 0.002$.

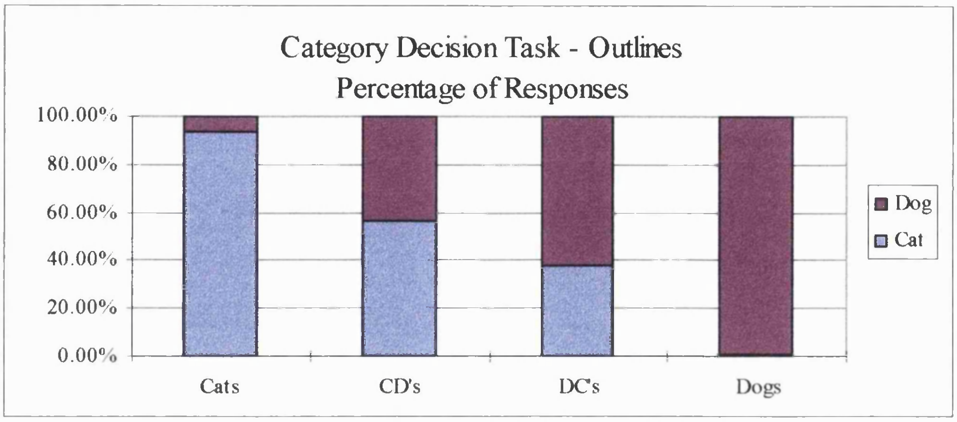


Figure 21. Experiment 9: Percentage of frequencies of CAT and DOG responses for the outlines of the various stimuli.

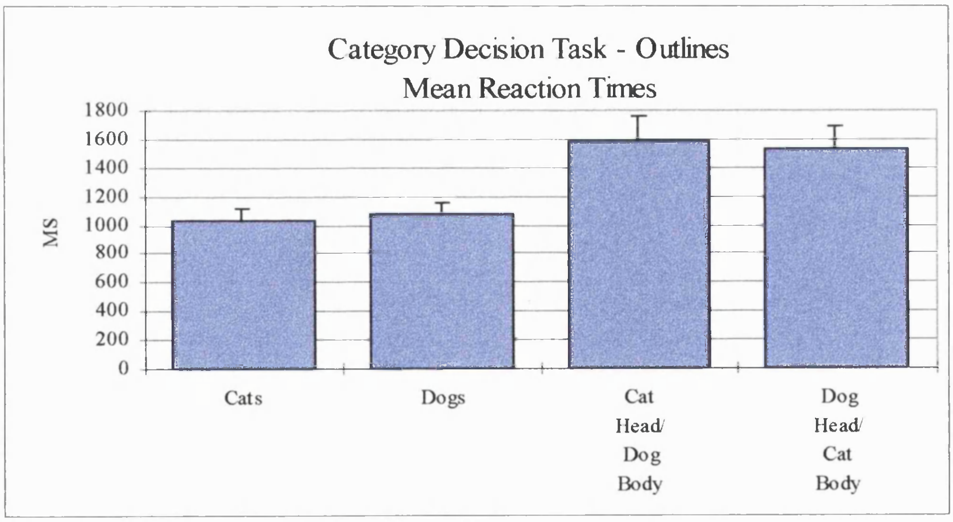


Figure 22. Experiment 9: Mean reaction times in MS for the four category types. A Tukey's HSD revealed that there was no difference in reaction times between the CAT and DOG stimuli, nor between the two HYBRID category types.

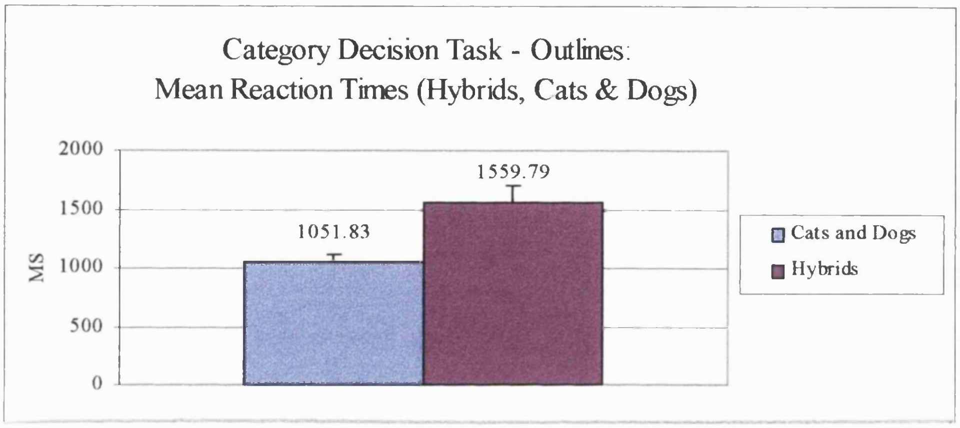


Figure 23. Experiment 9: Mean reaction times in MS collapsed over the CAT and DOG stimuli and the HYBRID stimuli. Using Tukey's HSD subjects were found to be significantly faster in their reaction times for assigning category membership to the normal CAT and DOG stimuli than they were to the HYBRID stimuli, $P < 0.0004$.

3.4.4 Discussion

The differences in reaction times for the outline stimuli for this experiment are best interpreted in relation to reaction times for the full-body stimuli experiments. The mean reaction times from this experiment were subsequently compared with the mean reaction times from Experiment 5 (whole CATS, DOGS, and hybrid stimuli as shown in Chapter 2). The reaction times for the CAT and DOG OUTLINES were 16.4% slower than for the WHOLE CAT and DOG stimuli shown in Experiment 5 (1051.83 versus 903.84). This indicates that reducing the amount of information has a marginal effect on reaction time. In other words, the information from the outlines of cats and dogs is sufficient to differentiate the two animals. However, when the reaction times from the hybrid stimuli outlines were compared with the reaction times from the whole hybrid stimuli from Experiment 5 the effect was much larger: (1559.79 versus 1197.1). Subjects' mean reaction times were 30.3% slower for the HYBRID OUTLINES than for the WHOLE HYBRIDS. In terms of processing these stimuli, there may be an interaction between low and higher-level visual mechanisms to account for these effects. Edge extraction is a low-level visual process. Recognising faces relies on this low-level processing but there are also specific cortical mechanisms tuned to facial information and expression. Therefore, in a forced-choice task when unambiguous information is presented, it is possible that perceptually-based processes predominate. However, when the stimuli are ambiguous, higher-level processes also seem to be required.

The findings from this experiment show that subjects are far slower at processing the outlines of the hybrid stimuli than either the outlines of cats and dogs or whole hybrids. The nature of a forced-choice task does not, however, allow for graded judgements. Therefore, in order to discover how subjects categorise the hybrid outlines, in the following experiment typicality judgements were obtained on the various outline stimuli.

3.5 Experiment 10

The purpose of this experiment was to see how subjects would rate the typicality of the outline stimuli used in Experiment 9. Of particular interest was subjects' typicality ratings of the more ambiguous hybrid stimuli. I hypothesised that subjects would find it harder to categorise the hybrids than the normal cat and dog outlines, as in addition to the mismatch between the heads and bodies, the absence of the facial configurations might increase the weighting to the body area of the stimulus items. Subjects assigning intermediate category ratings to the hybrid stimuli would evince this. Typicality judgements were therefore obtained on the outlines of the CAT, DOG, and HYBRID stimuli.

3.5.1 Method

3.5.1.1 Subjects

Subjects were 15 undergraduate students from University College London, 7 males and 8 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

3.5.1.2 Stimuli

The stimuli were the same as those used in the Experiment 10: 8 CAT OUTLINES, 8 DOG OUTLINES, 8 CAT HEAD / DOG BODY OUTLINES, and 8 DOG HEAD / CAT BODY OUTLINES.

3.5.3 Procedure

Subjects were seated in front of a computer screen, which displayed instructions for a standard typicality response study. The procedure was identical to that used in Experiment 8.

3.5.4 Results

The typicality ratings for individual stimuli within each of the four conditions were averaged together across subjects. The mean typicality ratings for the four general categories of, CATS, DOGS, CAT HEAD / DOG BODY (CD's), and DOG HEAD / CAT BODY (DC's) are illustrated in Figure 24. A single factor repeated measures ANOVA revealed a reliable effect of stimulus category, $F_{(3,43)} = 144.89$, $P < 0.001$. Post-hoc tests (using Tukey's HSD) indicated that the mean typicality rating for the CAT stimuli was significantly lower than for the CAT HEAD / DOG BODY stimuli, $P < 0.001$, and the DOG HEAD / CAT BODY was reliably lower than for the DOG stimuli. However, the mean typicality rating for the CAT HEAD / DOG BODY stimuli was not reliably lower than that for the DOG HEAD / CAT BODY stimuli as measured using Tukey's HSD, $P = 0.79$. Therefore, subjects did differentiate the normal CATS and DOGS from the HYBRIDS. However, there did not appear to be sufficient information in the HYBRID OUTLINES to differentiate them from each other.

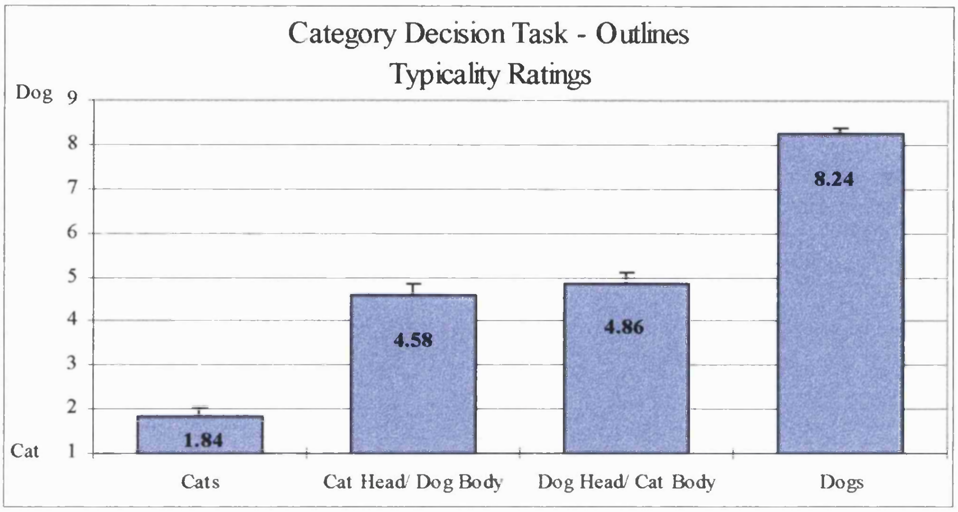


Figure 24. Experiment 10: Mean typicality ratings for whole outlines of CATS, DOGS, and HYBRID stimuli.

3.5.4 Discussion

If the results of this experiment are compared with the results from Experiment 4 (typicality judgements for WHOLE CATS, DOGS, and HYBRID stimuli) it is possible to see that it was no more difficult for subjects to assign category membership to the normal CAT and DOG OUTLINES than to the normal WHOLE CATS and DOGS (WHOLE CATS = 1.73 versus OUTLINE CATS = 1.84; WHOLE DOGS = 8.47 versus OUTLINE DOGS = 8.24). In contrast, the typicality ratings for the two types of WHOLE HYBRID stimuli from Experiment 5 were significantly different from each other. In the present experiment they were not (WHOLE CD's = 4.3 versus WHOLE DC's = 6.01; OUTLINE CD's = 4.58 versus OUTLINE DC's = 4.86). One possible explanation is that the ambiguity of the HYBRID OUTLINES means that subjects require further cues such as features or facial configurations in order to make definite similarity classifications judgements.

3.6 Experiment 11

So far in this chapter I have shown that head / facial information is a highly-diagnostic perceptual cue when making category decisions of cats and dogs. The results of the typicality studies together with the reaction time data, however, indicate that the less diagnostic body information is not ignored. This is true even when there is reduced perceptual information, as in the outline stimuli. Therefore, in the final experiment in this chapter, subjects' reaction times for heads versus bodies was compared when the only information available was the outline of each stimulus. Evidence shows that it is the edges of image components, that is, luminance boundaries, which determine object boundaries and shape, and these are processed early in the visual system (see, e.g., Wilson, Levi, Maffei, Rovamo & DeValois, 1990). This is why a monochrome outline of an object can often be recognised as quickly as the object itself. Therefore, if the outlines of heads are more diagnostic than the outlines of bodies, subjects should make category decisions faster for the head outlines than for the body outlines. However, given the reduced featural and textural information in these stimuli, reaction times should be slower when compared to the results of Experiment 6 (whole heads versus whole bodies). A 2-alternative forced-choice categorisation task was employed. Subjects were presented with photographic representations of the outlines of heads of CATS and DOGS, and bodies of CATS and DOGS, and asked to indicate whether each stimulus item was a cat or a dog. Once again, this experiment was carried out on a computer, allowing for reaction times to be measured.

3.6.1 Method

3.6.1.1 Subjects

Subjects were 16 undergraduate students from University College London, 8 males and 8 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

3.6.1.2 Stimuli

The stimuli were 40 outlines of CAT and DOG HEADS, and CAT and DOG BODIES (10 CATS HEADS, 10 DOG HEADS, 10 CAT BODIES, 10 DOG BODIES). All of the stimuli were taken from colour photographs of cats and dogs, and scanned and digitised using high quality computer software, as in previous experiments. The outlines were taken from the original colour photographs employed in the previous experiments using Adobe Photoshop™ (examples of the stimuli are shown in Figure 25).

3.6.2 Procedure

The procedure was identical to that employed in the previous 2-alternative forced-choice experiments in this thesis.

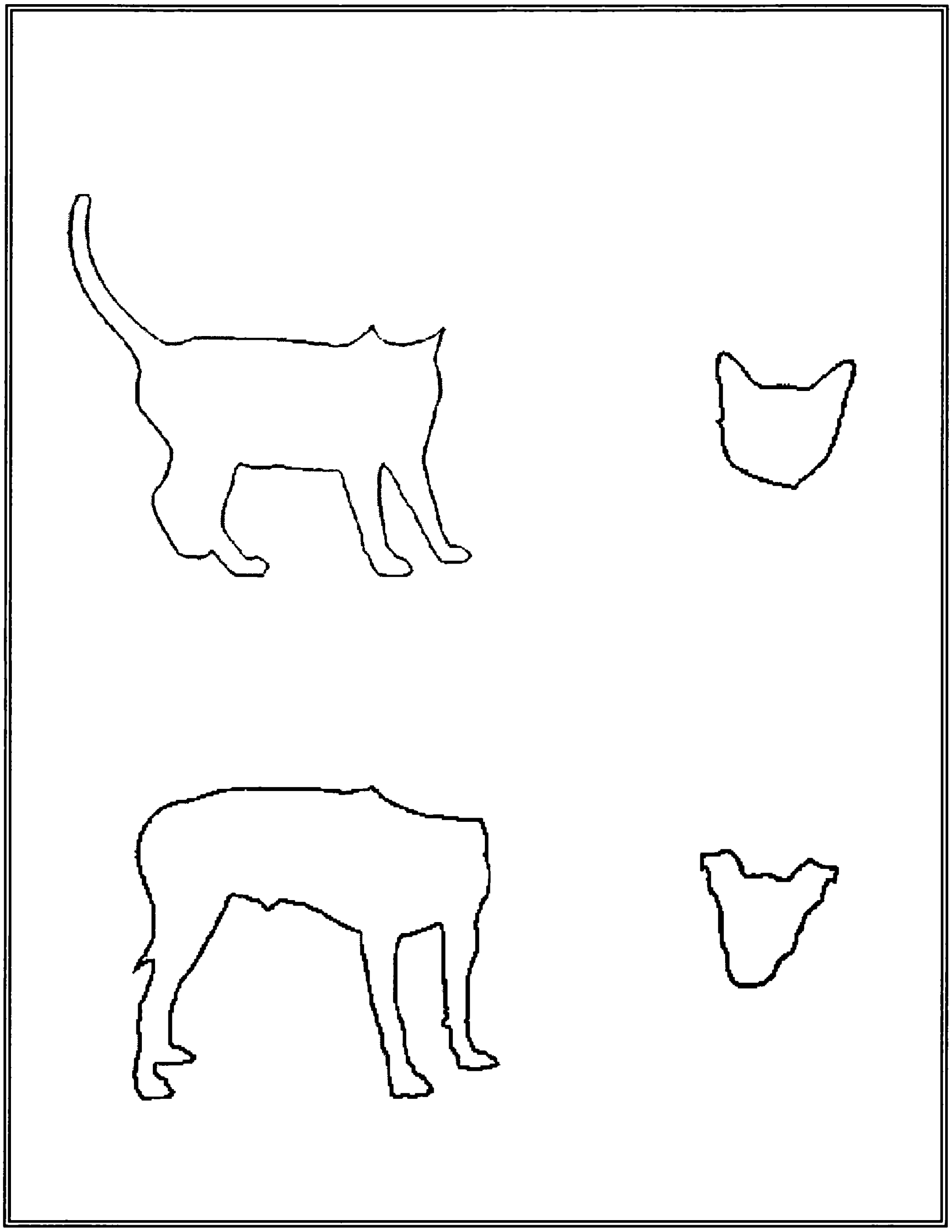


Figure 25. Examples of CAT and DOG HEAD OUTLINES, and CAT and DOG BODY OUTLINES.

3.6.3 Results

The various stimulus types were collapsed into four general categories, CAT HEADS, DOG HEADS, CAT BODIES, DOG BODIES. Figure 26 illustrates the percentage of CAT and DOG responses by category type. Table 10 gives the frequencies of CAT and DOG responses for the four category conditions. A Cochran's *Q* test indicates that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 208.5$, $p < 0.001$. A subsequent analysis of the individual variables determined that there was a significant difference in the CAT and DOG responses for each of the four different conditions. The individual chi-square values are given in Table 11. Thus, subjects performed significantly above chance when assigning correct category membership to the various stimuli.

Table 10 **Experiment 11: frequencies of responses by category type.**

	CAT	DOG
CAT HEAD	137	23
CAT BODY	132	28
DOG HEAD	26	134
DOG BODY	34	126

Table 12. **Experiment 11: Individual Chi-Square values and associated significance levels for the four category variables.**

	CAT_HEAD	CAT_BODY	DOG_HEAD	DOG_BODY
Chi-Square	81.2	67.6	77.9	52.9
df	1	1	1	1
Sig.	<0.001	<0.001	<0.001	<0.001

3.6.3.1 Data Analysis of Reaction Times

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (CAT HEAD, CAT

BODY, DOG HEAD, DOG BODY) were entered into a repeated measures ANOVA. There was a main effect of category: $F_{(3,45)} = 4.29$, $P < 0.01$. On a subsequent post hoc analysis it was revealed that there were no differences in the mean reaction times between the categories CAT HEAD and DOG HEAD, nor between the two categories CAT BODY and DOG BODY. However, there was a significant effect of whether the stimuli were heads or bodies with heads inducing shorter reaction times than bodies $F_{(1,15)} = 10.15$, $P < 0.007$ (see Figure 27). Again, this is further evidence that even though edges are sufficient for making category decisions, the outline of the head is more perceptually-diagnostic than the outline of the body in the case of cats and dogs.

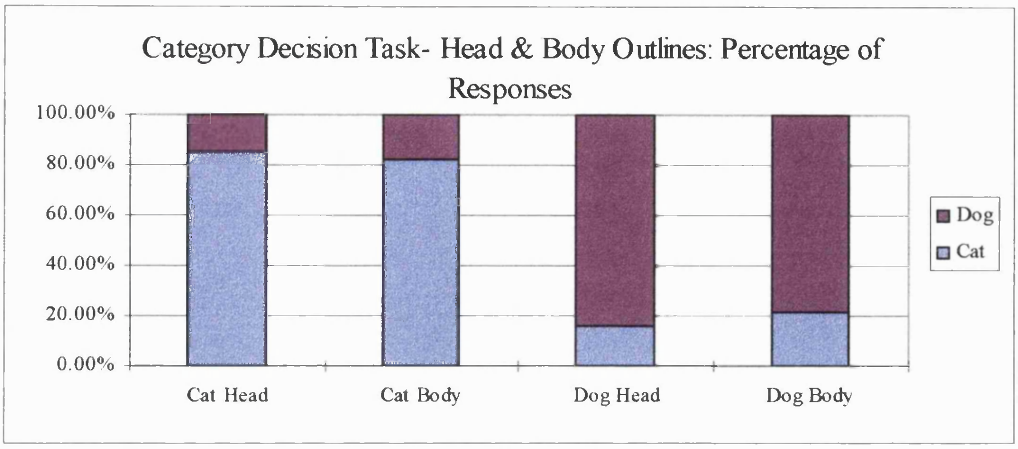


Figure 26. Experiment 11: Percentage of CAT and DOG responses for the outlines of CAT and DOG HEADS and CAT and DOG BODIES.

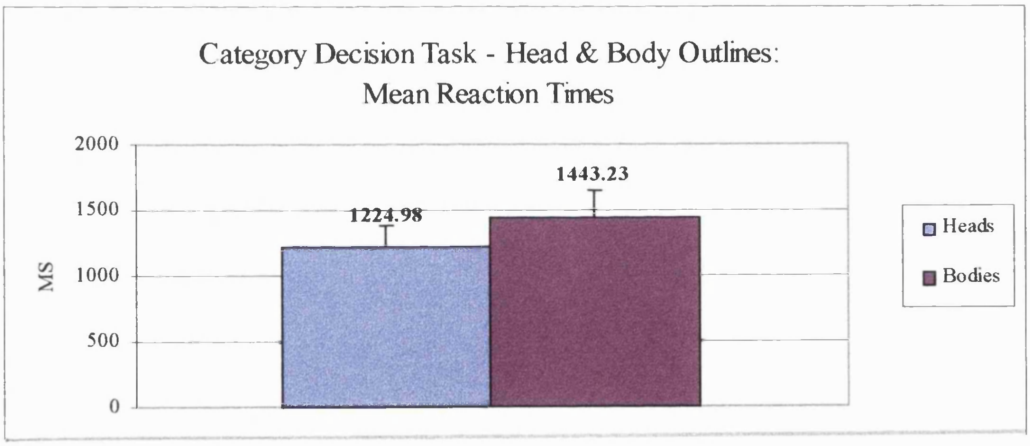


Figure 27. Experiment 11: Mean reaction times in MS collapsed over the outlines of the CAT and DOG HEAD stimuli, and the CAT and DOG BODY stimuli. The outlines of the heads induced shorter reaction times than the outlines of bodies.

3.6.4 Discussion

The results indicate that there were no differences in reaction times based on animal category membership. However, reaction times for categorising the heads of the cats and dogs were significantly faster than those for the bodies. A comparison of the reaction times from this experiment with those from Experiment 6 (WHOLE HEADS and WHOLE BODIES) is shown in Table 12. Subjects' reaction times were 39.71% slower for the OUTLINE BODY stimuli than for the WHOLE BODIES shown in Experiment 6. Furthermore, subjects' reaction times were 57.66% slower for the OUTLINE HEAD stimuli than for the WHOLE HEAD stimuli. Of course no direct statistical comparison between these cross-experimental groups can be made, but they are nevertheless indicative that subjects are able to distinguish cats from dogs on the basis of outlines alone; however, when facial configurations are present in the stimuli, processing time is considerably reduced.

Table 12. **Comparison of mean reaction times in MS from Experiment 6 and Experiment 11.**

	HEADS	BODIES
WHOLE HEADS AND BODIES **EXPERIMENT 6.**	776.98	1033.05
OUTLINES OF HEADS AND BODIES **EXPERIMENT 11.**	1224.98	1443.23

3.7 General Discussion

In the previous chapter it was argued that the weighting attributed to different stimulus properties may be a function of processing time.[16] However, with increased processing time, other, less diagnostic information is incorporated into the representation. This is true for both infants and adults. In the present chapter I looked more specifically at which properties of an object are most informative during the categorisation process.

It is commonly assumed that concepts are organised into taxonomies that vary in their level of inclusiveness or abstractness. For example, *vehicle, car, Renault Megane car;* or *animal, dog, black Labrador* are illustrations of hierarchical structures for artefacts and natural kinds. It has been argued that basic-level objects may differ qualitatively from other levels of categories. Tversky and Hemenway (1984) suggested that basic-level objects share a number of parts. This part configuration often determines the shapes of objects. Although members of subordinate categories share many more parts than members of a basic-level category, parts are most informative at the basic-level. At the superordinate-level, category members share few parts. Therefore, noticing the various parts of superordinate-level category members is not a very effective means for learning about that category. On the other hand, members of a subordinate category share such a large number of parts that it is difficult to distinguish between members on that basis. For example, noticing that *Pine trees* have trunks, a diagnostic part for differentiating trees from other plants at the basic-level, will not help to differentiate *Pine trees* from *Oak trees.* Similar to taxonomic hierarchies, individual objects are also believed to have an hierarchical structure made up from

---

[16] It is usually basic-level objects that share perceptually similar properties.

their constituent parts. Tversky and Hemenway have labelled part hierarchies "partonomies". For example, the body of a dog can be divided into *head, trunk, legs,* and *tail.* Each of these parts can then be separated into subparts (ibid.). Partonomies differ from taxonomies in that the latter allow for making inferences, whereas the former do not. "Taxonomies serve to organise numerous classes of entities and to allow inference from larger sets to sets included in them. Partonomies serve to separate entities into their structural components and organise knowledge of function by components of structure. The informativeness of the basic level may originate from the availability of inference from structure to function at that level." (Tversky & Hemenway, 1984. P. 169). In other words, basic-level categories are distinguishable on the basis of their parts. The category decisions that subjects have been asked to make in this thesis are between basic-level objects. Given that part configuration is argued to underlie the perceptual information that people use to differentiate objects at the basic-level, and that categorisation is believed to be based primarily on part recognition, it is important to determine which parts of the objects employed here are the most diagnostic and informative for making category decisions when processing time is limited. Six experiments were carried out in order to determine which parts of the stimuli were perceptually diagnostic, and if when subjects are trying to make category decisions as quickly as possible higher category weightings are associated with particular properties.

The evidence proposing that specific cortical mechanisms are specialised for face processing suggests that the head and face area of the stimuli might be the most perceptually diagnostic parts, and as such should be processed faster than the body parts. Therefore, in Experiment 6 subjects' reaction times were recorded when categorising either the HEADS or BODIES of the CATS and DOGS. Subjects were significantly faster at assigning category membership to the heads of the stimuli than to the bodies, thus providing further evidence that when distinguishing between perceptually similar basic-level category members, such as cats and dogs, the head and facial information is perceptually diagnostic and processed faster. In Experiment 6 subjects only ever saw heads separated from the body parts and vice versa. In real life of course, categorisation decisions are made when there is competing information, which could affect perceptual processing and categorisation. Therefore, Experiments 7 and 9 tested the effects of spatial configuration by splitting both the normal animal stimuli and the hybrid stimuli into their component parts.

In a visual search task, when a target object is placed amongst a number of dissimilar distracter objects (e.g., the figure ‘X’ is placed within a number of ‘L’ figures), the distracter objects do not effect the length of reaction time for picking out the target object (see e.g., Davis & Driver, 1994). Of course, when the target object is placed amongst a number of similar distracter objects, e.g., a ‘T’ placed amongst a number of ‘L’ figures, then subjects’ reaction times for picking out the target object is affected. However, if faces are the most highly diagnostic parts of the stimuli, and dissimilar to other parts of the animal, then when the animals are split up, regardless of the position of the face parts on the screen, subjects use the head/face as their primary categorisation criterion. It is possible that even when the stimuli were split into their constituent parts the face / head parts were the most informative in that they were still in possession of highly-diagnostic parts (i.e., the nose, eyes, mouth and ears) in their correct configuration of features.

Experiments 7 and 8 differed in the tasks subjects had to perform. Experiment 7 was a typicality judgement task and Experiment 8 was a 2-alternative forced-choice task. There was a slight difference in the results from the two tasks. When subjects were asked to make typicality judgements for the split animals, the body information was not ignored, as evinced by the ratings given to the hybrid split animals. However, the reaction times from the forced-choice task indicated that BODY PART information was disregarded. One possible explanation for the differences may reside in the nature of the tasks. During a forced-choice task, processing may be rapid, since subjects need to process only enough information to make a threshold judgement. When subjects are asked to make a binary classification as rapidly as possible, they need only use the most readily perceived feature that enables them to make such a discrimination. By contrast, typicality judgement tasks require that subjects decide how similar the presented object is to two possible target objects. Similarity judgements would seem by definition to require an appraisal of the entire stimulus feature set. This can be considered in terms of going beyond reproductive thought to productive thought which is a higher-level cognitive task (Wertheimer, 1959). Consequently, the two tasks may have called on two different processes. The forced-choice task used a faster, perhaps perceptually-based processes, whereas the typicality task may have made use of more analytic processes. The differences in results lend further support to the claim that during rapid categorisation decisions will be based mainly on the highly-diagnostic properties of an object. Whereas when categorisation is slower, less diagnostic information may also be used in the decision process.

The data from this chapter can be interpreted as supporting the notion that head and facial information are more diagnostic in the categorisation of cats and dogs, especially when subjects are instructed to make a category decision as quickly as possible. If this is the case, then this suggests that the head / face parts are more diagnostic than the other body parts. This still leaves unanswered whether it is the internal configuration of the face that is highly diagnostic, or the outline of the head shape. The initial stages of visual processing are usually considered in terms of representing input in terms of luminance changes across an image in the form of highly specialised edge-detectors (Marr, 1982). However, face recognition is a higher level visual process, which requires integrating information across space. For example, Tanaka and Farah (1993) ascertained that a specific part of a face is recognised more easily when shown in the whole face than when shown in isolation. If it is the internal configuration of the face that attracts attention to the head area, then when the internal attributes are removed (i.e., eyes, nose, mouth), subjects should find it more difficult to categorise the stimuli purely on the basis of the head information. This was investigated in the final three experiments of this chapter where the stimuli were reduced to outlines.

The results of this chapter point to the following conclusions. When an object is categorised fairly rapidly, then it may be sufficient for perceptual information to dominate the category decision processing of unambiguous stimuli. But, when ambiguity is encountered, as in the outlines of the HYBRID stimuli, purely perceptually-based processes may be insufficient. This interpretation is consistent with the view that the process of categorising basic-level objects accords bottom-up priority when processing time is limited, with top-down influences affecting later processing.

– oOo –

Chapter 4

Introduction

In this chapter, timing factors are investigated for subjects' recall of category members. Previously it was argued that during rapid categorisation, perceptually-diagnostic information is used for making category judgements. When presented with animal species such as cats and dogs, it is the head and face area that is highly-diagnostic. For tasks that require longer processing time, less diagnostic information is also used in the categorisation decision. I therefore hypothesise that whether or not perceptual information dominates the categorisation decision process is a function of processing time. In the experiments reported in this chapter, short presentation times are used in an attempt to force subjects to employ perceptual processes.

Making a decision on the basis of perceptual information is not simple. In the earliest stages, the perceptual system has to process the information in the visual field. One possible way of doing this is by identifying the object on a number of dimensions. For example, if the object is a car, then the perceptual system might identify that is has 4 wheels, is of a particular shape, that it has doors, and so on. Although the dimensions on which such an object can be described are infinite[17], the dimensions which are important for object identification may vary with context or task demands.

Once the dimensions for making a perceptual decision are identified, information needs to be retrieved from long-term memory. It has been argued that it is the perceptual representation of the object which directs this process

---

[17] For example, a car can be described in terms of being larger than an ant, and smaller than a bus, or heavier than a feather but lighter than a train, and so on ad infinitum (Murphy & Medin, 1985).

(Lamberts, 1997).[18] For the purposes of rapid categorisation, exemplar-based views may provide the best explanation of how categories are represented. Within exemplar models, the whole stimulus is thought to be imprinted in memory (Nosofsky, 1986). Whenever an object is perceived, a memory trace is formed for that stimulus. Perceptual tasks indicate that performance increases, and recognition time decreases, as a function of the amount of instances that are stored in memory. In other words, there is a correspondence between the familiarity of an object and the ease of retrieving an exemplar of it from memory. Only when the information has been retrieved from memory can a decision be made concerning what the object is.

So far, in the experiments with adults time has not been directly manipulated. The experiments in this chapter employ a different technique in an attempt to direct the perceptual processing of the stimuli. If perceptual categorisation involves a process of dimension sampling[19], then varying exposure time should have an effect on categorisation (Lamberts & Freeman, in press). Previously, it has been argued that either featural or configural processes are employed during categorisation (J. D. Smith, 1990). There is evidence to suggest that for all tasks except those that require subjects to make typicality or similarity judgements featural processes are employed (Sugimura & Inoue, 1987). Furthermore, it would seem that when processing time is limited subjects focus on particular features rather than configurations of features (Smith & Shapiro, 1989). Such findings are surprising, however, given that featural processing is more effortful in that it involves selective attention. Configural processing does not. Lamberts (1995), however, has proposed that the mode of processing depends on the nature of the classification task. When processing time is limited, a system that

---

[18] For a review of different theories of how categories may be represented in memory see chapter 1.
[19] This relates to using perceptually-diagnostic properties when processing time is limited, whereas with extended processing time other, less diagnostic properties will be employed.

attends to highly-diagnostic perceptual dimensions or properties for object identification may be more useful than processing the whole object (including the less diagnostic features or dimensions).[20] If this is the case, then such a process should also have an effect on which properties of a stimulus are remembered as a function of exposure time. This hypothesis is tested in Experiments 13 and 14 below.

The studies reported in this chapter manipulated the length of exposure time in the categorisation process employing a standard old-new recognition paradigm task. Recognition is often considered a special case of categorisation (Estes & Maddox, 1995). This can be justified on the grounds that some instance-based models of category learning can be readily construed as models of recognition (see e.g., Nosofsky, 1988), as can many adaptive network models of categorisation (Nosofsky, Kruschke & McKinley, 1992). Although recognition tasks may not appear as part of the set of prototypical categorisation tasks, subjects are nevertheless making categorisation judgements on the stimuli. Making a YES / NO recognition response involves accessing stored representations and deciding how similar the current to-be-judged object is to the stored representation of the object seen in the first phase of the experiment.

Among the most common recognition paradigms is the hybrid design. This requires a subject to view a large number of items, and then during a continuous recognition test phase the subject is presented with items which are either taken from the original sequence or are new distracters. This generates a great deal of data on list recognition (Estes & Maddox, 1995). In the present studies a number of stimuli were presented on screen for a short period of time and subjects were asked to remember what they saw. Following this presentation, these stimuli were

---

[20] Highly-diagnostic perceptual dimensions may be configurations of features or properties, such as eyes, nose, mouth, and shape of head.

presented again in a sequence including a number of NORMAL and HYBRID distractor items. Subjects made a YES / NO decision as to whether or not they remembered having seen the stimuli previously.

– oOo –

4.1 Experiment 12

This experiment was run in two phases. In the first phase subjects looked at CATS, DOGS, and CAT-DOG HYBRIDS on screen for 2000 ms. In the second phase their recall for the stimuli was measured. Subjects had only seen either the heads or the bodies in the first phase of many of the stimuli presented in the second phase. If subjects were using configural processing, their recall for those stimuli which they had only seen the bodies previously should not differ for those which they had only seen the head previously. However, if they were using dimensional processing, where one dimension could consist of the highly diagnostic properties, then their memory for heads should be significantly better than their memory for bodies.

4.1.1 Method

4.1.1.1Subjects

Subjects were 20 undergraduate students from University College London, 9 males and 11 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any previous experiments.

4.1.1.2 Design and Stimuli

The experiment was conducted in two stages. The stimuli in each stage were 36 colour photographs of CATS, DOGS and HYBRIDS as used in the previous experiments (14 CATS, 14 DOGS, 4 CAT HEAD / DOG BODY HYBRIDS and 4 DOG HEAD / CAT BODY HYBRIDS).

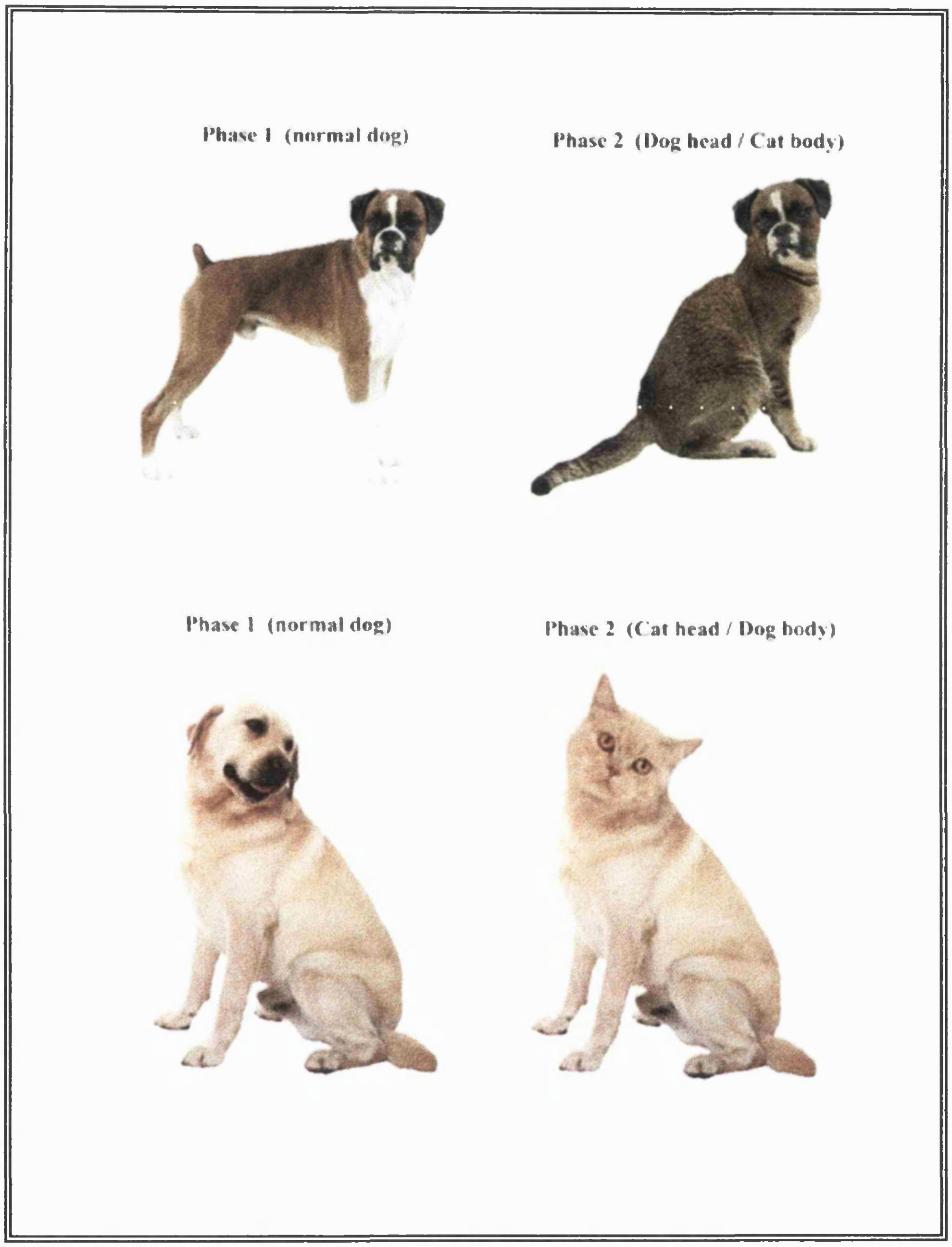
4.1.2 Procedure

In the initial trial phase, subjects were seated in front of a computer screen that displayed the instructions for the experiment. They were informed that the experiment was conducted in two phases. In the first phase they did not have to make any responses other than to try and remember what they were shown. They were then presented with the stimuli (14 CATS, 14 DOGS, 4 CAT HEAD / DOG BODY HYBRIDS and 4 DOG HEAD / CAT BODY HYBRIDS). Each stimulus item was displayed on screen for 2000 ms with a 1000 ms interval between the presentation of each stimulus. There were two different presentation orders to control for order effects.

Following the trial phase, subjects were shown a further set of photographs and asked to make a 2-alternative forced-choice decision for each stimulus as to whether or not they remembered having seen it in the trial phase. A standard button box with 2 buttons was provided. The left and right buttons on the box were marked with the words YES and NO accordingly. Subjects had to make either a YES or NO response in order to go onto the next stimulus item.

The stimuli presented in the test phase were made up of 3 CATS and 3 DOGS not presented in the trial phase (NEW CATS and DOGS) and 3 CATS and 3 DOGS which had been presented in the trial phase (OLD CATS and DOGS). A further 8 CATS and 8 DOGS were presented, of which either the head or the body had been used to make up a hybrid in the trial phase (OLD HEAD / NEW BODY, and NEW HEAD / OLD BODY, respectively). Four hybrids were presented in which subjects had previously only seen either the head or the body of a WHOLE CAT or DOG in the trial phase (HYBRID-OLD HEAD / NEW BODY, and HYBRID-NEW HEAD / OLD BODY, respectively). Additionally, 4 totally new hybrids were presented (NEW HYBRIDS). See Figures 28 and 29 for examples of the differences between the stimuli in phase 1 and phase 2.

The order of stimulus presentation was random, with two different stimuli orders to control for order effects. The length of presentation time of each stimulus item in phase 2 depended on the speed of the subjects' response. However, all subjects were instructed to make a decision as quickly and as accurately as they could. All reaction times were recorded.



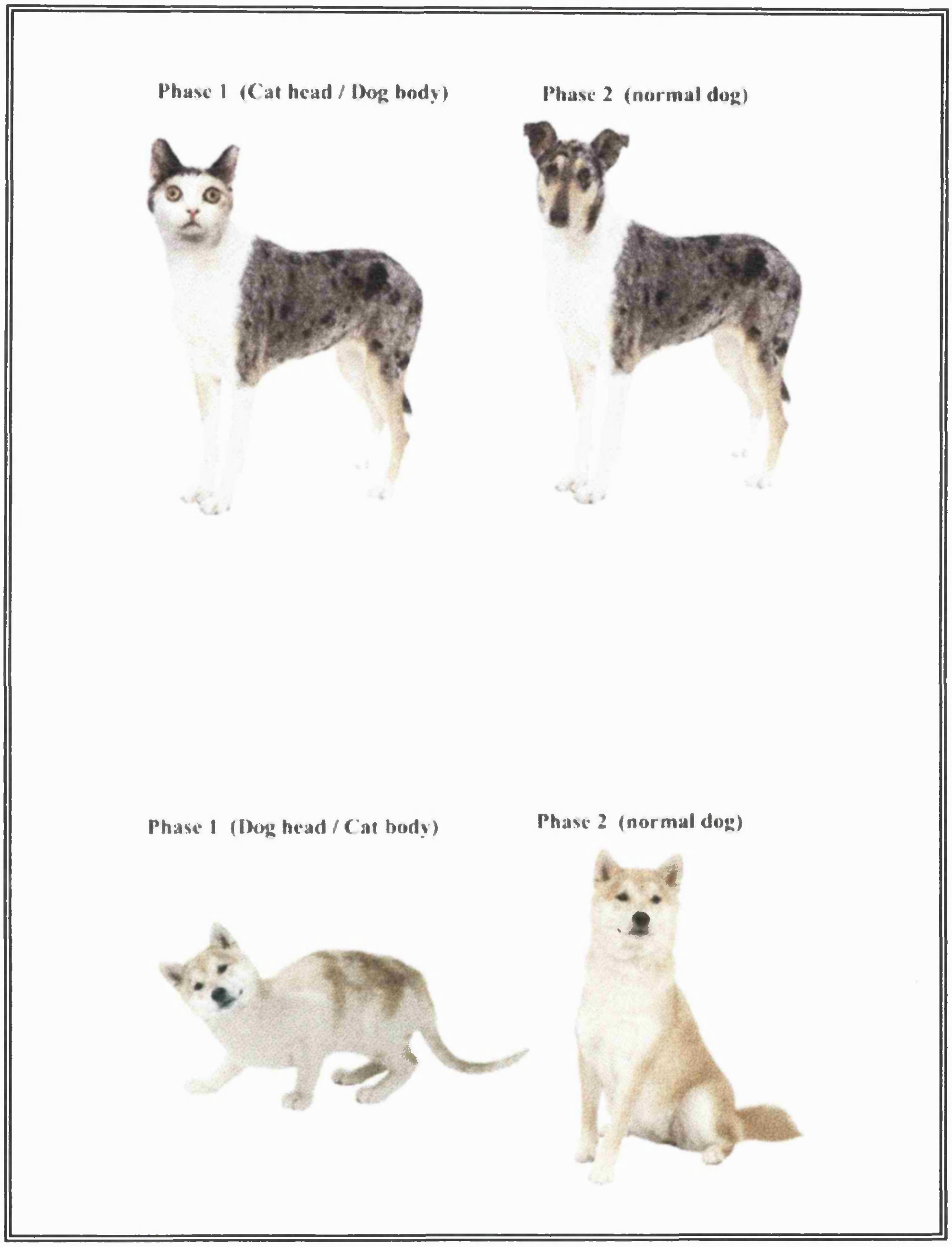
Phase 1 (normal dog)

Phase 2 (Dog head / Cat body)

Phase 1 (normal dog)

Phase 2 (Cat head / Dog body)

Figure 28. Examples of the differences between stimuli in phase 1 and 2.


Phase 1 (Cat head / Dog body)

Phase 2 (normal dog)

Phase 1 (Dog head / Cat body)

Phase 2 (normal dog)

Figure 29. Examples of the differences between stimuli in phase 1 and 2.

4.1.3 Results and Discussion

4.1.3.1 Data Analysis for Yes / No Response and for Reaction Times

In the hybrid design old-new recognition task, subjects were presented with a sequence of trials, some of which were signals (stimuli already shown, or 'old') and others noise (new stimuli that had not been presented to the subjects previously or 'new'). Signal detection theory was used as an index of recognition memory. The number of times each subject made a hit, i.e., said 'yes' to recognising an 'old' stimulus, and the number of times each subject gave a false positive response, i.e., said 'yes' to recognising a 'new' stimulus were recorded for each individual subject. D-prime values were then obtained for each subject. A one sample t-test was performed on the overall d-prime scores to see if they differed from zero. This was found to be the case: $d! = 0.95$, $t_{(19)} = 6.38$, $p < 0.001$. Therefore, subjects performed significantly above chance at distinguishing between 'old' and 'new' stimuli.

Subjects' reaction times were recorded for making a YES / NO decision to each individual stimulus item. The mean reaction times for the 7 cases, by type, are given in Table 13.

Table 13. Experiment 12: Reaction times in MS for correct and incorrect responses collapsed over all stimulus types.

Category Type	Mean	SD
OLD CATS and OLD DOGS	976.27	258.43
NEW CATS and NEW DOGS	1248.02	462.75
OLD HEAD / NEW BODY	1299.71	562.98
NEW HEAD / OLD BODY	1285.23	480.81
HYBRIDS: OLD HEAD/NEW BODY	1265.35	429.22
HYBRIDS: NEW HEAD/OLD BODY	1283.60	723.04
NEW HYBRIDS	1251.45	586.24

A repeated measures ANOVA was performed to test for differences amongst the means of the reaction times. Although there was an overall effect of reaction time, $F_{(114,6)} = 2.71$, $P < 0.02$, on a post hoc analysis (Tukey's HSD) the only differences in reaction times were between the OLD CATS and OLD DOGS and the other stimuli types (as shown in Figure 30). A subsequent analysis, however, showed that there was a significant difference in subjects' responses, depending on whether they gave correct or incorrect responses. An ANOVA revealed that subjects were significantly faster at making a correct response than an incorrect response: $F_{(5,1)} = 22.64$, $P < 0.006$ (see Figure 31).

The results of the reaction times suggest that although subjects were using what may have been the most diagnostic properties of the stimuli (the head and face) when categorising the animals, body information was also being processed. If only the head were used for observing the stimuli, there should be no difference in reaction times between the OLD CATS and DOGS seen in both phase 1 and phase 2 and those stimuli for which subjects had only seen the head before. Nor should there have been any differences in reaction times between correct and incorrect responses. This will be discussed further in the general discussion.

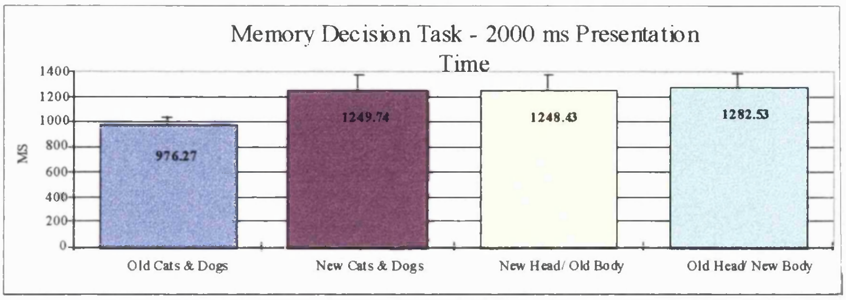


Figure 30. Experiment 12: Subjects were significantly faster in their reaction times for recognising the WHOLE CATS and DOGS they had seen in phase 1 than any of the other stimulus types.

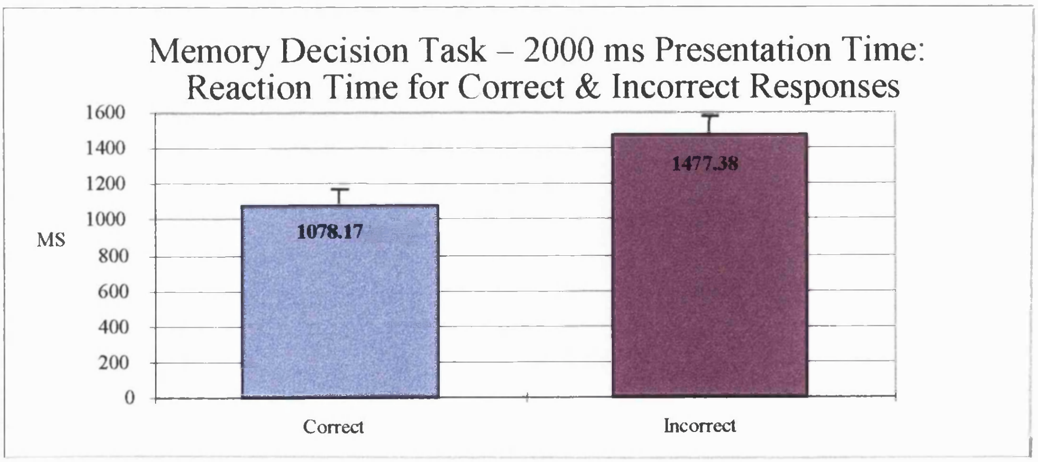


Figure 31. Experiment 12: Mean reaction times for correct and incorrect responses collapsed over all stimulus types.

4.2 Experiment 13

Experiment 12 provided evidence that when processing time is relatively short, subjects focussed on the highly-diagnostic dimensions / properties of the stimuli (the head / face area). The reaction time data, however, indicated that the less diagnostic body information was not ignored. The implication of such findings is that although the response data suggest that dimensional processing was being used, in fact, configural processes were also being employed. If the assumption is that those properties that are processed the fastest are those that are most critical for identification and subsequent classification purposes, then this suggests that dimensional or featural processes are employed when processing time is limited. One reason why subjects may have used configural processing, however, is that a 2000 ms presentation is not particularly rapid. It would seem that in everyday life the identification of objects is often made within milliseconds. Therefore, presenting subjects with the stimuli for 2000 ms may have been enough time for subjects to go on and identify the less-diagnostic properties, such as the body. This hypothesis is tested in Experiment 13.

4.2.1 Method

4.2.1.1Subjects

Subjects were 15 undergraduate students from University College London, 7 males and 8 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

4.2.1.2 Design and Stimuli

The stimuli and procedure was exactly the same as Experiment 13, with the exception that subjects were presented with the stimuli for 500 ms duration in the Trial Phase as opposed to 2000 ms.

4.2.2 Results: Data Analysis for Yes / No Response and for Reaction Times

Once again, subjects had been presented with a sequence of trials, some which were signals ('old' stimuli previously shown), and others were noise ('new' stimuli shown for the first time). Signal detection theory was used as an index of recognition memory. The number of times each subject responded 'yes' to recognising an 'old' stimulus, and the number times each subject responded 'yes' to recognising a 'new' stimulus were recorded for each individual subject. The d-prime values were then obtained for each subject. The 'old' stimuli are analogous to signal plus noise. The 'new' stimuli are analogous to noise. A one sample t-test was performed on the d-prime scores to see if they differed from zero. This was found to be the case: $d! = 0.82$, $t_{(14)} = 6.52$, $p < 0.001$. As before, subjects performed significantly above chance at distinguishing between 'old' and 'new' stimuli.

Subjects' reaction times were recorded for making a YES / NO decision to each individual stimulus item. The mean reaction times for the 7 cases, by type, are given in Table 14.

Table 14. Experiment 13: Reaction times in MS for all stimulus types.

Category Type	Mean	SD
OLD CATS and OLD DOGS	1238.02	582.43
NEW CATS and NEW DOGS	1577.68	1017.17
OLD HEAD / NEW BODY	1258.50	544.93
NEW HEAD / OLD BODY	1174.78	378.61
HYBRIDS: OLD HEAD/NEW BODY	1348.57	600.45
HYBRIDS: NEW HEAD/OLD BODY	1463.40	1076.28
NEW HYBRIDS	1281.72	662.27

A repeated measures ANOVA was performed to test for differences amongst the means of the reaction times. There was no significant effect of reaction time across all categories (see Figure 32.). One possibility for the null effect of reaction time is that the reduction in exposure duration in the trial phase may have prevented the subjects from even processing the less diagnostic body information. This is discussed more fully in the general discussion.

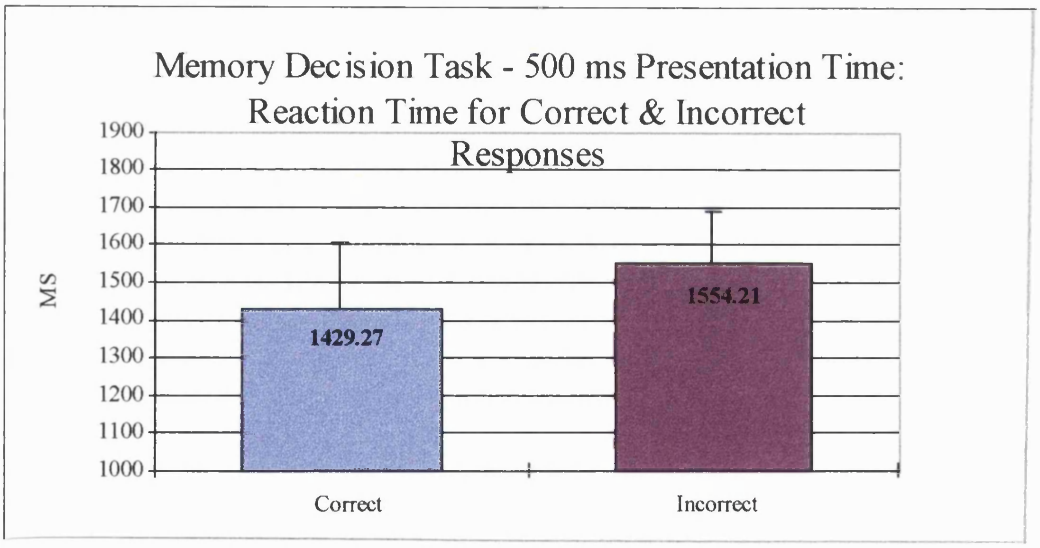


Figure 32. Experiment 13: Reaction times collapsed over the various stimulus types for correct and incorrect responses.

4.3 General Discussion

Thus far in the thesis I have attempted to demonstrate that although categorisation is often made on the basis of highly diagnostic perceptual information less perceptually diagnostic properties are also incorporated into the representation and can influence the categorisation decision. It is possible that the properties used for making a category decision vary as a function of exposure time. In this chapter I manipulated exposure time in an attempt to affect the perceptual processing of the stimuli.

J. D. Smith (1990) has claimed that categorisation involves either featural or configural processes. With respect to exposure duration, Smith and Shapiro (1989) found that individual features/properties are attended to when there is limited processing time available. With increased processing time, more features are incorporated into the representation. Furthermore, Lamberts (1995) suggested that with limited processing time, attention is directed towards highly-diagnostic perceptual dimensions. Such a process may be more efficient for object identification than a system that attends in the first instance to both the highly-diagnostic and less diagnostic perceptual dimensions. The experiments in this chapter tested whether some properties of the stimuli were remembered better as a function of exposure time. The findings from the experiments in Chapter 3 suggest that the head and face area of the stimuli used in this thesis is perceptually more diagnostic than the body information. Thus, if greater weighting is given to the most diagnostic dimensions of an entity early on in the object identification process, that is the face/head areas in these experiments, objects should be remembered on that basis if the exposure duration is not long enough to allow for processing other less diagnostic dimensions.

The general findings of the two experiments presented here suggest that regardless of whether exposure time is 500 or 2000 ms, subjects were able to remember whether or not they had seen a stimulus item previously. However, there was a possible problem with the instructions subjects received. Following the trial phase, subjects were told that they would be shown a further set of pictures and that they had to make a decision for each one as to whether or not they remembered having seen it in the trial phase. Subjects were then presented with a number of stimuli. The majority of the stimuli presented in the test phase were different with respect to either the head or the body from those presented in the trial phase. From the instructions, subjects may have been under the impression that they were being asked to make a positive decision only when they remembered having seen the whole animal from the trial phase. If this had been the case, the results should have shown that subjects only made correct decisions for the WHOLE CATS and WHOLE DOGS shown in both phases. This would have been evidence for simple configural processing. However, given that subjects showed significant recall of all the old stimuli indicates that they were not confused by the instructions.

The reaction time data indicated that body information was taken into account when encoding the stimuli in the trial phase, as shown by the results of the reaction time data in Experiment 12, but not in Experiment 13 when presentation time was reduced to 500 ms. One possibility is that subjects may have been focussing on both highly-diagnostic and less-diagnostic dimensions when the presentation time was relatively long, and only on the highly-diagnostic ones when it was short. This is consistent with the findings from the infancy studies in Chapter 2. Caution must be exercised in generalising these results, of course, in terms of an overall time dependency effect, since only two time durations were considered and this was a cross-experimental manipulation.

I speculate that there are two possible explanations for the apparent lack of purely dimensional processes being employed in Experiment 12 when the presentation duration was 2000 ms. First, making a category decision relies on both temporal and informational processes. In other words, the process of object identification and categorisation depends on a system that can procure the most information in the least processing time. This indicates that to some extent there is a trade-off between speed and accuracy in object identification. Written word recognition studies have determined that a word can be recognised between 200 and 250ms (Marslen-Wilson, 1987). Therefore, the findings from the experiments reported here are consistent with the view that 2000ms is not only sufficient time in which to process the highly-diagnostic perceptual information but also some of the less diagnostic perceptual properties. When exposure duration is 500ms, it is possible that only the highly-diagnostic perceptual information is processed.

Second, an alternative explanation for the differences in reaction time results between Experiments 12 and 13 is connected to the role of attention and encoding in memory retrieval and subsequent decision making. Parallels can be drawn with the instance theory of automaticity (Logan, 1988, 1990, 1992). The instance theory of automaticity is a memory-based model (ibid.). It is based on three main assumptions. First, attention to material involves obligatory encoding. Second, the retrieval of associations to the attended material from memory is obligatory. And third, the representations in memory are instance representations. For the purposes of this discussion only the first two assumptions are relevant. The term 'encoding' is used in the sense found in the memory literature. When information is encoded, the result is storage in long-term memory. The strong version of the obligatory encoding assumption argues that the only material encoded in memory is that which is attended to. The weaker version posits that some unattended material might also be encoded. The weaker version has been supported experimentally (Logan & Etherton, 1994). Consistent with the weaker version is the claim that both attended and unattended properties can also act as retrieval cues from memory. Given that in previous experiments I demonstrated that the faces of the cat and dog stimuli are assigned a higher weighting (see

Experiment 8, Chapter 3) it is conceivable that the highly-diagnostic head and facial properties were also given a greater weighting in Experiment 13, and therefore may have been represented more robustly, and therefore remembered more accurately. Also consistent with the weaker version of the obligatory encoding / retrieval model is that a 2000 ms presentation duration is sufficient for the less diagnostic properties to also act as retrieval cues. This would explain how subjects were able to take body information into account in the decision-making process in Experiment 12, but not in Experiment 13when the presentation time was only 500ms. Thus, it is possible that whether configural or dimensional processes are employed in object identification and subsequent categorisation may not be mutually exclusive. Rather, which process is used may depend on both temporal constraints and task demands.

– oOo –

Chapter 5

Introduction

In order to recognise an object by observation alone indicates that what is recognised are those properties that differentiate it from other objects. This view of object recognition suggests that when children learn to recognise an object, for example a dog, they do so by learning which properties characterise dogs. Which properties are perceived and used for recognising one object from another may depend on whether between- or -within category distinctions are being made. For example, one might expect that those properties that are used for recognising a cat amongst a herd of elephants will be different from those used for recognising a Burmese kitten in a litter of Siamese kittens. In other words, the properties that are optimal for characterising objects between categories will be different to those that are optimal for characterising objects within categories. If this is the case, then it is reasonable to assume that learning to classify objects at different levels, such as at the basic, superordinate, or even subordinate level will entail perceiving and attending to different properties of an object.

The experiments in this chapter are a further attempt to demarcate the lines along which category distinctions are made. The idea is not to ascertain how category differentiation is possible, say between cats and dogs, since the results from the previous experiments reported in this thesis have gone some way in establishing that highly-diagnostic perceptual properties influence the decision behaviour early on in the categorisation process. Rather, in the present experiments, the aim is to see how it is possible to differentiate between perceptually similar members from the <u>same</u> category.

5.1 Experiment 14

In Chapter 1, I cited the work of Schyns, Goldstone and Thibaut (1998) who argued that the properties that define category members are discovered via category learning. During the process of category learning, different task demands will require different properties to be discovered and this may result in the formation of distinct representations of the same categories. Of interest is whether category learning is more efficient when done within a category or with contrasting categories. Schyns et al., suggest that the properties which are extracted and used for making category decisions will vary according to whether they are learned alone or with contrasting categories. When a single category is learned, for example the category of cats, observers should pick out properties that are common amongst all exemplars. However, in learning the category of cats versus dogs, additional properties, which serve to distinguish the two categories, will also be extracted.

Consistent with these ideas are the findings from infancy studies suggesting that both basic-level and global or superordinate-level categories are formed by 3- to 4-month old infants on a perceptual basis (cf. Mandler & McDonough, 1993; Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997). Extrapolating from such findings, it is possible to predict that the development of more fine-grained category representations, such as at the subordinate-level, will emerge through the accumulation of increasingly more refined perceptual information. Visual texture is one such perceptual cue.

Smith and Heise (1993) have established that by 12-months of age, infants are receptive to global differences in texture which permit them to differentiate animals from vehicles. These findings indicate a perceptual dimension along which many naturally-occurring and manufactured objects may be distinguished and to which infants are sensitive. Additionally, these discoveries suggest that the human perceptual system can selectively enhance attention to such fine-grained perceptual properties in the appropriate contexts. Although Smith and Heise (ibid.) argue that visual texture may be one perceptual cue that permits infants to form global categories which can be used to distinguish between other global categories, such as natural kinds versus artefacts, I argue that visual texture may also be one perceptual cue for forming subordinate-level categories.

In the present experiment I investigated the perceptual cues that infants can use to differentiate within-category members. Apart from providing a starting point for understanding how humans learn to distinguish category members which are perceptually similar, such experiments are also important in terms of infant visual development per se. It has been established that visual acuity develops in the first three months of life. Other visual abilities, including the ability to discriminate visual texture patterns, develop from between 2- to 3-months and 6 months. Investigating the development of subordinate-level categorisation abilities in young infants can help in determining the interplay between perceptual and conceptual structure.

5.1.1 Method

5.1.1.1 Subjects

Subjects were 12 4-month old infants (mean age: 4 months 1 day, *SD* = 10 days). There were 7 males, and 5 females.

5.1.1.2 Design and Stimuli

The stimuli were 36 pictures of cats and dogs (18 CATS, 18 DOGS). All the stimuli were taken from the same colour photographs of cats and dogs used in the previous experiments and reduced to greyscale using high quality computer software. In addition to the normal CATS and DOGS, there were 7 CAT and 7 DOG transformations in which the normal fur was replaced with the texture from different natural kinds (e.g., lizards, grass, beetles, wood, snakeskin, leaves, and so on). The transformations were manipulated into the stimulus items using Adobe Photoshop™ computer software.[21] The stimuli were printed on photographic paper, thus making them as similar to real photographs as possible. The average height and length of the stimuli was 11 x 11cm. The stimuli were mounted onto white 17.7 x 17.7cm cards for presentation to the infants. Examples of both the normally textured cat and dog stimuli and the inappropriately textured stimuli are shown in Figures 33 and 34.

5.1.2 Procedure

The procedure was identical to the infancy experiments reported in Chapter 2. To recap, the infants were tested using a replica of the basic Fagan apparatus (Fagan, 1970). Each infant was tested reclining on the lap of the parent who sat on a low seat. When the parent and infant were comfortable the apparatus was wheeled into position. The display stage of the Fagan box was centred directly over the infant. At this stage the infant could no longer see the parent. The stimuli were then placed into the two compartments. Once the infant's attention was attained by talking to her or shaking a rattle, the familiarisation trials began. At no point could the parents see the stimulus items. During a trial, one experimenter looked through the peephole and, with a stopwatch in each hand, timed the infant's looking to the left vs. right stimulus item. This was measured by observing the corneal reflection of each stimulus in the infant's pupil. One experimenter timed the fixed length of the familiarisation trials and signalled when a trial was to end. Between familiarisation trials, the first experimenter opened the display stage away from the

---

[21] Both the normal cats and dogs, and the textured transformation cats and dogs were reduced to greyscale images to ensure that any differences subjects noticed between the two category types could not be due to colour variations between the normally textured cats and dogs, and the inappropriately textured ones.

infant's view, recorded the data, changed the stimuli, obtained the infant's attention, centred her gaze, and finally closed the stage re-exposing the new stimuli to the infant. The stimuli were presented in a random order by Experimenter 1. Experimenter 2 was always blind to the position of the stimuli. For the preference test trials, the first and second experimenter changed places. The experimenter who presented stimuli and measured the infant's fixations during familiarisation now measured trial duration and signalled the end of the test trials. The second experimenter now presented the test stimuli and measured fixations. The two experimenters changed roles across infants.

Infants were presented with 12 stimuli, either cats or dogs, during 6 20-second familiarisation trials (2 animals per trial)[22]. Half of the infants were familiarised with CATS, the other half with DOGS. The familiarisation stimuli were randomly selected for each infant, from the pool of 18 available. Immediately after familiarisation and without interrupting the procedure, a 10-second preference test trial was presented. The stimuli for these trials paired a novel NORMALLY TEXTURED CAT with an INAPPROPRIATELY TEXTURED CAT or a novel NORMALLY TEXTURED DOG with an INAPPROPRIATELY TEXTURED DOG depending on whether the infant had been familiarised to CATS or DOGS. The test stimuli were randomly selected for each infant. The left-right positioning of the test trial stimuli was counterbalanced across infants on the first test trial of each set of trials and reversed on the second test trial.

---

[22] The length of each familiarisation trial was 20 seconds in this experiment. In Experiment 3 it was shown that when familiarisation time was 20 seconds infants showed a preference for the body area of the stimuli than to the head / facial area. The difference in texture between the normal cats and dogs and the inappropriately textured animals was most noticeable on the body area. Therefore, 20 seconds familiarisation time should have been long enough for the infants to perceive and process the body area of the stimuli.

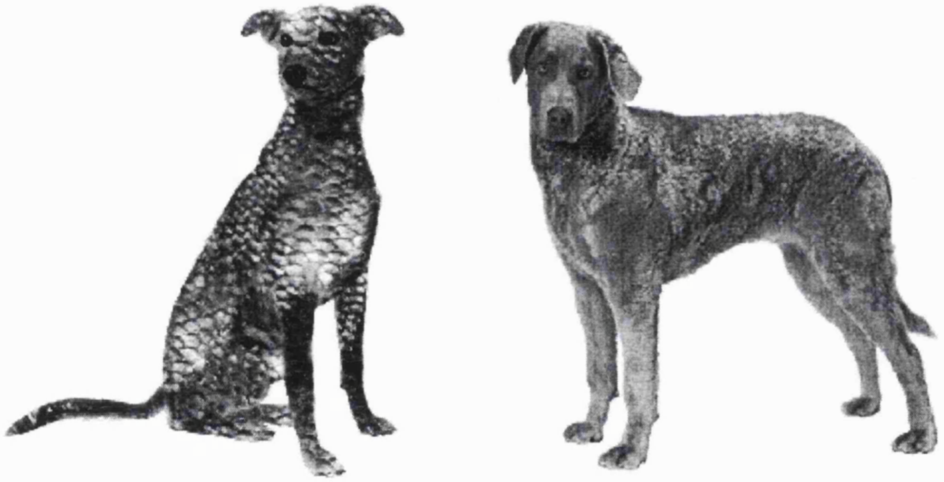


Figure 33. Examples of an inappropriately textured dog with a normally textured dog.

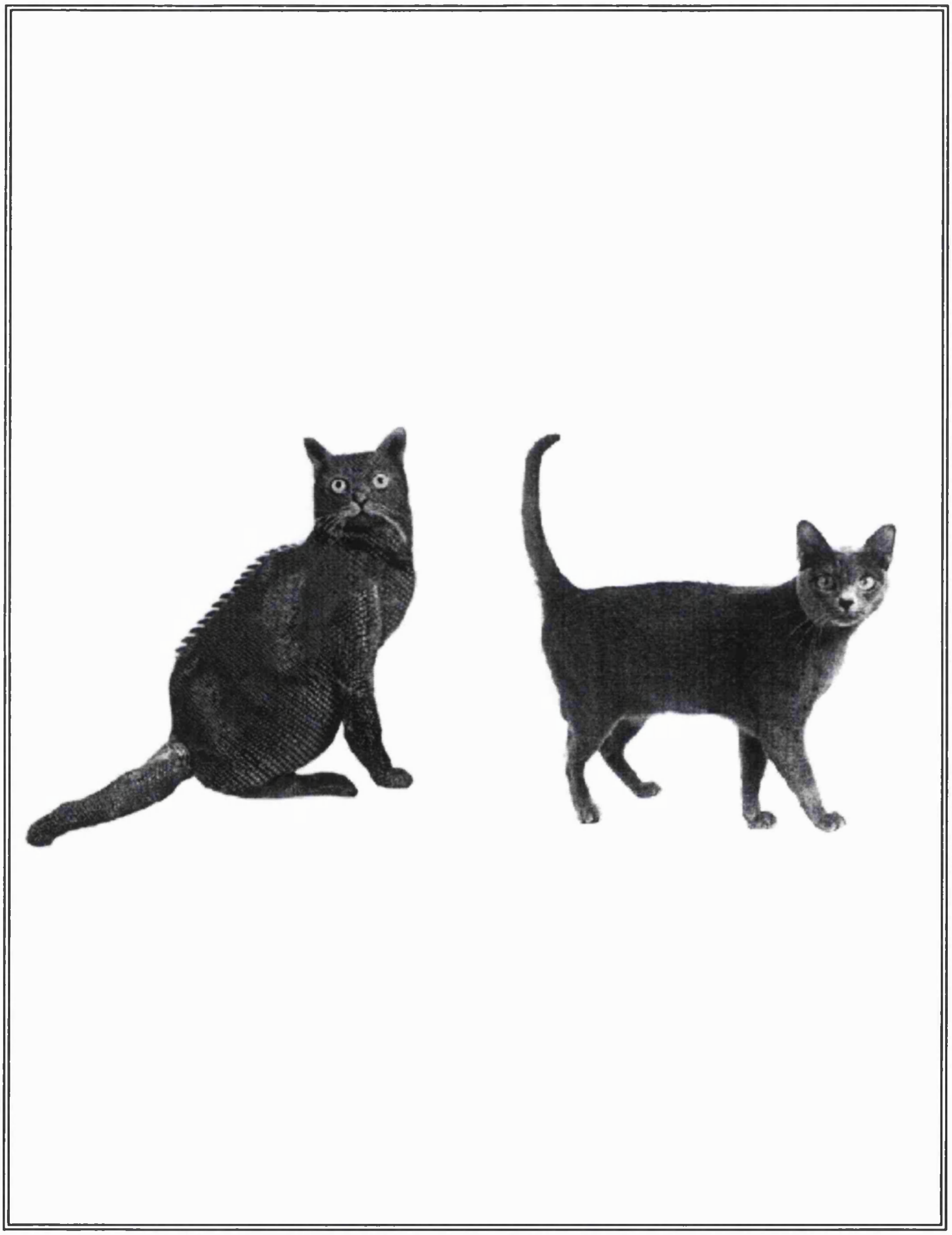


Figure 34. Examples of an inappropriately textured cat with a normally textured cat.

5.1.3 Results

5.1.3.1 Familiarisation Trials

Individual looking times were summed over both stimuli on each trial and then averaged together for the first block of three familiarisation trials and the last three. As in the previous infancy experiments, there was no significant difference in looking time as a factor of stimulus type (CATS or DOGS), nor was there a difference in looking time between the first three sets of stimuli presented and the last three sets. Infants thus failed to display a decrement in looking time from the first to last half of familiarisation (first three trials = 10.31, *SD* = 3.53; last three trials = 10.66, *SD* = 3.36). As mentioned previously, the fact that infants did not habituate is consistent with results obtained with similar stimuli presented over the same number and duration of trials (Eimas, Quinn, & Cowan, 1994; Quinn et al., 1993).

5.1.3.2 Preference Test Trials

The mean looking time for the novel category (i.e., the inappropriately textured stimuli) was divided by the total looking time for both category types (i.e., normal CATS or DOGS, and the transformed CATS or DOGS), and then converted into a percentage score for each infant. For both preference tests, the mean novel category preference score for infants familiarised with cats was not different from that for infants familiarised with dogs, $t_{(11)} = 0.86$, $p > 0.10$, in both cases. The mean novel category preference scores were then collapsed across both the CAT and DOG stimuli with the inappropriately texture for all infants (70.79%, *SD* = 10.06, $t_{(11)} = 7.16$, $P < 0.001$) indicating that the preference score for the transformed stimuli with the inappropriate texture was reliably above chance. Figure 35 displays infants' preferential looking to the normal and inappropriately textured stimuli.

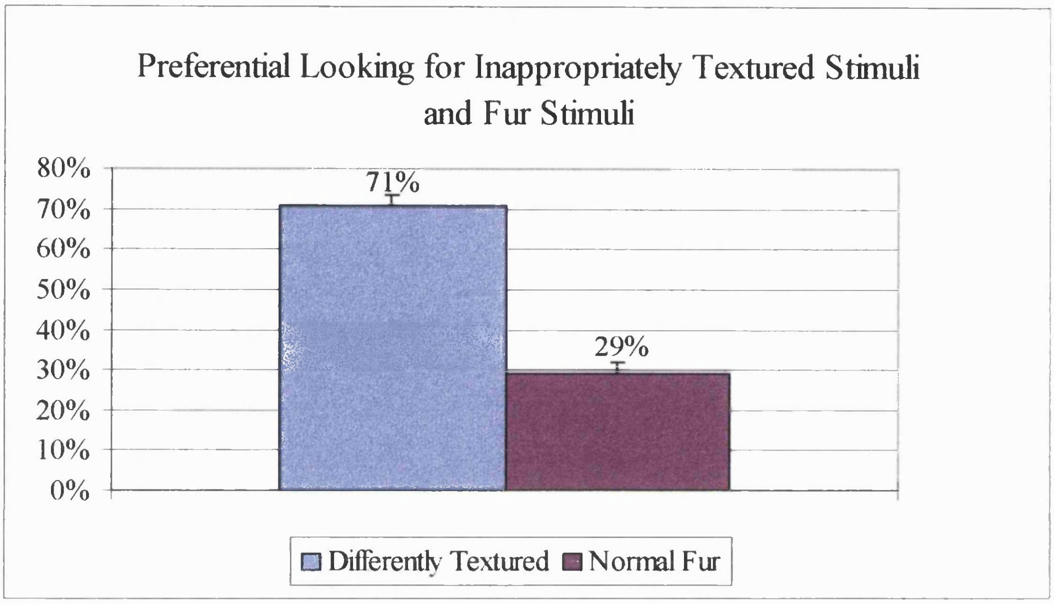


Figure 35. Experiment 14. Infants showed a significant preference for the INAPPROPRIATELY TEXTURED CATS and INAPPROPRIATELY TEXTURED DOGS over the NORMALLY TEXTURED CATS and NORMALLY TEXTURED DOGS.

5.1.4 Discussion

The results indicate that visual texture may be one perceptual cue that allows infants to begin to develop subordinate categories. Of course, since only cat and dog stimuli were used in the current experiments it is not possible to generalise these findings to other natural kind types without further experimentation.

One potential consideration of the stimuli used here, however, is that it is only possible to estimate what the stimuli actually look like to a young infant. At birth, the retinal cone cells of infants are short and stubby. They have short outer segments and so do not catch many photons of light. Furthermore, because they are loosely packed, they cannot transmit fine-grained spatial information. Moreover, even though their perceptions are not fully developed, it is doubtful that they are the same as those of adults whose vision is also blurry, such as the reduced acuity of elderly cataract patients. Nevertheless, it is possible to simulate the level of degradation in the sensory image for a 1-month old and a 3-month old based on knowledge of infants' acuity and contrast sensitivity at these ages (Anker, Atkinson, Braddick, Ehrlich, Hartley, & Wade, 1997), see Figure 36. This shows that even when visual acuity and contrast sensitivity are degraded, differences in texture patterns are not carried by high spatial frequencies alone, but also by much lower, readily perceived spatial frequencies. The differences in high and low spatial frequency shown in Figure 37 demonstrate that there are a lot of texture differences that can be perceived even with very low acuity. Therefore, even though the 4-month old infants may be unable to perceive the texture differences between the stimulus types to the same degree that adults can, there is enough information in the low spatial frequency information to make such differences potentially noticeable.

Even though the infants were tested using a very limited stimulus set, the findings that infants can differentiate normally textured cats from inappropriately textured cats (and normally textured dogs from inappropriately textured dogs) is compatible with Quinn and Eimas' (1996) evidence that by 4-months of age infants can use the body information from cats and dogs to make within-category discriminations.

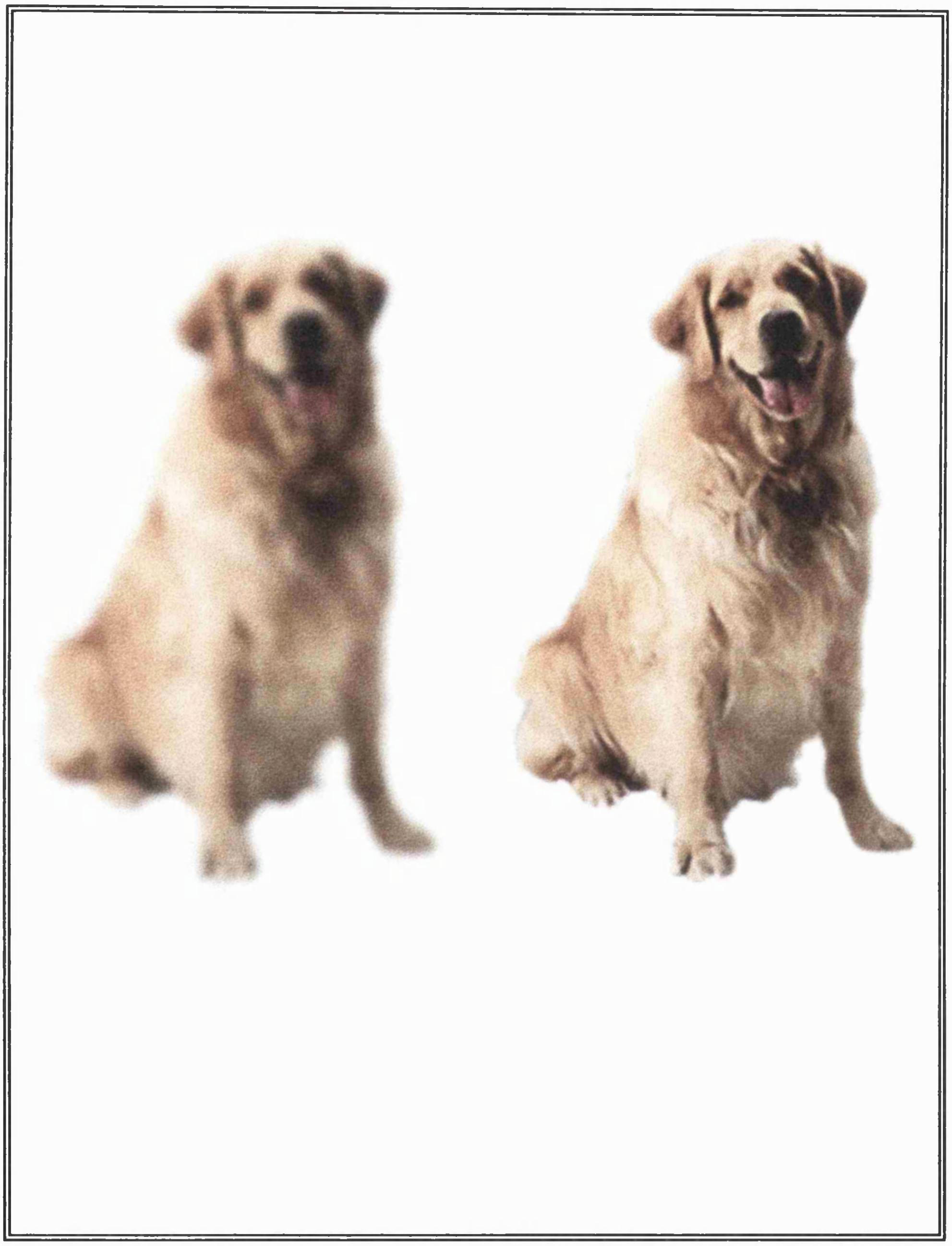


Figure 36. Differences in contrast sensitivity and visual acuity between 1 and 3-months of age. The acuity of the dog on the left has been reduced to the level of acuity for a 1-month old, and the dog on the right has been reduced to the acuity for a 3-month old infant.

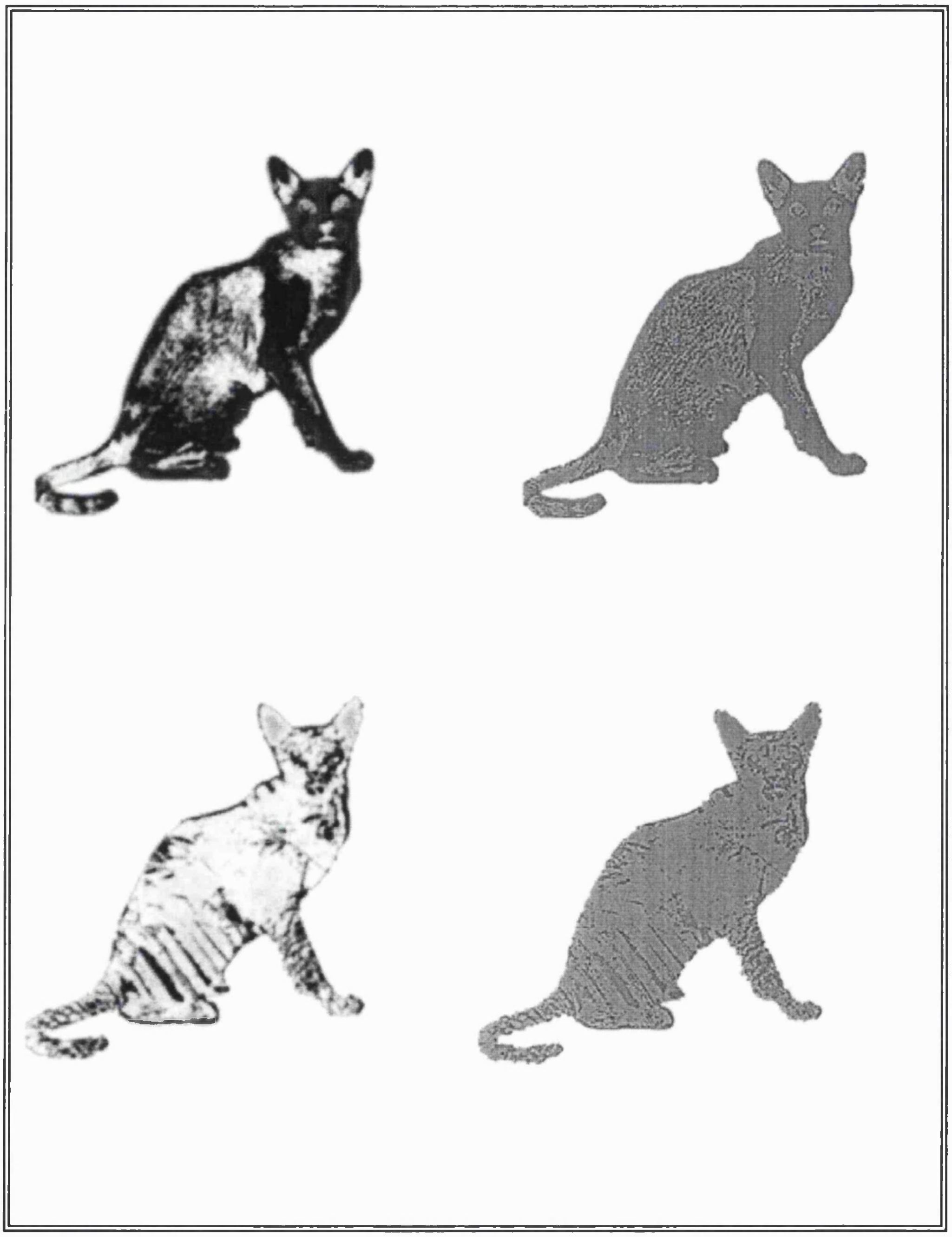


Figure 37. Examples of stimuli with the high or low frequency information removed. There is enough information in the low spatial frequency for the infant to notice texture differences between the appropriately textured stimuli and the inappropriately textured stimuli.

5.2 Experiment 15

In this experiment, the question of whether visual texture is an effective cue for affecting similarity judgements with adult subjects was explored. Typicality judgements were obtained for both the appropriately and inappropriately textured stimuli used in Experiment 14. A typicality judgement requires that a subject rate how similar a target object is compared with a number of other objects. Thus, a study of this sort is a good measure for ascertaining the relative weighting of textural information when assigning category membership. Although this experiment did not address within-category learning in adults, if texture similarity is an important perceptual cue for assigning category membership, then the results should reveal that stimuli which are inappropriately textured are judged as being less typical category members.

5.2.1 Method

5.2.1.1 Subjects

Subjects were 12 undergraduate students from University College London, 8 males and 4 females. Subjects were paid £2.00 for their participation. None of the subjects had taken part in any other experiments connected with this thesis.

5. 2.1.2 Stimuli

The stimuli were 46 greyscale pictures of cats and dogs (16 CATS, 16 DOGS), plus 14 CAT and DOG TEXTURAL transformations (7 INAPPROPRIATELY TEXTURED DOGS, and 7 INAPPROPRIATELY TEXTURED CATS). They were identical to those used in Experiment 14 with the exception that they were now presented on a computer screen rather than on cards.

5.2.2 Procedure

Subjects were seated in front of a computer screen, which displayed instructions for a standard bipolar typicality response. The viewing distance was approximately 45cm. For each stimulus item, subjects had to indicate whether it was more typical of a cat or a dog by pressing the numbers between 1 and 9 on a keypad. As before, a '1' indicated that the stimulus item was very typical of a cat, and a '9' indicated that it was very typical of a dog. Subjects were instructed to use the other numbers on the keypad to indicate varying degrees of typicality. The order of stimulus presentation was random, with two different stimuli orders to control for order effects. Subjects had to make a typicality response for the next stimulus item to be displayed. There was no time limit for making a typicality response, but subjects were instructed to make their decisions as quickly and as accurately as possible.

5.2.3 Results

The typicality ratings for individual stimuli within each of the four conditions were averaged together across subjects. The mean typicality ratings for the four general categories of NORMAL CATS, NORMAL DOGS, INAPPROPRIATELY TEXTURED CATS (TEX_CATS), INAPPROPRIATELY TEXTURED DOGS (TEX_DOGS) are illustrated in Figure 38. A single factor repeated measures ANOVA revealed a reliable effect of stimulus category, $F_{(3,33)} = 184.68$, $P < 0.001$. Post-hoc tests (using Tukey's HSD) indicated that the mean typicality rating for the normally textured CAT stimuli was significantly lower than for the normally textured dog stimuli, $P < 0.001$, This is expected, given that lower ratings reflect subjects' judgements that a stimulus is more typical of a cat and higher ratings that a stimulus is more typical of a dog. Further post-hoc tests, however, revealed a significant difference between all the stimulus types as shown in Table 15.

Table 15. Experiment 15: Tukey's HSD significance levels for post-hoc comparisons.

	NORMAL CATS	TEX_CATS	TEX_DOGS	NORMAL DOGS
NORMAL CATS	-	0.000169	0.000163	0.000163
TEX_CATS	0.000169	-	0.000163	0.000169
TEX_DOGS	0.000163	0.000163	-	0.000236
NORMAL DOGS	0.000163	0.000163	0.000236	-

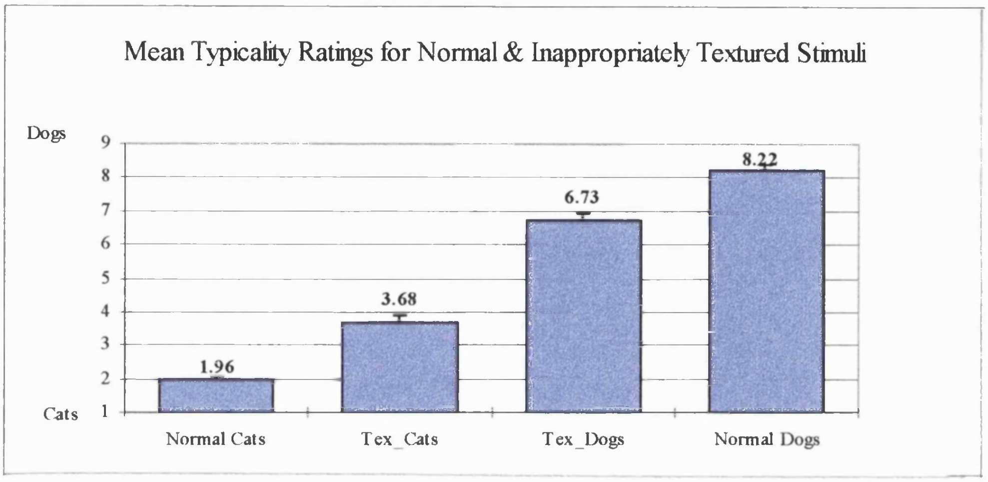


Figure 38. Experiment 15: Mean typicality ratings for the various category types.

5.2.4 Discussion

The results from this experiment indicate that the inappropriate texture of some of the stimuli did influence the typicality ratings given that the mean rating for the TEX_CATS was reliably higher than for the NORMAL CAT stimuli, and the mean typicality rating for the TEX_DOGS was reliably lower than for the NORMAL DOG stimuli. These results lend support to the idea that making similarity judgements may involve more detailed processing of the whole stimulus. The inappropriately textured cats were rated as less typical than were the normal cats. Of course this does not mean that they were closer to being typical dogs than were the the normal cats. Rather, TEX_CATS (and TEX_DOGS) were rated nearer the median 5-point on the scale which indicates an object being typical of neither cat nor dog. This provides evidence that subjects consider the texture of these objects' surfaces to be a relevant property in determining if they are typical of either the cat or the dog category. Nevertheless, this does not tell us if texture is a key feature, or highly diagnostic property of either category. When, however, subjects make a forced-choice between two conditions as rapidly as possible, they need only make use of the most diagnostic properties in the decision task. In order to determine whether the texture of the cat and dog objects influences such a judgement it is necessary to consider the results and reaction times for 2-alternative-forced-choice tasks with normally and abnormally textured stimuli. This is the purpose of the following experiment.

5.3 Experiment 16

The final experiment was undertaken to ascertain whether the perceptual cues, which are employed during a categorisation based on similarity, i.e., typicality ratings, differ from those that govern a categorisation task not based on similarity. A related issue is whether fine-grained textural differences are a better perceptual cue for making subordinate-level categorisations than for making basic-level ones. Although this experiment does not directly address the latter issue, the results will be a useful starting point for considering the perceptual cues that are predictive of category membership at the basic, subordinate, and even individual object level.

A 2-alternative forced-choice categorisation task was employed. Subjects were presented with photographic representations of both appropriately and inappropriately textured cats and dogs. As before, the task was carried out on a computer, permitting the measurement of reaction times.

5.3.1 Method

5.3.1.1 Subjects

Subjects were 15 undergraduate students from University College London, 7 males and 8 females. All subjects were paid £2.00 for their participation. None had taken part in any other experiments connected with this thesis.

5.3.1.2 Design and Stimuli

The same stimuli were used as in Experiment 16: 16 NORMAL CATS, 16 NORMAL DOGS, plus 14 CAT and DOG textural transformations (7 INAPPROPRIATELY TEXTURED DOGS, and 7 INAPPROPRIATELY TEXTURED CATS).

5.3.2 Procedure

The general procedure was a 2-alternative forced-choice task, identical to the other forced-choice experiments employed throughout this thesis. The only differences were in respect of the stimuli.

5.3.3 Results and Discussion

The various stimulus types were collapsed into four general categories of CATS, DOGS, INAPPROPRIATELY TEXTURED CATS (TEX_CATS), and INAPPROPRIATELY TEXTURED DOGS (TEX_DOGS). Figure 39 illustrates the percentage of CAT and DOG responses by category type. Table 16 gives the frequencies of CAT and DOG responses for the four category conditions. The frequency data show that subjects assigned the appropriate category labels to the stimuli. A Cochran *Q* test indicates that the frequencies of CAT and DOG responses were not equal between the different conditions: Cochran's $Q_{(3)} = 291.3$, $P < 0.001$. However, since this was a forced-choice task, which requires subjects to make either a CAT or DOG decision, the only way to discover whether the texture differences influenced subjects category judgements is to look at the reaction time data.

Table 16 Experiment 16: frequencies of responses by category type.

	CAT	DOG
NORMAL CATS	240	0
NORMAL DOGS	1	239
TEX_CATS	99	6
TEX_DOGS	3	102

5.3.3.1 Data Analysis of Reaction Times

The time subjects took to make a category decision for each stimulus item was recorded. The mean reaction times for the four category types (NORMAL CATS, NORMAL DOGS, TEX_CATS, TEX_DOGS) were entered into a repeated measures ANOVA. There was no main effect of category. In other words, there were no significant differences in reaction time, suggesting that the inappropriate texture did not increase the time a subject took to make a category decision (see Figure 40). Possible implications as a result of these findings will be discussed more fully in the general discussion.

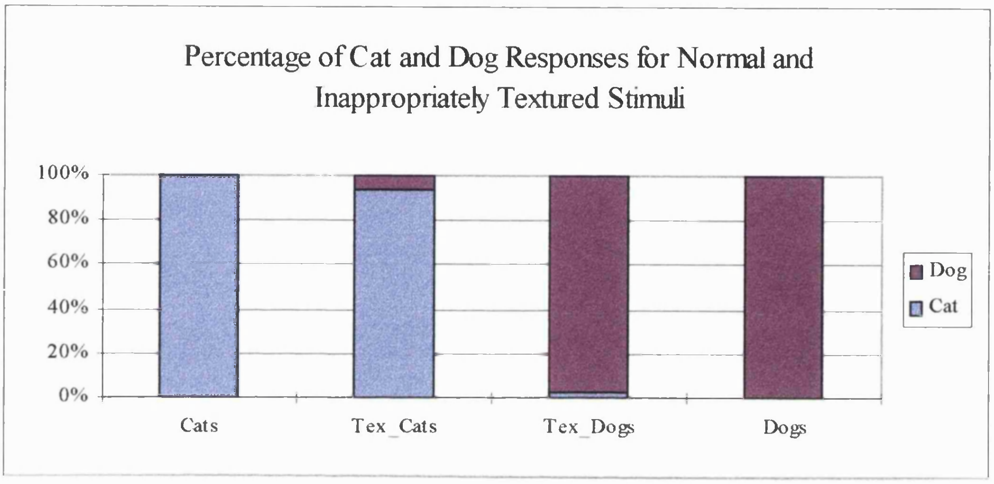


Figure 39. Experiment 16: Percentage of responses for both normal and inappropriately textured stimuli.

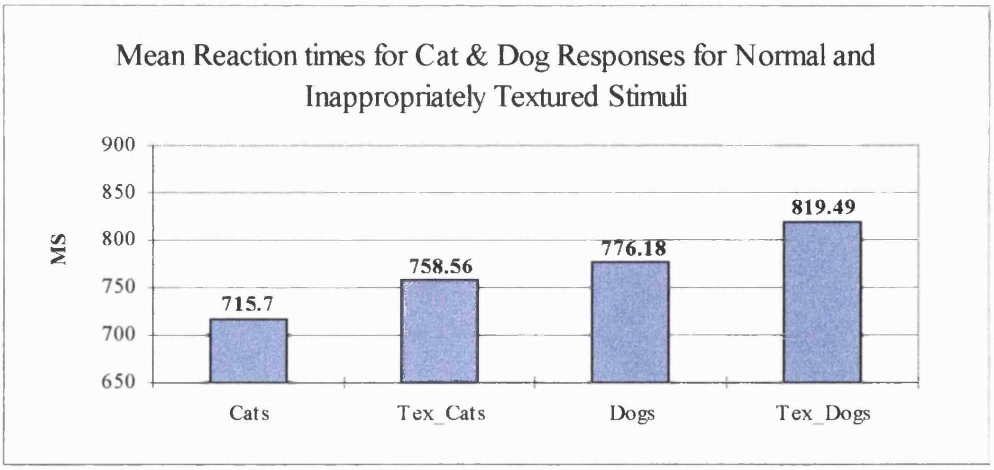


Figure 40. Experiment 16: There are no significant differences in the mean reaction times across the various category types.

5.4 General Discussion

The present studies were undertaken to investigate the role of visual texture in categorisation. Furthermore, the experiment with infants looked at whether texture information was a sufficient perceptual cue for forming subordinate categories. The results revealed this to be so in the case of cats and dogs. In order to generalise these findings however, infants need to be tested with a wider range of natural kind stimuli. Nevertheless, when infants are familiarised to either cats or dogs, and then shown two novel, within-category exemplars, the only perceptual cue differentiating them being visual texture, infants show a marked preference for the stimulus with the novel texture. This is a somewhat surprising finding given that forming subordinate categories is thought to be a relatively late developmental process. It should be noted, however, that these results do not suggest that infants do begin to form more fine-grained categories by 4-months of age. It is simply suggestive that their perceptual abilities are in place to do so, and that there are perceptual cues inherent in the stimuli, which permit making such fine-grained distinctions. In other words, the perceptual differences that the infants noticed does not necessarily entail them having made a category difference.

Adult subjects were tested with the same appropriately and inappropriately textured stimuli. In the first adult experiment, typicality judgements were obtained for the stimuli. Although this experiment was not equivalent to the infancy experiment, in that within-category learning was not investigated, by obtaining similarity ratings I demonstrated that when the stimulus' predominant visual texture is similar between the focus object and that of its target category members, it is judged to be a better member of that category than when the visual texture pattern is dissimilar. The reaction time data from the 2-alternative forced-choice task with adults indicated that the same perceptual cues, used in this task, are not used during a similarity-based categorisation task. This is not to say that subjects did not perceive the texture differences, but simply that they did not allow such differences to influence their decisions. However, caution should be exercised here. A small stimulus set from only two homogeneous categories was used. As such, further experimentation using a broader range of natural kind stimuli from within different categories should be conducted before these results can be fully generalised to explain the role of texture cues in categorisation. Nevertheless, comparing the results of the two adult experiments, it is possible to hypothesise that perception as used during categorisation may be a dynamic process which changes relative to task demands. Evidence for perception as a dynamic process can be found in the object recognition literature. Basic-level categorisations are usually made more rapidly than subordinate categorisations. However, Schyns (1998) argues that experts can recognise subordinate objects as rapidly as basic-level ones. On this account perceptual expertise changes the defining perceptual cues needed for making rapid classifications. In other words, perceptual learning occurs as a function of expertise. Infants first rely on highly diagnostic perceptual information in forming basic-level categories. As both their vision and experience with objects develop, they are able to make use of less perceptually diagnostic properties. Adults use the object cues that are appropriate for the task.

If texture is a sufficient perceptual property for making within-category distinctions, as shown by the infancy study, then it is of interest to determine why it is not always used for making less inclusive category decisions, such as at the basic-level. Object recognition research has revealed that shape almost always supersedes colour and texture cues (Schyns, 1998; Biederman, 1989; see Smith & Jones, 1992 for a developmental perspective). For making basic-level categorisations, attending to different dimensional aspects may be sufficient. It is only when a more fine-grained category decision has to be made that object discrimination based on spatial texture patterns will ensue. It could be postulated that a perceptual system that attended to more fine-grained dimensions of an object, such as texture, before making a category decision would be at a disadvantage to a system that could stop at dimensional processing when needed.

My argument is not that texture is the only perceptual property for differentiating objects at the subordinate level. Rather, attending to such fine-grained perceptual properties may be one way to establish, retain, and associate conceptual structure to perceptual realities. Given the results reported in this chapter, i.e., that both infants and adults are able to selectively assign greater weighting to different perceptual properties in different contexts, then it is possible to speculate that such a mechanism is crucially important for developing categorisation skills in general.

– oOo –

Chapter 6

6.1 Introduction

The experiments reported in this thesis were designed for the purpose of investigating the ways in which the head and body properties of cat and dog stimuli are categorised by both infants and adults. The stimuli were restricted to the cat and dog categories so as to minimise changes across the different tasks and age groups, and ensure that the stimuli would be familiar to all infants prior to the experiments. The intention was to assess the role of perceptual information in the categorisation process. The specific aims included making inferences pertaining to the time course of categorisation, the role of diagnostic perceptual information, and the development of categorisation processes from infants to adults. The experimental findings are summarised in section 6.2. In section 6.3 experimental and methodological issues, such as cross-experimental manipulations and comparisons between infant and adult data, are discussed. This is followed in section 6.4 by a consideration of the nature of the stimuli used and the extent to which the results found with them can be generalised to categorisation of other animal kinds. Finally, in section 6.5 the implications and scope of a face-first model of categorisation for animal kinds are considered.

6.2 Summary of Experimental Findings

In Experiments 1, 2, and 3 (reported in Chapter 2), a preferential looking task was conducted with 4-month old infants. The purpose of this set of experiments was to investigate the perceptual cues infants use to differentiate cats from dogs. In particular, I sought to ascertain whether different properties of cats and dogs are used for forming categorical representations as a function of processing time. Infants were familiarised to either cats or dogs for a set period of time (10-seconds in Experiment 1, 15-seconds in Experiment 2, and 20-seconds in Experiment 3). Following familiarisation, 2 preferential looking tests were conducted. One of the test trials paired a novel familiar category stimulus with a novel category stimulus (Whole Animal test). This was to ensure that the infants were able to form a category for either cats or dogs that excluded the other. The other preference test trial paired two hybrid stimuli, one with a head from the novel category and a body from the familiar category, and the other with a head from the familiar category and the body from the novel category. If the infants looked longer at the hybrid with the novel head / familiar body, then it was argued that this would go some way to confirm that infants form categorical representations of cats and dogs on the basis of head / face information, as argued by Quinn and Eimas (1996). However, if the infants looked significantly longer at the hybrid stimulus with the familiar head / novel body, then it was suggested that body information can also be used in the categorical formation of cat and dog categories. However, the new hypothesis that I introduced argued that whether infants demonstrate a preference for head / face information or body information might be a function of exposure duration. Across all three experiments, in the Whole Animal test the infants always showed a preference for the novel stimulus. However, the results were not unanimous across the three hybrid tests trials. When familiarisation time was 10-seconds the infants showed a significant preference for the hybrid with the novel head; when familiarisation time was increased to 15-seconds infants looked equally at both hybrid stimuli. However, when familiarisation time was increased to 20-seconds, the results of the preferential test trial showed that the infants now looked significantly longer at the hybrid stimuli with the novel body. Although a cross-experimental design was used, the results can be interpreted as suggesting that when processing time is limited infants perceive and process the highly differentiated head / face information. Contrary to others' claims that this is the only way that infants process categories, my experiments showed that by increasing processing time infants incorporate the less differentiated body information in their representations of cats and dogs. This means that exposure duration plays an important role in on-line categorisation processes in infants. There are other possible interpretations, but these will be discussed in section 6.4.

Chapters 2 and 3 consisted of 9 experiments relating to whole and hybrid stimuli in different configurations. Three of these were typicality judgement experiments (Experiments 4, 7, and 10), and five were 2-alternative-forced-choice tasks in which subjects' reaction times and binary choices were recorded (Experiments 5, 6, 8, 9, and 11). These experiments used hybrid cat and dog stimuli in which the heads and bodies of cats and dogs were juxtaposed. Experiments 4 and 5 employed the same hybrid stimuli as used with the infants. In experiments 7 and 8 the parts of the hybrids were scattered. In Experiments 9 and 10 only the outlines of the stimuli were used. In Experiments 6 and 11 isolated head and body parts were presented in normal (Experiment 6) or outline only (Experiment 11) formats.

The typicality experiments required subjects to rate a stimulus on a 9-point scale where '9' represented a dog, '1' a cat, and '5' neither a cat nor a dog. In Experiment 4 where subjects viewed normal cats, normal dogs and hybrids, the mean rating for cats and dogs tended towards the extremes of the scale. Hybrids were rated at the midpoint of the scale with those hybrids with the head of a cat being rated significantly more toward the 'cat' end of the scale, and those the head of a dog being rated significantly more towards the 'dog' end of the scale. This suggested that subjects gave head information higher weighting than body information in the categorisation task. This result was repeated in Experiment 7 where the stimuli were split up into their constituent parts. However, when only the outlines of the stimuli were shown (Experiment 10), the whole cat and whole dog stimuli were rated at the appropriate extreme ends of the scale, but subjects did not distinguish the two types of hybrid which were both rated at the midpoint. These results were discussed in terms of head and facial information being given the highest weighting in categorisation tasks, but with body information also contributing a significant weighting. It was furthermore suggested that subjects' inability to differentiate the hybrid outlines indicated that it is the facial configuration, rather than simply the head, that is the dominant attribute for categorising cats and dogs. This set of experimental results teased apart some of the finer details of how categorisation decisions are made that previous work has tended to confound.

The forced-choice experiments were designed not only to show which stimulus properties were the most highly weighted in a specific categorisation task, but also to reveal through comparison of reaction times whether other attributes are also processed during rapid categorisation. For example in Experiment 5 where subjects rated cats, dogs and the two types of hybrids as either cat or dog, the category judgement was always based on the head of the stimulus. Reaction times were significantly longer for the hybrid than for the whole normal stimuli. When, in Experiment 8 the stimulus parts were scattered, the head of the stimulus determined subjects' judgement of category membership, but reaction times for the hybrid stimuli were no slower than for the normals. This suggests that the configuration of body parts is more diagnostic than individual body part elements of a given animal category. In Experiment 9 the outlines of whole and hybrid stimuli were used. The whole cat and dog stimuli were correctly categorised, but for the hybrids there was no evidence for a higher weighting for head properties. Furthermore, reaction times were 50% higher. Experiments 6 and 11 demonstrated that subjects could make correct category judgements when (1) heads, and (2) bodies were shown alone even when the stimuli were only shown in outline (Experiment 11). In both cases, however, reaction times were significantly lower for heads than for bodies. The evidence from these experiments was used to support a postulated time course of categorisation, which is compatible with models of the categorisation time course such as EGCM-RT in which a subjects' response can vary as a function of processing time (Lamberts, in press).

In Chapter 4 exposure duration was manipulated in an attempt to effect the perceptual processing of the cat, dog, and hybrid stimuli. A standard old-new recognition paradigm was employed. In the trial phase subjects were presented with a series of normal whole cat, whole dog stimuli and hybrid stimuli for either 2000 ms (Experiment 12) or 500 ms (Experiment 13). They were then presented with a number of the previously seen stimuli as well as new stimuli and asked to make a 2-alternative-forced-choice decision as to whether or not they remembered having seen each stimulus item in the trial phase. The d-prime calculations revealed that in both experiments subjects were able to distinguish previously seen stimuli from new stimuli, even if only a part of a stimulus was old. However, the reaction time data indicated that it was only when presentation time was 2000 ms that body and head information was encoded. This was not the case when presentation time was reduced to 500 ms. The results were taken to provide further evidence for the view that 2000 ms is not only sufficient time in which to process highly-diagnostic perceptual information, but also to encode some of the less diagnostic perceptual properties. When the exposure duration is reduced to 500ms there is only sufficient time to process the highly-diagnostic perceptual information. This provides evidence that exposure duration plays a critical role in adult categorisation, even though the nature of the tasks prevents a direct comparison with the manipulation of exposure duration in infant preferential looking studies.

In Chapter 5 I investigated whether texture cues could be used in the categorisation of cats and dogs. Specifically, I sought to determine whether texture could be a useful cue for differentiating between perceptually similar members within the same category. Three experiments were conducted, one with 4-month old infants (a preferential-looking study, Experiment 14), and two studies with adults (a typicality confidence rating study, Experiment 15, and a 2-alternative-forced-choice task, Experiment 16). In the preferential-looking task infants were presented with normal cat or normal dog stimuli during a 20-second familiarisation trial. They were then immediately presented with a novel familiar category animal, i.e., either a normal cat or dog, paired with a familiar category abnormally textured cat or dog. The results revealed a preference for the novel stimuli, i.e., the abnormally textured stimuli. This was interpreted as suggesting that in the case of cat and dog animal kinds, visual texture may be one of the perceptual cues that infants use in the development of subordinate categories.

As before, the typicality judgement task required that subjects rate each stimulus item on a 9-point scale where '9' represented a dog, '1' a cat, and '5' neither a cat nor a dog. In Experiment 15 where subjects viewed normal cats, normal dogs and abnormally textured cats and dogs, the mean rating for normal cats and dogs tended towards the extremes of the scale. The abnormally textured cats and dogs were rated more towards the midpoint of the scale with the abnormally textured cats being rated significantly more toward the 'cat' end of the scale, and the abnormally textured dogs being rated significantly more towards the 'dog' end of the scale. This was taken to suggest that in the case of cat and dog stimuli, the texture of these objects' surfaces might be a relevant property in determining the degree of their category membership.

The final experiment (Experiment 16) employed a 2-alternative-forced-choice task in an attempt to determine whether or not texture is a key feature, or highly diagnostic property of either the cat or dog categories. Subjects were asked to rate the normal cats and dogs and the abnormally textured cats and dogs as either belonging to the category of cats of dogs. Unsurprisingly, given the limited response choices, subjects were shown to assign the correct category labels to the various categories. Thus, there was no way of knowing from the correctness of responses whether the texture of the stimuli influenced the subjects' category decisions, without examining the reaction time data. Inspection of the reaction time data, however, revealed no significant differences across the different stimulus types. These findings were interpreted as suggesting that the texture cues that were used in the similarity-based typicality task were not used in making category decisions in the forced-choice task, even though the texture differences between the stimuli may have been perceived. Overall the results show that in all the instances tested thus far head/face properties have a greater weighting than body information in categorisation tasks and are hence the determining factor in subjects forced-choice and typicality responses. However analysis of reaction times and typicality ratings indicates that other properties have a weighting that is significantly different from zero. It is suggested that less diagnostic properties are incorporated into an object representation over time in order not only that more detailed representations be formed, but also that subordinate categories can be learned.

6.3 Experimental and Methodological Issues

Throughout this thesis a number of methodological issues have arisen which require further consideration. The scope of this thesis was to examine the relationship between the ways in which infants and adults categorise animal natural kinds. However, the experimental design used to measure the categorisation abilities of infants necessarily differed from those used with adult subjects. All of the experiments with infants made use of a familiarisation / preferential looking technique. The basis of this procedure relies on measuring the preferences infants show for novel stimuli (Fantz, 1964), and has been demonstrated to be a reliable tool for measuring the categorisation abilities of young infants within the domain of vision and audition. To recap, the standard preferential looking procedure consists of showing the infants a number of exemplars from within a single category, and then giving them a preference test where both stimuli are new, but one is a new exemplar from the familiar category and the other an exemplar from a novel category. To test for preferences, the differential looking-times of the infants are measured. Extended looking-time for the stimuli from the novel category is taken to suggest that the infant has formed a representation of the familiar category and recognises the new exemplar from the familiar category as familiar and the one from the novel category as new. Although this technique has been repeatedly shown across numerous laboratories across the world to be reliable (see chapter 2), the standard procedure does have some limitations. Infants have a short attention span; they get tired and hungry and are unable to concentrate for prolonged periods of time. These factors pose further problems when the aim of the experiment involves measuring the effect that different familiarisation times have on categorisation, as was the case in this thesis. When the effect of exposure duration is analysed across experiments with different groups of subjects, rather than within a single experiment with a single group of subjects, there is the in principle problem of exposure duration being confounded with the order of study. Ideally it would have been best to have a run a block design experiment, rather than a cross-experimental design. However, the nature of the task together with the very young age of the subjects made this impossible for the following reasons. A block design experiment takes a considerable amount of time to run. With adults this is not normally a problem. However, 4-month old infants have a limited attention span and will not stay still for prolonged periods of time. There is also a high drop-out rate within an infancy experiment. As well as the usual factors of tiredness and lack of concentration, the recruitment procedure takes a considerable amount of time. Often mothers are recruited very soon after the birth of their child and frequently change their mind about allowing their infant to be tested by the time they are due to come in. Additionally, limited resources and facilities which are shared by a large number of people (as was the case at the MRC Cognitive Development Unit), means that researchers are restricted in the number of infants that can be brought in for testing in any one week. Inevitably babies have to be brought in at different times of the year. Consequently, it is necessary to manipulate variables between experiments as well as employing indirect measures of babies' responses to stimuli. In order to surmount these problems to the greatest extent possible, the experimental conditions across the infancy experiments reported in this thesis were kept very constant. Given that research has shown that running a cross-experimental design gives similar results to within-subjects design, it is unlikely to be a factor in explaining the differences in the preferential looking effect across the infancy experiments (Spelke, 1995; Baillargeon, 1994). Nevertheless, to entirely rule out all such provisos further empirical testing is required.

Another methodological issue is related to the nature of the adult experiments. Firstly, the studies carried out on adult subjects were either 2-alternative-forced-choice or typicality experiments. The nature of the typicality tasks differed from the standard typicality design. Normally, a standard typicality experiment involves asking subjects to rate how typical a given item is as a member of a particular category. For example, a subject might be asked to rate on a scale from '1' to '9' how typical a rose is of the flower category. However, this basic design was unsuitable for the experiments in this thesis, given that a number of the stimuli were made up from parts of animals belonging to two different categories. This was why it was essential to use a bipolar scale confidence-rating task where subjects were asked to rate whether a stimulus was more typical of an item from one category or another. Although this differed from a normal typicality task, Rosch and Mervis (1975) have shown that results from confidence rating tasks are very similar to those obtained in standard typicality tasks. When subjects generate lists of property attributes for an object, they do so by contrasting it with other objects (Tversky and Hemenway, 1984). Rosch and Mervis (1975) found that there is a correlation between the attribute lists subjects generate and the typicality ratings assigned to the objects depending on whether or not they have these attributes. Therefore, a bipolar contrast scale, as used in this thesis, should elicit similar responses to a standard typicality task. The results of these typicality bipolar contrast scale tasks indicated significant evidence of inter-experiment reliability. For example, the normal cat stimuli were always rated between 1.4 and 1.8 and the normal dog stimuli were always rated between 8.2 and 8.8, even though in two of the typicality experiments the normal cat and dog stimuli were either split into their constituent parts or were outlines. This suggests a consistency across the experiments indicative of a robust methodology.

The aim of this thesis was to investigate the categorisation abilities of infants and adults, and the effect of timing on the categorisation process. Therefore, it was necessary to make comparison between the results of the infancy studies with those of the 2-alternative-forced-choice adult studies where reaction times were measured. However, there was a crucial difference between the two paradigms. In the 2-alternative-forced-choice tasks, inspection time was not directly manipulated, whereas in the preferential-looking tasks it was. Although the adult subjects were asked to make a category decision as quickly as possible, the stimulus remained on the screen until a response was made. As such, it was not possible to directly compare the course of processing that adults engaged in when accessing pre-existing representations of the categories and the category representations that infants form as a function of exposure duration, without further empirical testing taking these considerations into account. In Chapter 4, however, exposure duration was manipulated with the use of a standard old / new paradigm. Although recognition tasks differ from the prototypical set of categorisation tasks, Estes and Maddox (1995) have argued that in a recognition task subjects still make a categorisation judgement on the stimuli, and as such they can be considered a special case of categorisation. However, in the experiments reported here a cross-experimental design was employed, and therefore it is not appropriate to generalise the results in terms of an overall time dependency effect without further empirical testing using a broader range of stimuli.

Forced-choice and typicality methodologies are predicated on a specific distinction between diagnosticity and differentiability. Throughout this programme of research I have suggested that head/face information is more diagnostic of cat and dog category membership than body properties. Although I have not argued that these properties can necessarily be generalised as being diagnostic of other animal category members, I have argued that the head/face properties are not simply the most differentiable, but that they are also the most diagnostic properties for categorising cats and dogs. There is a clear distinction between those properties that permit one to categorically differentiate objects, and properties that are diagnostic of category membership. For example, the presence of thorns on the stem of a plant may be highly diagnostic of the genus of plant (rose versus gardenia). Differentiable properties make obvious a difference between objects. However, they are not necessarily sufficient for making category membership decisions. A red flower is visually very dissimilar to a yellow flower and as such they are highly differentiable, but the property of colour is not *necessarily* diagnostic of the genus of plants to which the two flowers belong.

A further consideration of the methodology concerns the experiments in Chapter 5 examining the role of texture in categorisation. A preferential-looking study was conducted with 4-month old infants to test whether infants use texture cues when forming representations of categories. However, it is only possible to estimate what the stimuli look like to a young infant. Visual abilities change developmentally. At birth, the retinal cone cells of infants are not fully developed and they cannot transmit fine-grained spatial information. However, Anker, Atkinson, Braddick, Ehrlich, Hartley, and Wade (1997), have shown that there are a lot of texture differences that young infants can perceive even with very low visual acuity. Therefore, even though there may be a difference in the degree to which 4-month old infants and adults can perceive the texture differences between the stimuli, the low spatial frequency information is sufficient to make such differences potentially noticeable even for very young infants. An additional consideration is the limited stimulus set. The role of texture cues on categorisation was measured using a small set of stimuli from only two homogeneous categories: cat and dog. Therefore, it is only possible to speculate about the importance of texture cues in the categorisation of natural animal kinds and further studies are necessary using a broader range of stimuli from a number of different natural kind categories to make more extensive generalisations about the role of texture in categorisation processes.

Finally, throughout this thesis, comparisons between 2-alternative-forced-choice and typicality tasks have been made. I have argued that there are two main differences between the tasks. First, a 2-alternative-forced-choice task is faster simply because subjects are presented with only two response choices. The typicality rating scale used gave subjects a choice of 9 possible responses. Second, a typicality judgement task requires that subjects give a confidence rating of the "catness" or "dogness" of each stimulus. In contrast, rather than having to assess all the appropriate properties which contribute to a stimulus' "catness" or "dogness" the 2- alternative forced-choice task does not require subjects to go beyond the most diagnostic properties of the stimuli.

6.4 Generalisability of Results

It is necessary to consider how the results of the infancy experiments can be compared with the results of the adult experiments and subsequently to categorisation in general. The findings raise two questions. First, what inferences can be drawn from the infant preferential-looking tasks, and how do these relate to the adult 2-alternative-forced-choice and typicality rating tasks? Second, to what extent can the interpretation of the data with cat and dog stimuli can be extended to other animal kinds?

In all of the infancy studies, inspection time was manipulated. In the 2-alternative-forced-choice and typicality experiments with adults, it was not. It is therefore necessary to consider how it is possible to compare the time course of categorisation of infants and adults. The manipulation of familiarisation time in Experiments 1, 2 and 3 indicated that exposure duration may influence which perceptual properties of cat and dog stimuli are given greater weighting by infants in forming categories of these stimuli. Although timing was not directly manipulated in the majority of the adult studies, I argued that the reaction times measured for adult categorisation tasks give an indication of those object properties which are assigned a greater weighting in the categorisation process.

While a subject's response in a 2-alternative-forced-choice task can indicate which property is assigned the highest weighting, analysis of reaction times can show whether this judgement is reached rapidly or more slowly. The former suggests that a particular property had a much higher weighting than another or reached random walk critical threshold (Lamberts, in press) much sooner; the latter that other properties had weightings not greatly different from the critical property. Of course, this is not the unequivocal interpretation of a longer reaction time, but it is consistent with the interpretation of the infant data, and with the adult typicality results. For example, where reaction times to hybrids in cat/dog 2-alternative-forced-choice tasks are longer than those to whole cats or dogs, so typicality ratings are more intermediate. While in both cases it is clear that it is the head or facial feature which determine category membership, both the longer reaction times and the intermediate typicality rating are suggestive of other properties influencing subject responses.

One difficulty of interpretation arises through the use of natural kinds as stimuli. Even though only two types of animal natural kinds were employed, the total number of possible properties of each that could be considered categorically diagnostic is very large, and it is difficult to determine precisely what these are. Studies in which interpretation of reaction times is more direct typically employ restricted artificial categories, in which there are a specific number of controlled properties which precisely determine category membership (Nosofsky, 1986; Nosofsky & Palmeri 1997; Lamberts in press). However, to ensure ecological validity between the infant and adult studies it was crucial to employ the same cat and dog stimuli to both groups. While the data presented here are clearly indicative that heads are the most diagnostic properties for both infants' and adults' categorisation of cats and dogs, in order to generalise this result to the categorisation of other natural kinds, further experimentation would be required.

The stimuli used throughout the experimental programme were digitally manipulated photographic images of cats and dogs. These two animal kinds were purposely chosen because there are a very large number of distinctive examples of them at the basic level. For example, poodles, labradors and dachshunds are all readily categorised as members of the class dog, yet are highly distinctive from each other. Had, say, tigers been employed, it is not clear that there would be a very large number of distinctive within-category members. The same rationale applies to cats as to dogs. Furthermore both cats and dogs are probably the most familiar domestic animals, they are readily apparent in all forms of child- and adult-oriented media, and they also have a large number of correlated attributes in common.

If the experiments were to be repeated, for example, with horses and cows instead of cats and dogs, it might be anticipated that reaction times in 2-alternative-forced-choice tasks might be longer for cow/horse hybrids than whole cows or horses, yet this difference might not be as great as that between hybrid and whole dogs or cats. This difference will depend on the weighting assigned to different animal properties in the categorisation process.

While it is only possible to determine empirically the precise weighting of different animal properties in categorisation tasks for each species or kind, it might be predictable from the cat and dog data that there will be the same pattern for other mammalian quadrupeds with distinctive facial characteristics. What is clear is that although it is not possible to make definite cross-species generalisations, the methodology employed in this thesis can distinguish not only what property is most diagnostic in categorisation, but can also give an indication of the extent to which other properties influence the categorisation process, in a pattern of typicality ratings, increased reaction times, or, for infants, differences in preferential looking.

It is also not possible to determine the precise process which occurs during categorisation in either infants or adults. The present findings could for example be used to support, for example, Lamberts' EGCM-RT (in press) or, Nosofsky and Palmeri's EBRW (1997), or even a much simpler threshold model. What can be demonstrated is the extent to which the less diagnostic properties influence the categorisation process. In the instance of cat and dog stimuli, precisely what these properties are, have necessarily to be defined at the general level because the focus has been principally on the head/face and body, the outline of these, and the configuration of the body parts.

Another question arises: to what extent can the results reported here be generalised to other tasks? In the adult experiments, subjects were given very specific tasks to perform. It might be argued that making a forced choice decision between cat and dog for a given stimuli is artificial, and not representative of the way objects are categorised in normal circumstances. For example, subjects might learn to adopt a strategy of only considering the head of each stimulus, in order to make their response as rapid as possible (i.e., in order to satisfy the experimental demands). However, the pattern of reaction times in the 2-alternative-forced-choice tasks is indicative of an immutable perceptual-categorisation process, because even if subjects attempt to consider only the head/facial information in a stimulus, the longer reaction times for hybrids suggest that they cannot but help take into account other stimulus properties such as the body, or body part configuration.

The results of the forced choice experiments also help illuminate the process underlying the typicality rating tasks. It is not the case that the 9-point typicality task is a simple extension of the (effectively) 2-point forced choice task, since subjects must take some consideration of *similarity* into account. This is not an artificial situation however (where a stimulus is quickly rated as either 1-cat or 9-dog, with points added or deducted for a-typical properties such as an ill-fitting body, or an inappropriate stance), because the 2-alternative-forced-choice reaction time data demonstrate that subjects take into account the a-typical properties automatically, whether they need to or not.

A case can therefore be made that the categorisation process is immutable in adults. This makes a valid comparison with the infant data more straightforward. The infants do not have a fixed task to perform, and the experimenter cannot control whether they actively consider the stimuli, or passively view them, nor even for how long they are focussed on during an exposure. But, the difference in preferential looking as a function of exposure duration suggests that the longer the looking time, the more properties of a stimulus must be encoded in a categorical representation. In other words, even when an adult viewer need only categorise on the basis of a single property, atypical properties are also processed and influence reaction time. This is comparable with infants looking more at less diagnostic properties (albeit over a much longer time span) when given the opportunity (via longer exposure duration) to do so.

6.5 Implications and Scope

The experimental findings suggest that both infants and adults categorise cats and dogs on the basis of head and facial information. In this section I address the issue of whether it is possible to conclude, therefore, that basic-level animal kind categorisation is "face first". This means that the face property (be it face shape or sub-feature configuration) comes first in the competition between stimulus properties to determine object categorisation. This should not be confused with rapidity of perceptual processing. In a number of studies, Quinn & Eimas (1996, 1997) have presented a body of evidence demonstrating the importance of facial information in the categorisation of cats and dogs by 4-month old infants. There are indications, however, that whether or not facial information determines infants' categorisation of cats and dogs may be a function of presentation time (Quinn & Eimas, 1996; Vidic et al, 1996). In this thesis I examined this hypothesis by varying exposure duration during the familiarisation process.

When, in the infant preferential looking tasks (Experiments 1-to-3, Chapter 2), stimuli were presented for only 10-seconds in the familiarisation phase, infants looked longer at the novel head of the hybrid in the subsequent test phase. For a familiarisation time of 15-seconds there was no clear pattern of infants' looking preferences. For the longest familiarisation time of 20-seconds the preference was for the novel body of the hybrid test stimulus. This indicates that the shorter the exposure duration, the fewer properties an infant can be familiarised to. It is clear from this data that the first property to be encoded is the face / head.

The evidence for adults making use of a "face first" categorisation strategy is equally compelling. In all the typicality experiments, it was the head/face of a stimulus which determined the confidence of category membership. The only exception to this was when the stimuli were presented as outlines alone, suggesting that it is the configuration of facial elements which is the critical property. When subjects were forced to categorise an ambiguous stimulus as either a cat or a dog, a hybrid with a cat's head was always categorised as a cat; a hybrid with a dog's head was always categorised as a dog. When the parts of a hybrid were scattered, it was always the head that determined a subject's response. Only when the stimuli were presented in outline alone was there uncertainty in subjects' responses – both types of hybrid were categorised at chance. It is not the case that "face first" relies on the scanning artifact of heads being at the top of an image, since when the parts were scattered, faces were used wherever in the image they were located. It is possible that faces dominate because they contain sufficient information for categorisation within a small area, while bodies may require integration of information over a much larger area: the size of the attentional focus might be tuned for a face-first categorisation model. Furthermore, the face is likely to be a preferred stimulus because it gives other information such as emotion, direction of gaze, and so on. Additionally, a "face first" model of categorisation may have implications beyond understanding patterns of classification. For example, it has been suggested that a possible reason for a large number of humans having phobias for insects and snakes is a result of being unable to use the same visual cues in the categorisation process. Having to categorise a creature on visual aspects such as texture or number of legs because the eyes, nose, and mouth are not clearly visible results in a feeling of discomfort (Hawton et al, 1992).

What do the present findings show about the categorisation process? The experiments were not designed to determine the *process* of categorisation, but rather, what properties determine its outcome. The data show what property is used to determine category membership, but also that other properties influence subjects' reaction times, even when they do not influence a forced choice response. This is consistent with models of categorisation (e.g., Lamberts in press) in which many properties are processed (taken into account), but it is only one that "wins" the categorisation threshold race, depending on how rapidly it is processed, and how close it is in perceptual space to the corresponding property of a stored representation.

In both infants and adults, then, there is evidence that information spurious to a basic level categorisation is encoded. This was demonstrated by the results of the 20-second familiarisation task in infants, and the typicality and reaction time data in adults. Furthermore, when abnormal textures were applied to the stimuli, infants always looked to a novel texture. The abnormal texture distanced a typicality rating for a stimulus from its normally textured counterpart.

Categorisation needs to extend beyond the basic level, in order that discrimination be made within a basic level, such as between breeds of the basic level dog. We might care to interpret rapid, basic-level categorisation in terms of fleeing responses, and slower, more intricate responses, (leading to more abstract categorisation), in terms of a more planning-based orientation, involved in higher cognitive function and more subtle social cues. Going beyond diagnostic information permits the building of hierarchies, and of subordinate levels, gleaning more detail about the object. In the case of animals this involves learning to recognise emotions useful for social purposes, and therefore giving rise to greater cognitive flexibility. Going beyond the diagnostic makes for a richer cognitive system.

The experiments reported here focussed on infant and adult responses, and demonstrated similarities between the two, despite the inevitable methodological differences between them. In order to specify a more precise developmental process, more age groups will now have to be studied on the basis of the foundation that my findings laid. There is also limited evidence from which to generalise from the dog and cat stimuli used in these experiments, to other mammalian quadrupeds. As such, to determine more precisely the relative role of head and body information in the categorisation of animal natural kinds, a far broader range of stimuli needs to be employed in the next stage of empirical work.

The evidence for the effect of stimulus exposure duration on the categorisation process requires further substantiation with further within-experiment designs which can be made to satisfy the constraints of an infancy study. This also needs to be studied over developmental time, in order to more fully compare the initial and steady state of the categorisation development process.

In order to explain why less diagnostic information is incorporated over time in terms of forming within-category representations (i.e., why infants pick up on texture differences), a greater range of potential within-category properties at a variety of hierarchical levels require testing.

Most categorisation studies look at the development of the basic level and superordinate level (e.g., Quinn, Eimas, & Rosenkrantz, 1993; Quinn & Eimas, 1997; Mandler, 1997). What remains for future research is an empirical consideration of how less diagnostic properties are encoded, in order to form subordinate level categories. For example, infancy research shows that by 4-months of age infants are able to form basic-level perceptual categories that appear to be remarkably similar to the basic-level categories of adults (e.g., Quinn, Eimas, & Rosenkrantz, 1993; Quinn & Eimas, 1997). Mandler (1997) has argued that by 9-months of age infants categories are more global in nature and no longer correspond to the basic-level ones made earlier in infancy. The apparent discrepancy in categorisation abilities is claimed to be evidence of different types of categorisation: conceptual representations as opposed to perceptual representations. Mandler claims that there is an important distinction between the perceptual categories that young infants form and the representations that permit thinking and inference. She is doubtful that the progressive enhancement of perceptual associations will eventually result in forming concepts, and posits a separate mechanism that can extract meaning via a process of perceptual analysis. Her argument is that forming superordinate-level category representations is not really a perceptual process. While perceptual processing may be sufficient for basic level categorisation, and more abstract processing for superordinate levels, the further subordinate level may be satisfied purely by perceptual cues. In other words, it might be necessary to re-represent perceptual data for the superordinate level, in order to form conceptual categories (such as, bird *flies)*, but this is not necessarily the case for the subordinate level, where cues may be subtle, secondary, or more slowly processed, but still perceptual in nature (such as, lions having sharp teeth). Moreover, given that both between-category and within-category discrimination are essential for the development of fully-fledged categorisation skills, further consideration of both the perceptual and abstract processing involved is required. The present study has furthered our knowledge of infant and adult categorisation processes and has laid the foundations for future studies of this fascinating area of human cognition.

– oOo –

References

Adler, S. A. (1997). Selective integration of temporally distinct perceptual information in infant memory. *Infant Behavior and Development.* Vol. **20(1):** 3-28.

Atran, S. (1996). *From folk biology to scientific biology.* Oxford, England UK: Blackwell Publishers.

Baillargeon, R. (1994). How do infants learn about the physical world? *Current Directions in Psychological Science*, Vol. **3(5):** 133-140.

Barsalou, L. W. (1987). The instability of graded structure: Implications for the nature of concepts. In Neisser, U. (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Emory symposia in cognition, 1. (pp. 101-140). New York, NY, USA: Cambridge University Press.

Barsalou, L. W., & Sewell, D. R. (1985). Contrasting the representation of scripts and categories. *Journal of Memory and Language.* Vol. **24(6):** 646-665.

Barsalou, L.W. (1983). Ad hoc categories. *Memory & Cognition*, Vol. **11,** 211-227.

Bauer, P. J., Dow, G. A., & Hertsgaard, L. A. (1995). Effects of prototypicality on categorization in 1- to 2-year-olds: Getting down to basic. *Cognitive Development.* Vol. **10(1):** 43-68.

Behl-Chadha, G. (1996). Basic-level and superordinate-like categorical representations in early infancy. *Cognition.* Vol. **60(2):** 105-141.

Behl-Chadha, G., Eimas, P. D., & Quinn, P. C. (1995). *Perceptually driven superordinate categorization by young infants.* Paper presented at the meeting of the Society for Research in Child Development. Indianapolis, Indiana.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review.* Vol. **94(2):** 115-117.

Biederman, I. (1989). "Recognition-by-components: A theory of human image understanding": Clarification. *Psychological Review.* Vol. **96(1):** 2.

Bolhuis, J. J., Johnson, M. H., & Horn, G. (1985). Effects of early experience on the development of filial preferences in the domestic chick. *Developmental Psychobiology,* 1985, Vol. **18(4):** 299-308.

Bomba, P. C., & Siqueland, E. R. (1983). The nature and structure of infant form categories. *Journal of Experimental Child Psychology.* Vol. **35(2):** 294-328.

Bringham, J.C. (1986). The influence of race on face recognition. In H.D. Ellis, M.A. Jeeves, F. Newcombe, & A.W. Young (Eds.), *Aspects of face processing*, Dordrecht: Martinus Nijhoff.

Brooks, L. R. (1987). Decentralized control of categorization: The role of prior processing episodes. In Neisser, U. (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Emory symposia in cognition, 1. (pp. 141-174). New York, NY, USA: Cambridge University Press.

Brooks, L. R., Norman, G. R., & Allen, S. W. (1991). Role of specific similarity in a medical diagnostic task. *Journal of Experimental Psychology: General,* Vol. **120**, 278-287.

Bruce, C. J., Desimone, R., & Gross, C. G. (1986). Both striate cortex and superior colliculus contribute to visual properties of neurons in superior temporal polysensory area of macaque monkey. *Journal of Neurophysiology.* Vol. **55(5):** 1057-1075.

Bruce, V. (1988). *Recognising faces.* Lawrence Erlbaum Associates.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). *A study of thinking.* NY, John Wiley and Sons.

Caan, W.; Perrett, D. I.; Rolls, E. T. (1984). Responses of striatal neurons in the behaving monkey: II. Visual processing in the caudal neostriatum. *Brain Research.* Vol. **290(1):** 53-65.

Carey, S. (1985). *Conceptual change in childhood.* Bradford books.

Clark, E. V. (1983). "Meanings and concepts." In Flavell, J. & Markman, E. (Eds.), *Handbook of child psychology.* Vol. **3.** New York: Wiley.

Cohen, B., & Murphy, G. L. (1984). Models of concepts. *Cognitive Science.* Vol. **8(1):** 27-58.

Cohen, L. B., & Strauss, M. S. (1979). Concept acquisition in the human infant. *Child Development.* Vol. **50(2):** 419-424.

Cohen, L. B., & Younger, B. A. (1983). Perceptual categorization in the infant. In E.Scholnick (Ed.), *New trends in conceptual representation: Challenges to Piaget's theory* (pp. 197-220). Hillsdale, NJ: Erlbaum.

Colombo, J., Mitchell, D. W., Coldren, J. T., & Freeseman, L. J. (1991). Individual differences in infant visual attention: Are short lookers faster processors or feature processors? *Child Development.* Vol. **62(6):** 1247-1257.

Colombo, J., O'Brien, M., Mitchell, D. W., & Horowitz, F. D. (1987). A lower boundary for category formation in preverbal infants. *Journal of Child Language,* Vol. **14,** 383-385.

Cook, G. L., & Odom, R. D. (1992). Perception of multidimensional stimuli: A differential-sensitivity account of cognitive processing and development. *Journal of Experimental Child Psychology,* **54,** 213–249.

Davis, G., & Driver, J. (1994). Parallel detection of Kanizsa subjective figures in the human visual system. *Nature.* Vol. **371(6500):** 791-793.

Eimas, P. D., & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development.* Vol. **65(3):** 903-917.

Eimas, P. D., Quinn, P. C., & Cowan, P. (1994). Development of exclusivity in perceptually based categories of young infants. *Journal of Experimental Child Psychology.* Vol. **58(3):** 418-431.

Estes, W. K., & Maddox, W. T. (1995). Interactions of stimulus attributes, base rates, and feedback in recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Vol.21(**5**)**:** 1075-1095.

Evans, G. (1982). *The varieties of reference.* Oxford University Press.

Fagan, J. F. (1970). Memory in the infant. *Journal of Experimental Child Psychology,* Vol. **9**, 217-226.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention familiar patterns relative to novel ones. *Science.* Vol. **146 (Whole No. 3644):** 668-670.

Fodor, J. (1983). *The modularity of mind.* Cambridge: MIT Press.

Franks, B. (1995). Sense generation: A "quasi-classical" approach to concepts and concept combination. *Cognitive Science.* Vol. **19(4):** 441-505.

Gelman, R. (1986). Toward an understanding based theory of mathematics learning and instruction, or, in praise of Lampert on teaching multiplication. *Cognition and Instruction.* Vol. **3(4):** 349-355.

Gibson, E. J. (1969). *Principles of perceptual learning and development.* New York, N.Y., Appleton-Century-Crofts.

Gibson, J. J. (1966). The problem of temporal order in stimulation and perception. *Journal of Psychology.* Vol. **62(2):** 141-149.

Gibson, J. J. (1977). On the analysis of change in the optic array. *Scandinavian Journal of Psychology.* Vol. **18(3):** 161-163.

Gibson, J. J. (1979). *The ecological approach to visual perception.* Boston: Houghton-Mifflin.

Goldstone, R. L. (1994). Influences of categorization on perceptual discrimination. *Journal of Experimental Psychology: General,* Vol. **123**, 178-200.

Goldstone, R. L. (1998). Perceptual learning. *Annual Review of Psychology.* Vol. **49:** 585-612.

Goldstone, R. L., & Medin, D. L. (1994). Time course of comparison. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Vol. **20(1):** 29-50.

Goldstone, R. L., & Barsalou, L. W. (1998). Reuniting perception and conception. *Cognition.* Vol. **65,** 231-262.

Goodman, N. (1972). *Problems and Projects.* Indianapolis: Bobbs-Merrill Company.

Haaf, R. A., Brewster, M., de Saint Victor, C. M., & Smith, P. H. (1989). Observer accuracy and observer agreement in measurement of visual fixation with fixed-trial procedures. *Infant Behavior & Development,* Vol. **12**, 211-220.

Hamlyn, D. W. (1961). *Sensation and Perception: A history of the philosophy of perception.* London, Routledge & Keegan Paul.

Hampton, J. (1993). Prototype models of concept representation. In Van Mechelen, I., & Hampton, J. (Eds.), *Categories and concepts: Theoretical views and inductive data analysis.* Cognitive science series. (pp. 67-95). London, England UK: Academic Press, Inc.

Hawton, K., Salkovskis, P. M., Kirk, J., & Clark, D. M. (1992). Cognitive Behavioural Therapy for Psychiatric problems: a practical guide. Oxford University Press. Oxford.

Hummel, J. E., & Biederman, I. (1992). Dynamic binding in a neural network for shape recognition. *Psychological Review* , Vol. **99**, 480-517.

Johnson, M. H. (1992). Imprinting and the development of face recognition: From chick to man. *Current Directions in Psychological Science.* Vol. **1(2):** 52-55.

Johnson, M. H., & Horn, G. (1988). Development of filial preferences in dark-reared chicks. *Animal Behaviour,* Vol. **36(3),** 675-683.

Johnson, M. H., & Morton, J. (1991). *Biology and Cognitive Development.* Cambridge, MA: Blackwell.

Johnson-Laird, P. N. (1987). The mental representation of the meaning of words. *Cognition.* Vol. **25(1-2):** 189-211.

Jones, S. S., & Smith, L. B. (1993). The place of perception in children's concepts. *Cognitive Development,* Vol. **8(2)**, 113-139.

Kahneman, D., & Miller, D. T. (1986). Norm theory: Comparing reality to its alternatives. *Psychological Review.* Vol. **93(2)**: 136-153.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development.* Cambridge, MA, USA: MIT Press.

Keil, F. C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In Hirschfeld, L. A., & Gelman, S. A. (Eds.) *Mapping the mind: Domain specificity in cognition and culture.* (pp. 234-254). New York, NY, USA: Cambridge University Press.

Lamberts, K. (1994). Flexible tuning of similarity in exemplar-based categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Vol. **20(5):** 1003-1021.

Lamberts, K. (1995). Categorization under time pressure. *Journal of Experimental Psychology: General.* Vol. **124(2):** 161-180.

Lamberts, K. (1997). Process models of categorization. In Lamberts, K., & Shanks, D. (Eds.), *Knowledge, concepts and categories.* Psychology Press.

Lamberts, K. (in press). The time course of categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Lamberts, K., & Brockdorff, N. (1997). Fast categorization of stimuli with multivalued dimensions. *Memory and Cognition.* Vol. **25(3):** 296-304.

Lamberts, K., & Freeman, R. P. J. (in press). Categorizing briefly presented objects. *Journal of Experimental Psychology: Human Perception and Performance.*

Livingston, K. R.., & Andrews, J. K. (1995). On the interaction of prior knowledge and stimulus structure in category learning. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology.* Vol. **48A(1):** 208-236.

Lockhead, G. R. (1972). Processing dimensional stimuli: A note. *Psychological Review.* Vol. **79(5):** 410-419.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review.* Vol. **95(4):** 492-527.

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology.* Vol. **22(1):** 1-35.

Logan, G. D. (1992). Shapes of reaction-time distributions and shapes of learning curves: A test of the instance theory of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Vol. **18(5):** 883-914.

Logan, G. D., & Etherton, J. L. (1994). What is learned during automatization? The role of attention in constructing an instance. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* Vol. **20(5):** 1022-1050.

Lowe, D. G. (1985). Further investigations of inhibitory mechanisms in attention. *Memory and Cognition.* Vol. **13(1):** 74-80.

Mandler, J. M. (1988). How to build a baby: On the development of an accessible representational system. *Cognitive Development.* Vol. **3(2):** 113-136.

Mandler, J. M. (1992). How to build a baby: II. Conceptual Primitives. *Psychological Review*, Vol. **99**, 587-604.

Mandler, J. M. (1997). Representation. In D. Kuhn & R. Siegler (Eds.), *Cognition, perception, and language,* Vol. 2 of W. Damon (Series Ed.), Handbook of child psychology. New York: Wiley.

Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development,* Vol. **8**, 291-318.

Mandler, J. M., Bauer, P. J. (1988). The cradle of categorization: Is the basic level basic? *Cognitive Development.* Vol. **3(3):** 247-264.

Marr, D. (1982). *Vision.* San Francisco: W. H. Freeman.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word-recognition. *Cognition.* Vol. **25(1-2):** 71-102.

Marslen-Wilson, W. D., Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology.* Vol. **10(1):** 29-63.

McClelland, J. L., & Rumelhart, D .E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review.* Vol. **88(5):** 375-407.

McCloskey, M. & Glucksberg, S. (1978). Natural categories: Well-defined or fuzzy sets? *Memory & Cognition,* Vol. **6**, 462-472.

Medin, D. L., & Ortony, A. (1989). Psychological essentialism. In Vosniadou, S., & Ortony, A. (Eds.), *Similarity and analogical reasoning.* (pp. 179-195). New York, NY, USA: Cambridge University Press.

Medin, D. L., & Schaffer, M. M. (1978). Context theory of classification learning. *Psychological Review.* Vol. **85(3):** 207-238.

Mervis, C .B., Johnson, K. E., & Scott, P. (1993). Perceptual knowledge, conceptual knowledge, and expertise: Comment on Jones and Smith. *Cognitive Development.* Vol. **8(2):** 149-155.

Mervis, C. B. (1987). Child-basic object categories and early lexical development. In Neisser, U. (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Emory symposia in cognition, 1. (pp. 201-233). New York, NY, USA: Cambridge University Press.

Murphy, G. L. (1991). Parts in object concepts: Experiments with artificial categories. *Memory and Cognition,* Vol. **19**, 423-438.

Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review,* Vol. **92**, 289-316.

Neisser, U. (1987). From direct perception to conceptual structure. In Neisser, U. (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Emory symposia in cognition, 1. (pp. 11-24). New York, NY, USA: Cambridge University Press.

Nosofsky, R. M. (1986). Attention, similarity, and the identification-categorization relationship. *Journal of Experimental Psychology: General,* Vol. **115(1)**, 39-57.

Nosofsky, R. M. (1991). Tests of an exemplar model for relating perceptual classification and recognition memory. *Journal of Experimental Psychology: Human Perception and Performance,* Vol. **17**, 3-27.

Nosofsky, R. M. (1991). Typicality in logically defined categories: Exemplar-similarity versus rule instantiation. *Memory and Cognition.* Vol. **19(2):** 131-150.

Oakes, L. M., Coppage, D. J., & Dingel, A. (1997). By land or by sea: The role of perceptual similarity in infants' categorization of animals. *Developmental Psychology.* Vol. **33(3):** 396-407.

Odom, R. D., & Cook, G. L. (1996). Valuing of identity, distribution of attention, and perceptual salience in free and rule-governed classifications. *Journal of Experimental Child Psychology,* **61,** 173–189.

O'Neill, J. M., Jacobson, S. W., & Jacobson, J. L. (1994). Evidence of observer reliability for the Fagan Test of Infant Intelligence (FTII). *Infant Behavior and Development.* Vol. **17(4):** 465-469.

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. D., & Jeeves, M. A. (1984). Neurones responsive to faces in the temporal cortex: Studies of functional organization, sensitivity to identity and relation to perception. *Human Neurobiology,* Vol. **3**, 197-208.

Pinker, S. (1997). *How the mind works.* New York, NY, USA: W. W. Norton and Co, Inc.

Quine, W. V. (1969). 'Natural Kinds'. In Quine, W. V. *Ontological relativity and other essays.* (pp. 114-138). Columbia, New York.

Quine, W. V. (1977). Natural kinds. In Schwartz, S. P. (Ed.), ***Naming, necessity, and natural kinds.*** Cornell University Press, Ithaca, NY, pp. 35-59.

Quinn P. C., & Eimas, P. D (1996). Perceptual cues that permit categorical differentiation of animal species by infants. *Journal of Experimental Child Psychology,* Vol. **63,** 189-211.

Quinn, P. C., & Eimas, P. D. (1986). On categorization in early infancy. *Merrill-Palmer Quarterly,* Vol. **32,** 331-363.

Quinn, P. C., & Eimas, P. D. (1997). A reexamination of the perceptual-to-conceptual shift in mental representations. *Review of General Psychology.* Vol. **1(3):** 271-287.

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception*, Vol. **22(4):** 463-475.

Rakison, D. H., & Butterworth, G. E. (1998). Infants' use of object parts in early categorization. *Developmental Psychology,* Vol. **34(1):** 49-62.

Reeves, A., & Sperling, G. (1986). Attention gating in short-term visual memory. *Psychological Review.* Vol. **93(2):** 180-206.

Rips, L. J. (1989). Similarity, typicality, and categorization. . In Vosniadou, S., & Ortony, A. (Eds.), *Similarity and analogical reasoning.* (pp. 21-59). New York, NY, USA: Cambridge University Press.

Rips, L. J., & Collins, A. (1993). Categories and resemblance. *Journal of Experimental Psychology: General.* Vol. **122(4):** 468-486.

Roberts, K., & Cuff, M. D. (1989). Categorization studies of 9- to 15-month-old infants: Evidence for superordinate categorization? *Infant Behavior and Development.* Vol. **12(3):** 265-288.

Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General,* Vol. **104**, 192-233.

Rosch, E. (1978). Principles of categorisation. In E. Rosch & B. B. Llyod (Eds.), *Cognition and Categorisation*. Hillsdale, NJ: Erlbaum.

Rosch, E., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology,* Vol. **7,** 573-605.

Rosch, E., Mervis, C. B., Gray, W., Johnson, D. & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, Vol. **8**, 382-439.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Vol. **13**, 501-518.

Schyns, P. G. (in press). Diagnostic recognition: Task constraints, object information, and their interactions. *Cognition.*

Schyns, P. G., & Murphy, G. L. (1994). The ontogeny of part representation in object concepts. In Medin, D. L. (Ed.), *The psychology of learning and motivation: Advances in research and theory,* Vol. **31,** (pp. 305-349). San Diego, CA, USA: Academic Press, Inc.

Schyns, P. G., Goldstone, R. L, & Thibaut, J. (1998). Development of features in object concepts. *Behavioral and Brain Sciences.* Vol. **21,** 154.

Slater, A. M. (1995). Visual perception and memory at birth. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research,* Vol. **9**, (pp. 107-162). Norwood, NJ: Ablex.

Smith, E. E., & Osherson, D. N. (1984). Conceptual combination with prototype concepts. *Cognitive Science.* Vol. **8(4):** 337-361.

Smith, E. E., Shoben, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review.* Vol. **81(3):** 214-241.

Smith, J. D. (1990). Analytic and holistic processes in categorization. In Shepp, B. E., & Ballesteros, S. (Eds.), *Object perception: Structure and process* (pp. 297-323). Hilsdale, NJ: Erlbaum.

Smith, J. D., & Shapiro, J. H. (1989). The occurrence of holistic categorization. *Journal of Memory and Language.* Vol. **28(4):** 386-399.

Smith, L. B. (1989). A model of perceptual classification in children and adults. *Psychological Review.* Vol. **96(1):** 125-144

Smith, L. B. (1993). The concept of same. In Reese, H. W. (Ed.), *Advances in child development and behavior,* Vol. **24,** (pp. 215-252). San Diego, CA, USA: Academic Press, Inc.

Smith, L. B., & Heise, D. (1992). Perceptual similarity and conceptual structure. In Burns, B. (Ed.), *Percepts, concepts and categories: The representation and processing of information.* Advances in psychology, Vol. **93,** (pp. 233-272). Amsterdam, Netherlands: North-Holland.

Smith, L. B., & Jones, S. S. (1993). Cognition without concepts. *Cognitive Development.* Vol. **8(2):** 181-188.

Spelke, E. S. (1994). Preferential looking and intermodal perception in infancy. *Infant Behavior & Development,* Vol. **17(3):** 285-287

Spencer, J. (1997). *Timing effects in categorisation.* In proceedings of Similarity and Categorisation: An interdisciplinary workshop on similarity and categorisation. University of Edinburgh, UK.

Spencer, J., Quinn, P. C., Johnson, M. H., & Karmiloff-Smith, A. (1997). Heads you win, tails you lose: evidence for young infants categorizing mammals by head and facial attributes. *Early Development and Parenting, special issue on Perceptual Development.* Vol. **6,** 113-126.

Sperber, D., & Wilson, D. (1995). *Relevance: Communication and cognition* (2nd ed.). Oxford, England UK: Blackwell Publishers, Inc.

Sugimura, T., & Inoue, T. (1987). Categorization modes in young children and adults. *Japanese Journal of Educational Psychology.* Vol. **35(4):** 357-362.

Tanaka, J .W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology.* Vol. **46A(2):** 225-245.

Tanaka, J .W., & Gauthier, I. (in press). Expertise in object and face recognition. In Goldstone, R. L., Schyns, P., & Medin, D. (Eds.), *Mechanisms of perceptual learning.* New York: Academic Press.

Thompson, L. A. (1994). Dimensional strategies dominate perceptual classification. *Child Development,* **65,** 1627–1645.

Tsal, Y., & Lavie, N. (1993). Location dominance in attending to color and shape. *Journal of Experimental Psychology: Human Perception and Performance.* Vol. **19(1):** 131-139.

Tversky, B., & Hemenway, K. (1984). Objects, parts and categories. *Journal of Experimental Psychology: General,* Vol. **113**, 169-193.

Vidic, J. M., Haaf, R. A., Loboschefski, T. W. (1996). *Four-month-old infants categorization of animals: What roles do body parts play?* Presented at the International Conference on Infant Studies, Providence, RI, April, 1996.

Weinberger, N. M. (1993). Learning-induced changes of auditory receptive fields. *Current Opinion in Neurobiology,* Vol. **3**, 570-577.

Wertheimer, M. (1959). *Productive thinking.* NY, Harper.

Wilkening, F., & Lange, K. (1987). When is children's perception holistic? Goals and styles in processing multidimensional stimuli. In T. Globerson & T.

Zelniker (Eds.), *Cognitive style and cognitive development.* Norwood, NJ: Ablex.

Wilson, H. R., Levi, D., Maffei, L., Rovamo, J., & DeValois, R. (1990). The perception of form: Retina to striate cortex. In: Spillmann, L., & Werner, J. S. (Eds.), *Visual perception: The neurophysiological foundations.* (pp. 231-272). San Diego, CA, USA: Academic Press, Inc.

Wittgenstein, L. (1953). *Philosophical investigations. Philosophische Untersuchungen.* NY, Macmillan.

Younger, B. A. (1990). Infants' detection of correlations among feature categories. *Child Development,* Vol. **61**, 614-620.