Prototype effects in high functioning children with autism

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Background: This thesis represents the application of cognitive psychology, specifically phenomena reported in the concepts and categorisation literature, to autism research. The studies reported here tested the claim that prototype formation and therefore prototype effects are impaired in autism (Klinger & Dawson, 2001). The claim is supported by other theories: weak central coherence (Frith, 1989; Frith & Happé, 1994) and a reduced perception of similarity (Plaisted, 2001). Additionally, supporting evidence suggests that individuals with autism do not show prototype effects (Klinger & Dawson, 2001; Plaisted, O'Riordan, Aitken, & Killcross, Submitted). **Method:** There were three studies each with two participant groups: high-functioning children with autism and a matched control group of typically developing children. The first study used stimulus cards to test whether prototype effects were shown in recognition memory (Experiments 3.1 - 3.3). The second used dot pattern stimuli presented on computer to compare the influences of recognition and categorisation on prototype effects (Experiment 4.1). The final study used stimulus cards to investigate the influence of ambiguity on children's categorisation responses (Experiments 5.1 - 5.3). **Results:** The majority of participants with autism demonstrated prototype effects similar to those of controls in all three studies. Other findings reported for the autism groups were reduced visual recognition memory for old, meaningless stimuli (Experiment 4.1) and reduced category membership decisions (Experiment 5.3). **Conclusion:** The convergence of experimental findings showed that most children with autism do show intact prototype effects. These findings limit the theoretical claims presented earlier. The discussion (Chapter 6) also summarises suggestions for future research into visual recognition memory and category membership decisions. Finally it is argued that a major implication of the research presented in this thesis together with other relevant findings is that considerable instability exists (on whether or not participant group differences are shown) both with the demonstration of prototype effects and in the perception of similarity. It is argued that elucidating the causes of instability in the latter is a priority for future research.

CHAPTER 1 – Autism and the psychological theories of autism: their characteristics

1.1 What is autism?

The first descriptions of autism

By reference to early psychiatric literature, historical accounts, myths and legends, Frith (1989) makes a cogent case that the constellation of characteristics, now referred to as autism, has existed for centuries. However, autism and the closely related condition, Asperger syndrome (AS) were not delineated until the early 1940s. Working independently, Kanner (1943) and Asperger (1944, 1991) published case studies of children, that each author viewed as constituting a new and hitherto undefined syndrome. Both Kanner and Asperger emphasised the pervasive social difficulties. For example, when children visited Kanner's office, they completely ignored all other people in the room and headed straight for the toys and objects that caught their interest. In a similar vein, Asperger commented on the tendency of the children to act on their own impulses and interests without concern for the social consequences. His case studies detail many examples of the ensuing conflict within both family and school environments. Both Kanner and Asperger observed numerous other features: Both were struck by a lack of eye contact, stereotypies (repetitive movements) and resistance to change. There are also contrasts between the accounts. For example, Asperger's cases possessed fluent and communicative language, whereas Kanner's cases had little useful language. There is also some indication that Asperger's cases were more intellectually able: He commented on their capacity for abstract thought. Kanner, instead, emphasised the rote learning skills of the children that he observed. Asperger also commented on the clumsiness of his cases – both at the level of gross motor co-ordination (used in school sports)

and fine motor co-ordination (used in handwriting). However, Kanner, whilst observing a clumsy gait in some of his cases, specifically highlighted their manual dexterity.

Coincidentally and perhaps misleadingly, Asperger and Kanner both described their cases as autistic, a term coined to describe an entirely distinct psychiatric disorder: schizophrenia (Bleuler, 1911). Bleuler used the term to convey a sense of shutting off from the environment as well as the predominance of an inner mental life. Kanner's use of the name autism has remained in place to refer to cases that resemble his. In contrast, the syndrome that Asperger described later came to bear his name.

The diagnosis of autism and AS

According to Happé and Frith (1996) autism has formed a distinct psychiatric category since it was first included in an internationally agreed diagnostic system: the Diagnostic and Statistical Manual of Mental Disorders, 3rd edition (DSM III) published by the American Psychiatric Association (APA, 1980). This innovation followed converging evidence that suggested that Kanner's observations constituted a distinct syndrome (e.g. Rutter, 1978). An influential study carried out by Wing and Gould (1979) provided further justification for viewing autism in this way. These researchers studied all children, within a former London borough, who possessed either learning difficulties, or any of the autistic features described by Kanner, or both. Wing and Gould observed that a "triad" of impairments in socialisation, communication, and imagination tended to co-occur in classic "Kanner-type" cases thus reinforcing the notion of an autistic syndrome. The study went further in demonstrating that this triad occurred in a wider sample of children.

Additionally, the researchers recorded considerable heterogeneity in how impairments were expressed. For example, children exhibited social abnormalities in different ways: some were withdrawn and aloof, others showed unusual passivity, and others were socially active but in an inappropriate manner.

The study also gave rise to the notion of an autistic continuum. Wing and Gould observed a great range in ability amongst individuals possessing the "triad of symptoms". These ranged from individuals with serious intellectual and physical disabilities to whom social impairments were an additional problem through to very able individuals with subtle social deficits. Happé and Frith (1996) point out that the concept of a triad informed the next update of the DSMIIIR (APA, 1987). Asperger's original paper received little research interest until Wing's (1981) review and case studies. It was not until the latest version of the DSM-IV, APA, (1994) and the International Classification of Diseases (ICD-10, World Health Organisation, 1993) that AS has been included as a separate diagnostic category.

Both autism and AS are located within a wider spectrum of pervasive developmental disorders (DSM-IV, APA, 1994). These are loosely described as having severe and pervasive impairments in the development of social and communicative functions or displaying stereotyped patterns of behaviour or interest. Furthermore, such abnormalities are usually observable in the first few years of life. In common with other psychiatric disorders, autism and AS are diagnosed according to behavioural criteria. These still reflect some of the central observations made by Kanner and Asperger. Both DSM-IV and ICD-10 diagnostic criteria for autism and AS require observed abnormality in reciprocal social interaction. This might include, for example, "a failure to develop peer relationships appropriate to developmental level." (pp. 70&77, DSM-IV). Additionally, both diagnostic systems require the

presence of stereotypies, repetitive behaviour, or restricted interests. An example of these would be an, "apparently inflexible adherence to specific, non-functional routines or rituals." (pp. 71&77, DSM-IV). The diagnostic systems state an additional necessary requirement for the diagnosis of autism: a qualitative impairment in communicative language. This might include, "stereotyped and repetitive use of language or idiosyncratic use of language." (p.70, DSM-IV). Also, it is necessary for delays or abnormalities to be present before 3 years of age in a least one of the three following areas: social interaction, communicative language, or symbolic play. In contrast, the criteria for AS state that there should be no (clinically significant) abnormalities or delays in these areas. Additionally, there is no requirement for impairments in communicative language.

In practice, the use of the ICD-10 and DSM-IV to differentiate between AS and higher functioning autism (HFA) can be highly problematic. The following two examples to illustrate this point will be taken from the DSM-IV because the provision of extra guidelines appears to make it the stronger of the two for differential diagnosis:

Example 1: There are cases for which the guidelines are self-contradictory. The DSM-IV states a default rule: An AS diagnosis is not made if criteria are met for autism. It also states that the lack of language delay associated with AS distinguishes the disorder from autism. This means that all individuals who meet the criteria for both disorders should receive a diagnosis of autism. However, a subset of these individuals without language delay should simultaneously receive an additional diagnosis of AS. Herein lies the conflict: for the diagnostic schedules do not admit dual diagnosis!

Example 2: If any candidate meets the criteria for both AS and autism and possesses any delay or abnormalities in the functions of communicative language, social interaction, or play (before age 3) the application of the above mentioned default rule will result in a diagnosis of autism. Therefore, even though the criteria for AS state delays in functioning must not reach clinical significance, in practice it is necessary to demonstrate that development in these key areas is completely typical. The difficulty lies in establishing this. Usually, parents supply relevant information on early development. Gillberg and Ehlers (1998) discuss the inherent difficulties in relying on parental report for establishing normality in language development. Parents may either not notice or remember abnormalities and delays: particularly the more subtle ones. The same points apply to the other areas of functioning.

The lack of delineation provided by the diagnostic systems reflects current controversy in the field over the differential diagnosis of AS from HFA. Some authors regard AS and HFA as separate disorders, (Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Rhinehart, Bradshaw, Brereton, & Tonge, 2001; Rhinehart, Bradshaw, Moss, Brereton, & Tonge, 2000, 2001). Others such as Wing (1998) and Miller and Ozonoff (2000) conclude that there is no evidence to justify regarding the two syndromes as separate disorders. (This is discussed further in Chapter 2.)

Aetiology and Epidemiology

The prevalence of autism depends on which diagnostic criteria are used. According to Wing (1993), the incidence of classic "Kanner-type" autism has remained similar to the first epidemiological study: at about 4.5:10,000 (Lotter,

1966). The wider spectrum of autistic disorder, as defined by Wing's (1988) triad, is much more prevalent. This is estimated at about 1 per 1000 (Gillberg & Coleman, 2000). The incidence of AS in school-age children appears to be somewhat higher, estimated as 3-5 per 1000 (Gillberg & Coleman, 2000). The gender ratio for both disorders is striking. More males than females are affected and population studies indicate that the boy: girl ratio for both disorders is very similar: between 3:1 and 4:1 (Gillberg & Coleman, 2000). Another characteristic associated with autism is the additional presence of learning disabilities (defined by an IQ below 70) in 75% of cases (Lockyer & Rutter, 1970; Wing, 1993).

Initially, it was believed that autism was the result of a damaged personality structure caused by adverse parenting (Bettelheim, 1967; Kanner, 1949). However, the prevalence of associated learning difficulties (Lockyer & Rutter, 1970) and a high incidence of epilepsy (Rutter, 1970) pointed to a biological cause. In keeping with the biological view is the fact that the most consistent evidence to date suggests that autism is largely genetic in origin. In support of this assertion, Rutter (1999) cites studies comparing the concordance rates of monozygotic (identical) twins with those of dizygotic (fraternal) twins (Bailey et al., 1995; Steffenburg et al., 1989). The following concordance rates refer to the percentage of twin-pairs where both twins received a diagnosis of autism. The concordance rates for the monozygotic twins ranged from 60 to 91%. In contrast, concordance rates for the dyzogotic twins were 0%. Thus, it appears that a predisposition for autism increases dramatically with an increase in genetic material shared with an affected other.

1.2 The psychological theories of autism

Preface

The psychological study of autism has spanned just over six decades. This has been sufficient time for major paradigm shifts to occur in the study of the mind. These shifts in turn have been reflected in theorising about autism. Psychodynamic models were predominant in the late 40s and 50s. In Section 1.1, mention has already been made of two theoretical viewpoints influenced by these: the psychogenic theories of autism (Bettelheim, 1967; Kanner, 1949). The domination of the psychodynamic models floundered on a lack of empirical evidence and the behaviourist models of the 1960s and 1970s superseded these. The application of these theories to autism involved the use of operant conditioning to both study and change behaviour (e.g. Ferster, 1961; Jensen & Womack, 1967; Lovaas, Schreibman, Koegel, & Rehm, 1971; McConnell, 1967). Behaviourism's neglect of the mind eventually triggered the third paradigm shift, dubbed the "cognitive revolution" (Gardner, 1985).

The following review will focus on theories of autism developed with this cognitive approach as the prevailing theoretical backdrop. This backdrop can be roughly characterised by Gardner's list of key features possessed by cognitive science. Some of these are as follows: Cognitive scientists by necessity posit their own distinct level of analysis: that of mental representations, described in the form of symbols, rules, schemata, and images, for example. These are not observable but are deduced from the relations between input (in the form of sensory stimuli) and output (behaviour). Additionally, in cognitive science human thought is seen as a form of information processing with the computer playing a central role as a model for this. The discipline is characterised by an attempt to partition out the influences of affect,

behavioural and mental context, and historical and cultural influences. Gardner also cites interdisciplinary work as another feature of cognitive science. He gives the example of linguistic processing that has drawn upon evidence from psychology, neuroscience, and artificial intelligence.

The reader may observe from the following review that the theories vary considerably in the extent to which they have been influenced by the cognitive revolution. Some such as the theory of mind (TOM; Baron-Cohen, Leslie, & Frith, 1985) and executive function deficits (Russell, 1997) with their emphasis on cognitive deficits, firm information processing viewpoint, and interdisciplinary roots reflect a strong influence. At the other end of the spectrum, it is arguable whether Hobson's theory (1982, 1989, 1993) with its emphasis on viewing cognition, affect, and conation as a unitary whole, as well as its focus on inter-personal relatedness, belongs within the cognitive revolution at all. None the less, Hobson's theory has been included within this review as an influential contemporary of the other theories. The primary purpose of this review is to introduce the theories and only brief mention is made of empirical evidence.

Theories of autism within the cognitive revolution: A proliferation of basic level 'deficits'

The title of this section is derived from the fact that each theory outlined here has, as a unique defining characteristic, one or more particular abnormalities of function which are considered "basic". The word *basic* here is used in one of the senses that Hobson (1993) used the word meaning a primary cause of several secondary features of autism. The first account to be covered here is that of Hermelin and O'Connor (1970). They built upon earlier research in the 1960s and

1970s that indicated a deficit in autism in the cognitive skills of sequencing and abstraction. After completing a series of experiments with a lower functioning autism (LFA) group, (i.e. those with learning disabilities), Hermelin and O'Connor concluded that the thought processes and memory of children with autism were less dependant upon meaning than children without autism. They proposed that a cognitive deficit involving abstraction or conceptual inference lay behind the observed behavioural and social abnormalities.

Rutter (1999) pointed out that researchers at this time became aware of the necessity of looking at possible ways in which such a cognitive deficit might lead to abnormalities in social reciprocity and social functioning. One approach to understanding the social difficulties was provided by Hobson (1982, 1989, 1993). Hobson argued from clinical experience that individuals with autism were lacking a particular biologically innate capacity: namely the ability to directly perceive, empathise with, and respond to the observable communicative cues given out by other people. He also argued that such inability prevents individuals with autism forming interpersonal relations, and this lack of subjective experience then causes a lack of understanding of the minds of other people. Hobson's account is unique with respect to the theories discussed here because of his emphasis on considering conation, affect, and cognition jointly when considering autism. Another unique feature of Hobson's account is that he believed that the basic units of analysis should include the nature of interpersonal interaction as well as the individual's thoughts, beliefs, and feelings.

Another account of social abnormalities was provided by the TOM hypothesis (Baron-Cohen et al., 1985). This represented an integration of theoretical and empirical work from philosophy, primatology, and developmental psychology.

Premack and Woodruff (1978) first introduced the phrase "theory of mind" in their study of non-human primates. They argued that in order to predict and explain the behaviour of others it is necessary first to be able to attribute mental states to self and others. To have this ability is to possess a TOM. Dennett (1978) and Pylyshyn (1978) both commented that a capacity to form second order representations (e.g. "C believes that E believes that p", Dennett, 1978, p. 569) was a prerequisite for a TOM. Leslie (1987) developed earlier work in specifying a computational model of meta-representational development. This specified a mechanism by which the ability to form second order representations developed. According to Leslie such a capacity does not emerge, during typical development, until about two years of age. In addition, Leslie argued that this capacity was necessary for pretend play and eventually developed into a TOM.

Baron-Cohen et al. (1985) noted the lack of pretend play, the social difficulties of children with autism, and the fact that these impairments appeared to be independent of IQ. They hypothesised that this pair of impairments had a common cause: specifically a lack of second order representations and a concomitant TOM. To test their hypothesis, Baron-Cohen et al. adapted a false belief task developed by Wimmer and Perner (1983). Baron-Cohen et al.'s version involved the enactment of a play with two doll protagonists. In the absence of one of the protagonists "Sally" a desired object (a marble) was moved from the location that "Sally left it in" to a new hiding place. The critical test question was designed to test ability to hold second order representations: "Where will Sally look for her marble?" (p. 41). Participants answered correctly if they managed to suppress their own knowledge of the marble's true location and take into account Sally's "false belief": that the marble was where "she had left it". Baron-Cohen et al. found that the

majority of LFA children failed the task whereas control groups with lower chronological ages (CAs) and mental ages (MAs) tended to pass. Hence, the authors concluded that individuals with autism have a particular cognitive deficit: a failure to employ a TOM.

In contrast to Hobson's and Baron-Cohen's focus on explaining the social abnormalities of autism, the advent of weak central coherence theory represented an attempt to account for the cognitive deficits in autism. Frith (1989) coined the term "central coherence" to refer to the natural human tendency to "draw together diverse information to construct higher-level meaning in context" (Frith & Happé, 1994, p. 121). Frith argued that this tendency is weakened in autism.

Supporting evidence spans a range of processing levels. For example, there is evidence of difficulty integrating high-level verbal semantic information. In Frith and Snowling's (1983) study, LFA children failed to use sentence context to disambiguate homographs. For instance, they tended to use inappropriate pronunciations of the word *bow* when reading the following sentences: "He had a pink bow" and "He made a deep bow". These findings have also been replicated with an HFA group (Happé, 1997).

Jolliffe and Baron-Cohen (2001) have reported an example of weak visuoconceptual coherence. They found that HFA and AS adults were impaired at an object identification task that required the ability to integrate object fragments conceptually. There is also evidence of weak visuospatial coherence. For example, LFA performance on the embedded figures task was superior to that of controls (Shah & Frith, 1983). This test requires the respondent to locate a simple geometric figure (e.g. a triangle) buried within a more complex figure (e.g. a picture of a pram).

Happé (1994) suggested the weaker central coherence possessed by the LFA group meant that they were less susceptible to the *gestalt* of the complex figure.

Additionally, Happé (1996) reported an example of difficulty with low-level perceptual integration: She found that LFA children tended not to succumb to visual illusions. Happé argued that these children failed to integrate the relevant parts of the figures with their "illusion-inducing context". However, Ropar and Mitchell (1999, 2001) failed to replicate this finding with three separate experiments. They found that children with autism and AS were susceptible to visual illusions. This was the case whether the participants responded verbally, as they did in Happé's study, or whether they responded manually. The latter required participants to press computer keys to alter shapes and lines to match a target. The leading explanation offered for the failure to replicate Happé's findings was that sub-groups existed within the autism population. Happé happened to sample a group that was immune to visual illusions whereas Ropar and Mitchell sampled groups that were susceptible to these effects. The moot issue then is which sub-group is the more representative of the autism population as whole. As Ropar and Mitchell (2001) pointed out, their findings could be seen as more representative because they tested more samples from the autism population.

The theories, discussed so far, have sought (at least initially) to account for secondary characteristics within a single domain: either social or non-social. One theory that from its outset extended to cover both social and non-social secondary deficits was the executive dysfunction hypothesis of autism (Russell, 1997). This proposed that a severe and early impairment in working memory resulted in pervasive deficits in abilities to plan and execute complex behaviour. Such behaviour, Russell argued, includes social concept formation, which requires the

integration of information within context and over time. Russell suggested that the notion of an executive dysfunction theory of autism "probably" arose first in the writing of Damasio and colleages (e.g. Damasio & Maurer, 1978). However, key papers triggering mainstream research interest in the area were not written until 1991, when three papers were produced.

Ozonoff, Pennington, and Rogers (1991) showed that executive measures were at least as good as TOM tasks in distinguishing an HFA group from controls. Ozonoff, Rogers, and Pennington (1991) compared HFA and AS participants on both TOM and executive function measures. They found again that the HFA group was deficient on both: however, the AS group was deficient on the executive function measure alone. Russell, Mauthner, Sharpe, and Tidswell (1991) tested LFA children, with control groups matched on verbal mental ages (VMAs) between 3 and 5 years, on a test of strategic deception. This task was adapted from one designed originally to test "TOM" in chimpanzees. Russell et al.'s (1991) task required the participant to "deceive" the experimenter by pointing to a false location for a salient and desirable item: a piece of chocolate. When the chocolate was visible to participants, the LFA group alone, tended to fail the deception task by pointing to the true location of the chocolate. Russell et al. (1991) observed the perseverative nature of this response: The LFA group persisted in pointing to the baited box despite repeated learning trials and corrective feedback. These authors argued that the TOM hypothesis was unable to account for the steadfast refusal of the LFA group to learn deceptive behaviour. Instead, Russell et al. (1991) suggested that failure on the task was really due to an inability to shift cognitive set away from the chocolate: a very salient stimulus. A follow up experiment, designed to compare directly these two hypotheses, confirmed this view (Hughes & Russell, 1993).

The only theory that straddles both social and non-social deficits at the basic level is the extreme male brain theory of autism (Baron-Cohen, 1999, 2002, 2003). An explanation of this theory starts with the study of gender differences. Baron-Cohen proposed two new dimensions of variability: *empathising* and *systemising*. Empathising is defined as the attribution of mental states to other people and the production of a reciprocal affective responses to that of others. Systemising is defined as the use of "if-then rules" to understand and predict the behaviour of variables within a system. Examples of systems include technical ones (e.g. computers), and abstract ones (e.g. mathematics). According to Baron-Cohen, these if-then rules have most explanatory power when applied to systems that are lawful, finite, and deterministic. Human behaviour possesses none of these characteristics and empathising is the best means of predicting it.

According to Baron-Cohen (2003), within the human population, the normal distributions of male and female systemising ability are slightly separated, with the male distribution shifted in the direction of high ability. Conversely, a similar separation of the population distributions occurs for empathising ability, with the female distribution shifted in the direction of high ability. These two dimensions, systemising and empathising, are used to create a taxonomy of "brain types". For example, an individual with a female brain (not necessarily a female) would show strength in empathising and weakness in systemising. Conversely, an individual possessing a male brain type (not necessarily a male) would show the opposite pattern, with strength in systemising and weakness in empathising.

Baron-Cohen (2002) suggested that autism could be characterised as the possession of a more exaggerated pattern of the male-brain, that is, the possession of extremely good systemising and extremely poor empathising. This notion originated

in the writings of Asperger (1944) who suggested that autism may represent an exaggeration of patterns of intelligence that are typically male. Baron-Cohen cites a variety of evidence suggesting that individuals with autism are worse at empathising than typical males. For example, on TOM tests girls out perform boys who in turn outperform LFA children (Happé, 1995). Also, children with HFA or AS are worse than males at recognizing faux pas (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). Additionally various pieces of evidence are cited for the superior systemising skills of individuals with autism. For example, obsessional interests displayed by children with autism represent tend to focus on topics that appeal more to males than females. Such topics are "closed systems" such as train spotting (Baron-Cohen & Wheelwright, 1999).

The final major area of study to be discussed here is the study of attentional deficits in autism. This line of enquiry has run like a thread along side and interacting with the other theoretical developments. As Barkley's (1996) brief review indicates, there are many definitions of attention. Many viewpoints converge in considering attention a function that selects certain processes or information from others for additional processing. Certain behavioural abnormalities observed in autism led researchers to consider attentional processes. These abnormalities include a tendency to fixate on small details of the environment to the exclusion of other information (Bryson, Wainwright-Sharp, & Smith, 1990) and a tendency towards perseverative behaviour (Russell et al., 1991).

In addition, the advent of the TOM theory has lead to interest in deficits in joint attention. This term describes the situation where two or more individuals are attending to the same phenomenon. Examples include following another's gaze and non-verbal communicative acts such as pointing and showing objects to others.

Leekam and Moore (2001) cite a number of studies demonstrating a lack of joint attention in children with autism (for example, Baron-Cohen, 1989; McEvoy, Rogers, & Pennington, 1993). Various explanations for this have been offered from within various theoretical perspectives. Hobson (1993) viewed the case of joint attention deficits as a primary deficit in intersubjective relatedness. Baron-Cohen et al. (1985) viewed the origins of the deficit as a purely cognitive one. The deficits prevent the child from forming the second order relations that are necessary for understanding the relationship between another person and the object holding that person's interest. This is viewed as part of a larger TOM impairment. An executive dysfunction explanation of the joint attention deficit instead suggests that the primary causes are problems in disengaging and shifting visual attention (Pennington & Ozonoff, 1996; Russell, 1996).

This concludes a brief overview of one of the overarching theoretical paradigms governing research into autism and some of the main theoretical areas within it. The next chapter will introduce another theoretical area upon which this thesis is based.

CHAPTER 2 – Prototype effects in autism: theory and method

2.1 Theory

The focus in Section 2.1 is on the study of concepts and categorisation in autism. This topic was briefly alluded to in Chapter 1 with the mention of Hermelin and O'Connor's work and their conclusion that many social and behavioural characteristics of individuals with autism may be attributable to a cognitive deficit in abstracting and using concepts. This topic will be discussed further after the following review of concepts and categorisation as reported in the mainstream literature.

Brief review of concepts and categorisation

The formation of concepts and how they are employed in categorisation has long been of interest to psychologists. The classical view of concepts dominated the field until the 1970s. (See Hampton, 1997, and Murphy, 2002, for a review.) This view held that concepts were represented by shared properties that were individually necessary and jointly sufficient to define the concept. For example, the defining properties of a square are that the item has a closed figure, four sides, sides of equal length and equal angles. Categorisation was thought to proceed by means of simple *if... then* rules. If, for example, a figure possessed all four properties listed above then it would be classified as a square.

In practice, attempts to list defining features for many concepts have proven unsuccessful (Smith & Medin, 1981). By the mid-1970s, it had become apparent that such a view does not describe adequately how many real-world categorisation decisions are made. For instance, people perceive typicality differences when making category membership decisions and tend to agree on which items are more

typical than others. For example, apples are rated as a better example of fruit than water melons (Rosch, 1975a). Such typicality effects are not predicted from the classical view under which category membership is regarded as either present or absent. Furthermore, the purported use of if ... then rules cannot account for evidence that category boundaries are 'fuzzy' (Medin & Smith, 1984; Rosch, 1978). On certain category membership decisions people disagree with each other and show inconsistency in their own decisions over time (McCloskey & Glucksberg, 1978). For example, for the category *furniture* participants disagreed with each other and showed inconsistency with their own decisions over time on items of intermediate typicality such as *bookends*. This was not found to be the case for typical items (e.g. *chair*) and non-category items (e.g. *cucumber*).

An alternative to the classical view was the idea that many categories are represented by prototypes (best examples of the categories) and that these provide a summary of information in the category (Rosch, 1975b). From this viewpoint the categorisation of novel exemplars is carried out on the basis of how similar an exemplar is to the relevant category prototype: the greater this similarity, the greater the probability of category membership (Rosch, Simpson, & Miller, 1976). A wide variety of categories encompassed the prototype view. These included natural language superordinate categories (e.g. *furniture*, *vehicle*) and natural language basic level categories (e.g. *chair*, *car*). In these cases, similarity was defined by the number of attributes (e.g. *you can eat it*) in common (Rosch & Mervis, 1975). Similarity could also be defined by some metric such as size. For example, Reed (1972) created prototype schematic faces where attributes such as the length of the nose were the average of those in the study set.

Alternative accounts of conceptual representation, exemplar views, regard concepts as being represented by individual category instances (Medin & Schaffer, 1978; Nosofsky, 1988). Exemplar views can also account for the sort of typicality phenomena described earlier (Hampton, 1997; Murphy, 2002). According to these views, the items receiving the highest typicality ratings are the ones that bear greatest similarity to most category members. The fuzziness of category borders is attributable to the fact that borderline exemplars are equally similar to members of two or more categories.

In support of the prototype view, similarity between category exemplars and the corresponding prototype determines a wide range of learning and categorisation responses: for example, speed of classification and production order of items in a generation task (Rosch et al., 1976). Similarity also determines prototype effects. These can be observed in recognition memory where individuals tend to display false recognition to a previously unstudied prototype. Also characteristic of the effect is the fact that the degree of similarity between the exemplar and the prototype, is reflected in recognition levels: the higher the similarity, the more likely a positive recognition response (Cabeza, Bruce, Kato, & Oda, 1999; Omohundro, 1981; Solso & McCarthy, 1981). A similar prototype effect has been observed using categorisation. Unstudied prototypes are categorised with an accuracy that is at least equal to that of previously studied but less typical exemplars (Metcalfe & Fisher, 1986; Posner & Keele, 1968). Exemplar views also account for prototype effects by assuming that responses are determined by the mean similarity between a target exemplar and other relevant category members stored in memory (Hintzman & Ludlam, 1980; Nosofsky, 1991).

Concepts and categorisation in autism

The idea that conceptual difficulties might be a critical feature of autism was expressed much earlier than Hermelin and O'Connor by writers such as Scheerer, Rothmann and Goldstein (1945) and Rimland (1964). These suggested that autism is characterised by an over-reliance on concrete thinking and an inability to form and use abstract concepts. Since then the picture has been somewhat mixed. For example, Ungerer and Sigman (1987) found no difference between LFA children and controls on the ability to categorise on a single basis (e.g. colour or form.) Tager-Flusberg (1985a, 1985b) also found that LFA children showed comparable performance to controls in the ability to categorise exemplars into basic level categories (e.g. *boat*, *bird*) and superordinate categories (e.g. *food*, *tool*). Furthermore, prototypicality affected the responses of all participant groups in a similar way. Fewer errors were made classifying prototypical items than classifying more peripheral category members. However, Shulman, Yirmiya, and Greenbaum (1995) found that LFA children performed worse than controls in a free sorting task in which participants selected their own bases for categorising representative objects such as trees or animals. Also, Dunn, Gomes, and Sebastian (1996) found an abnormal response to prototypicality. Participants completed word fluency tasks. HFA children generated a lower proportion of prototypical responses than controls when asked to produce as many examples of animals and vehicles as possible.

Klinger and Dawson (1995, 2001) characterised the pattern of categorisation abilities in autism by proposing a dissociation: specifically that individuals with autism behave in the manner predicted by the classical model of concepts. They rely exclusively upon rule-based categorisation because of difficulty with one aspect of concept formation: abstracting and using prototypes. Although Tager-Flusberg's

(1985a, 1995b) studies demonstrated that LFA participants are as susceptible to the influence of prototypicality as controls, Klinger and Dawson (2001) argued that studies such as these only demonstrate the ability to categorise without revealing whether or not individuals with autism form novel concepts in the same manner as controls.

In support of the dissociation, Klinger and Dawson (1995, 2001) observed that children with autism are able to infer rules during the Wisconsin Card Sorting Test and similar set shifting tasks (Bennetto, Pennington, & Rogers, 1996; Berger, Van Spaendonck, Horstink, Buytenhuijs, & et al., 1993; Hughes, Russell, & Robbins, 1994). The Wisconsin Card Sorting Task requires respondents to sort cards into categories according to three possible dimensions (colour, shape, and number). The sorting basis shifts without warning throughout the task and the participant discovers and uses the correct principle via feedback from the experimenter. (Individuals with autism were able to discover and apply the rules but had difficulty switching to new ones. This sort of difficulty, however, is attenuated with computerised versions of the task, Ozonoff, 1995).

From clinical observation and anecdotal evidence, Klinger and Dawson (1995), formed the view that individuals with autism persist in rule-use on occasions where such a rigid approach is sub-optimal and where a prototype-based form of categorisation would be more appropriate. For example, these authors report the frustration of a father who tried to warn his adolescent autistic son not to interact with strangers. The problem was that his son kept on asking for a set of criteria that were necessary and sufficient for this concept. In a similar vein, Baron-Cohen, Wheelwright, Stone, and Rutherford (1999) reported their observations of Case DB,

a highly intelligent man with AS, who admitted attempting to codify social behaviour as a set of formal rules in an effort to understand it.

Evidence suggesting that individuals with autism are unable to abstract prototypes and associated theories

To test the notion that prototype formation is impaired in autism, Klinger and Dawson (2001) compared prototype-based categorisation with rule-based categorisation for three groups: an LFA group, a Down Syndrome group (both with an average CA of 14 years and an average VMA, of 6-7 years) and a typically developing group (average CA: 7 years). The stimuli were schematic animals very similar to those used in studies of infant categorisation (e.g. Younger, 1990). Several categories were used: Each was organised around a central prototype that possessed features (e.g. tails) that were a mean size of those possessed by other category members.

All participants completed three conditions. Two required rule-based categorisation: The categorisation rule was either stated or left implicit. One condition required prototype-based categorisation. Study phases for all conditions involved familiarisation with a named target category (e.g. "Mip"). In the rule-based conditions, a single feature such as a long foot defined the target categories. The test phases progressed by asking participants to select the target category member from a pair containing a non-member (as a lure). Both target and lure were identical save for the presence or absence of the feature defining category membership (such as the long foot). In the test phase of the prototype condition, participants were again asked to select a target category member from a pair. This comprised an unstudied category prototype (the target) and a novel composite: a category member which

possessed individual features that had appeared in the study phase but in a novel combination. If, during any of the test phases, participants responded that both members of the pair were category members, they were instructed to select the best one. Only the typically developing group behaved as if they had abstracted prototype representations by selecting the prototype at levels significantly above chance. Neither of the selections made by the clinical groups differed from chance. By contrast, in the rule-based conditions, all participant groups selected category members at levels that were above chance. The authors' main conclusion was that individuals with autism and Down syndrome had impairments in prototype formation.

Dunn et al.'s finding that HFA participants generated a lower proportion of prototypical items is consistent also with this account. In addition, one other study found that individuals with autism failed to show prototype effects. Plaisted, O'Riordan, Aitken, and Killcross (Submitted), also described in Plaisted (2001), created two categories of 10-pointed, coloured, geometric shapes. Two shapes were designated prototypes and exemplars were generated from each by distorting the locations of the points. HFA adults and a normal control group were trained to categorise the exemplars over the course of 150 trials. A subsequent test phase required participants to categorise both old exemplars (presented during the study phase), new exemplars (unseen during study phase but representing a similar level of distortion from the prototype as the training exemplars) and the category prototypes. In general, HFA participants made more errors than controls when learning to categorise stimuli in the study phase. Furthermore, the control group, but not the HFA group, demonstrated a prototype effect, by categorising the prototype at a greater level of accuracy than the other exemplars.

These findings were accounted for in terms of a perceptual abnormality: that individuals with autism have a reduced perception of similarity and so process features held in common between stimuli relatively poorly and unique features relatively well. As discussed earlier, a prototype effect reflects perceived similarity between category exemplars and the prototype. Therefore, such a reduced perception of similarity would lead the autism group to demonstrate reduced or absent prototype effects.

In addition to prototype effects, this account has been extended to a range of phenomena (Plaisted, 2001). For example, Plaisted et al. (1998a) presented a perceptual learning task to HFA adults and controls. During an initial training phase, participants learnt to discriminate between a pair of dot patterns that shared common elements (i.e. some dot positions). In the subsequent test phase, the control group demonstrated a perceptual learning effect: They were better able to discriminate between a pair of familiar patterns than between a pair of completely novel ones. Neither pair had been presented in the training phase but the familiar pair alone shared the same common elements as the training pair. The autism group failed to show a perceptual learning effect despite success at discriminating between patterns. They appeared unable to exploit the commonalities between the training and test phase. Plaisted et al. attributed this finding to a difficulty processing features held in common between the learning and transfer situations (again, a manifestation of a reduced perception of similarity).

Another example of supporting evidence for this view includes the HFA superiority in a conjunctive visual search task (Plaisted, O'Riordan, & Baron-Cohen, 1998b). The task is difficult for normal participants because they are required to detect a target from a field of distracters that are similar to the target (e.g. the target

might be a green X and the distracters would be green Ts and red Xs). Plaisted (2001) argued that this reduction in perceived similarity renders the task easier for HFA participants because for them the target is less confusable with the distracters.

Klinger and Dawson (2001) suggested that the prototype impairment in the autism group might be a manifestation of another general cognitive processing abnormality: weak central coherence (Frith, 1989; Frith & Happé, 1994). As discussed earlier in Chapter 1, this account holds that individuals with autism are less able to integrate meaningful information to extract the gist of a situation or scene. Klinger and Dawson argued that failure in prototype formation represents an example of weak central coherence because of the failure to integrate information over multiple experiences to abstract summary information in the form of a prototype.

Aims of thesis

The aim of this thesis is to explore impairments in prototype effects in autism. If prototype abstraction is faulty in autism, then decrements in prototype effects should be observable using a variety of stimuli and methods.

2.2 Methodology: Participant selection

The clinical participants taking part in the studies reported in this thesis were high functioning children and adolescents with autism. In practice, those with a proportion of VMA over CA of 0.7 or higher were selected. This proportion was determined by the availability of age and VMA-matched controls from UK mainstream schools. (VMA was measured by the British Picture Vocabulary Scale, BPVS, L. M. Dunn, Dunn, Whetton, & Burley, 1997.)

Previously, some cognitive impairments found in LFA people that were attributed to autism are now considered a function of mental retardation and developmental delay (e.g. stimulus overselectivity, Wilhelm & Lovaas, 1976). The fact that Klinger and Dawson's (2001) clinical groups both had some intellectual impairment, means that their failure to show a prototype effect could be attributable to this factor. Testing HFA participants was intended to provide a more stringent evaluation of prototype formation in autism by eliminating the confound of intellectual impairment.

This focus on the more able portion of the autistic spectrum, however, raises the difficulty of differential diagnosis between HFA and AS participants alluded to in Chapter 1. This issue was addressed in this thesis by grouping both diagnoses together in a single group, labelled HFA participants, and defined by a relatively narrow IQ banding, rather than attempting to separate out the two. (The number of formal AS diagnoses are stated in the method section of each experiment as acknowledgement that other researchers may take a different view.) Reasons for this combined grouping are as follows:

The position taken in this thesis is that of Miller and Ozonoff (2000): AS is High-IQ autism. Miller and Ozonoff subjected a group of HFA and AS participants

to a battery of tests of intellectual, motor, visuospatial, and executive function domains. Once the superior intellectual abilities of the AS group were controlled, statistically via ANCOVA and by comparing IQ-matched subgroups of participants, no significant group differences were apparent (apart from marginally significant poorer fine motor control in the AS group).

Other studies have found group differences. For example, Rhinehart, Bradshaw, Moss, Brereton, and Tonge (2000) observed participant group differences on a version of a task that explored the relationship between local and global processing (Navon, 1977). Participants were presented with a large (global) number comprising smaller (local) numbers. The task was to correctly identify either the large or the small number. The autism group had more difficulty recognising the large number than their control group. In contrast, the AS group did not differ from their matched control group. In addition, Klin, Volkmar, Sparrow, Cicchetti, and Rourke (1995) found significant participant group differences on various components of non-verbal learning. These included motor skills, visual-motor integration, and visual–spatial perception.

However, neither of these studies controlled for the higher abilities of the AS groups. Furthermore, Klin et al. used diagnostic criteria that were more stringent than those present in the ICD-10 or DSM-IV. Wing (1998) made the point that these criteria probably produced many of the significant differences that were found between the two groups. For example, Klin et al. used motor skills as a diagnostic criterion. Participants that lacked these skills were assigned to the AS group and those that possessed them were assigned to the HFA group. Unsurprisingly, this particular skill significantly differentiated participant groups.

These observations fit well with Wing's (1998) arguments: that there is simply no evidence that AS exists as a separate syndrome. According to Wing, the two syndromes cannot be delineated by cause or neuropathology since these are either unknown or evidence is inconclusive. (This still appears to be the case, e.g. see Lotspeich et al., 2004). In addition, Wing argued that there is no clear symptomatology that divides the two. She cited Klin et al.'s study where members of one participant group sometimes exhibited features more commonly found in the other group.

In contrast to diagnosis, it appears that IQ is highly predictive of symptomatology. For example, Wing (1988) described the different manifestations of repetitive behaviours (one diagnostic feature of autism or AS). Those with low IQs might insist on adopting the same body posture or show stereotypies, such as rocking. Those with the highest IQ express this feature intellectually or verbally with obsessions with accumulating facts on certain topics such as railway timetables. This observation provides a further rationale for defining autism groups by IQ rather than a diagnosis of AS or autism.

Although there is no real evidence yet for AS as a distinct syndrome, Miller and Ozonoff's (2000) study, however, is far from conclusive. It may simply be that they failed to measure the precise syndrome delineating functions. In addition, their participant groups are small enough to be sensitive to any errors in diagnosis (12 for the HFA group and 23 for the AS group). However, several features make their position attractive and consistent with the methodological approach taken in this thesis. These include the established difficulties of diagnosis, discussed in Chapter 1, the lack of convincing evidence that the two syndromes are separate entities, and the

fact that IQ does appear to be highly predictive of differing symptomatologies in autism.

CHAPTER 3 – Prototype effects in autism: Intact in recognition memory?

Background: There are two accounts of categorisation performance in autism: that there is an impairment in prototype formation (Klinger & Dawson, 2001) and that there is a reduced perception of similarity and an impairment in processing features held in common between stimuli (Plaisted et al., Submitted; Plaisted et al., 1998a). These accounts, together with central coherence theory (Frith, 1989; Frith & Happé, 1994), imply a reduced or absent prototype effect in autism. **Method:** Children with autism or AS (n = 15) matched on age, gender, and verbal mental age with typically developing children (n = 15) completed a picture recognition task (Experiment 3.1). These participants also studied categories of cartoon animals possessing either an average prototype structure (Experiment 3.2) based on Younger's (1985) stimuli or a modal structure (Experiment 3.3) based on Hayes and Taplin's (1993b) stimuli. Following the study phases, participants completed recognition tests comprising prototypes and other exemplars with varying degrees of similarity to the prototypes. **Results:** For both participant groups, recognition memory appeared intact (Experiment 3.1) and a full prototype effect in recognition memory was observed in both Experiment 3.2 and Experiment 3.3. **Conclusions:** The present studies fail to support predictions of impaired prototype effects in autism. The discussion focuses on key methodological differences between these studies and those that support claims that central coherence, prototype formation, and common feature processing are impaired in autism.

As stated in Chapter 2, the aim of this thesis is to investigate the demonstration of prototype effects in autism. As described earlier, two teams of researchers, Klinger and Dawson (2001) and Plaisted et al. (Submitted), found that individuals with autism failed to show prototype effects. In both cases, the display of these effects was assessed by means of a categorisation task presented in the test phase. Participants in the former study were asked to select the best example of a category. LFA children, in contrast to controls, tended not to select the prototype. Participants in the latter study completed a classic categorisation test requiring the classification of geometric shapes into two categories. HFA adults and adolescents, in contrast to controls, failed to categorise the prototype with the greatest accuracy.

Accounts supporting impaired prototype effects in autism included impairment in prototype formation (Klinger & Dawson, 2001), a reduced perception of similarity or difficulty processing common features (Plaisted et al., Submitted; Plaisted et al., 1998a) and central coherence theory (Frith, 1989; Frith & Happé, 1994). One implication of all these accounts is that children with autism differ in their use of similarity: specifically that they represent individual stimuli with very steep generalisation gradients and do not perceive stimuli as similar unless they are very close in the stimulus space. If this is the case then children with autism should show reduced or absent prototype effects. This prediction is consistent with both exemplar and prototype accounts of category learning. These two theories are alike in their assumption that response to unseen category members is determined by high similarity to previously presented stimuli. Two studies reported here, Experiment 3.2 and Experiment 3.3, used the prototype effect in recognition memory to test the theories concerning prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998a).

Intact general recognition memory has been found in HFA children and adolescents (Barth, Fein, & Waterhouse, 1995; Bennetto et al., 1996) as well as in AS adults (Bowler, Gardiner, Grice, & Saavalainen, 2000; Bowler, Gardiner, & Grice, 2000). A memory task (Experiment 3.1) was included to check that this was true also of the HFA children in the present study. This had the additional purpose of familiarising all participants with the experimental procedure.

Experiment 3.1

Method

Participants. Two groups took part in the study: 15 HFA children and 15 typically developing controls. The participant groups were matched on gender (all participants were boys), individually matched on chronological age (to within four months), and globally matched on VMA. The children in the autism group had been diagnosed by clinicians as having either AS (8) or autism (7) according to established criteria such as those specified by the DSM-IV(American Psychiatric Association, 1994). They were recruited from special education facilities and ranged in chronological age from 8 years and 9 months to 13 years and 11 months. Children in the control group were recruited from local schools in South East England. Their ages ranged from 8 years and 5 months to 14 years and two months. VMA was assessed by the BPVS (L. M. Dunn et al., 1997). Nonverbal mental age was assessed using Standard Progressive Matrices (Raven, 1996). Table 3.1 summarises participant characteristics.

Table 3.1 Participant characteristics

	Autism Group (n = 15)	Control (n = 15)
Chronological age (years)		
M	11.71	11.73
SD	1.65	1.75
VMA (years)		
M	11.68	11.51
SD	3.02	2.98
Range	5.67 - 17	6 - 17
BPVS raw scores		
M	107.40	106.13
SD	21.58	20.38
Range	58 - 145	61 - 140
RPM raw scores		
M	38.27	35.07
SD	7.08	10.69
Range	28 - 52	12 - 45

Note. VMA = verbal mental age. BPVS = British Picture Vocabulary Scale. RPM = Ravens Progressive Matrices. VMA was derived from the BPVS raw scores. Maximum group difference: $t(24) = .97, p = .34$ (equal variances not assumed).

Materials. All stimuli were black line drawings presented singly on white 13 cm by 10 cm cards. There were two response cards differing only with respect to the relative positions, top or bottom, of two sentences: "I have seen the picture before" / "I have not seen the picture before". The response cards served as reminders as to what decision had to be made over the stimuli. In addition, once participants were trained in their use, these cards enabled participants to make responses without verbal prompts from the experimenter.

There were 16 practice items. These were divided equally into two categories: plants and buildings. Each category was divided equally into study and test items. There were 32 memory task items. These were divided equally into two categories: animals and vehicles. Again, each of these categories was divided equally into study and test items. For both practice items and memory task items, half the test stimuli were "old" replicas of the study items, the remainder being novel items.

Procedure. Participants were tested singly in a quiet room. The practice session was completed first. Participants were told that they had five seconds to study each of the practice study cards. Boucher and Lewis (1992) mention the difficulty of keeping the attention of some children focused on tasks like this so participants were encouraged to pay attention to the study cards by means of a straightforward categorisation task. They had to sort each card into one of two piles according to category: plants versus buildings. They were told to look at each card carefully and were warned that their memory for these cards would be tested. The study cards were shuffled and handed one at a time to each participant who was told to leave the card face up obscuring the other items beneath it in the pile. If the participant's

attention wandered, he was prompted to look at the card again and any mistakes in placing cards were corrected immediately by the experimenter. Participants then completed the practice test session. At the start, they were told that some of the test cards were exact copies of cards they had seen before, and some were new. They had to look at each card carefully and decide if they had seen the same picture before. They were familiarised with a response card and told to guess if unsure of the answer. The test cards were shuffled and placed face up in a single pile on the table one at a time. Participants responded in their own time by pointing to the relevant place on the response card. The memory task followed immediately with a procedure that was identical to the one described above for the practice session. Response card type was counterbalanced across participants.

Results and Discussion

The mean proportion of correct recognition responses from the memory task was similar for both participant groups: .87 (SD = .13) for the autism group and .81 (SD = .17) for the controls. The difference between groups was not significant: $t(28) = 1.05, p = .30$. One sample t-tests revealed that for each group responding was significantly above the chance level of .5: $t(14) = 11.19, p < .01$ for the autism group and $t(14) = 6.91, p < .01$ for the control group. These reasonably high levels of memory task performance indicated successful use of the response cards by both participant groups and that recognition memory was intact in both groups. The absence of group differences suggested that performance on these two variables was similar for both participant groups.

Experiment 3.2

In this experiment, participants were familiarised with categories that were very similar to those used by Klinger and Dawson (2001). The stimuli were cartoon animals that were organised around average prototypes. These prototypes possessed features (e.g. legs or nose) that were the category average in size. Following a short study phase participants made recognition responses to five exemplar types that were of decreasing similarity to the prototype. If there is a problem in integrating information across experience, as proposed by central coherence theory (Frith, 1989; Frith & Happé, 1994), and if there is an impairment in the formation of prototypes (Klinger & Dawson, 2001) and in processing common features (Plaisted et al., 1998a) , then the usual prototype effect should not be replicated in the autism group using a recognition test. The recognition responses of the autism group should not reflect similarity to the prototype to the same extent as those of the control group. It is unlikely that such a reduced effect could be attributable to poorer recognition memory. This is because the autism group performed similarly to the control group on the memory task in Experiment 3.1.

Method

Participants. The same participants from Experiment 3.1 were recruited.

Materials. The stimuli were presented on white cards identical to those used in Experiment 3.1. A similar method to that described in Younger (1985) and (Klinger & Dawson, 2001) was used to create average category stimuli consisting of cartoon animals. Similarity was manipulated by varying the size of animal features. Each

exemplar possessed six features that were varied along a dimension with five equal steps from value 1 to value 6. One particular feature could have any of the six discrete values. Alternatively, if it belonged to the prototype, it took the average value (3.5 on the scale). The size of the steps between values varied across features but was constant for each single feature (e.g. for the "insect neck" the values 1, 2, 3, 4, 5, and 6 represented increments of 4mm). Exemplars varied in their global similarity or family resemblance (FR) to the prototype. In addition to the prototype (with all feature values set at 3.5), three exemplar types were generated. These possessed features that could take one of two possible values. The exemplar types with corresponding feature values in parentheses are as follows: high FR (3, 4), medium FR (2, 5), and low FR (1, 6).

There were 16 study items, 8 "monsters" and 8 "insects", and 34 test items: 17 from each category. The study items bore medium FR to their respective prototype. See Table 3.2 for a description of study item structure for insects. The monster study items had an identical structure.

The test items for each category consisted of 4 replicas of study items (old medium FR exemplars) and 13 new items. The latter comprised one prototype and four items each of high, medium and low FR exemplars. Table 3.3 gives a description of feature values for insect test items. Monster test items had an identical structure. Figure 3.1 illustrates the prototype and other new test exemplars from the insect category.

The studies of Klinger and Dawson (2001) and Younger (1990) each had two types of exemplar represented within the study sets. One type had features with values of 2 and 4: similar in size to those of the prototype that had features values all set at 3. The other exemplar type had features with values of 1 or 5: less similar to

the prototype features. In contrast, the study sets of the present experiments contained only medium FR exemplars. This single exemplar type was selected so that the results would reveal more information about what strategies participants were using. If they simply memorised single features from the study set, failed to integrate them, and then responded to test items on the basis of how confusable test item features were with study item features then recognition scores would not reveal a prototype effect. Medium FR exemplars would receive the highest recognition because they shared identical features with the study set. Also, recognition scores for prototype, high FR, and low FR exemplars would be very close because their features all differed from the most similar study item features by roughly the same value (1.5, 1, and 1 units respectively). If however participants were integrating the features to produce an average then their responses would be determined by similarity to this average (i.e. the prototype) and therefore would demonstrate a prototype effect. (The prototype, high FR, medium FR, and low FR feature values all differed from prototype feature values by 0, .5, 1.5, and 2.5 units respectively.)

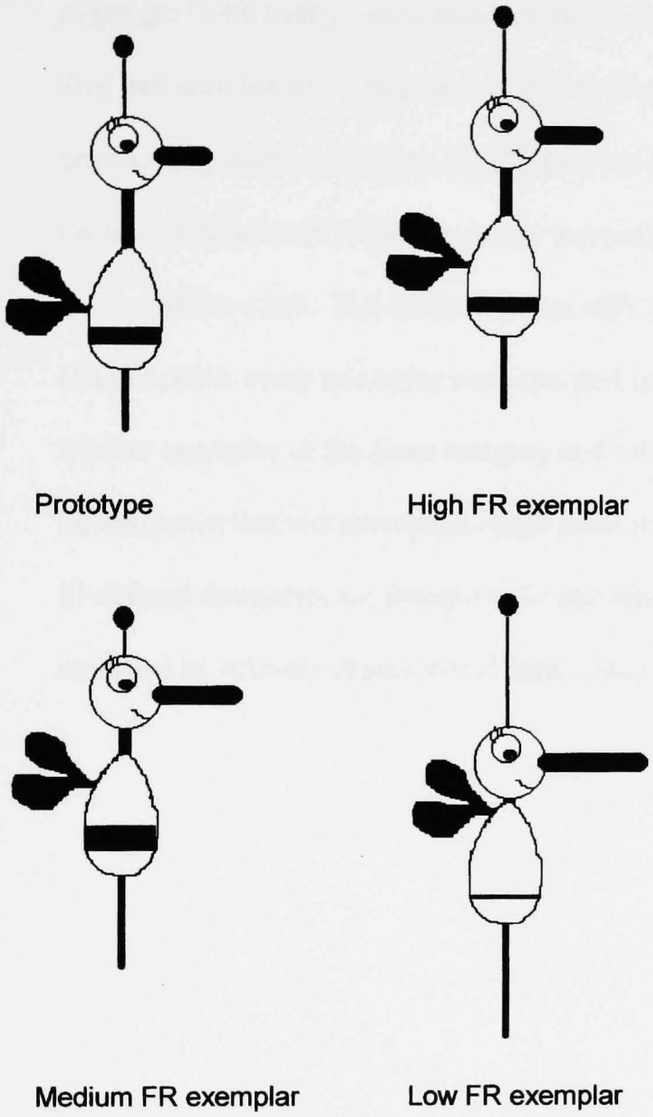

Figure 3.1 Examples of average category test stimuli. All are from the insect category.

Procedure. All participants completed the average category task (Experiment 3.2) after the memory task (Experiment 3.1) and both tasks were completed within a week. The instructions and procedure for the average category recognition task were identical to those used for the memory task except that during the study phase participants had to sort the cards into "monster" and "insect" categories. Also before

the test phase participants were warned that deciding if they had seen a card before might get "a bit tricky" since many of the cards might look very similar to the ones they had seen before. They were told to try their best and to guess if they were unsure. The study cards were shuffled before each presentation as before. However, the test cards were divided into one of two possible blocked orders: one being the reverse of the other. The blocked orders were counterbalanced across participants. In each order, every exemplar was separated by a minimum of seven cards from another exemplar of the same category and FR level. This was intended to reduce the influence that test exemplars might exert on each other because representations of ill-defined categories are thought to be dynamic in the sense that they are easily modified by relevant experience (Homa, Goldhardt, Burruel-Homa, & Smith, 1993).

Table 3.2 Study stimuli for average prototype categories: Insect feature values

	Insect features					
Item No.[a]	Neck length	Nose length	Wing position[b]	Body Sting length	band width	Antenna length
1	5	2	2	5	2	5
2	2	2	5	5	2	5
3	5	5	2	2	2	5
4	2	5	2	5	2	5
5	2	5	5	2	5	2
6	2	2	5	5	5	2
7	5	5	2	2	5	2
8	5	2	5	2	5	2

Note. [a] All items are medium family resemblance exemplars. [b] As measured from the bottom of the neck.

Table 3.3 Test Stimuli for Average Prototype Categories: Insect Feature Values

Item No. (Exemplar Type)	Insect features					
	Neck length	Nose length	Wing position[a]	Sting length	Body band width	Antenna length
1 (Old Medium FR)	5	2	2	5	2	5
2 (Old Medium FR)	5	5	2	2	2	5
3 (Old Medium FR)	2	5	5	2	5	2
4 (Old Medium FR)	2	2	5	5	5	2
5 (New Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
6 (New High FR)	3	4	3	4	3	4
7 (New High FR)	4	3	4	3	4	3
8 (New High FR)	3	3	4	4	3	4
9 (New High FR)	4	4	3	3	4	3
10 (New Medium FR)	2	5	5	2	2	5
11 (New Medium FR)	5	2	5	2	2	5
12 (New Medium FR)	5	2	2	5	5	2
13 (New Medium FR)	2	5	2	5	5	2
14 (New Low FR)	1	6	1	6	1	6
15 (New Low FR)	6	1	6	1	6	1
16 (New Low FR)	1	1	6	6	1	6
17 (New Low FR)	6	6	1	1	6	1

Note. FR = Family resemblance. [a] As measured from the bottom of the neck.

Results and Discussion

The frequency of positive recognition responses, selecting the answer "I have seen the picture before", was counted for each subject and exemplar type. The proportion of positive recognition responses was then calculated. This represented true recognition for the "old" exemplars and incorrect responses (i.e. false alarms) for the remainder. The maximum possible number of positive recognition responses was 2 for the prototypes and 8 for each of the other exemplar types. (For each exemplar type, a chance level response would be 1 and 4 respectively.) The two participant groups were very similar in terms of the number of prototypes that they recognised. All individuals recognised at least one prototype, with 11 individuals from the autism group and 10 from the control group recognising both. An independent samples *t*-test revealed no significant difference between the proportion of prototypes selected by the two participant groups: $t(28) = .39, p = .70$.

Both participant groups showed the same pattern of results. A higher proportion of prototypes and high FR exemplars were identified (incorrectly) as old than the actual study item replicas (old medium FR exemplars). There was no difference in recognition levels between old and new medium FR items, and the least false recognition was received in response to the low FR exemplars. Figure 3.2 illustrates data from all exemplar types. These comprised five levels: prototype, high FR, medium (old) FR, medium (new) FR, and low FR. The presentation order of Experiments 3.2 and 3.3 was counterbalanced across participants and included in the following analysis: The proportion of positive recognition responses were analysed using a 2 (group) x 5 (exemplar type) x 2 (order) mixed, repeated measures ANOVA. This revealed a significant main effect of exemplar type: $F(4,104) = 52.47, p < .01$. No other effects or interactions were statistically significant: maximum $F(1,26) =$

1.72, $p = 0.20$[1]. Repeated contrasts confirmed that high FR exemplars received a significantly greater proportion of positive recognition responses than old medium FR exemplars, $F(1,26) = 10.59$, $p < .01$, and that new medium FR exemplars received a significantly greater proportion of positive recognition responses than low FR exemplars, $F(1,26) = 119.44$, $p < .01$. The contrasts between the remaining exemplar types were not significant: prototype and high FR, $F(1,26) = 1.63$, $p = .21$, also old medium FR and new medium FR, $F(1,26) = .15$, $p = .70$.

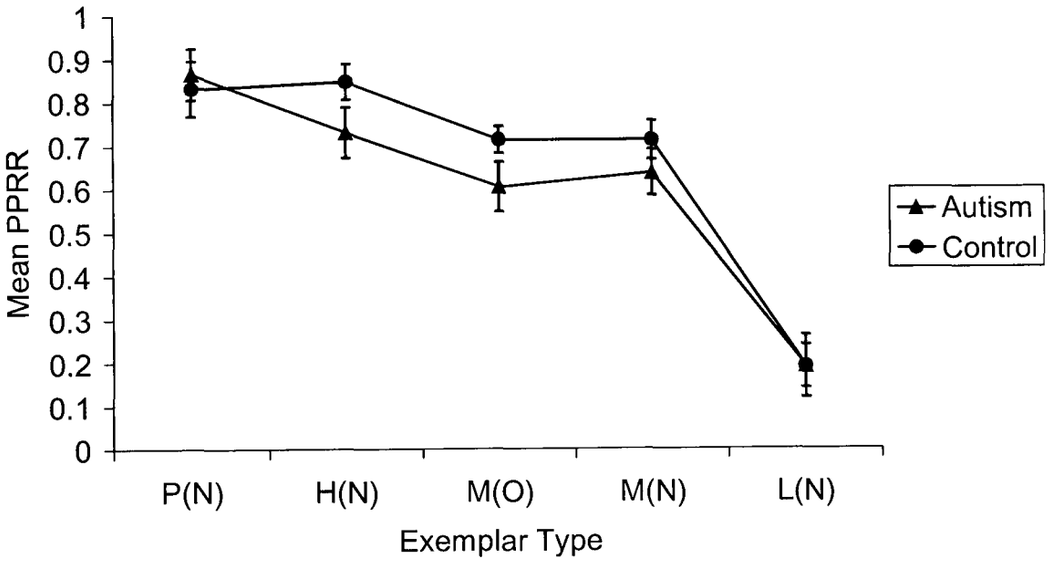

Figure 3.2 Average category: Mean proportion of positive recognition responses (PPRR) for each participant group and exemplar type. FR = family resemblance. P = prototype, H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars, (N) = new exemplars, and (O) = old exemplars. Error bars represent standard error of the mean. PPRR was calculated out of responses to two prototypes and to eight each of the remaining exemplar types.

The aim of this experiment was to see whether a prototype effect could be obtained in the recognition memory of HFA children using an average category structure. The full effect was obtained in both the autism and control groups. New category prototypes and high FR exemplars received greater levels of recognition than exemplars that were actually studied. Furthermore, the two participant groups differed neither in overall level of exemplar recognition nor in the degree to which similarity to a category prototype affected recognition. In both groups the lower the family resemblance of novel exemplars the less false recognition they tended to receive. Thus it seems unlikely that individuals in either group responded on the basis of how confusable individual features belonging to test items were with individual features belonging to study items. If they were doing this, as discussed earlier, there would be no prototype effect. The proposals that autism is characterised by impairments in prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998a) were unsupported by this study. No group differences were found in how the correlational structure of stimuli was represented in memory.

Experiment 3.3

Hayes (1993a; 1993b) used an alternative method for manipulating inter-exemplar similarity within prototype-based categories. This involved the creation of modal prototypes. These possessed the feature types that occurred most frequently in the study sets. Such feature types varied in identify, for example, a head feature could be square, circular, or a diamond in shape. If there is an abnormality

concerning the perception of similarity as implied by the theories concerning prototype formation (Klinger & Dawson, 2001) and common feature processing (Plaisted et al., 1998a) then a reduced or absent prototype effect in recognition memory should be manifest with the use of modal prototypes.

Method

Participants. The same participants from Experiments 3.1 and 3.2 took part.

Materials. The modal category stimuli consisted of drawings of cartoon animals presented on cards as in Experiment 3.2. Two categories were represented by 16 study items: 8 "animals" and 8 "birds". The stimuli were constructed using similar methods to those of Hayes and Taplin (1993b). The exemplars had six features each of which could take on one of five possible feature values. For example, the bird beaks could take on one of five different shapes. Each study item (medium FR exemplar) shared three out of six features with the relevant category prototype. For each of the two categories, eight study items were constructed so that all the prototype feature values occurred four times in the set. Non-prototype features occurred only once. Table 3.4 shows the configuration of the study item feature values for the bird category. The animal study items had an identical structure.

Table 3.4 Study stimuli for modal prototype categories: Bird feature values

	Bird features					
Item No.[a]	Beak	Wing	Head crest	Foot	Tail	Body marking
1	1	1	1	2	2	2
2	2	1	1	1	3	3
3	3	2	1	1	1	4
4	4	3	2	1	1	1
5	1	4	1	3	1	5
6	5	1	3	1	4	1
7	1	1	4	4	5	1
8	1	5	5	5	1	1

Note. [a]All items are medium family resemblance exemplars. (The prototype feature value = 1.)

There were 34 test items with 17 items from each category. These consisted of a prototype and four items each of the following exemplar types: high FR, old medium FR, new medium FR, and low FR. For each category, the prototype shared five features in common with high FR exemplars, three features in common with both the new and old medium FR exemplars, and one feature in common with the low FR exemplars. See Table 3.5 for test stimuli feature values for birds. Animal test items had an identical structure. See Figure 3.3 for examples of modal category test stimuli.

Table 3.5 Test stimuli for modal prototype categories: Bird feature values

Item No. (Exemplar Type)	Bird features					
	Beak	Wing	Head crest	Foot	Tail	Body marking
1 (Old Medium FR)	1	1	1	2	2	2
2 (Old Medium FR)	4	3	2	1	1	1
3 (Old Medium FR)	2	1	1	1	3	3
4 (Old Medium FR)	1	5	5	5	1	1
5 (New Prototype)	1	1	1	1	1	1
6 (New High FR)	1	5	1	1	1	1
7 (New High FR)	1	1	4	1	1	1
8 (New High FR)	1	1	1	3	1	1
9 (New High FR)	1	1	1	1	2	1
10 (New Medium FR)	3	1	1	2	1	4
11 (New Medium FR)	1	1	3	3	1	5
12 (New Medium FR)	5	2	1	1	4	1
13 (New Medium FR)	1	4	4	1	5	1
14 (New Low FR)	4	4	1	3	2	5
15 (New Low FR)	5	3	3	1	4	2
16 (New Low FR)	2	1	4	4	5	3
17 (New Low FR)	3	2	2	2	1	4

Note. FR = Family resemblance.

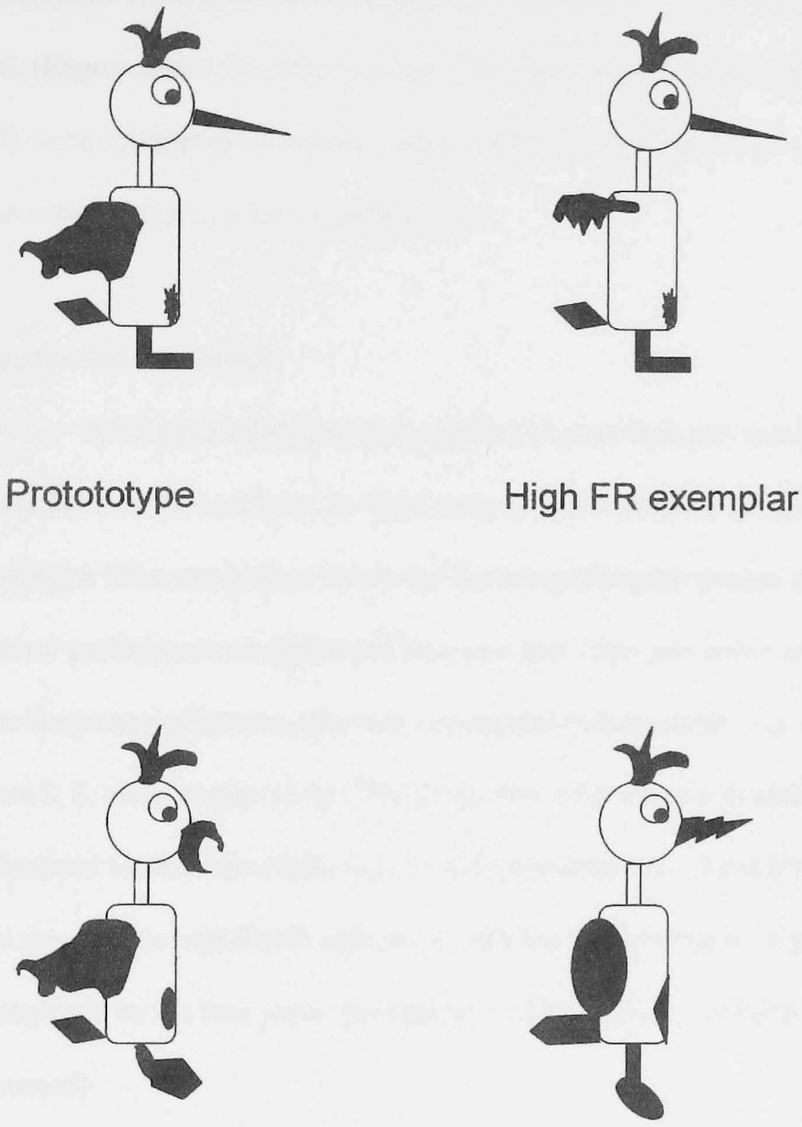

Figure 3.3 Examples of modal category test stimuli. All are from the bird category.

Procedure. The procedure was identical to that of Experiment 3.2 except that children were told to sort the study cards into two piles of birds and animals. All participants completed the memory task (Experiment 3.1) and the modal category task (Experiment 3.3) within a week. The two category tasks (Experiments 3.2 and 3.3) were completed on separate days and the presentation order of these two tasks was counterbalanced across participants.

Results and Discussion

A data-recording problem resulted in data from one matched pair being excluded from the analysis, so there were 14 individuals in each participant group. Prototype false recognition levels for the two participant groups were similar. All control participants recognised at least one prototype and seven recognised both. The frequency of participants with autism recognising none, one, and both prototypes were 3, 3, and 8 respectively. The proportion of positive recognition responses was calculated for each exemplar type as in Experiment 3.2. An independent samples *t*-test revealed no significant difference between the proportion of prototypes recognised by the two participant groups: $t(22) = .54$, $p = .59$ (equal variances not assumed).

For both participant groups, a higher proportion of prototype and high FR exemplars were incorrectly identified as old than the actual replicas of study items. There was no difference in recognition levels between both old and new medium FR items. Low FR exemplars elicited the least false recognition. Figure 3.4 illustrates data from all the exemplar types. The order in which participants completed Experiments 3.2 and 3.3 was entered into the following analysis: The proportion of positive recognition responses were analysed using a 2 (group) x 5 (exemplar type) x

2 (order) mixed, repeated measures ANOVA. This revealed a significant main effect of exemplar type: Greenhouse-Geisser $F(3, 66) = 12.66$, $p < .01$. No other main effects or interactions were significant: maximum $F(1,24) = 1.24$, $p = .28^2$. Repeated contrasts confirmed that high FR exemplars received a significantly greater proportion of positive recognition responses than old medium FR exemplars $F(1,24) = 10.05$, $p < .01$ and that new medium FR exemplars received a significantly greater proportion of positive recognition responses than low FR exemplars $F(1,24) = 8.92$, $p < .01$. The contrasts between the following exemplar types were not significant: prototype and high FR, $F(1,24) = .06$, $p = .81$, also old and new medium FR, $F(1,24) = 1.30$, $p = .26$.

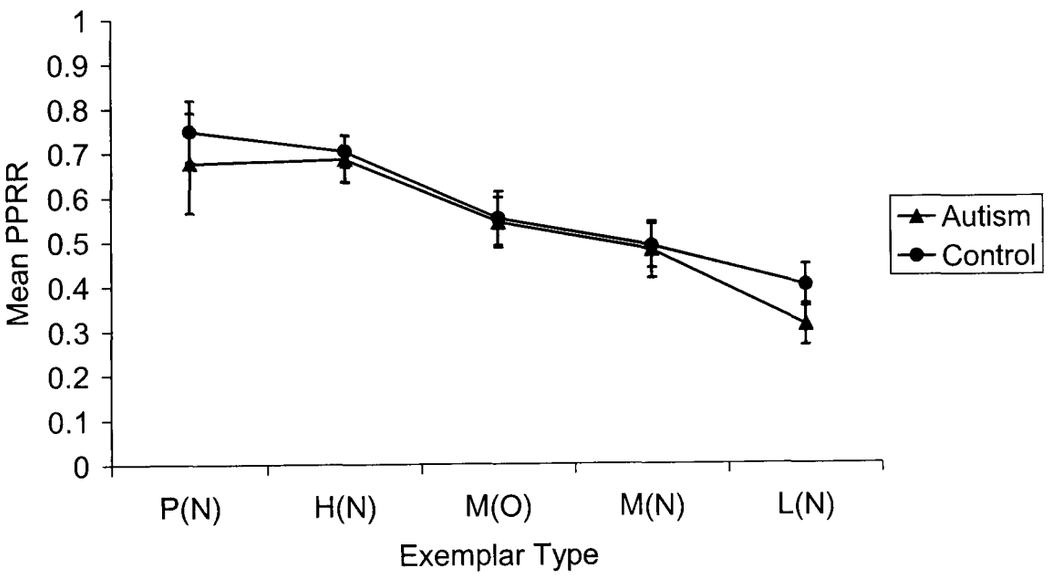

Figure 3.4 Modal Category: Mean proportion of positive recognition responses (PPRR) for each participant group and exemplar type. FR = family resemblance. P = prototype, H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars, (N) = new exemplars, and (O) = old exemplars. Error bars represent standard error of the mean. PPRR was calculated out of responses to two prototypes and to eight each of the remaining exemplar types.

The aim of this experiment was to test the hypothesis that children with autism would fail to demonstrate a prototype effect in recognition memory using a modal category structure. Such an effect is dependent upon sensitivity to the common elements present between stimuli. The fact that the HFA children exhibited the effect represents a lack of support for the accounts that suggest impairments in prototype formation (Klinger & Dawson, 2001) and in common features processing (Plaisted et al., 1998a). The two groups did not differ in overall recognition levels or in the degree to which similarity to the prototype affected recognition. The more features that an exemplar shared with the category prototype the greater recognition it tended to receive.

General Discussion

The hypotheses that children with autism would fail to demonstrate a full prototype effect in recognition memory using an average category structure (Experiment 3.2) and a modal category structure (Experiment 3.3) were unsupported; a full prototype effect was demonstrated in recognition memory in both these experiments. The fact that effects were obtained with different stimulus structures supports the generality of the findings. Klinger and Dawson (2001) describe what can be considered both "strong" and "weak" accounts of category learning in autism. The strong version holds that individuals with autism may fail to form prototype representations. The present studies limit the generality of this version by demonstrating that HFA children can show prototype effects. These results also fail to support the weak version of Klinger and Dawson's theory, that prototype formation is impaired, as well as failing to provide evidence of a deficit in common

feature processing or reduced perception of similarity (Plaisted et al., Submitted; Plaisted et al., 1998a).

Several methodological differences between the studies could account for the discrepancies between their results. As mentioned in the introduction, both Klinger and Dawson's (2001) and Plaisted et al.'s (Submitted) study tested the formation of prototype effects via categorisation responses. In the present studies, participants simply had to make a recognition decision by deciding whether or not they had seen the stimulus before. Several studies have demonstrated that experimental manipulations can differentially affect recognition and categorisation performance (Homa et al., 1993; Knowlton & Squire, 1993; Nosofsky & Zaki, 1998; Palmeri & Flanery, 1999). For example, Knowlton and Squire found that amnesic patients demonstrated intact categorisation prototype effects despite impaired recognition. So, the possibility remains that prototype effects are also dissociable in autism with intact recognition memory and impaired categorisation processes. Another possibility is that the LFA children in Klinger and Dawson's study were confused by the experimental task. The question that asked them to select the Mip from two category members was ambiguous; either choice was "correct" because both items were Mips. These children may have been less able to use context to guide their answers because of difficulty understanding the pragmatic implications of language (Baron-Cohen, 1988; Eales, 1993; Tager-Flusberg, 1981). In contrast, the question used in the present studies was relatively straightforward with a single correct answer: Participants were asked if they had seen the test item before.

Both clinical groups in Klinger and Dawson's study, neither of which showed a prototype effect, had developmental delay. Additionally, their VMA was lower on average than that of the HFA group in the present studies. There are two

ways in which both these factors, developmental delay and low VMA, could affect the expression of the prototype effect. They could directly influence the mental representations assumed to drive the prototype effect. Alternatively, these two factors could exert their influence indirectly by interacting with the demands of the experimental tasks involved in producing the effect. Although a direct influence is a theoretical possibility, existing evidence suggests that this is unlikely. The fact that a prototype effect has been observed in infants (Younger, 1985, 1990) suggests that the effect does not follow a developmental trajectory. There is also evidence that mild non-organic developmental delay does not affect prototype formation (Hayes & Taplin, 1993a). Indeed, the fact that the prototype effect has been demonstrated by pigeons (Huber & Lenz, 1996; Jitsumori, 1996) seems to indicate that a fundamental learning process is responsible.

The developmental delay or lower VMA of the participants in Klinger and Dawson's (2001) study may have affected aspects of performance indirectly. For example, the LFA group may have failed to respond to the prototype because they had difficulty retaining visual information. There is evidence that LFA (but not HFA) children perform at chance on delayed matching-to-sample visual recognition tests (Barth et al., 1995). The HFA group in the present study appeared not to share this difficulty as shown by the presence of prototype effects and high memory task scores.

Also, the findings of the current study appear to contradict Plaisted et al's (Submitted) findings of impaired prototype effects shown by HFA participants. One possibility (suggested by Kate Plaisted, personal communication) is that the stimuli used in the current study rendered the prototype effect task much easier for the HFA participants. This is because verbal labels could be attached the features of the

cartoon animals, thus increasing their salience and relevance. The geometric shapes used by Plaisted and colleagues could not be labelled so easily in this manner.

The studies reported here appear to provide examples of intact central coherence in autism. Both participant groups responded to the test exemplars as if they had integrated visual information from the study phases. The test exemplars varied in the level of integration that they represented. For example, average medium FR exemplars represented an absence of integration because they possessed features that were identical to those of the study sets. The average prototypes represented high levels of integration because they possessed features that were the category average in size and that had not actually appeared in the study sets. Participants' simple binary responses were influenced by the degree of integration represented by the test stimuli: the higher the integration, the greater the level of positive recognition. These findings stand in contrast to studies that demonstrate a reduced ability to integrate information in autism and that refer to this impairment as weak central coherence (e.g. Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 2001).

These studies required participants to produce responses that are more complex. For example, the object identification task employed by Jolliffe and Baron-Cohen, presented participants with pictures of object fragments. The required response was the name of the whole object. The preceding observations imply that: Central coherence is intact where individuals with autism make simple judgements that reflect the levels of integration already inherent in stimuli; central coherence is weak where individuals with autism are required to make a response that is a direct integration of stimuli. If this dichotomy is replicable, there are two possibilities. The apparent weak central coherence impairment in integration may actually represent a

deficit of late processing. Specifically, this deficit would occur at the point where an integrated mental representation is translated into a response that reflects that integration, for example, the naming of a whole object (Jolliffe & Baron-Cohen). The other possibility is that this particular type of weak central coherence represents a dissociation: implicit (unconscious) processing is intact and explicit (conscious) processing is impaired. The participants in Jolliffe and Baron-Cohen's study, for example, could not name the objects correctly without some conscious awareness of the processes involved in integrating the fragments. However, participants in the present studies could make responses that were influenced by the degree of integration present in stimuli, without any conscious awareness of this particular stimulus property.

In conclusion, the present studies failed to support predictions of an impaired or absent prototype effect in autism. These predictions were derived from accounts suggesting impairments in prototype formation (Klinger & Dawson, 2001), in common feature processing (Plaisted et al., 1998a), and in central coherence (Frith, 1989). The present studies possess several methodological aspects that are absent in one or more of the studies that support these accounts. Any one of these aspects may have favoured the expression of prototype effects by children with autism. These include: an autism group that is high functioning, cartoon animal stimuli, and a requirement for simple binary responses. Also, the task question was unambiguous and taxed recognition memory. Further research is required to isolate and test these methodological differences to see which ones critically affect the performance of individuals with autism.

Footnotes

[1] The design of Experiment 3.2 (average categories) permitted calculation of A' (an estimate of memory sensitivity free from response criteria) for medium FR exemplar items only. Hit rates (proportion of correct responses to old items) and false alarm rates (proportion of incorrect responses to new items) were combined to produce A' scores for each participant (Rae, 1976). The autism group appeared to have reduced memory sensitivity (M = .67, SD = .21) compared to the control group (M = .80, SD = .10). This was confirmed by an independent samples t-test, $t(20)$ = 2.30, p = .03 (equal variances not assumed).

[2] A' scores were calculated for modal category medium FR exemplars also. There appeared to be no difference in memory sensitivity (autism group: M = .50, SD = .25, control group: M = .53, SD = .24). This was supported by an independent samples t-test, $t(26)$ = .24, p = .81.

CHAPTER 4 - Prototype effects in autism: recognition and categorisation compared

Background: The aim of the current study was to test the suggestion made in Chapter 3 that individuals with autism would show intact prototype effects in recognition memory (as reported in Experiments 3.2 and 3.3) but impaired prototype effects in categorisation responses (as reported by Klinger & Dawson, 2001; Plaisted et al., Submitted). **Method:** Prototype effects were assessed in 18 HFA children and 18 controls matched on CA and VMA. This was done by obtaining recognition and categorisation responses to new (unstudied) and old (previously studied) dot pattern exemplars created using statistical distortion rules outlined in Posner, Goldsmith, and Welton (1967). Additionally, the effect of varying learning trials (one vs. six) was examined. **Results:** No participant group differences were observed in responses to new items. Both participants groups demonstrated some evidence of prototype effects in recognition and categorisation tasks. The HFA group performed significantly less well than controls on the recognition of old stimuli after one learning trial. After six learning trials, performance matched that of the control group. **Conclusions:** There was no evidence of a dissociation between recognition and categorisation performance in autism. Following Ameli, Courchesne, Lincoln, Kaufman, et al. (1988) the impairment in recognition memory for old items was interpreted as difficulty encoding meaningless stimuli.

Experiments 3.2 and 3.3 demonstrated that HFA children do show prototype effects in recognition memory with both average prototypes and modal prototypes. These findings appear to be inconsistent with studies showing that LFA children (Klinger & Dawson, 2001) and HFA adults and adolescents (Plaisted et al., Submitted) fail to abstract prototypes.

As discussed in Chapter 3, a key methodological difference between the experiments reporting intact and impaired effects is the nature of the task used to assess category learning. Where no prototype effect was obtained, the task was one of categorisation. In Experiments 3.2 and 3.3 where HFA children exhibited full prototype effects, the task was one of simple recognition: Participants had to indicate whether or not they had seen each test item previously. The possibility remains therefore that individuals with autism exhibit a dissociation: being able to show a prototype effect in recognition memory but not via categorisation responses. This possibility is consistent with either one of two states for categorisation responses. A general difficulty with transfer performance to new category members would result in a reduced prototype effect because performance on all exemplars would tend towards chance levels of responding. This would mean that a category prototype would lose much of its advantage over other exemplar types. Alternatively, even if transfer performance is unaffected, a specific difficulty with prototype abstraction via categorisation should also result in a reduced or absent prototype effect (prototype abstraction is considered a prerequisite for the demonstration of such an effect).

In support of the plausibility of the former notion, there is considerable evidence that recognition and categorisation processes in general are separable. For example, a double dissociation has been reported in the neuropsychological literature. Knowlton and Squire (1993) and Squire and Knowlton (1995) found that patients

with amnesia show impaired recognition performance but intact categorisation where they exhibited an identical prototype effect to a control group. Knowlton, Mangels, and Squire (1996) tested patients with Parkinson's disease who showed the reverse dissociation to the amnesic patients. Whilst their recognition performance matched levels of the control group, their early classification learning was inferior to that of both the amnesic and normal control group. (Later classification learning eventually reached the level of the amnesic group.) Also, Palmeri and Flanery (1999) obtained a dissociation between recognition and classification performance by inducing "amnesia" in normal participants. They achieved this by leading participants to believe that they had received a subliminal presentation of dot patterns, when in fact there was none, before the test phase. Unsurprisingly, participants made recognition judgements that were at chance levels of performance. However, their classification performance revealed a prototype effect and was at a level similar to that of the controls and amnesic patients reported by Knowlton and Squire (1993) and Squire and Knowlton (1995).

None of these neuropsychological studies, whether real or simulated, examined prototype effects in recognition memory, they only tended to examine those in categorisation. There is evidence, however, that recognition and categorisation prototype effects are experimentally separable. Metcalfe and Fisher (1986) obtained both recognition and classification judgements on dot patterns. They manipulated participants' expectations concerning the nature of the experimental task. Expectation of a classification task enhanced classification performance and increased size of the prototype effect. In contrast, expectation of a recognition task failed to enhance recognition prototype effects.

The dissociation observed in amnesia has triggered ongoing debate as to whether or not recognition and categorisation processes are subserved by one or two memory systems. Knowlton and Squire used the dissociations observed in amnesia and Parkinson's disease to argue for the case that recognition and categorisation processes are achieved by separate memory systems (Knowlton et al., 1996; Knowlton & Squire, 1993; Squire & Knowlton, 1995).

Palmeri and Flanery (1999) argued, however, that at least one part of the double dissociation, that showed by amnesic patients, did not necessarily imply separate memory systems. They pointed out that their study, where prototype effects in categorisation were obtained without a study phase, demonstrated that prior learning and hence use of a special memory system, were unnecessary for categorisation. Instead, they suggested that an intact working memory was all that was needed for successful categorisation performance.

Nosofsky and Zaki (1998) described how a single-system exemplar model could also account for the amnesic dissociation. They suggested that patients with amnesia suffered a general reduction in memory sensitivity (the ability to discriminate between individual exemplars). This abnormality would deteriorate recognition performance. However, such reduced memory sensitivity need not impair categorisation performance on Knowlton and Squire's task, because participants were identifying a single category from a collection of random lures. This means that all that was required was to detect broad similarities between an item and the category, a capability generally intact in amnesia, without the need for fine-grained discrimination. In support of this argument Nosofsky and Zaki reduced memory sensitivity in controls by introducing a one-week delay between training and

testing. Results were comparable to those shown by amnesic patients with intact categorisation performance and considerable impairment in recognition accuracy.

The issue of whether one or more memory systems subserve recognition and categorisation prototype effects is not addressed directly here. Instead, this study is designed to test the notion that individuals with autism behave like patients with Parkinson's disease: that is able to show prototype effects in recognition memory, but not via categorisation. If such a dissociation is found a multi-system account could explain these findings in a straightforward fashion (i.e. by positing impairment in some aspect of the categorisation system). The onus would then be on single system theorists to demonstrate how such a model could also account for the dissociation.

Given the parallels that have been drawn between the memory profiles observed in autism and amnesia, this prediction of a reverse performance profile to amnesia would perhaps be surprising from a traditional viewpoint. Initially, both behavioural and neuropsychological evidence gave rise to the view that the two disorders were analogous. Medial temporal lobe amnesia is characterised by particular difficulty with recall and "yes/no" recognition after filled delays between study and testing whereas cued recall remained intact (Baddeley & Warrington, 1970; Warrington & Weiskrantz, 1970, 1974). Boucher and Warrington (1976) reported a similar memory profile in autism: LFA participants showed impaired recognition and recall after filled delays. Also, post-mortem studies of individuals with autism found abnormalities in the medial temporal region containing the hippocampal formation and associated structures (e.g. Bauman & Kemper, 1985). LFA in particular has been associated with extensive medial temporal lobe abnormalities (Delong & Heinz, 1997).

Later studies, however, have cast doubt on the applicability of this analogue to HFA individuals. Minshew and Goldstein (1993) and Bennetto, Pennington, and Rogers (1996) found that HFA performance on the recognition and free recall elements of the California Verbal Learning Test matched that of control groups. Likewise, neuroanatomical evidence does not support the comparison between the disorders. For example, hippocampal abnormalities have not been found to be universally present at autopsy (Bailey et al., 1998).

The following experiment was designed to compare recognition-based and categorisation-based prototype effects within the same group of participants. The paradigm and methods of stimuli construction were the same as those used by Knowlton and Squire (1993). The paradigm was further adapted by comparing the effect of manipulating the number of learning trials (one vs. six) on test responses as done by Homa, Goldhardt, Burruel-Homa, and Smith (1993). The purpose was to facilitate the production of prototype effects. Homa et al. observed that prototype effects were greater in recognition memory after one trial but the greatest in categorisation after several trials.

If there is a dissociation between prototype effects in recognition and categorisation then the autism group should show intact prototype effects in the recognition conditions and impaired prototype effects in the categorisation conditions relative to controls. Furthermore, the differences between participant groups should be most pronounced after six trials in the categorisation test (and if participant group differences were to be found in recognition memory, they should be most pronounced after one learning trial). A further advantage of comparing responses examining the effect of learning is that this may provide further information about the nature of any deficits that may be observed. Of particular interest is whether or

not such deficits become attenuated with increased learning as was the case with the categorisation performance of patients with Parkinson's disease (Knowlton et al., 1996).

Experiment 4.1

Method

Participants

Eighteen HFA children and 18 typically developing children completed the study. Participants groups were matched globally on CA and VMA. Children in the autism group had been diagnosed by clinicians as having either AS (14) or autism (4) according to standard specifications such as those listed in the DSM-IV (American Psychiatric Association, 1994). They were recruited from special education facilities and ranged in chronological age from 10 years of age to 16 years and 6 months. Children in the control group were recruited from schools in South East England. Their ages ranged from 10 years and 4 months to 16 years and 4 months. VMA was assessed by the British Picture Vocabulary Scale (L. M. Dunn et al., 1997). Nonverbal mental age was assessed using Standard Progressive Matrices (Raven, 1996). Table 1 summarises participant details.

Table 4.1 Participant characteristics

	Autism Group ($n = 18$)	*Control Group* ($n = 18$)
Chronological age (years)		
M (SD)	13.00 (1.84)	12.84 (1.66)
VMA (years)		
M (SD)	13.60 (2.20)	13.21 (2.39)
Range	9.58 - 17.00	9.58 - 16.83
BPVS raw scores		
M (SD)	120.56 (14.56)	117.5 (14.62)
Range	94 - 152	94 - 139
RPM raw scores		
M (SD)	39.56 (10.08)	43.44 (6.46)
Range	23 - 53	31 - 57

Note. VMA = verbal mental age. BPVS = British Picture Vocabulary Scale. VMA was derived from the BPVS raw scores. RPM = Ravens Progressive Matrices. Maximum group difference: $t(29) = 1.38$, $p = .18$ (equal variances not assumed).

Apparatus and stimuli

All stimuli appeared in black as lines or solid shapes against a white background and unless mentioned otherwise, all stimuli were presented on a Toshiba

Satellite laptop computer with a screen measuring 286mm x 214mm. Foam pads attached to the *A* and *L* keys formed response buttons.

Experimental stimuli. Four dot patterns were created: each by randomly placing nine black dots (of 1mm diameter) on a hypothetical square grid. These were denoted the prototypes of categories *A* to *D*. From each prototype the statistical distortion rules of Posner, Goldsmith, and Welton (1967) were used to create study and test items. The study items comprised six medium FR items. Four of these were also presented as test items in addition to four each of medium FR, high FR, and low FR items. The distortion level, as defined by Posner et al., for each exemplar type was as follows: high FR – 3 Bits/Dot, medium FR – 5 Bits/Dot, low FR – 7.7, Bits / Dot. The dot patterns occupied a maximum computer screen area of 5 x 5 cm. See Figure 4.1 for examples of study and test stimuli.

The selection of exemplar types was the same as those used in Knowlton and Squire's (1993) study with one exception. Old medium FR exemplar types were included in the test phase following Experiments 3.2 and 3.3 and Homa et al. (1993). Old medium FR exemplar types were included to provide a more complete picture of recognition memory. The actual prototypes were excluded because responses to prototypes are unnecessary to demonstrate a prototype effect. Instead, what is necessary is that similarity to the prototype determines categorisation or recognition responses (as discussed in Chapters 2 & 3).

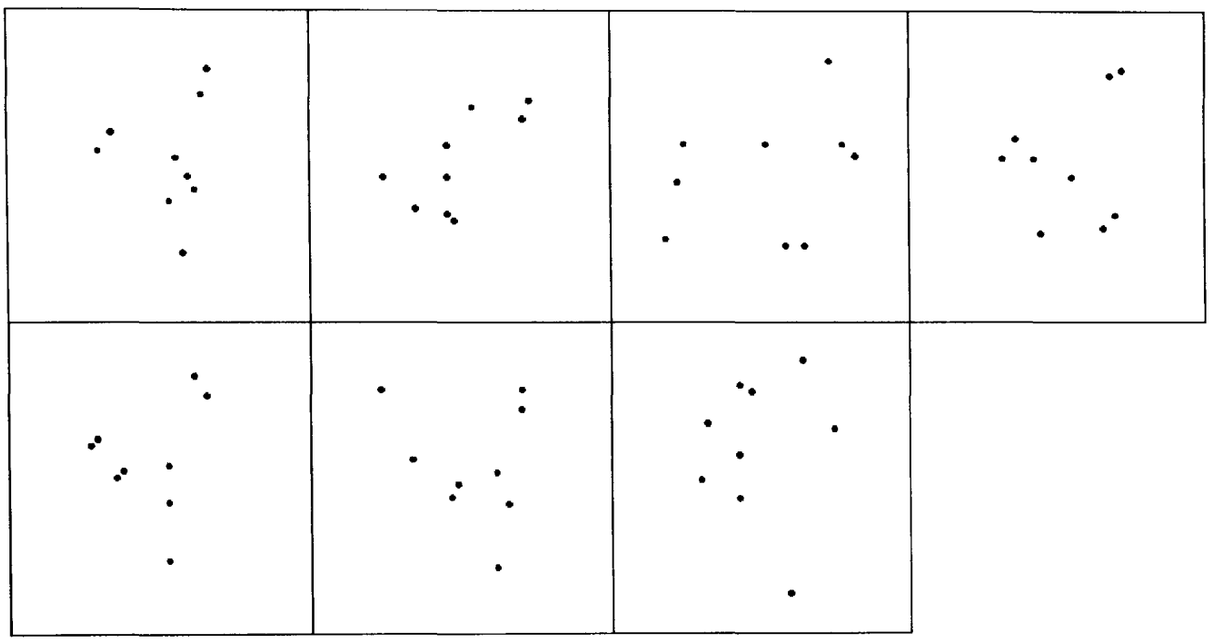

Figure 4.1. Examples of study stimuli (top row) and test stimuli (bottom row). Top row, from left to right (all medium FR exemplars): one each from categories *A* – *D*. Bottom row, from left to right (all new from category *A*): high FR exemplar, medium FR exemplar, and low FR exemplar.

Practice stimuli. These included eight circles and eight squares. Six stimuli of each shape were white with black borders and occupied screen areas ranging from 5 x 5 mm to 18 x 18 mm. Additionally, the smallest and largest of each shape were replicated and presented as solid black shapes.

As a visual aid for instructing participants, each screen event from the practice sessions, study and test phases, was printed on separate sheets of paper. Additionally, two further random dot patterns were generated and denoted Prototypes *E* and *F*. From each of these, four medium FR exemplars (5 Bits/ Dot) each were generated and printed out.

Procedure

Each participant completed the one-trial condition and the six-trial condition on separate days. No more than two weeks passed between these test sessions. Each condition comprised a study phase and a test phase. Before each phase, participants received instructions and completed a practice session designed to familiarise them or remind them of tasks involved in the main experimental sessions. All phases of each condition were completed one immediately following the other in the order presented here.

Practice study session: This familiarised participants with the process of categorising stimuli using feedback from the computer. Eight white practice stimuli, four from each category and each of these taking one of four different sizes, were presented in sequence. Participants learnt to categorise the shapes, each flanked by two labels that denoted the available categories (*X* for squares, and *Y* for circles), by pressing the response button located on the same side as the relevant label. Learning was achieved by means of feedback from the computer. After each response, the correct category label remained on screen together with the stimulus until the participant pressed a key to proceed. Wrong answers only were marked by a beep. See Figure 4.2 for a diagram of screen events and their duration. A randomly varying presentation time was selected for the fixation point that preceded each stimulus to discourage participants from settling into a mode of automatic responding. Participants were instructed how to complete the practice session with the aid of the pictures of screen events. They were told to start looking at the fixation point until the first stimulus arrived. For the first four responses, they were given verbal reinforcements to corroborate the computer feedback. A message

appeared at the completion of each study session stating the number of correct responses.

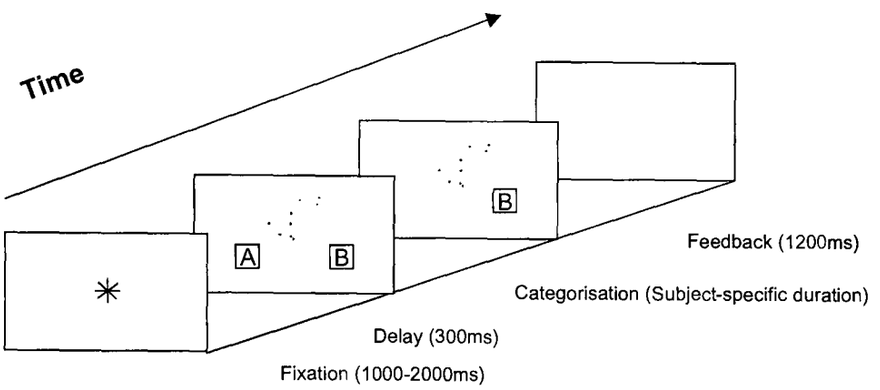

Figure 4.2. Diagram of screen events during study phase. Fixation duration varied randomly within range. (The stimuli and labels depicted are those shown in the experimental study phase).

Experimental study session. Immediately preceding this session, participants were told that they would be completing another game very similar to the shape sorting game (practice study session) in that they had to sort pictures into two groups. They were shown pictures of the dot patterns belonging to the *E* and *F* categories and shown how all *E* dot patterns looked a bit similar to each other and similarly the *F* dot patterns. They were told that in the new game, they would be sorting some different dot patterns.

Participants then commenced the study session. The procession of screen events was identical to that illustrated in Figure 4.2. Participants were presented with 12 medium FR exemplars, 6 each from categories *A* and *B*, or categories *C* and *D* in random order. Category type was counterbalanced across conditions (one-trial vs. six-trial). As in the practice study session, each stimulus was flanked by two

category labels. The experimental task involved learning to categorise the dot pattern into an appropriate category and feedback was provided by the computer. In the one-trial condition, participants had the chance to categorise each exemplar once. In the six-trial condition, participants cycled through all twelve exemplars six times. In both conditions, each cycle of exemplars was presented in a different random order. No message appeared stating the number of correct responses.

Practice test session. This was identical for both one trial and six-trial conditions. The aim of this task was to teach participants how to indicate recognition and categorisation responses. Eight stimuli, comprising the largest and smallest of each category presented in the practice study phase together with their replicas coloured black, were presented sequentially in random order. Following presentation of the fixation point, the stimulus appeared flanked by two recognition response labels: "Have seen" and "Not seen". If participants decided that they had seen the stimulus before in the study session, they were asked to select the "Have seen" label by pressing the relevant response button. Conversely, if the stimulus was viewed as new they selected the "Not seen" label. After participants had made a recognition response, the stimulus remained on screen whilst the labels changed to the categorisation response options: *X* and *Y*. Participants indicated their responses as they had in the practice study session. The position of the "Seen / Not seen" labels and category labels was counterbalanced across categories and conditions. No feedback was provided throughout the test phase. See Figure 4.3 for a diagram of screen events and durations for the test phase. Instructions were provided before the test phases by showing participants pictures of each screen event they would

encounter. At completion, the sum of correct recognition and categorisation responses was displayed.

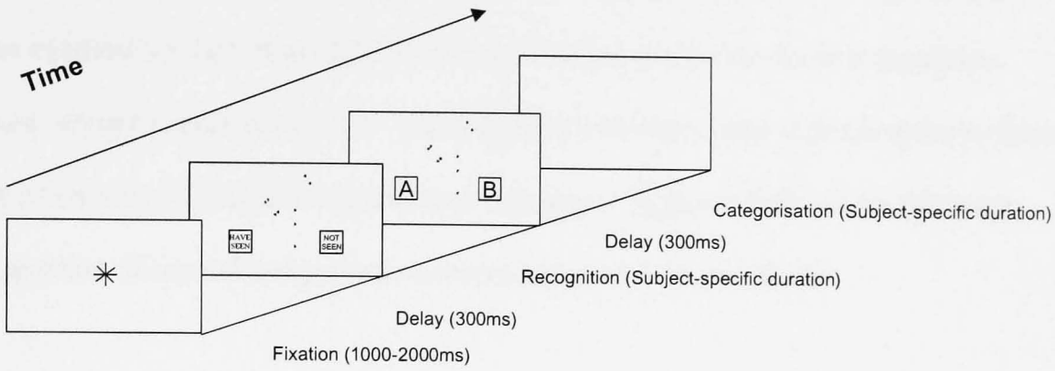

Figure 4.3. Diagram of screen events during the test phase. Fixation duration varied randomly within range. (The stimuli and labels depicted are from the experimental test phase.)

Experimental test phase: Following the practice test phase, participants were told they would be doing another game, just like the test practice session, but instead of shapes they would be making recognition and categorisation judgements to dot patterns. During this task, participants were presented with exemplars from two categories (either *A* and *B*, or *C* and *D*) that they had just studied. They were presented with four items of high FR exemplars, old medium FR exemplars, new medium FR exemplars, and low FR exemplars from each category. These were presented sequentially in a different random order for each participant and condition. The screen events and the responses required by each participant were identical to those of the practice study phase. At completion, the sum of correct recognition and categorisation responses was displayed.

Results

Study phases

The number of correct categorisation responses made by each participant was counted for each trial of the one-trial condition and of the six-trial condition (max. score for each trial = 12). These figures were converted to proportions to form the proportion of correct categorisation responses. Figure 4.4 illustrates the mean proportion of correct categorisation responses from both conditions

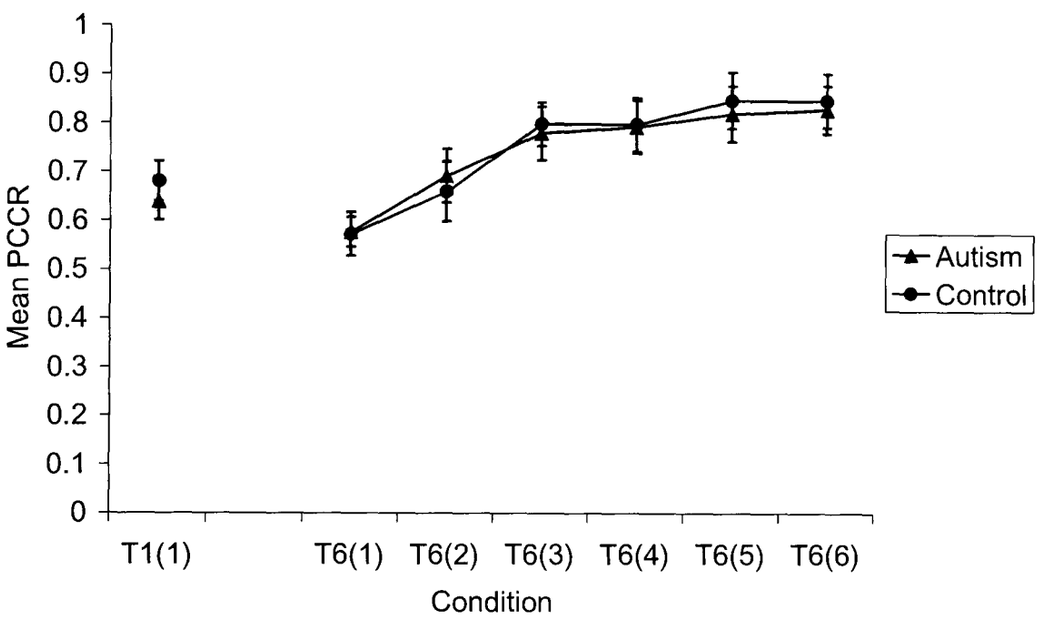

Figure 4.4. Study phases: Mean proportion of correct categorisation responses (PCCR) for each condition. T1 = one-trial condition. T6 = six-trial condition. Trial number is given in parentheses. Error bars represent *SEM*.

As can be seen from the graph, both participant groups performed similarly in both conditions. In addition, both participant groups in the six-trial condition showed a marked learning effect with categorisation performance improving over learning trials. These observations were confirmed by analysis. The order in which

participants completed the experimental conditions was entered in a 2 (order) x 2 (group) ANOVA analysis of proportion of correct categorisation responses for the one-trial condition. This revealed no significant effects: maximum $F(1,32) < 1$. A 2 (order) x 2 (group) x 6 (trial number) mixed, repeated measures ANOVA analysis of proportion of correct categorisation responses for the six-trial condition revealed a significant main effect of trial number: Greenhouse-Geisser $F(3, 92) = 16.74$, $p < .001$. The other significant main effect was that of order: $F(1,32) = 4.99$, $p = .03$. See *Order effects* section for further details. No other main effects or interactions were significant: maximum: $F(3, 92) < 1$.

Test phases

Knowlton and Squire (1993) tested categorisation on new items only so for comparability old and new FR items were analysed separately.

Test phase – recognition – new exemplars. The number of positive recognition responses (i.e. selections of the "Have seen" label) made by each participant was counted for each exemplar type and condition (one-trial vs. six-trial). The maximum possible score was 8 and these figures were converted into proportions to form the proportion of positive recognition responses.

Data for both old and new items are illustrated in Figure 4.5. As can be seen from the graph, the responses to new items were very similar for both participant groups. Each group showed a partial prototype effect in both conditions in that low FR exemplars received less recognition than medium FR exemplars. High FR items were recognised at equal or slightly higher levels than the medium FR items. These observations were confirmed by a 2 (order) x 2 (group) x 2 (conditions)

x 3 (exemplar type) mixed, repeated measures ANOVA. (Conditions comprised one-trial vs. six-trial and exemplar type refers to FR level: high, medium and low.) This analysis revealed a significant main effect of exemplar type: $F(2,64) = 27.64$, $p < .001$. Repeated contrasts revealed a significant difference between medium and low FR exemplars, $F(1,32) = 42.74$, $p < .001$, but none between high FR and medium FR exemplars, $F(1,32) = 1.45$, $p = .24$. There was also a significant interaction of exemplar type by order: $F(2,64) = 5.15$, $p = .008$. See *Order effects* section for further details. No other effects or interactions were statistically significant: maximum: $F(1,32) = 2.88$, $p = .10$.

Thus, the earlier prediction of no participant group differences in recognition memory prototype effects was supported. (Although, the findings provided no support for the proposition stated earlier that recognition prototype effects may be more pronounced after one learning trial than six learning trials.)

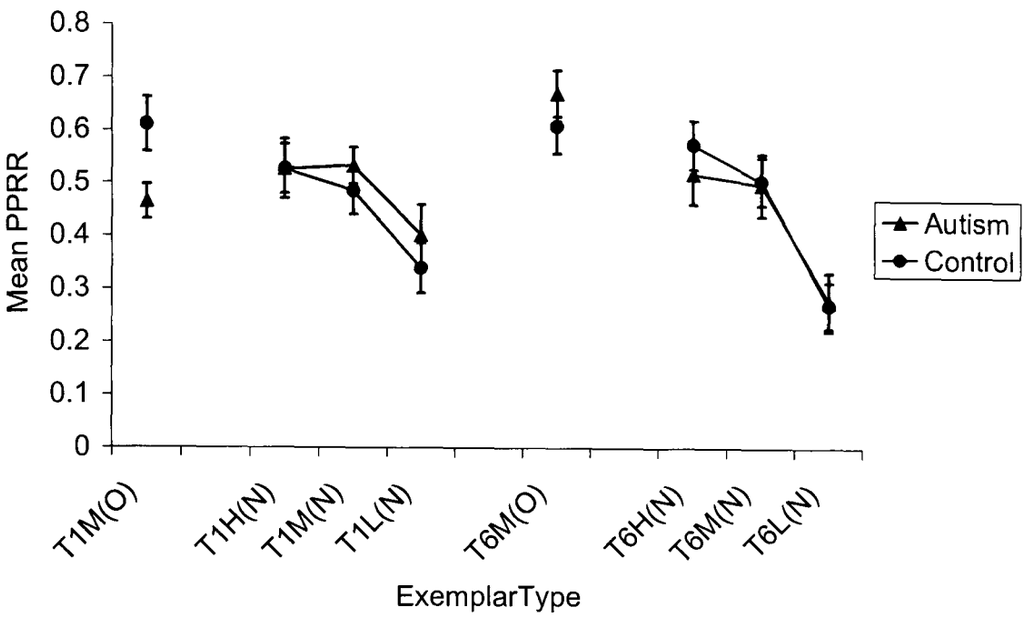

Figure 4.5. Test phases: Mean proportion of positive recognition responses (PPRR) for each condition and exemplar type. T1 = one-trial condition. T6 = six-trial condition. H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars. (N) = new exemplars, and (O) = old exemplars. Error bars represent *SEM*.

Test phase – recognition – old exemplars. Inspection of Figure 4.5 would suggest that the autism group showed less recognition to old medium FR exemplar types than controls in the one-trial condition, but this recognition performance matched that of controls after six learning trials. This observation was borne out by analysis with a 2 (group) x 2 (order) x 2 (condition) mixed, repeated measures ANOVA. This showed a main effect of condition: $F(1,32) = 4.81$, $p = .04$ and a significant interaction of group by condition $F(1,32) = 4.81$, $p = .04$.

Following Howell (1997, pp. 412 – 415), simple effects analysis with F_{crit} (1,32) ~= 4.17, and alpha = .05, revealed significant participant group differences in responses to the one-trial condition: F_{obs} (1,32) = 4.40. Group differences in the six-

trial condition were not significant: F_{obs} (1,32) < 1. The other effects of the main analysis were not significant: maximum $F(1,32) = 2.41, p = .13$[1].

The group differences obtained here contrast with evidence discussed in this chapter and Chapter 3 suggesting that visual recognition memory is intact in HFA children.

Test phase – categorisation – new exemplars. The number of correct categorisation responses made by each participant was counted for each exemplar type and condition (one-trial or six-trial). As with the recognition responses, the maximum possible score for each exemplar type was 8. As in the study phase, these figures were converted into proportions.

Figure 4.6 illustrates categorisation responses during the test phase. As can be seen from the graph, the transfer performance of both participant groups improved from the one-trial condition to the six-trial condition. In general, both participant groups showed partial prototype effects. Medium FR items were classified with greater accuracy than low FR items and this difference was increased after six learning trials.

The proportion of correct categorisation responses for new items were analysed with a 2 (order) x 2 (group) x 2 (condition) x 3 (exemplar type) mixed, repeated measures ANOVA. (Conditions comprised one-trial vs. six-trial and exemplar type refers to FR level: high, medium, and low.) There was a significant main effect of condition: $F(1,32) = 14.19, p = .001$. There was also a significant main effect of exemplar type: $F(2,64) = 9.71, p < .001$. Repeated contrasts revealed a significant difference between medium and low FR exemplars: $F(1,32) = 6.41, p = .02$ but not between high and medium FR exemplars: $F(1,32) = 3.24, p = .08$. The

interaction between condition and exemplar type showed a trend towards significance: Greenhouse-Geisser $F(2,50) = 3.29$, $p = .06$. There was a significant interaction between order and exemplar type: $F(2, 64) = 4.45$, $p = .02$. See *Order effects* section for further details. No other effects were significant: maximum Greenhouse-Geisser $F(2,50) = 2.23$, $p = .13$.

Thus, the findings failed to support the prediction made earlier of a participant group difference in prototype effects in categorisation. (There was mild support for the idea that categorisation prototype effects might be more pronounced after six learning trials.)

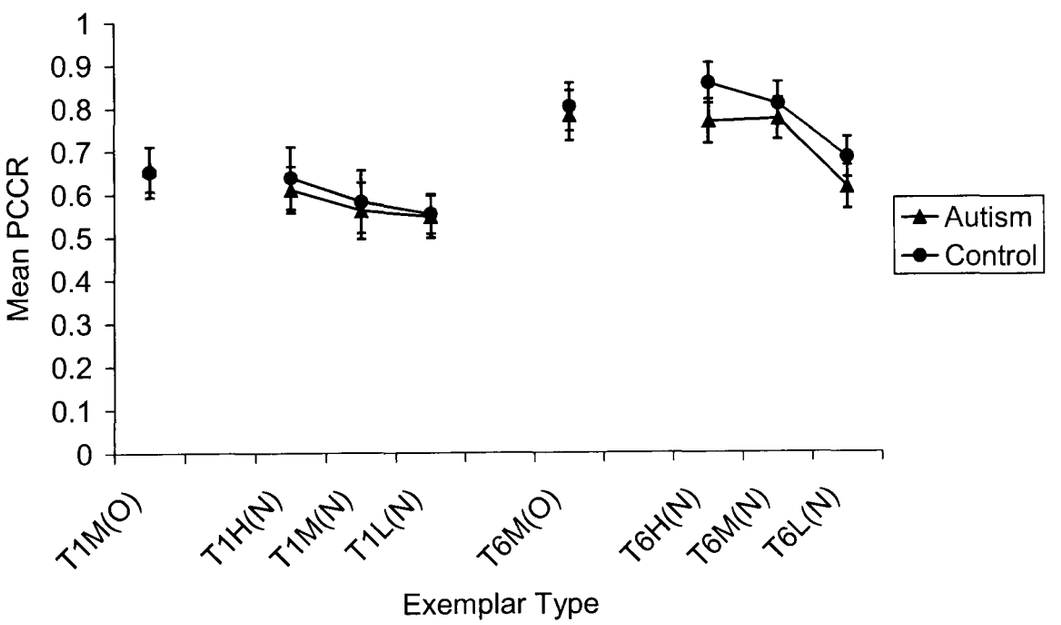

Figure 4.6. Test phases: Mean proportion of correct categorisation responses (PCCR) for each condition and exemplar type. T1 = one-trial condition. T6 = six-trial condition. H = high FR exemplars, M = medium FR exemplars, L = low FR exemplars. (N) = new exemplars, and (O) = old exemplars. Error bars represent *SEM*.

Test phase – categorisation – old exemplars. As Figure 4.6 shows both participant groups were better at categorising old items after six learning trials than one, and both participants groups behaved similarly. This was supported by the results of a 2 (order) by 2 (condition) by 2 (group) mixed, repeated measures ANOVA. This revealed a main effect of condition: $F(1,32) = 7.98, p = .008$. The main effect of order was also significant: $F(1,32) = 4.46, p = .04$. See *Order effects* section for further details. Neither the main effect of group or any other interactions were significant: all $F(1,32) < 1$.

Order effects

With the exception of recognition responses to old exemplars, all categorisation and recognition responses from the current study involved order effects. These all tended to form a consistent pattern. During the study phase of the six-trial condition, participants who completed this condition first tended to perform rather better during this condition than those who completed the six-trial condition last.

Although the test phase findings represented the combination of one-trial and six-trial data, these results are likely to be heavily biased by the six-trial condition because of the greater learning afforded during this condition. It seems likely therefore that the superior learning that occurred when the six-trial condition was presented first was reflected in the test phases. This was shown by lower false recognition for low FR items, and more accurate categorisation of medium FR exemplars.

Study phase. In general, performance on the six-trial condition was better when presented first (*est. MM* = .81, *SEM* = .04) than when this condition was presented last (*est. MM*= .68, *SEM* = .04).

Test phase – recognition – new exemplars. Analysis with repeated contrasts revealed a significant interaction involving medium FR and low FR items, and order: $F(1,32) = 12.91$, $p = .001$. Low FR items received less recognition when the six-trial condition was presented first (*est. MM* = .26, *SEM* = .04) than when the six-trial condition was presented last (*est. MM* = .41, *SEM* = .04). There was little difference in medium FR recognition between orders: six-trial condition first (*est. MM* = .52, *SEM* = .03); six-trial condition last (*est. MM* = .48, *SEM* = .03). The interaction involving medium FR and high FR items, and order was not significant.

Test phase – categorisation – new exemplars. Analysis with repeated contrasts revealed an interaction involving medium FR and low FR, and order: $F(1,32) = 7.12$, $p = .01$. Medium FR items received more correct categorisation when the six-trial condition was taken first (*est. MM* = .75, *SEM* = .04) than when the six-trial condition was taken last (*est. MM* = .61, *SEM* = .04). There was little difference in low FR categorisation performance between orders (six-trial condition first - *est. MM* = .60, *SEM* = .03 vs. six-trial condition last - *est. MM* = .61, *SEM* = 0.04). The interaction involving medium FR and high FR items, and order was not significant.

Test phase – categorisation – old exemplars. In general, categorisation was better when the six-trial condition was completed first (*est. MM* = .78, *SEM* = .04) than when the six-trial condition was completed last (*est. MM* = .65, *SEM* = .05).

Discussion

The main aim of the current study was to see whether or not individuals with autism exhibited a dissociation between recognition and categorisation performance analogous to that shown by patients with Parkinson's disease: showing prototype effects in recognition memory but not via categorisation responses. Another aim was assess learning in autism over multiple learning trials.

Analysis of responses to new exemplars failed to support an analogy between HFA and Parkinson's disease. The prediction of a dissociation was unsupported. No participant group differences were observed with either the recognition or the categorisation responses. The findings provide some support for the idea that HFA children can show prototype effects in both recognition and categorisation responses. Both participant groups tended to obtain higher recognition and categorisation scores in response to medium FR exemplars than to low FR exemplars. However, such prototype effects were only partial in that no significant differences were observed between responses to high FR and medium FR exemplars in either participant group. As similarity is assumed to determine responses (whether recognition or categorisation) it is possible that the distortion level selected for the high FR exemplars was insufficiently similar to the prototype and too similar to medium FR exemplars, therefore promoting responses to high FR items that are indistinguishable from those to medium FR items.

In general, both participant groups were affected by multiple learning trials in the same way, with the exception of recognition responses to old medium FR items. HFA participants showed reduced recognition of old items after one learning trial but recognition levels reached levels similar to that of the control group after six learning trials. Although this is a form of recognition impairment and categorisation

performance on the same stimuli matched that of controls, the overall pattern of findings do not fit those observed in amnesia. (A disorder characterised earlier by impaired recognition and intact categorisation performance.) Impaired recognition performance was displayed by amnesic patients after multiple learning trials (e.g. five items presented eight times, Knowlton & Squire, 1993). This contrasts with the fact that intact recognition performance of the old items was shown by the HFA group reported here, after multiple learning trials (twelve items presented six times).

Furthermore, neither of the accounts of the amnesic dissociation can explain the discrepancy between responses to old and new exemplars observed in the current study. Knowlton and Squire's (1993) account of separate memory systems for recognition and categorisation and impairment in the recognition sub-system does not make a distinction between recognition for old and new items. In addition, Palmeri and Flanery (1999) demonstrated directly that reduced memory sensitivity would result in equal impairments across old and new items so this explanation can not account for the pattern of impairments observed in the current study either.

Although a number of studies, as discussed earlier, have demonstrated intact recognition performance in HFA children, these studies all tested recognition of meaningful stimuli. At least one other study has reported recognition impairments for meaningless stimuli that may be similar to those reported here. Ameli et al. (1988) directly compared visual recognition performance on meaningful stimuli (pictures of illustrated concrete nouns e.g. glove, flower) and meaningless stimuli (abstract patterns created with lines, curves and geometric shapes). They tested HFA adults and adolescents using a non-matching to sample method. This involved presenting a series of trials each comprising two presentations. The first presentation displayed 5-7 stimulus items and the second displayed the same items plus an

addition. The task aim was to identify the addition. Individuals with autism showed recognition impairments on the meaningless stimuli but not the meaningful stimuli. Ameli et al. argued that flexible encoding, organisation of information was necessary for successful memory performance on meaningless materials, and it was this that individuals with autism found difficult.

This account is consistent with the findings reported here for old exemplars. This is because the dot patterns are also meaningless stimuli, and a decrement in recognition performance was observed after a single presentation as was the case in Ameli et al.'s (1988) study. One difference between the studies, however, is that the design of Ameli et al.'s study does not permit distinction between the recognition of old and new items. The findings, however, are congruent with a decrement in the recognition of old items: Participants may have failed to select the new addition because of difficulty recognising the other items in the display as old.

Despite the transient difficulty with meaningless old stimuli, the display of prototype effects with the new stimuli suggested that there was no evidence to support Kate Plaisted's suggestion (Chapter 3) that individuals with autism might need stimuli to which verbal labels could be attached before displaying prototype effects. It seems likely that the dot patterns are as resistant to verbal labels as the stimuli used in Plaisted et al., (Submitted).

The order in which the one-trial and six-trial condition were presented had a marked effect on participant responses. As argued in the Results section, it seems likely that order effects observed in the test phase could be attributable to those that were observed in the study phase. The fact that performance was worse during the study phase of the six-trial condition when this condition was preceded by the very similar one-trial condition implied that practice effects were not responsible.

Therefore, it seems likely that the training procedures employed in the study were effective in teaching participants how to complete the study successfully. Instead, these order effects perhaps reflect some heterogeneity in category learning amongst both participant groups.

In sum, no evidence was found to support the notion that conceptual deficits in autism can be characterised by a dissociation analogous to Parkinson's disease, with impaired prototype effects in categorisation and intact prototype effects in recognition. Partial prototype effects were found in recognition and categorisation alike in both participant groups.

Participant group differences were observed in the recognition responses to old items. The HFA group was less likely to correctly identify old exemplars as such after one learning trial than controls. After six learning trials, recognition performance on these items matched that of controls. Following Ameli et al. (1988) these results were interpreted as a difficulty encoding meaningless stimuli with the proviso that any decrement to recognition is transient and limited to old items.

No evidence has been found to support either Klinger and Dawson's suggestion of a dissociation between rule-based and prototype-based categorisation (Chapter 3) nor for the dissociation between recognition and categorisation. Thus, the best method of characterising conceptual deficits in autism remains an open question.

One methodological feature of Klinger and Dawson's study raised in Chapter 3, was that the question wording may have been ambiguous and thus specifically problematic for the group with autism. This question is addressed in the studies reported in the following chapter.

Footnote

[1] As for Experiments 3.2 and 3.3, A' scores were calculated for recognition responses to medium FR exemplars. The autism group showed reduced memory sensitivity (A' scores) compared to controls after one trial (Autism: M = .46, SD=.20; Control: M=.64, SD = .26). However performance matched that of controls after six trials (Autism: M = .71, SD = .21; Control: M = .62, SD = .27).

When these scores were analysed with a 2 (group) x 2 (order) x 2 (condition) mixed, repeated measures ANOVA, the general pattern of findings mirrored those reported for recognition responses to old medium FR exemplars. The main effect of condition showed a trend towards significance, $F(1,32) = 3.94$, p = .06, and the interaction of group by condition was significant: $F(1,32) = 4.84$, p = .04. An analysis of simple effects with F_{crit} (1,32) ~= 4.17, and alpha = .05, revealed significant participant group differences in responses to the one-trial condition: F_{obs} (1,32) = 4.50 but not the six-trial condition: F_{obs} (1,32) = 1.07. The other effects and interactions of the main analysis were not significant: maximum $F(1, 32) = 1.74$, p = .2.

CHAPTER 5 - When prototypes are not best and category membership is restricted: Judgements made by children with autism.

Background: Klinger and Dawson (2001) reported that children with autism were unable to abstract prototype representations. In contrast, we found that they could (Chapter 3). The current study was designed to test whether children with autism had difficulty with the requirement, present in the former study, to select the best category member, rather than with prototype formation per se. **Method:** Children with HFA or AS (n = 18) and typically developing children (n = 18) completed a prototype effect test by selecting the best examples of categories (Experiment 5.1). A control task followed (Experiment 5.2) designed to test understanding of the prototype effect test. This task required the selection of the best example of a target category from an array. Participants then indicated that their selection was not the only possible choice on the control task by indicating the number of items belonging to the target category (Experiment 5.3). **Results:** Most participants with autism displayed prototype effects via selection of best category members (Experiment 5.1). Furthermore, an association was observed between performances on the control task and the prototype effect test (Experiment 5.2). In general, participants indicated that the item selected as best was not the only category member in this control task and individuals with autism made more conservative category membership decisions (Experiment 5.3). **Conclusions:** The findings suggest that children with autism can abstract prototypes and there was evidence of difficulty with the requirement to select the best category member. The implications of the conservative category membership decisions for broader theoretical accounts of autism and concept formation are discussed.

Chapter 2 described how Klinger and Dawson (1995, 2001) suggested that individuals with autism behave in the manner predicted by the classical model of concepts. That is they tend to rely solely upon rule-based categorisation owing to difficulty abstracting prototypes. Chapter 3 outlined some of the conflicting evidence on this issue. Klinger and Dawson (2001), for example, familiarised LFA participants with particular named categories (e.g. Mip). Then, during the test phase participants were presented with a binary forced-choice between two previously unseen category exemplars. Both of these ostensibly were from the same category. One member of the pair was the category prototype, the other possessed features that had been seen during the familiarisation phase but the combination of features in that particular animal was novel. Participants were asked to identify the Mip (for example). If any pointed out, correctly, that both items were Mips they were instructed to select the best one. The normal control group tended to select the prototype at levels exceeding chance whereas individuals with autism failed to do so. From these findings, Klinger and Dawson concluded that individuals with autism were unable to abstract summary information from categories in the form of prototypes.

We obtained conflicting findings with an HFA group as reported in Chapter 3. Both this group and typically developing controls demonstrated a prototype effect twice via recognition responses: once where within-category similarity was defined in terms of feature size as in Klinger and Dawson's (2001) study and once where within-category similarity was defined in terms of the number of features held in common between an exemplar and prototype. This discrepancy could be attributable to methodological differences between the two experiments. One difference was that

in Klinger and Dawson's prototype condition, participants were expected to select the best category member. This requirement was either implicit or made explicit if the participant sought clarification. It is possible that such a requirement presented greater difficulty for the autism group. Both items of each pair presented in the test phases looked as if they belonged to the same target category and so there was no clear right or wrong answer. This created ambiguity. In addition, no explicit or implicit rule was provided to aid the selection of the best item. This type of ambiguity was absent in the tasks that the autism groups were successful at. In Klinger and Dawson's rule-based conditions, described in Chapter 2, there was only one correct answer: Only one item of each test pair was a member of the target category. Similarly, in the study reported in Chapter 3, there was only a single correct answer: either the test item had been seen before or not. Furthermore, in these tasks, either implicit or explicit rules were provided. For example, participants were taught how to indicate recognition responses. In Klinger and Dawson's rule-based conditions participants learnt the correct classification rule (either implicitly or explicitly).

There is some evidence that individuals with autism have difficulty interpreting ambiguity in either spoken or written language. This includes problems pronouncing homographs correctly. For example, LFA children failed to used context to determine the correct pronunciation of the word *bow* in such sentences as: "He had a pink bow" and "He made a deep bow" (Frith & Snowling, 1983). The effect has been noted also in HFA and AS groups (Happé, 1997; Jolliffe & Baron-Cohen, 1999). Jolliffe and Baron-Cohen (1999) report, also, that HFA and AS groups had difficulty using context to disambiguate the meaning of spoken sentences

such as: "The roar of the fans disturbed the team" where such sentences were preceded by a contextualising sentence, for example "The boiler house was noisy".

One possibility is that children with autism failed to show a prototype effect in Klinger and Dawson's (2001) study because of difficulty interpreting the ambiguous task requirement rather than any difficulty in prototype formation per se. Experiments 5.1 and 5.2 reported here were designed to test this possibility. Participants completed a prototype effect test using cartoon animal categories given names (e.g. "Hov"). The requirement to select the best category member was made explicit using *best test questions* (Experiment 5.1). These took the form, for example: "Where is the best Hov?" Then, the same participants completed two control tasks, the shapes test, and the numbers test (Experiment 5.2). These were designed to test interpretation of best test questions by asking participants to make selections from alternatives but without the need to abstract a prototype. The aim of Experiment 5.3 was to establish an assumption that participants taking the shapes test genuinely perceived two or more alternatives from which to choose.

Experiment 5.1

The prototype effect test used here was similar to that used by Klinger and Dawson (2001) but with a few differences, designed to make the task more sensitive to the effect and therefore more sensitive to possible participant group differences. Asking participants to study six categories instead of two increased the range on the dependent variable (e.g. participants could select a maximum of six prototypes). Items that bore low FR to the prototype were added to the test phase to provide a more stringent test. To show a prototype effect participants should choose both more prototypes and fewer low FR items than medium FR items. The wording of the test

question (e.g. "Where is the best Hov?") made the requirement to choose the best category member explicit for all participants. (As discussed earlier, in Klinger & Dawson's study, only those who queried the task were told to choose the best category member.) If participants have trouble understanding the best test question then they should fail to show a prototype effect, or show one that is reduced relative to controls.

Method

Participants. Two groups took part in the study: HFA children and typically developing controls. Two children with HFA and one without were excluded because of a recorded history of epilepsy or attention deficit hyperactivity disorder. The remaining participants were matched on gender (2 girls and 16 boys per group), and globally matched on CA and VMA. The children in the autism group had been diagnosed by clinicians as having either AS (13) or autism (5) according to criteria such as those specified by the DSM-IV (American Psychiatric Association, 1994). They were recruited from specialist schools and units and ranged in age from 9 years and 5 months to 15 years and 8 months. Children in the control group were recruited from schools from Central and South East England. Their ages ranged from 9 years and 7 months to 15 years and 7 months. VMA was assessed by the BPVS (L. M. Dunn et al., 1997). Table 5.1 summarises participant characteristics.

Table 5.1 Participant characteristics

	Autism Group (n = 18)	Control (n = 18)
Chronological age (years)		
M	13.13	12.88
SD	2.02	2.04
VMA (years)		
M	12.00	12.33
SD	3.47	3.28
Range	6.75-17.00	7.42-17.00
BPVS raw scores		
M	110.11	112.39
SD	24.59	22.19
Range	69 - [1]51	76-150

Note. VMA = verbal mental age. BPVS = British Picture Vocabulary Scale. VMA was derived from the BPVS raw scores. Maximum group difference: $t(34) = .38, p = .71$.

Materials. Six categories of cartoon animal were created using the method described in Experiment 3.2. Each was labeled (e.g. Hov) and structured around a central prototype. This possessed features (e.g. neck or nose) that were the category average in size. All category members possessed six features that varied along a dimension

from value 1 to value 6. All study stimuli were black line drawings occupying a maximum area of 9 cm by 10 cm on white 20 cm by 12.5 cm cards. Eight study items were created for each category. The features of each study item had values of either 2 or 5. These bore medium FR (an intermediate level of similarity) to their respective category prototypes (each with feature values all at 3.5). See Table 5.2 for a description of feature values for the Hov category. The study items of all other categories shared the same value structure.

Table 5.2 Study stimuli: Hov feature values

Item No.[a]	Horn length	Ear length	Neck length	Leg length	Tail length	Back crest width
1	5	2	2	5	2	5
2	2	2	5	5	2	5
3	5	5	2	2	2	5
4	2	5	2	5	2	5
5	2	5	5	2	5	2
6	2	2	5	5	5	2
7	5	5	2	2	5	2
8	5	2	5	2	5	2

Note. [a] All items are medium family resemblance exemplars.

Test items were printed in the form of a booklet for each participant. (The last eight pages contained stimuli for Experiment 5.2.) Each page illustrated a prototype, an unstudied medium FR exemplar, and a low FR exemplar all from the same category. The positions of exemplars on each page formed an inverted and flattened triangle. Figure 5.1 illustrates one page of items belonging to the Hov category. Table 5.3 shows the feature values for the test items of all categories.

Each booklet presented to each HFA participant was assigned to one of two counterbalancing orders: Set A or Set B. On each page of the section of the Set A booklet used in this experiment, the position of each exemplar type was counterbalanced across categories and each occurred in the same position twice. For example, the prototype appeared in the middle on the Mek and Gip category pages in all Set A booklets. This was the case also with the Set B booklets. However, the location - category configurations were varied from Set A. For each prototype effect test, page order and category order was randomised. The control group received replicas of these booklets.

Procedure. For each participant, the sixteen study items from the pair of categories depicted on the first two pages of the test booklet were shuffled together. The first item was placed face up towards one side of the participant and named (e.g. Hov). The experimenter (first author) told the participant to study this (and all further cards) for three minutes because there would be a memory test later. (Three minutes was the maximum amount of time that some of the younger participants with autism could be prompted to study the cards.) The experimenter selected an item belonging to the other category, placed it towards the other side of the participant, and named it (e.g. Mek). From then on study cards were handed singly to the participant who was

encouraged to study the card and then place it face up on the pile of cards from the same category. Any mistakes in placing the cards were corrected immediately by the experimenter. Immediately afterwards, the participant was shown the first page of the test booklet. The experimenter said, "Look at all these", pointed briefly to each exemplar (from left to right), and asked where the best category item was: for example, "Where is the best Hov?" If the participant did not respond immediately, the question was repeated together with the comment, "There is no right or wrong answer, just choose the one that you think is best". Any hesitant participants responded after a second prompt. Participants indicated selections by marking a response box beneath the chosen item. They were then asked to select the best item from the other category, that was studied. This was depicted on the second page. This study and test procedure was repeated twice more. In this way, each participant studied and was tested on all six categories, one pair at a time.

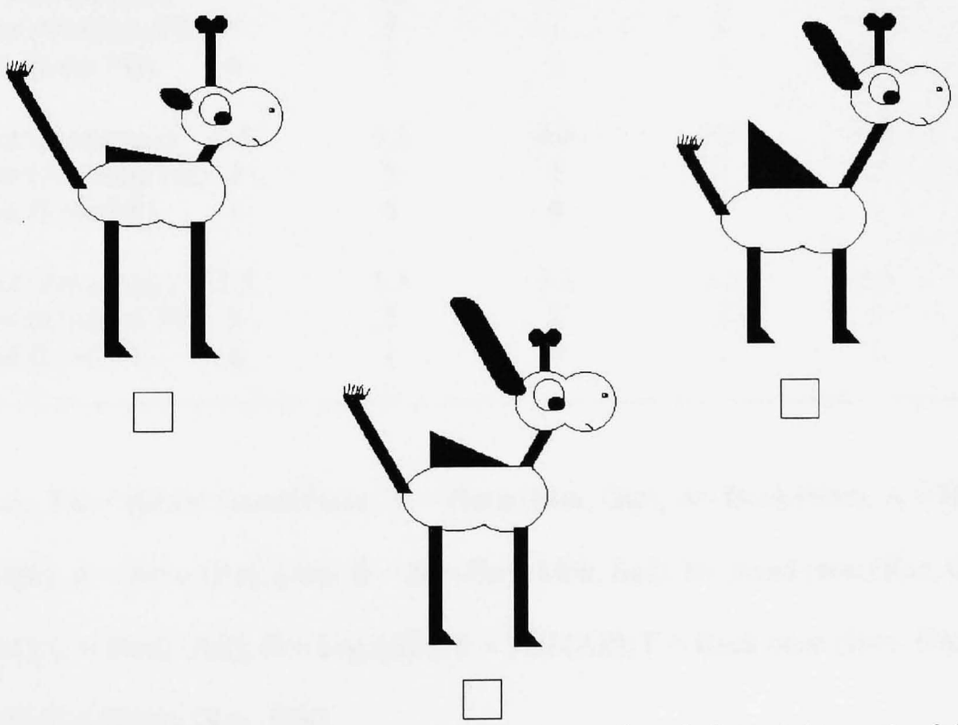

Figure 5.1 Test page for the Hov category. Items from left to right are the following exemplar types: low FR, medium FR, and prototype.

Table 5.3 Test stimuli: Feature values for all categories

	Features					
Category (Exemplar Type)	A	B	C	D	E	F
Hov (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Hov (Medium FR)	2	5	2	5	5	2
Hov (Low FR)	6	1	1	1	6	6
Raz (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Raz (Medium FR)	2	5	5	2	2	5
Raz (Low FR)	1	6	1	6	6	1
Mek (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Mek (Medium FR)	5	2	5	2	2	5
Mek (Low FR)	1	6	6	6	1	1
Gip (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Gip (Medium FR)	5	2	2	5	5	2
Gip (Low FR)	6	1	1	1	6	6
Dut (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Dut (Medium FR)	2	5	5	5	2	2
Dut (Low FR)	1	6	6	1	1	6
Bef (Prototype)	3.5	3.5	3.5	3.5	3.5	3.5
Bef (Medium FR)	5	2	2	2	5	5
Bef (Low FR)	6	1	6	1	1	6

Note. FR = family resemblance. A = Horn (Hov, Gip), A= Beak (Raz), A = Hair (Mek), A = Nose (Bef, Dut); B = Ear (Hov, Mek, Bef), B= Head crest (Raz, Gip, Dut); C = Neck (All); D = Leg (All); E = Tail (All); F = Back crest (Hov, Gip, Mek, Bef), F = Wings (Raz, Dut).

Results and discussion

Across the six categories, each exemplar type could be chosen as best between 0 and 6 times. The total number of prototypes selected by each participant was counted and converted to a proportion out of 6. These choice proportions were calculated for medium FR items and low FR items also. The mean choice proportion for each exemplar type and participant group is displayed in Table 5.4. Support for the idea that a prototype effect shown in response to best test questions would be impaired in autism was somewhat equivocal. The data illustrated in Table 5.4 suggests that both participant groups showed a prototype effect. The mean choice proportions increased as similarity to the prototype increased. In addition, the autism group appeared to show a weaker effect: They selected fewer prototypes and more low FR items than the control group. This observation was confirmed by the fact that a Friedman test showed that the difference between exemplar types was significant for the control group: Chi-Square = 15.61, $df = 2$, $p < .001$; but that the difference between exemplar types only showed a trend towards significance for the HFA group, Chi-Square = 5.32, $df = 2$, $p = .07$. However, this apparent difference between participant groups was not supported by t-tests. No significant participant group differences were observed for either the low FR items, $t(34) = 1.52$, $p = .14$, or the prototypes, $t(34) = .99$, $p = .33$[1].

Table 5.4 Mean choice proportions (and standard deviations) for each exemplar type and participant group

Exemplar Type	Autism Group CP	Control CP
Prototype		
M (*SD*)	.49 (.27)	.57 (.23)
Medium FR		
M(*SD*)	.28 (.16)	.30 (.18)
Low FR		
M(*SD*)	.23 (.23)	.13 (.17)

Note. CP = choice proportion. FR = family resemblance.

Experiment 5.2

Participants completed two control tasks: The shapes test and the numbers test. Both were designed to test understanding of best test questions without the requirement to abstract summary information in the form of prototypes from test materials. Participants had to consider several alternatives before selecting one item in response to a question as to which was best. The shapes test was designed to possess ambiguity similar to that present in Klinger and Dawson's (2001) prototype condition and Experiment 5.1. Participants were asked to select the best category member from an array of candidates and no rule was provided to aid with selection. Both control tasks were structurally identical. However, ambiguity was absent in the

numbers test in that a selection rule was provided and for each question, there existed a single objectively correct answer. If difficulties lie specifically with ambiguity then impairment should be observed with the shapes test only. Furthermore, if difficulty with ambiguity is responsible for the weaker prototype effect shown by the HFA group (Experiment 5.1) then there should be a relationship between performances on the shapes test and the prototype effect test.

Method

Participants. The same participants from Experiment 5.1 took part.

Materials. The last eight pages of the booklet described in Experiment 5.1 formed the control tasks. Each page of the shapes test depicted six items, presented in a row, with a response box beneath each item. Within each row was a pair of canonical shapes or letters as follows: letter *C* and letter *O*, letter *H* and letter *A*, square and diamond, and circle and oval. The remaining four items of each row were hybrids representing intermediate points along a continuum of similarity between the two canonical items. These intermediates were spaced evenly across the continuum. For example, varying the size of the gap at the apex of the letter *A* created intermediates of the H-to-A array. The size of this gap increased by a standard measurement (2mm) as the intermediate approximated the canonical letter *H*. This array was similar to that created by Hampton (1996). The remaining arrays were created specifically for the study. See Figure 5.2 for an illustration of the shapes test arrays.

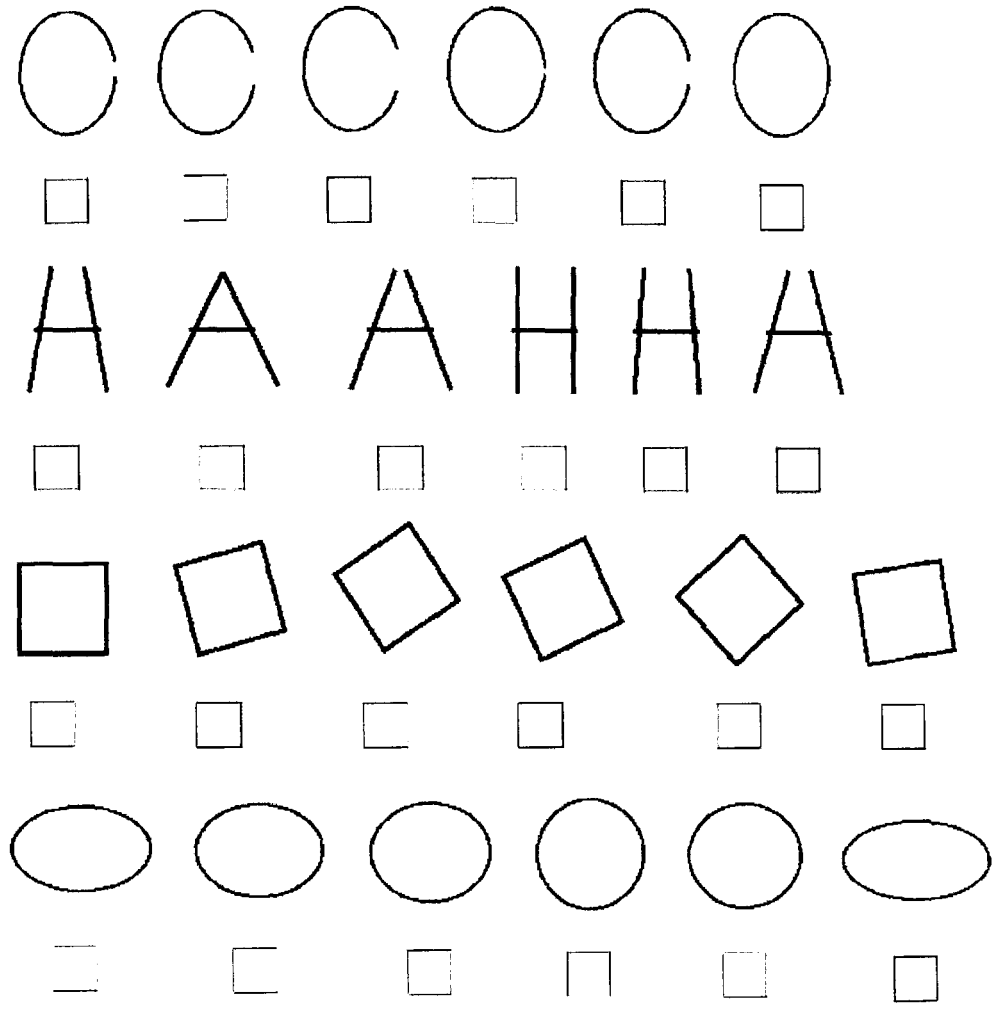

Figure 5.2 Shapes test stimuli. Arrays from top to bottom: letter *C* to letter *O*, letter *H* to letter *A*, square to diamond, and circle to oval. Each row of shapes or letters together with the row of response boxes below was presented on a separate page.

Each page of the numbers test presented a table of numbers as if they were school test results. The top row listed the subjects: English, mathematics, French, or science. The second row listed children's names: different for each subject. The third row listed the test scores. The fourth row was left empty for the participants to place their responses. (The test scores were as follows: science – 14, 27, 36, 53, 99, 100; mathematics – 17, 24, 37, 69, 70, 84; English – 10, 18, 29, 80, 86, 88; French - 3, 32, 56, 58, 59, 94.)

All participants completed the control tasks immediately after completing the prototype effect test (Experiment 5.1). This order was selected to avoid any

possible training effect from the control tasks. The pages depicting the shapes and numbers tests of each booklet belonged to the same counterbalancing order, Set A or Set B, as the rest of the booklet presented in Experiment 5.1. For both sets, the position of items within each array or table varied randomly. These random orders were held constant within each set. The order of arrays or school subjects was randomised within each booklet and the presentation order of the shapes and numbers tests was counterbalanced across each set. As mentioned in Experiment 5.1, control group participants received replica booklets.

Procedure. For each page of the shapes test the experimenter said, "Look at all these" and pointed briefly to each item (from left to right). Then the participant was asked to point to the target canonical item, for example, "Where is the best letter *H*?" Other targets comprised the letter *C*, the square, and the circle. The participant responded by marking a response box. At the first page of the numbers test, the participant was told that the numbers represented test marks for each of the named children, that high numbers were "good", and low numbers were "bad". At each page, the participant was told to look at all the numbers and asked, "Who has the best science (mathematics, English, or French) score?" The participant responded by marking the row beneath one of the numbers.

Results and discussion

Shapes test. Each selection from each array of the shapes test was assigned an integer from 1 to 6. These integers reflected similarity between the selected item and the target canonical item: for example, 6 was assigned to the correct canonical item, 5 was assigned to the next most similar item, and so forth. The integers,

corresponding to the items chosen from each array, were summed to give a total score (maximum = 24). This was then converted to proportions to give the proportion of shapes score for each participant. Every control group participant obtained the maximum proportion of shapes score of 1. The number of autism participants scoring a proportion of shapes score of 1 was 12 out of 18. The mean proportion of shapes score of the HFA group was .97 (SD = .04). The difference between participant groups was significant: $t(17) = 2.61$, $p = .02$ (equal variances not assumed).[2]

To explore a possible relationship between the proportion of shapes score and developmental variables in the HFA group, CA and VMA were split on the mean proportion of shapes score for all participants (.99). Those in the low proportion of shapes score group (scoring below the mean) had a lower average CA (M = 11.89 years, SD = 2.31) and lower average VMA (M = 10.61 years, SD = 3.44) than the high proportion of shapes score group (that scored above the mean): CA: M = 13.76, SD = 1.63; VMA: M = 12.70, SD = 3.41. The difference in CA showed a trend towards significance: $t(16) = 2.00$, $p = .06$. The difference in VMA was not significant: $t(16) = 1.22$, $p = .24$) although, with a sample size of six, power was low. It appears that the six HFA participants in the low proportion of shapes score group were unlikely to be making random selections. A one-sample t-test demonstrated their proportion of shapes scores to be well above chance (.58): $t(5) = 22.13$, $p <$ .001.

Numbers test. As with the shapes test, each selection from each table of the numbers test was scored separately and assigned an integer from 1 (for the lowest test score) to 6 (the highest test score). The integers were summed to give a total (maximum =

24) and converted to proportions to give the proportion of numbers score for each participant. All but one of the control participants obtained the maximum proportion of numbers score of 1, the remaining participant scored .96. The number of HFA participants scoring a proportion of numbers score of 1 was 13. The mean proportion of numbers score of the HFA group and control group was .96 (*SD* = .11) and 1 (*SD* = .01) respectively. The difference between participant groups was not significant: $t(17) = 1.52, p = .15$ (equal variances not assumed).[3]

The finding of group differences on the shapes test but not the numbers test is in keeping with the prediction made earlier that HFA participants would have trouble with the shapes test if they had difficulty understanding the ambiguity inherent in the task. However, this conclusion applies only to one third of HFA participants tested here.

Relationship between prototype effect test and shapes test. Although there was no statistically significant difference between groups on the prototype effect test, the HFA group appeared to show a somewhat weaker effect. To see if there was any relationship between the shapes test scores and the prototype effect test scores, participants were split into three groups: Six HFA participants who scored below the mean (HFA low scorers), twelve HFA participants who scored above the mean (HFA high scorers) and eighteen control participants that also scored above the mean. Figure 5.3 illustrates the choice proportion means of each exemplar type for each of these groups. This shows almost identical prototype effects for the HFA high scorers and the control group. In contrast, means obtained by the HFA low scorers do not form a prototype effect as shown by the relatively high choice proportion mean for low FR items and the relatively low choice proportion mean for prototypes.

Consistent with this observation, Friedman tests revealed a significant difference between exemplar types for the HFA high scorers: Chi-Square = 6.89, $df = 2$, $p = .03$, but no significant difference for the low scorers: Chi-Square = 1, $df = 2$, $p = .6$.

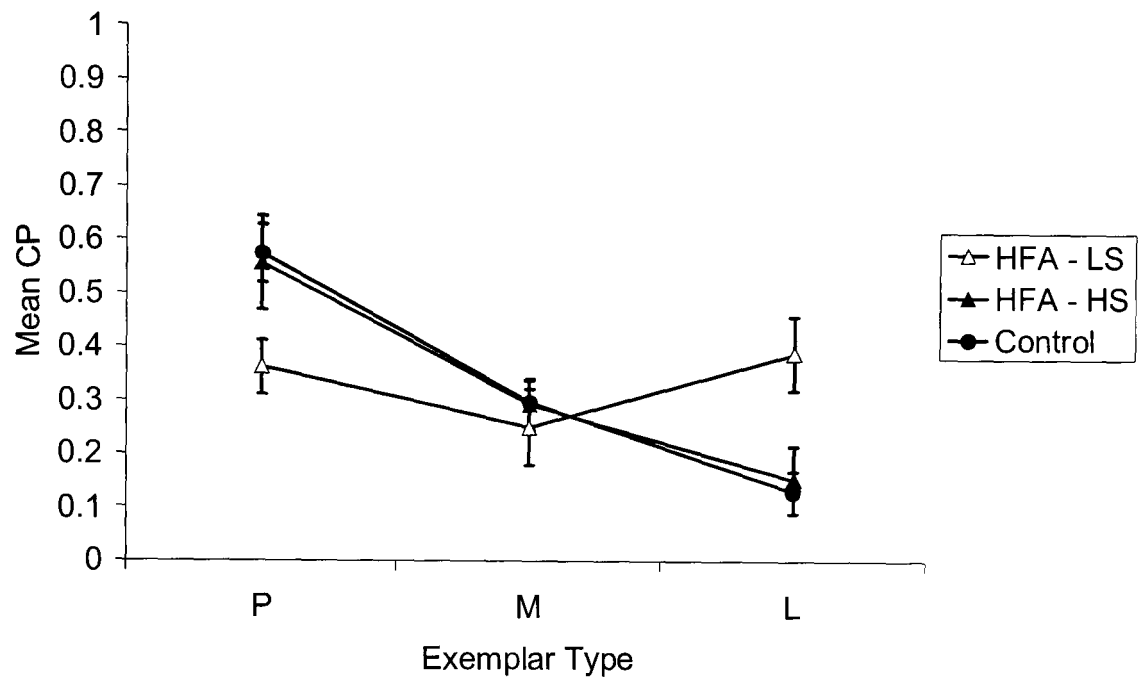

Figure 5.3 Mean choice proportion (CP) for each participant group and exemplar type. P = prototype, M = medium FR, L = low FR. HFA-HS = HFA high scorers: participants scoring above the mean on the shapes test ($n = 6$). HFA-LS = HFA low scorers: participants scoring below the mean on the shapes test ($n = 12$). Control group: $n = 18$. Error bars represent standard error of the mean.

To examine participant group differences directly, the presentation order of the control tasks was included in the following analysis of choice proportion scores for prototypes: A 3 (group) x 2 (order) ANOVA, where group comprised HFA high scorers, HFA low scorers and the control group. (Levene's test of equality of error variance was significant at $F(5,30) = 4.87$, $p = .002$.) Neither of the main effects or the interaction was significant: maximum $F(2,30) = 1.66$, $p = .21$. Games-Howell

post-hoc tests revealed significant differences between the HFA low scorers and the control group: mean difference = .21, p = .03. No other differences were significant: HFA low scorers versus HFA high scorers: mean difference = .19, p = .17 and HFA high scorers versus control group: mean difference = .02, p = .98. The choice proportion scores for low FR exemplars were analysed by a 3 (group) x 2 (order) ANOVA. The main effect of group was significant: $F(2,30) = 4.30$, p = .02. Neither the main effect of order or the interaction was significant: maximum $F(1,30) = .36$, p = .55. Games-Howell post-hoc tests revealed significant differences between the HFA low scorers and the control group: mean difference = .26, p = .03. None of the other differences were statistically significant: HFA low scorers versus HFA high scorers: mean difference = .24, p = .06 and HFA higher scorers versus controls: mean difference = .02, p = .95.

In keeping with the prediction made earlier there did seem to be some association between performance on the shapes test question and performance on the prototype best question. HFA participants that failed to perform at ceiling on the shapes test also failed to show a prototype effect.

Experiment 5.3

The aim of this experiment was to check an assumption made for the shapes test: When participants were asked to select the best example of the target category (e.g. the letter *C*), they were genuinely perceiving two or more candidates as belonging to this category. This issue pertained to the shapes test only because this test was unique in one respect: Participants were making selections from exemplars belonging to one of two categories. Potentially, only one item in each array could be perceived as a target category member, with the remainder belonging to the non-

target category. If this were the case performance on the shapes test could not be affected by ambiguity as claimed earlier because participants would perceive only one answer to such questions as, "Where is the best letter C?"

Method

Participants. Twelve of the eighteen HFA participants from Experiments 5.1 and 5.2 took part. Five HFA participants completed Experiment 5.3 immediately after Experiments 5.1 and 5.2. The remainder completed Experiment 5.3 after a lapse of up to 17 months. For this experiment, the ages of the HFA participants ranged from 10 years 9 months to 15 years 10 months (M = 13.84 years, SD = 1.45 years). The VMA of the HFA participants ranged from 7 years 10 months to 17 years (M = 12.60 years, SD = 3.05 years). Four of the participants had diagnoses of autism and eight had a diagnosis of AS. Three were HFA low scorers. All members of the control group participated and completed Experiment 5.3 immediately after the earlier experiments. There was no significant group difference (HFA vs. controls) on either of the developmental variables: CA - t (28) = 1.51, p = .14 (equal variances not assumed) and VMA – t(28) = .23, p = .82.

Materials. These comprised the shapes test booklet used in Experiment 5.2.

Procedure. Using the test booklet he or she had completed in Experiment 5.2, each participant was asked to indicate which items were members of the target category for each shapes test array: for example, "You chose this one as the best letter *C*, now show me all the ones that you think are a letter *C* too. You can choose all of these or none of these or anything in between". Most participants indicated their responses

by putting a mark underneath their selected items. Five HFA participants did not respond to this question, but responded when the experimenter pointed to each item asking, for example, "Is this a letter *C*?" The experimenter moved onto the next array after the participant indicated that they had completed their response.

Results and discussion

The number of items selected as belonging to the target category was counted for each array and each participant (maximum = 6). All selections included the previous choice of best category member. This score was converted to proportions: the proportion of membership decisions. Figure 5.4 illustrates the mean proportion of membership decisions for each array and participant group. As can be seen from the graph, target categories in general were perceived as containing more than one category member. Furthermore, the HFA group made target category selections which were fewer and which varied less across arrays than those made by the control group. Significant participant group differences were observed on arrays that elicited a high proportion of membership decisions from the control group (the square-to-diamond array and the C-to-O array). The scores were analysed with a 2 (group) x 4 (array) mixed, repeated measures ANOVA. This revealed significant main effects of group: F (1,28) = 5.28, p = .03 and of array: Greenhouse-Geisser F (2, 63) = 11.75, p < .001. The interaction of group by array was significant also: Greenhouse-Geisser F (2, 63)= 4.46, p = .01. Using the method described by Howell (1997, pp. 470-471), simple effects analyses, with F_{crit} (1,110) ~= 3.92 and alpha = .05, revealed significant participant group differences on the proportion of membership decisions for both the Squares and the letter *C*s: Square – F_{obs} (1,110) =

25.50, letter *C* - F_{obs} (1,110) = 4.24. Group differences on the letter *H* and the circles were not significant: letter *H* – F_{obs} (1,110) = .63, circles – F_{obs}(1,110) < .01.

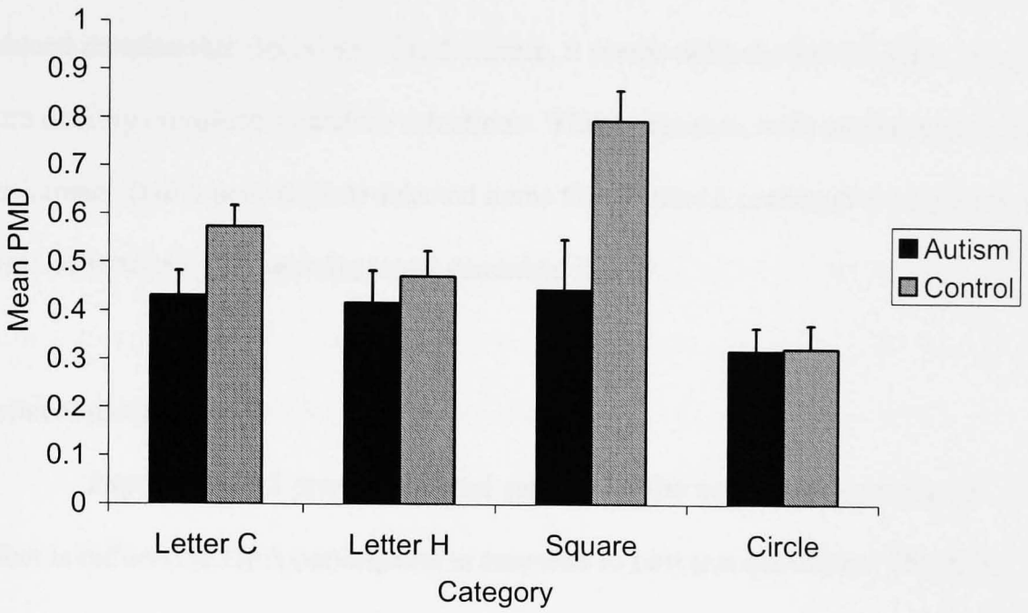

Figure 5.4 Mean proportion of membership decisions (PMD) for each participant group and array in the shapes test. Error bars represent standard error of the mean.

As mentioned earlier, some HFA participants would not select items in response to a single question and only responded when asked to judge each item individually. To see whether the introduction of this alternative question form was responsible for the narrower category judgements shown by the HFA group the data for this participant group was entered into a 2 (question wording) x 4 (array) mixed, repeated measures ANOVA. Neither the main effect of question wording or the interaction was significant: maximum $F(3,30) = .54$, $p = .66$.

It seems unlikely that the restricted category membership decisions shown by the HFA children could be attributable to response poverty. This condition would result in fewer item selections in response to the original question wording (e.g.

"...show me all the ones that you think are a letter *C* ...") but not to the alternative (e.g. "Is this a letter *C*?"). Therefore, the fact that the manipulation of question wording had no effect on item selection provides not support for this explanation of reduced membership decisions. Furthermore, it seems unlikely that the HFA group were making completely random selections. This is because, with one exception, all participants (HFA and control) selected items that formed a consecutive sequence, in terms of similarity, around the target canonical item.

General discussion

Experiment 5.1 provided partial support for the notion that a prototype effect is reduced in HFA participants in response to best test questions. The effect shown by the HFA group was weaker than that shown by the control group but the difference was insufficient to reach statistical significance. Experiment 5.2 clarified the picture further by showing a clear association between performance on one of the control tasks, the shapes test, and the prototype effect test. One third of HFA participants failed to obtain full marks on the shapes test and to show a prototype effect. The remainder performed at ceiling on the shapes test and showed a prototype effect identical to that of the control group. Thus, it seems that the performance of the HFA group as a whole, in Experiment 5.1, masked the performance of a subgroup that failed to show any prototype effect.

The shapes test was assumed to possess a similar form of ambiguity to the prototype effect test: Participants were expected to choose from two or more alternatives with no clear rules to guide them. The assumption that alternatives were perceived was checked in Experiment 5.3 by asking participants to indicate the number of items in each array that they regarded as belonging to the target category.

The findings supported this assumption. In general, participants were selecting from two or more options. In addition, the HFA children identified fewer items as members of the target categories, and the number of selections varied less across arrays, than those of the control group.

The findings reported here suggest that a dissociation between rule-based and prototype-based categorisation, as proposed by Klinger and Dawson (1995), does not apply to HFA participants. The majority of whom, in the current study, did show a prototype effect in response to best test questions. Those that failed to show an effect, these tended to be the younger participants, also failed to perform optimally on the shapes test. This association supports the idea presented earlier, that children with autism might fail to show a prototype effect in response to best test questions because of difficulty resolving the ambiguity of the task, rather than an inability to abstract prototypes per se. Finally, it appeared that the HFA group was not behaving like classical categorisers as suggested by Klinger and Dawson (1995). If HFA participants were behaving in the manner predicted by the classical view, they would apply if...then rules to all items in the square-to-diamond array presented in Experiment 5.3. This would result in the classification of all items as squares, because all possessed the necessary and sufficient criteria for membership of this category. However, HFA participants classified fewer items of the array as squares than controls.

The association between performances on the shapes test and the prototype effect test casts doubt also on Klinger and Dawson's claim that LFA participants are unable to form prototypes. The implication is that these participants may also fail to show a prototype effect because of difficulty resolving the ambiguity inherent in the

task. If other tests of prototype formation with this population, without such ambiguity, provided no evidence of impairment this view would be supported.

Experiment 5.3 identified another possible area of abnormality in categorisation. The HFA group made restrictive category membership decisions. This finding is consistent with the view that autism is characterised by a reduction in generalisation ability (Plaisted, 2001; Plaisted et al., Submitted; Plaisted et al., 1998a). This is the view, discussed in Chapters 2 and 3, that individuals with autism process similarity between stimuli or situations relatively poorly and similarity between unique features relatively well. Such a reduced perception of similarity would also mean that the intermediates of the arrays presented in the shapes test, Experiment 5.3, would be perceived as less similar to the target canonical item. Consequently, the boundaries of the category defined by this target item would contain fewer items. It is generally accepted that such boundary placements are determined by perceived similarity (Hampton, 1997; Murphy, 2002). Furthermore, this perceptual abnormality is consistent with the lack of variability in category membership decisions, made by the HFA group, across arrays. Presumably, a reduction in perceived similarity would place a ceiling on the maximum number of category members that could be selected for each array and this in turn would reduce variability across arrays.

One difficulty with this account is that the majority of HFA participants do not behave as if they have a reduced perception of similarity when they display prototype effects (Chapter 3, and Experiment 5.2). As discussed earlier, a common assumption is that perceived similarity between exemplars and a prototype determines prototype effects so a reduced perception of similarity should lead to a reduced or absent prototype effect. It appears that the perception of similarity, by

individuals with autism, is dependent upon the nature of the tests that are used. It is unclear, at present, why certain tasks and stimuli should affect perceived similarity but not others.

An alternative way of viewing participant group differences in category membership decisions is that they reflect differences in processing style. According to central coherence theory (Frith, 1989; Frith & Happé, 1994) normal individuals tend by default to process globally taking in the overall appearance of a scene before focusing on smaller details. However, individuals with autism have a tendency towards a local processing style: a focus on details at the expense of global configuration. Evidence for this preference includes the fact that individuals with autism show superiority on the embedded figures task (Shah & Frith, 1983). This task necessitates a focus on local parts at the expense of the whole and the aim is to discern a small shape within a larger picture. If members of the control group, in Experiment 5.3, were processing globally, they might consider not only the similarity between a single item in an array and the target canonical item, but also the similarity between a single item and all other items in the array. This seems plausible given evidence that the category membership of an exemplar is determined not only by similarity to a prototype, as discussed in the introduction, but recent evidence suggests that such exemplars are compared also with other category members (Stewart, Brown, & Chater, 2002). For instance, similar exemplars are likely to belong to the same category and conversely dissimilar exemplars are likely to belong to different categories. A preference for local processing might mean that HFA participants focused only on the similarity between a single item and the target canonical item whilst ignoring the other items in the array. Therefore, the difference in category membership decisions between the two participant groups could be

attributable to differences in processing style and correspondingly, a tendency to use different information for making the similarity judgements from which category membership decisions are made.

The preceding discussion highlights two accounts of how aspects of the category membership task may have led the HFA participants to make restrictive category membership decisions. Theoretically, it is also possible that the restricted category membership decisions reflect conceptual representation in autism: that is concepts represented with tighter boundaries containing fewer exemplars. Such representations would contain only the most prototypical items because, as well as selecting fewer items, HFA participants in the current study selected items that were most similar to the target canonical items. Available evidence suggests that such a representation is unlikely. As mentioned in the introduction, no participant group differences were found in how prototypicality affected errors in categorising exemplars from basic level and superordinate categories (Tager-Flusberg, 1985a, 1985b). If such concepts were represented by fewer and more typical exemplars, then participant group differences should have been found, with the LFA group making more errors on the peripheral category members. (Such members would be less likely to be included within the concepts). In addition, performance on the word fluency task presented by Dunn et al. (1996) does not support the idea that concepts in general have narrower representations in autism. No participant group differences were found in the number of correct exemplars produced. If representation of these semantic categories contained fewer category members, then the production of exemplars should be reduced relative to controls (assuming equivalent verbal fluency between the two participant groups). Moreover, the HFA participants tended to produce a higher proportion of peripheral items as category examples. If category

membership were restricted to only the most typical items, then the reverse should be the case. The exclusion of the most peripheral items from the category representations should result in a relatively low production of these items.

In summary, the findings of the current study suggest that the dissociation proposed by Klinger and Dawson (1995, 2001) between rule-based and prototype-based categorisation does not extend to HFA participants. In addition, the current study identified another area of abnormality in categorisation, as shown by the tendency of HFA participants to make restricted category membership decisions. Existing evidence suggests that in general conceptual representations in autism are not reduced. Therefore, it seems that the findings may be specific to the particular task used in Experiment 5.3. Only further studies, in which a variety of methods are used to assess breadth of category membership, can establish the conditions under which such decisions are restricted and the relationship of these findings to broader theoretical accounts such central coherence theory (Frith, 1989; Frith & Happé, 1994) and the view that the perception of similarity is reduced in autism (Plaisted, 2001).

Footnotes

[1]An analysis of difference scores (low FR choice proportions subtracted from prototype choice proportions) also failed to find a significant difference between participant groups: $t(34) = 1.32, p = .20$.

[2]Fisher's Exact Test also revealed a significant participant group difference on the proportion of participants scoring above and below the mean proportion of shapes score: $p = .02$.

[3]Fisher's Exact Test also failed to show a significant participant group difference on the proportion of participants scoring above and below the mean proportion of numbers score ($M = .98$, $SD = .08$): $p = .18$.

CHAPTER 6 – From prototype formation to perception of similarity

6.1 Summary

Introduction

A formal description of autism and the closely related condition AS first appeared in the writings of Kanner (1943) and Asperger (1944). Today the conditions are recognised as belonging within a continuum of pervasive developmental disorders. They are diagnosed following the detection of abnormalities in reciprocal social interaction, and the demonstration of marked stereotypies in behaviour or interest. A diagnosis of autism requires an additional impairment in communicative language. The prevalence rate for these disorders ranges from 4-50:10,000 depending on the diagnostic criteria used. Evidence of a genetic cause is overwhelming.

Since the early eighties, theorising in autism research has tended to operate from the viewpoint of cognitive psychology. The defining feature of these theories tends to be the nature of the particular abnormality adopted as a basic level to other secondary characteristic of autism. Theories that adopt cognitive (non-social) basic level abnormalities include impairments in abstraction and concept use (Hermelin & O'Connor, 1970), the TOM hypothesis (Baron-Cohen et al., 1985), weak central coherence (Frith, 1989), executive function deficits (Russell, 1997), and attentional deficits (e.g. Baron-Cohen, 1989). An exception to this trend is Hobson's account (e.g. R. Peter. Hobson, 1993) which considers the basic level deficit to include cognition, affect, and conation considered jointly at the inter-personal level. Also Baron-Cohen's (2002) extreme male brain hypothesis spans both social and cognitive domains at the basic level.

This thesis focussed on conceptual impairments in autism. This notion has a long history and the evidence is somewhat mixed. Straightforward categorisation tasks testing well-established knowledge revealed no differences between autism and control groups, whereas other tasks testing the processes involved in concept formation have tended to reveal impairments. This thesis examined one particular abnormality: that individuals with autism fail to show prototype effects (Klinger & Dawson, 2001; Plaisted et al., Submitted). This finding has been described variously as representing: an inability to form prototypes (Klinger and Dawson,), the operation of weak central coherence (Frith, 1989; Frith & Happé, 1994), and an effect of a reduced perception of similarity (Plaisted, 2001). HFA children were tested to remove the confound of intellectual disability. Owing to problems of differential diagnosis, and lack of evidence that HFA and AS are distinct syndromes, children that had received either diagnosis were included within the same participant group.

Experimental chapters

All studies reported in the thesis involved two participants groups, one of HFA children and one of typically developing controls. The three studies reported in Chapter 3 tested whether or not children with autism could show prototype effects in recognition memory.

Experiment 3.1 was designed as a control task to test general recognition memory. Participants studied line drawings of representational objects (e.g. animals and vehicles). Then, they were tested with a mixture of "old" and "new" pictures and asked to indicate recognition of each item. Both participant groups performed similarly with high levels of correct recognition scores. Thus, any impairment on the subsequent prototype effect test using an identical recognition test procedure could

not be attributable to deficits in visual recognition memory. Stimuli were picture cards representing cartoon animal categories, very similar to those used by Klinger and Dawson (2001). All study stimuli bore medium FR to respective category prototypes. Test stimuli comprised (in order of decreasing similarity to the prototype): the prototype, high FR, medium FR (both old and new), and low FR exemplars. The two experiments (3.2 and 3.3.) differed only in the similarity structure of the categories (average vs. modal).

In both experiments, all participant groups demonstrated full prototype effects. Higher levels of positive recognition were obtained for prototypes and high FR items than for medium FR items, and these in turn received higher levels of positive recognition than low FR exemplars. Thus the studies reported in Chapter 3, demonstrated that HFA children could show full prototype effects and behave as if they had abstracted prototypes from categories.

The results suggested that impairments in prototype formation were not characteristic of HFA children. They also represented an instance where HFA individuals appeared not to suffer a reduced perception of similarity. Furthermore, the findings were seen as an example of intact central coherence.

Several methodological differences were noted between the studies reported in Chapter 3, demonstrating full prototype effects, and the studies reported earlier that failed to show prototype effects with the autism group. One difference concerned the nature of the task at test. Impaired prototype effects were obtained via categorisation responses (Klinger & Dawson, 2001; Plaisted et al., Submitted) whereas intact prototype effects were obtained via recognition responses (Chapter 3). Thus, the aim of the study described in Chapter 4 was to investigate the suggestion that individuals with autism might exhibit a dissociation: impaired prototype effects

shown via categorisation responses and intact prototype effects shown via recognition memory responses. An additional aim was to explore the effect of repeated learning trials on both recognition and categorisation responses. Stimuli were dot patterns presented on computer. All participants completed four conditions: two recognition tests and two categorisation tests counterbalanced with exposure to study exemplars (one trial vs. six trials).

Each condition followed the same classic prototype effect paradigm used in Chapter 3. Participants completed a study phase followed by a test phase. During the study phase, participants viewed medium FR exemplars from two dot pattern categories and during the test phase, participants viewed high FR exemplars, medium FR exemplars (old and new), and low FR exemplars. This time, similarity to the prototype was determined by Posner et al.'s (1967) distortion rules.

Separate analyses were carried out on old recognition responses, new recognition responses, old categorisation responses, and new categorisation responses. Analysis of new responses showed no support for the notion that recognition and categorisation prototype effects were dissociable in autism. Both participant groups showed prototype effects via both recognition and categorisation responses. However, in contrast to the findings reported in Chapter 3, these effects were only partial, reflecting differences between medium and low FR exemplars only. The difference between medium and high FR exemplars was not significant for either participant group. The interpretation offered was that the high FR exemplar types were insufficiently similar to the prototype and too similar to the medium FR exemplars to produce differential responding between the two exemplar types.

Unsurprisingly, for both participant groups, the categorisation of both old and new items was more accurate after six learning trials than after one learning trial. This variable, condition (one vs. six learning trials), had little difference on recognition responses to new items. On old items though, there was an interaction between trial and group on recognition responses. HFA children were less likely to recognise items as old than controls after one learning trial, though their performance caught up with that of the control group after six learning trials. Calculation and analysis of A' (Ch. 4, Footnote 1) suggested that this was genuinely an effect of memory sensitivity rather than one of response bias or criterion. These findings contrast with previous studies demonstrating intact visual recognition memory in HFA children, including Experiment 3.1. (However, the analysis of A' scores for recognition responses to medium FR exemplars of the average category did reveal a reduced memory sensitivity on the part of the autism group. See Ch. 3, Footnote 1.) One suggestion was that the impairment reflected difficulty encoding meaningless stimuli (of which the dot patterns were an example). This possibility was raised by Ameli et al.(1988) who found that HFA participants performed poorly on tests of visual recognition for abstract, meaningless shapes. Performance on meaningful materials matched that of controls, however. These authors' interpretation was that the difficulty with meaningless material reflected the use of inflexible cognitive strategies that failed to organise and encode the visual information effectively.

Experiment 4.1 was marked also by a pervasive influence from presentation order effects (one-trial condition first vs. six-trial condition first). These were viewed as being the result of differences in category learning occurring within both participant groups.

The aim of the studies reported in Chapter 5 was to test the suggestion raised in Chapter 3 that individuals with autism may have failed to show a prototype effect during Klinger and Dawson's study because of task-related ambiguity. Participants completed a prototype effect task (Experiment 5.1), procedurally similar to those reported in Chapter 3. The stimuli were similar, also, to those used in Experiment 3.2 (cartoon animals structured around an average prototype). During the study phases, participants studied medium FR exemplars.

During the test phases, participants were asked to select the best category member (e.g. Hov). This selection was from three exemplars, all new unstudied items: a high FR, medium FR, and low FR exemplars. Both participant groups appeared to show prototype effects although that of the HFA group appeared somewhat weaker. However, no participant group differences were obtained. Experiment 5.2 was designed to test whether HFA participants interpreted the test question used in Experiment 5.1 similarly to controls. The numbers test required participants to select the best result from a table of school test results. The shapes test required the selection of the best example of a particular shape or letter. For both tasks, scores were at or near ceiling for most participants. Participant group differences were found on the shapes test but not the numbers test. On this task, HFA participants performed less well than controls. The account offered was that some of these participants had difficulty with the ambiguity present in the shapes test.

Another finding was the presence of a relationship between performances on the shapes test and the prototype effect task. One third of the HFA participants who did not reach ceiling on the shapes test also did not show a prototype effect. The remainder of HFA participants demonstrated a prototype effect that was identical to

that shown by the control group. This relationship was seen as support for the suggestion made in Chapter 3, that children with autism might find the ambiguity inherent in a "best test question" problematical rather prototype formation per se. However, this notion was applicable to only to the third of HFA participants this study that failed to show a prototype effect.

A further study, Experiment 5.3, was designed to test an assumption behind the design of the shapes test. This is that participants were genuinely selecting the best item from more than one member of a category. Participants were shown shapes test materials and were asked to select the number of items that belonged to each target category. The findings supported this assumption. Furthermore, HFA children tended to select significantly fewer items as belonging to a particular category. These findings were interpreted either as an example of reduced perception of similarity or as representing different processing preferences between the two participant groups: with the HFA group preferring local processing and the control group tending to rely upon global processing.

6.2 Conclusion

Implications for prototype formation in autism and associated theories

Considered together the studies reported in the experimental chapters (3-5) suggested that the majority of HFA participants do show prototype effects and there was no evidence to suggest that such effects were weaker than those displayed by the control groups. The fact that variation in methodology between the studies nonetheless produced results that converged upon a similar pattern indicates that these findings are robust. Such variation included the inclusion of three separate pairs of participant group (HFA vs. controls). The nature of the materials used also

varied across studies. Three used cartoon animals (Chapter 3 and Chapter 5), and one employed abstract dot patterns (Chapter 4). Additionally, similarity between a prototype and exemplars was defined differently. With cartoon animal categories, similarity was defined in terms of the size of animal features or in terms of the frequency with which features occurred in the study set. When dot patterns were used, similarity was defined in terms of the two dimensional loci of individual dots. Finally, the nature of the test phases varied across experiments. These included old/new recognition, classical categorisation (classifying stimuli into one of two categories), and identification of the "best" category member.

The clear presence of prototype effects in HFA participants has implication for the various theoretical accounts, introduced in Chapter 2. Firstly, the demonstration of prototype effects showed that Klinger and Dawson's notion that prototype formation is impaired in autism does not apply to HFA participants. Secondly, according to Klinger and Dawson (2001), the failure of their autism group to show prototype effects represents the operation of weak central coherence. If this is the case, intact prototype effects, as reported here, reflect the operation of intact central coherence.

The use of the word *if* in the previous sentence reflects some of the difficulty present in defining examples of weak central coherence. Central coherence has been defined both as a preference for local processing over global processing and as a difficulty in integrating information in context. The exhibition of prototype effects, according to Klinger and Dawson (2001) reflect the operation of the latter definition. These definitions are rather general and, in practice, weak central coherence is often defined in terms of examples of tasks with which individuals with autism show different behaviour from controls. This practice involves the risk of

circularity and makes the theory difficult to falsify. The only certain implication that can be drawn from the thesis studies for central coherence is that if Klinger and Dawson's findings represent a manifestation of weak central coherence, then the studies reported here represent examples of intact central coherence. One scenario cannot be true without the other being true also.

The prototype effects shown by HFA participants also provide a demonstration that individuals with autism do not always suffer a reduced perception in similarity, contrary to the implications of the account proposed by Plaisted (2001). (As perceived similarity between exemplars and the prototype is thought to determine the size of a prototype effect, a reduced perception in similarity should result in reduced or absent prototype effects.) To account for the findings reported in this thesis, the account would need to be adapted to explain why and how perception of similarity might vary within an HFA group, from a normal perception to a reduced perception.

Limitations

Although, the current studies have established that HFA participants can show prototype effects, they are far from establishing why the two other empirical studies, Klinger and Dawson (2001) and Plaisted et al. (Submitted), failed to show such effects. A number of features, perhaps, contributed to this state of affairs:

Overall, the studies reported here were without developmental perspective. Children varying in age from 9 to 17 years were included within single experimental groupings. The performance of different age groupings was not directly compared with each other. Although, as discussed in Chapter 3, prototype abstraction is not thought to follow a developmental trajectory, the possibility remains that the mental

functions that support the display of prototype effects do follow a developmental trajectory. Therefore, the age of participants may have a bearing on whether or not prototype effects are shown. Although the average age of Klinger and Dawson's participants was similar to those in the studies reported here, their participant groups included younger children. The failure of their autism group to show a prototype effect therefore could be attributable to the lower chronological ages of some of the participants. Without a direct comparison of age groupings, this possibility cannot be excluded. Furthermore, there was some indication from findings reported in Experiment 5.2 that age may be a critical factor. The sub-group of HFA children that failed to show a prototype effect tended to be younger than the HFA children that did show an effect.

A similar point could be made regarding IQ level. The narrow focus on HFA participants meant that the effect of learning disability on prototype effects was not directly examined. Again, as was the case for CA, it appears that prototype formation is independent of IQ, but that functions supporting the display of prototype effects may be dependent upon IQ. One example cited in Chapter 3, was that LFA children, but not HFA children, showed a decrement on visual recognition tests (Barth et al., 1995). Such an impairment could have prevented the LFA participants in Klinger and Dawson's study from encoding the animal features necessary for prototype formation. No LFA participants were included as comparison groups in the studies reported in this thesis so this contribution of developmental delay was not directly tested.

Another limitation is the fact that each set of experiments described in each chapter showed considerable methodological variation from the studies carried out by Klinger and Dawson (2001) and Plaisted et al (Submitted). For example, in

Experiment 5.1, low FR exemplars were included and these were absent in Klinger and Dawson's study. These types of alteration made it difficult to pinpoint which methodological variations were responsible (if any) for discrepancies between the findings.

In addition, methodology varied considerably across the set of studies reported in each chapter. This meant that any participant group differences found need to be regarded with some caution until these are replicated. The reason for this is that the well-documented heterogeneity of the HFA group means that single findings obtained from small samples, as was the case with these group differences, may not be generally applicable to HFA participants as a whole.

A discussion of these limitations would be incomplete (and unnecessarily gloomy) without pointing out that many of the same decisions that resulted in these limitations also contributed to the main strengths of the studies described here. The methodological variety of the studies added weight to the conclusion above that HFA participants can and do show prototype effects. In addition, the resultant unanswered questions, and varied findings open several avenues for future research and it is to this we now turn.

Future research

Suggestions for future research already put forward in this thesis can be divided roughly into two categories: further testing of the key theories put forward in Chapter 2 (impaired prototype formation, Klinger & Dawson, 2001, reduced perception of similarity, Plaisted, 2001, and weak central coherence, Frith, 1989; Frith & Happé, 1994) and the follow up of individual findings (chiefly impaired

visual recognition memory, Experiment 4.1, and reduced category membership decisions, Experiment 5.3).

When the first studies reported in Chapter 3 demonstrated clear prototype effects in autism two suggestions were put forward. One was that a dissociation between recognition and categorisation produced differences in prototype effect performance. No evidence was found to support this (Chapter 4). The other suggestion that was tested was that children with autism found the ambiguity inherent in Klinger and Dawson's test question problematic. Some of the findings reported in Chapter 5 were consistent with this notion: specifically the association between the prototype effect test and the shapes test. Further research into this area could consist of replication of the prototype effect task and the use of a shapes test that did not produce ceiling effects. This would allow a correlation between performances on the two tasks and as such would constitute a more rigorous test of an association between them. Including comparison groups of younger autism participants and LFA children would enable an analysis of the contribution of these developmental variables to the demonstration of prototype effects.

Owing to the problems in defining weak central coherence, it is perhaps better at this stage to avoid direct testing of this construct. Instead, a greater understanding of the phenomena underlying central coherence and greater definitional clarity might be achieved by investigating why tasks that tax a function considered impaired by weak central coherence should lead to such varied effects in the autistic population. One such function is the integration of information within context. Two examples of tasks thought to tax this function include the prototype effect tasks in the studies reported here and Jolliffe and Baron-Cohen's (2001) study, first discussed in Chapter 3. This required HFA participants to integrate object

fragments in order to identify and name an object. On the former task, HFA participants behaved like controls but on the latter task, HFA performance lagged behind. The mechanisms suggested in Chapter 3 could be directly investigated. For example, one possibility is that the impairments observed by Jolliffe and Baron-Cohen actually represented a deficit in late processing and that the identification and naming of the object is where the problem lies. This later process is absent from the prototype effect experiments reported in this thesis, and therefore, no difficulty in integrating information is apparent.

As well as the implications for theoretical accounts, some individual findings reported in the experimental chapters could be explored further. Literature was discussed at the start of Chapter 4, suggesting that visual recognition memory was intact in HFA participants. This view was supported by the visual recognition test, using line drawings of representational objects reported in Experiment 3.1. However, when recognition memory for dot patterns was tested after one study trial, HFA participants performed worse than controls. This finding was interpreted as an impairment in recognising meaningless stimuli following Ameli et al, (1988). Further research could constitute a direct comparison of meaningful and meaningless stimuli within the same experiment. A performance decrement on the meaningless stimuli would support this explanation further. Additionally, a manipulation of the number of learning trials used in the study phase, as well as a direct comparison between old and new stimuli would reinforce the findings of Experiment 4.1 that only old items are affected and that repeated learning trials ameliorate the lower recognition performance. An analysis of A' may also aid clarification by teasing apart which participant group differences are a result of alterations in memory

sensitivity, and which if any, can be attributed to use of a particular response criterion.

Another proposal for future research made in Experiment 5.3 concerned the finding that category membership decisions are restricted in autism. The suggestion was that, initially, the findings would need replication using a greater number of arrays. Then the specific accounts for the findings suggested in Chapter 5 could be directly tested. These were that the reduced category membership decisions were a reflection of reduced similarity or that they reflected the operation of local detailed-focussed processing. The two suggestions could be tested as follows: A category membership decision task, similar to that described in Experiment 5.3, could be completed together with a task that obtained similarity ratings between individual items and the canonical target item. If category membership decisions were restricted because of a reduced perception of similarity, then within-target category similarity ratings should be similar for both participants groups. However, intermediate items (i.e. those occupying objective mid-points between the target canonical item, such as the letter *C* and the non-target canonical item, such as letter *O*) in the array should receive lower similarity ratings from the autism participants than controls and be less likely to be included in the target category.

If a focus on local processing was responsible for reduced category membership decisions, then the performance of controls could be brought to match that of the autism group, by removing the opportunity for global comparisons. This could be done by asking for single category membership judgements on a single item and providing only the target canonical item for reference without presenting other category members.

Once the pattern of findings presented in this thesis are considered *en masse*, together with other related studies another issue emerges which I shall argue is a research priority. This is the observation that prototype formation and the perception of similarity are both highly unstable within the autism population as a whole. This chapter has already discussed the discrepancy between findings of intact prototype effects (reported in Chapters 3 – 5) and studies that demonstrate failure to show a prototype effects (Klinger & Dawson, 2001; Plaisted et al., Submitted). Chapter 2, in addition, cited more conflicting evidence. On the one hand, Tager-Flusberg (1985b) found that children with autism made categorisation decisions that were affected by prototypicality in a similar fashion to controls (i.e. the categorisation of prototypical items was more accurate than the categorisation of more peripheral items). Whereas, Dunn et al. (1996) found that HFA children were not affected by prototypicality in the same manner as controls in a word fluency task.

The perception of similarity appears also to be unstable. Several lines of evidence (reviewed in Chapter 2) suggest that individuals with autism do have a reduced perception of similarity. Whereas, the intact prototype effects reported in this thesis suggest that it not reduced and does not differ from that of controls.

Further research into this instability is needed for several reasons. The causes are unknown. The underlying assumption presented in the experimental chapter has been that prototype formation is intact and any instability in the display of prototype effects is a result of interaction between individual abilities and the specific demands of the various tasks (e.g. the nature of test questions). This has led to a focus on methodology as a source of variation in the findings. The implication drawn from mixed findings on the perception of similarity has been that the mental function itself, the perception of similarity, is highly variable reduced on some

occasions, but not on others. However, the distinction is a false one. As prototype formation is thought to be predicated upon the perception of similarity then any variation in the latter should affect the former. In principle, also, task demands, unrelated to similarity perception may affect findings that are cited in contradiction of or support of claims of reduced similarity perception. No converging evidence has emerged from this thesis as to the underlying cause of the instability.

Furthermore, neither theory on prototype formation or on the perception of similarity takes account of the possible existence of instability. Klinger and Dawson (2001) simply state that prototype formation is impaired, with no mention of the fact that it may be intact on occasion. Similarly, Plaisted (2001) implies that a reduction in the perception of similarity is a permanent state of affairs. Focusing firstly on why the latter should vary should give insight into variation in the former given the apparent dependence of prototype formation on similarity perception.

Researching the causes of instability within similarity perception is a priority because knowledge of its causes and underlying mechanisms would assist in devising appropriate experiments to test the suggestions summarised earlier in this chapter. For example, one suggestion following from Experiment 5.3 required direct measurement of similarity perception. However, without some idea of why the perception of similarity might vary there is no way of knowing whether the actual measurement method is directly influencing the variable being measured.

Furthermore, similarity appears to play a central role in many theories of cognition in addition to the conceptual and categorisation processes discussed in this thesis. As Medin, Goldstone, and Gentner write (1993) similarity "...pervades theories of cognition". These include theories of problem solving, memory, and learning and contextual influence (Markman & Gentner, 1993; Medin et al., 1993).

Thus, it seems likely that a greater understanding of the perception of similarity in autism and the way that it fluctuates would lead to a more general understanding of cognition within this disorder.

6.3 Overall Conclusion

The research reported in this thesis has operated within the cognitive science paradigm, described in Chapter 1, to investigate concepts and categorisation in autism. In particular, a particular phenomenon of cognitive psychology, prototype effects, was employed to test the suggestion that prototype formation was impaired in autism (Klinger & Dawson, 2001). This prediction was supported also by other theories, weak central coherence (Frith, 1989; Frith & Happé, 1994), the reduced perception of similarity (Plaisted, 2001) as well as studies revealing prototype effect impairment in autism (Klinger & Dawson, 2001; Plaisted et al., Submitted).

No evidence for the prediction was found however. Prototype effects were obtained from the responses of HFA children on no less than five occasions. These findings have nonetheless given rise to a consideration of several issues. No support was found for the main theoretical accounts. The experimental findings demonstrated that prototype formation could be intact in autism, that the perception of similarity is not necessarily reduced, and that central coherence is not always weak (assuming the relevance of this particular theory).

Other issues included the observation that the main strengths and limitations of the thesis seem to derive from the same decisions on design and experimental procedure. For example, the methodological variety presented both between the studies reported in this thesis and between these studies and other relevant ones, reported in the literature, all made the convergence of findings on intact prototype

effects quite robust. Additionally, this same variety generated several potential research avenues. However, this methodological variety also made it difficult to establish why other research groups obtained no prototype effects from their autism groups. Additionally, the participant group differences that were obtained in the thesis studies run the risk of being spurious owing to small sample sizes and lack of replication.

Several ideas for future research were discussed within the experimental chapters. These included a further exploration of the suggestion that ambiguity was problematic for Klinger and Dawson's participants rather than prototype formation. Additionally, an investigation was proposed into the ability of individuals with autism to integrate information within context as well as one into impairments in visual recognition memory with meaningless materials. Finally, research suggestions were included as to why category membership decisions might be reduced in autism.

An overview of the findings identified an emerging theme: that of instability of participant group differences on the display of prototype effects and of the perception of similarity. It was argued that investigating the cause of instability in similarity should be a research priority. Several reasons were provided in support. No evidence or theoretical account currently exists to explain this phenomenon and understanding it would provide useful if not essential information for any of the research ideas proposed within the experimental chapters. Additionally understanding how the perception of similarity might vary within the autism population is likely to lead to broader insights into cognition within autism, in addition to the causes of instability in the display of prototype effects. In short, the experimental evidence presented in this thesis has resulted in a change of research question from "do individuals with autism show prototype effects?" to "what causes

instability (in participant group differences) in the perception of similarity by individuals with autism?"

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APPENDICES

Note: Drawings are not to scale

Appendix to Chapter 3

Appendix A: Participants' data from Experiments 3.1 - 3.3

KEY

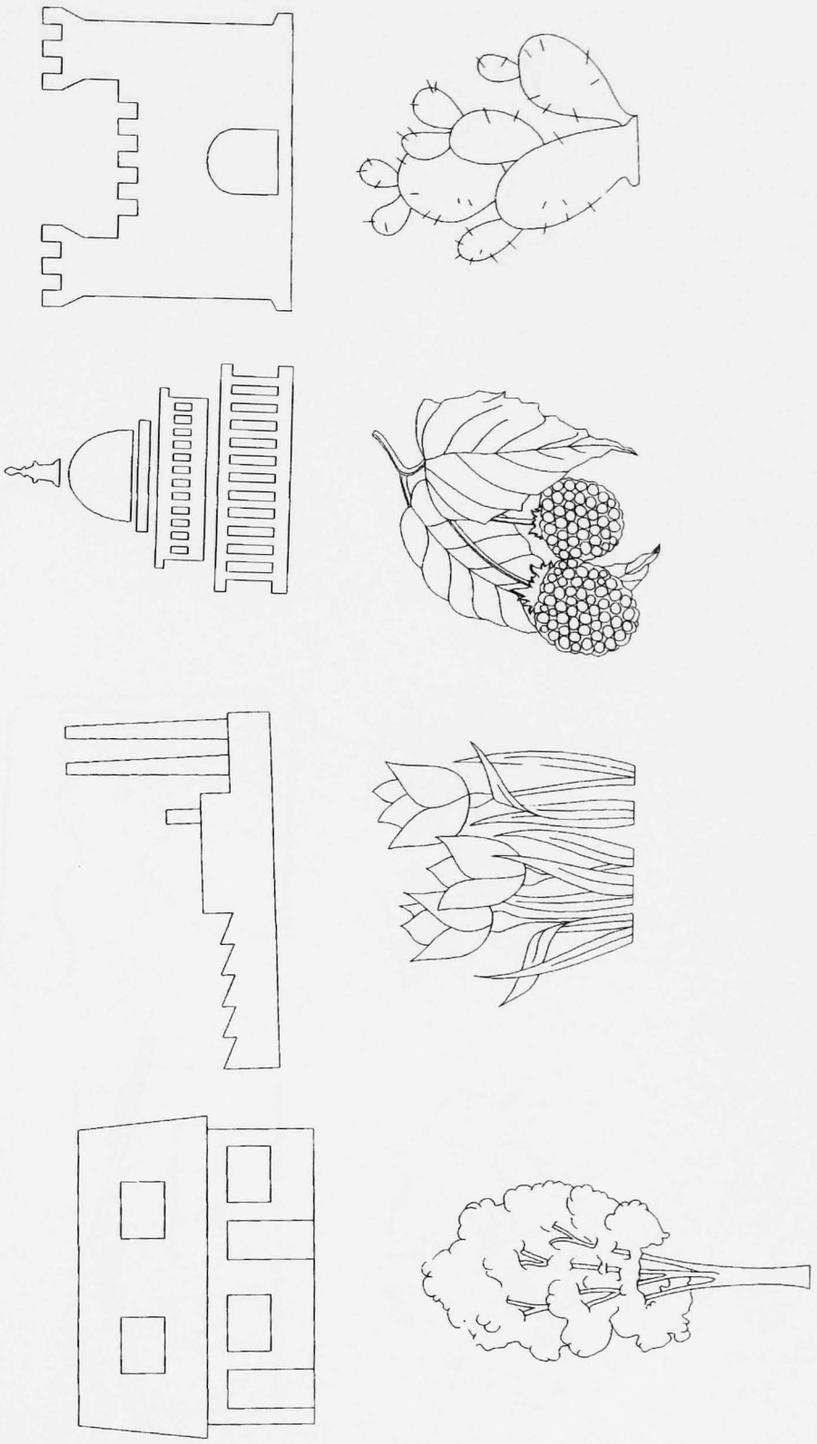
Column heading	*Description*
Id	Participant identity number
group	Participant group: 1 = high functioning autism; 2 = control
diagnosis	Diagnosis of participants with autism: 1 = autism; 2 = Asperger syndrome
ca_yrs	Chronological age (years)
bpvs	Raw scores from the British Picture Vocabulary Scale (BPVS)
vma_yrs	Verbal mental age derived from BPVS raw scores (years)
rvns	Raw scores from the Ravens Progressive Matrices test
memory	Memory task scores
order	Presentation order of average category task and modal category task: 1 = average category task first; 2 = modal category task first
av_p	Average category prototype proportion of positive recognition responses (PPRR)
av_h	Average category high family resemblance (FR) exemplar PPRR
av_mo	Average category medium FR exemplar (old) PPRR
av_mn	Average category medium FR exemplar (new) PPRR
av_l	Average category low FR exemplar PPRR
mod_p	Modal category prototype PPRR
mod_h	Modal category high FR exemplar PPRR
mod_mo	Modal category medium FR exemplar (old) PPRR
mod_mn	Modal category medium FR exemplar (new) PPRR

id	group	diagnosis	ca_yrs	bpvs	vma_yrs	rvns	Memory	order	av_p	av_h	av_mo
1	1.00	1.00	8.75	86.00	8.42	36.00	0.56	1.00	1.00	0.75	0.50
2	1.00	2.00	9.58	83.00	8.08	33.00	0.94	2.00	0.50	0.63	0.75
3	1.00	1.00	10.50	99.00	10.17	28.00	0.81	1.00	0.50	0.75	0.50
4	1.00	2.00	11.17	118.00	13.08	52.00	0.94	2.00	1.00	1.00	0.75
5	1.00	1.00	11.17	129.00	15.17	29.00	1.00	1.00	1.00	1.00	0.88
6	1.00	1.00	12.08	98.00	10.08	38.00	0.94	1.00	1.00	0.50	0.13
7	1.00	2.00	12.25	119.00	13.42	35.00	1.00	1.00	1.00	0.25	0.50
8	1.00	2.00	12.33	123.00	14.00	38.00	0.69	2.00	1.00	0.75	0.75
9	1.00	1.00	12.58	100.00	10.42	51.00	0.75	2.00	0.50	0.75	0.50
10	1.00	2.00	12.75	108.00	11.58	37.00	0.94	1.00	1.00	0.75	0.50
11	1.00	1.00	13.08	116.00	12.75	42.00	0.81	2.00	1.00	0.50	0.75
12	1.00	2.00	13.25	126.00	14.58	38.00	0.81	2.00	1.00	0.88	0.38
13	1.00	2.00	13.42	145.00	17.00	46.00	1.00	1.00	1.00	0.50	0.50
14	1.00	2.00	13.92	103.00	10.83	32.00	0.88	2.00	1.00	1.00	1.00
15	1.00	1.00	8.83	58.00	5.67	39.00	0.94	2.00	0.50	1.00	0.75
16	2.00		8.50	91.00	9.00	21.00	0.81	1.00	1.00	1.00	0.75
17	2.00		9.75	82.00	8.00	44.00	0.94	2.00	1.00	0.88	0.63
18	2.00		10.58	96.00	9.83	38.00	0.94	1.00	0.50	0.50	0.88
19	2.00		11.50	114.00	12.42	31.00	0.69	2.00	1.00	1.00	0.88
20	2.00		10.92	132.00	15.67	45.00	1.00	1.00	1.00	1.00	0.50
21	2.00		12.33	97.00	9.92	22.00	0.94	1.00	0.50	0.75	0.50
22	2.00		12.42	110.00	11.83	32.00	0.88	1.00	1.00	1.00	0.75
23	2.00		12.33	125.00	14.42	43.00	1.00	2.00	0.50	0.88	0.75
24	2.00		12.50	97.00	9.92	44.00	0.88	2.00	1.00	0.88	0.63
25	2.00		13.25	107.00	11.33	42.00	0.50	1.00	1.00	1.00	0.75
26	2.00		12.83	112.00	12.08	43.00	0.88	2.00	1.00	0.88	0.75
27	2.00		13.42	126.00	14.58	43.00	0.88	2.00	1.00	0.63	0.63
28	2.00		13.00	140.00	17.00	42.00	0.69	1.00	1.00	0.88	0.88
29	2.00		14.17	102.00	10.67	24.00	0.69	2.00	0.50	0.63	0.75
30	2.00		8.42	61.00	6.00	12.00	0.44	2.00	0.50	0.88	0.75

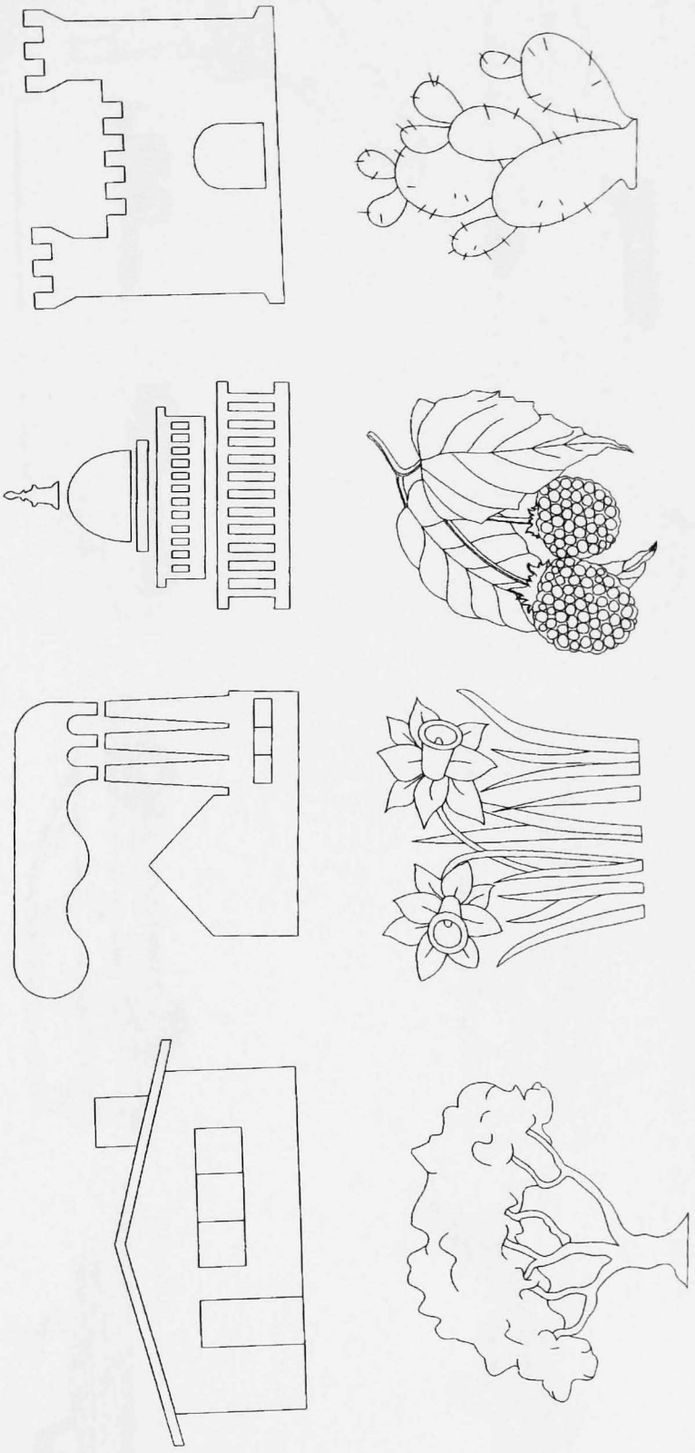
Id	av_mn	av_l	mod_p	mod_h	mod_mo	mod_mn	mod_l
1	0.50	0.25	1.00	0.75	0.50	0.50	0.50
2	0.75	0.13	1.00	1.00	0.63	0.88	0.38
3	0.75	0.63	1.00	0.50	0.50	0.63	0.13
4	0.50	0.00	0.00	0.75	0.38	0.25	0.38
5	0.50	0.25	1.00	0.88	1.00	0.75	0.50
6	0.63	0.13	0.50	0.63	0.63	0.13	0.38
7	0.50	0.25	0.00	0.50	0.38	0.25	0.25
8	1.00	0.50	1.00	0.50	0.63	0.63	0.63
9	0.50	0.25	1.00	0.88	0.25	0.38	0.13
10	0.75	0.00	1.00	0.75	0.38	0.38	0.00
11	0.38	0.00	0.50	0.25	0.25	0.75	0.38
12	0.63	0.00	0.50	0.75	0.75	0.13	0.13
13	0.38	0.00	0.00	0.75	0.75	0.50	0.25
14	1.00	0.38	1.00	0.75	0.63	0.63	0.38
15	0.88	0.13					
16	0.50	0.38	0.50	0.50	0.50	0.50	0.38
17	0.88	0.13	0.50	0.88	0.75	0.13	0.38
18	0.75	0.13	1.00	0.50	0.50	0.63	0.13
19	0.75	0.63	1.00	0.88	0.75	0.75	0.50
20	0.63	0.13	0.50	0.75	0.38	0.38	0.50
21	1.00	0.00	1.00	0.50	0.63	0.50	0.50
22	0.63	0.13	0.50	0.75	0.50	0.38	0.13
23	0.63	0.00	0.50	0.75	0.75	0.63	0.38
24	0.75	0.00	1.00	0.63	0.63	0.88	0.63
25	0.63	0.25	1.00	0.75	0.13	0.50	0.50
26	0.88	0.13	1.00	0.75	0.63	0.50	0.75
27	0.63	0.00	1.00	0.63	0.38	0.38	0.25
28	0.75	0.00	0.50	0.75	1.00	0.38	0.25
29	0.38	0.00	0.50	0.88	0.25	0.38	0.38
30	1.00	1.00					

Experiment 3.1

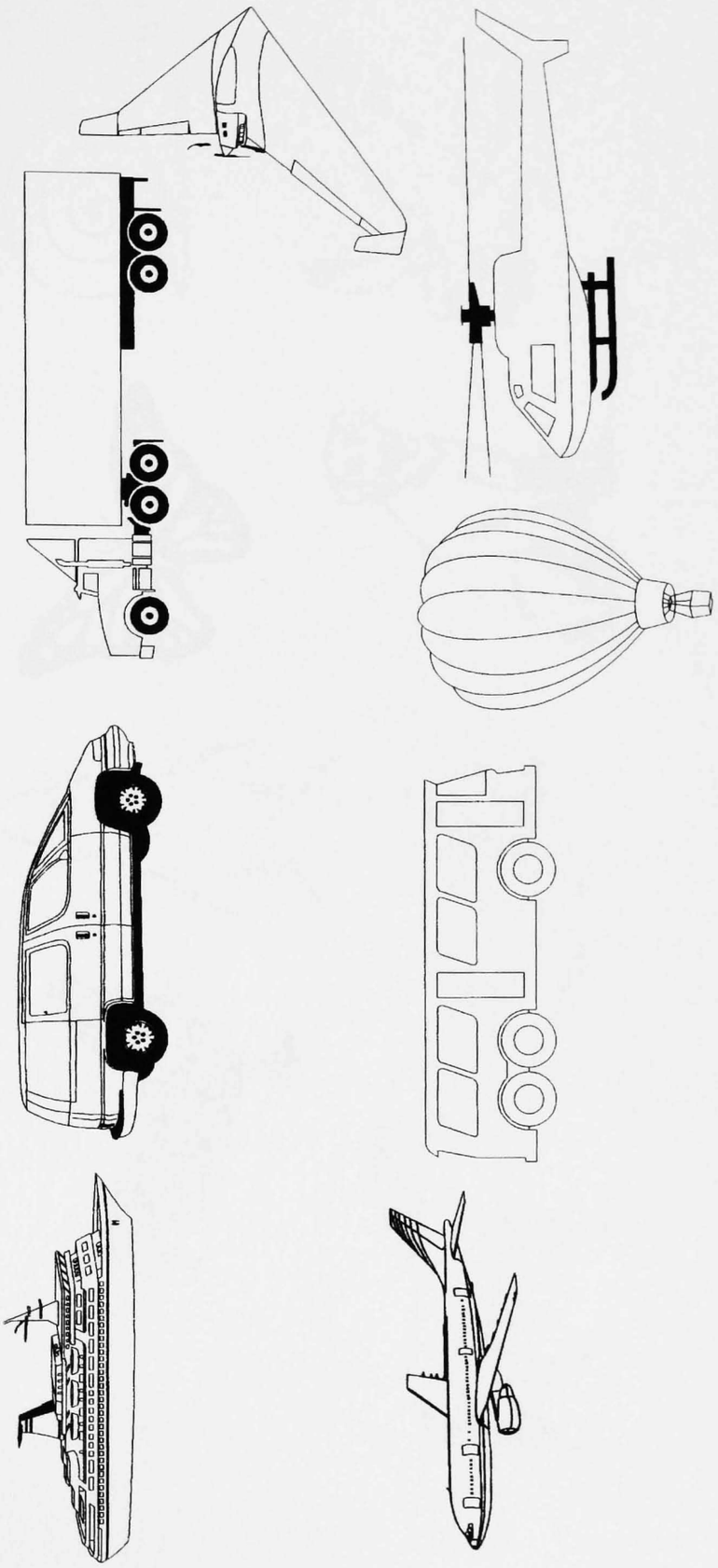
Appendix B: Practice memory test – study stimuli

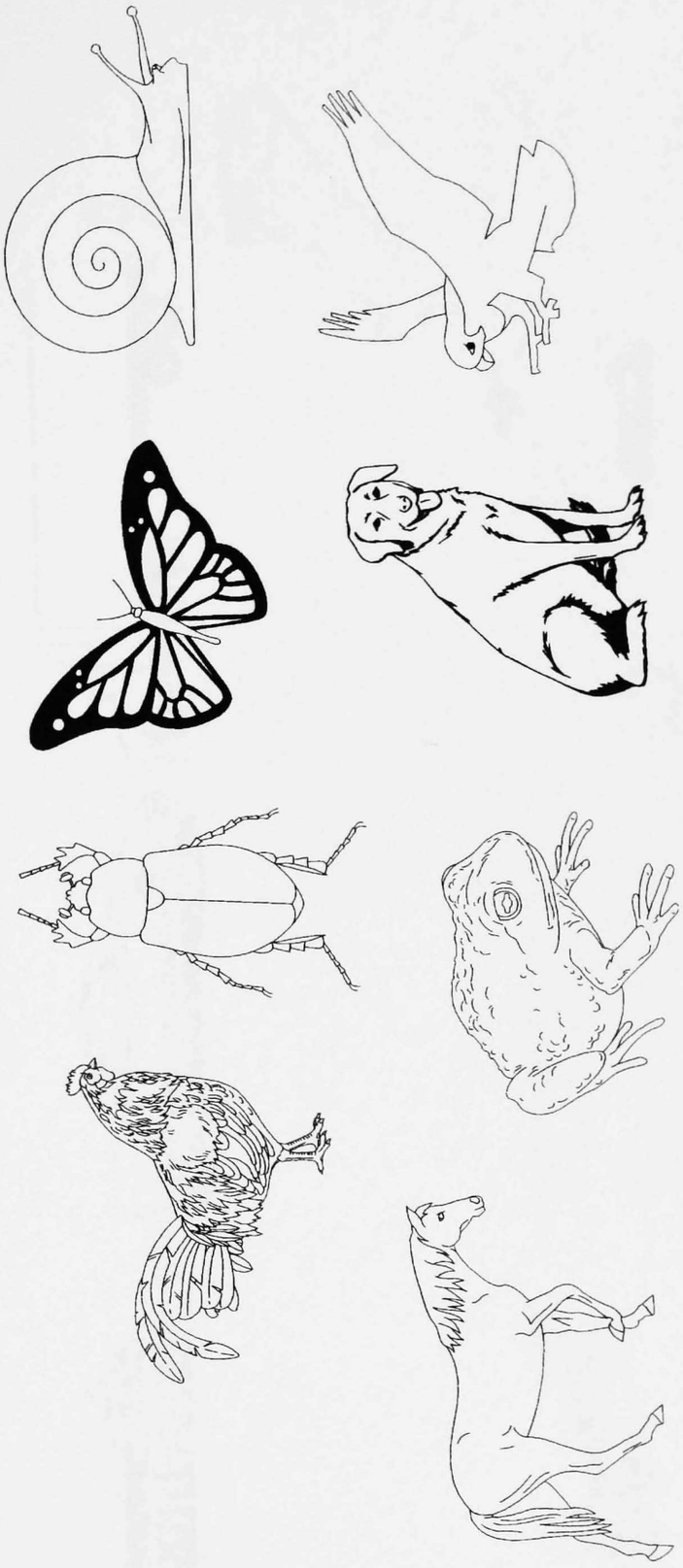


Appendix C: Practice memory test – test stimuli

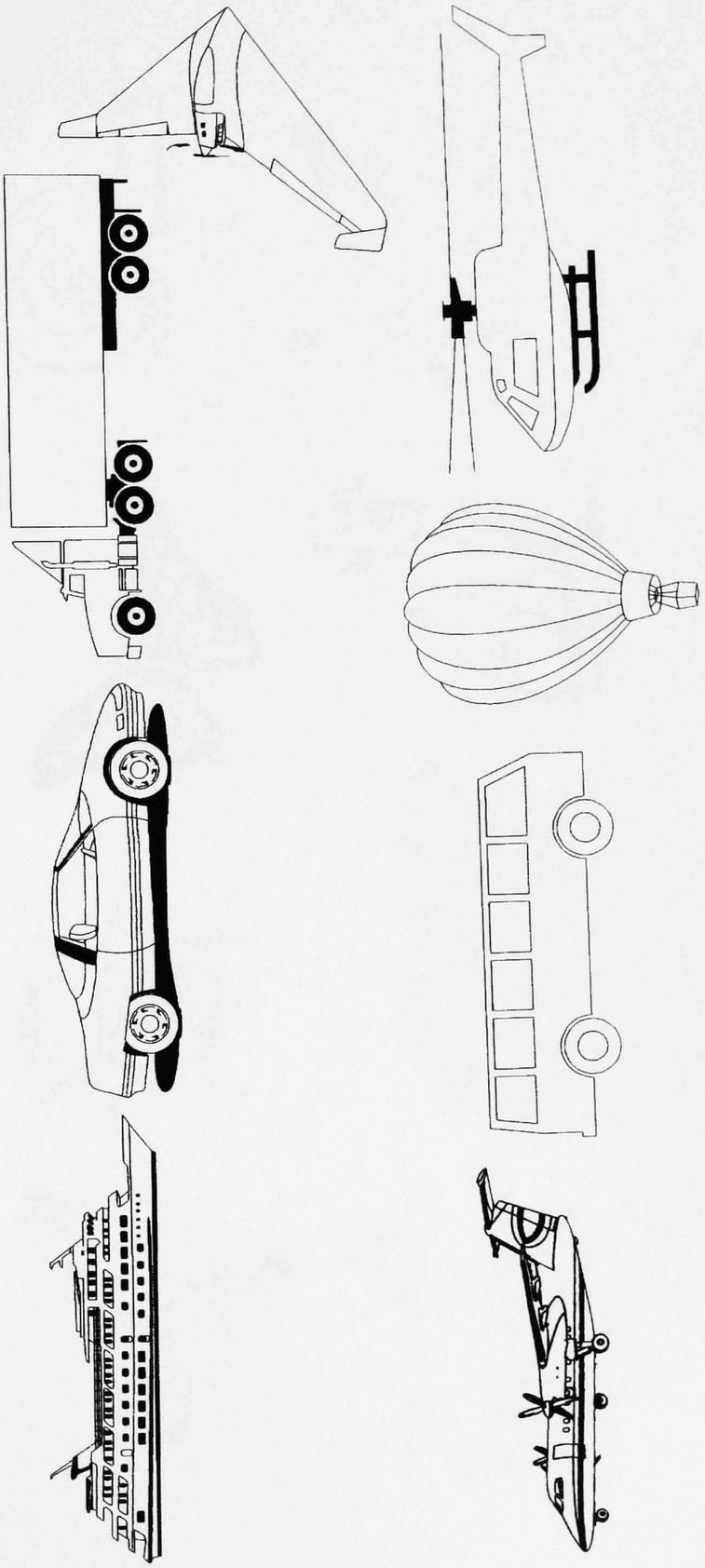


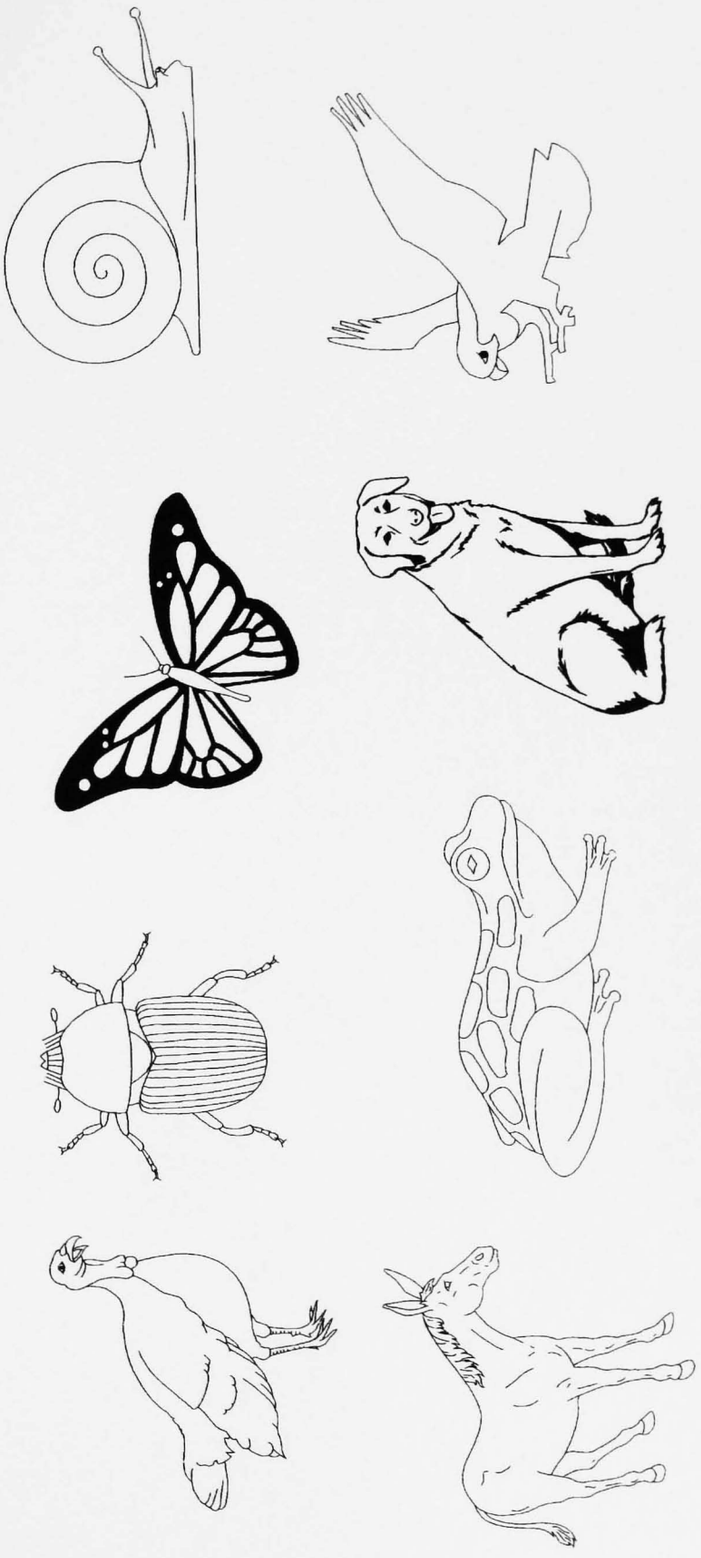
Appendix D: Memory test – study stimuli





Appendix E: Memory test – test stimuli



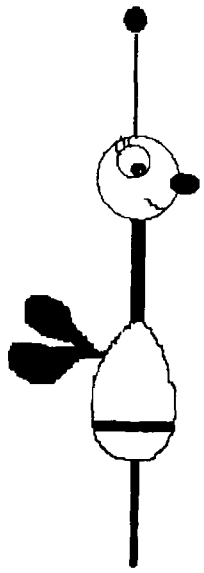


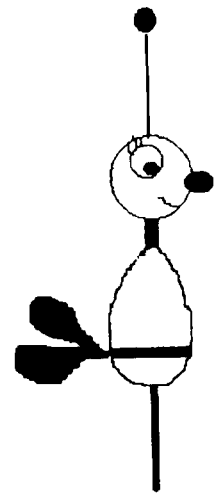
Experiment 3.2

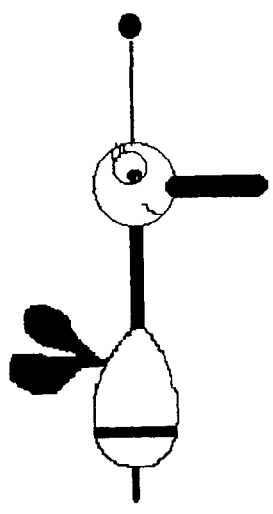
Appendix F: Prototype effect test – average study stimuli

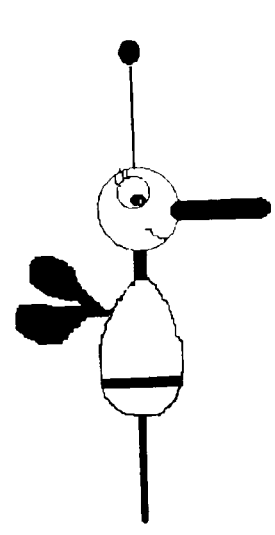
ALL MEDIUM FR ITEMS

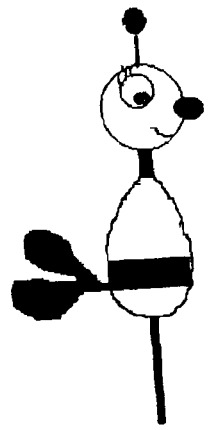
Insect category

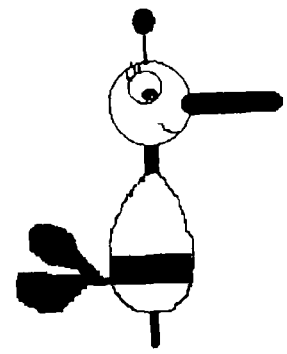


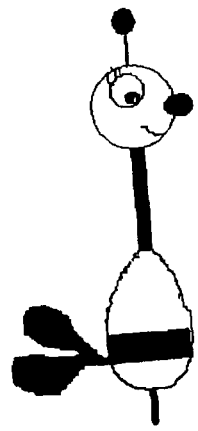


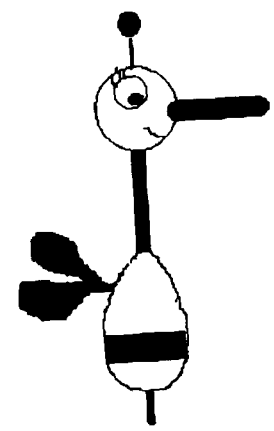




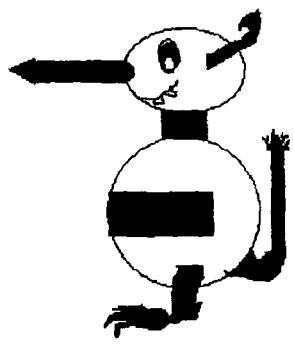


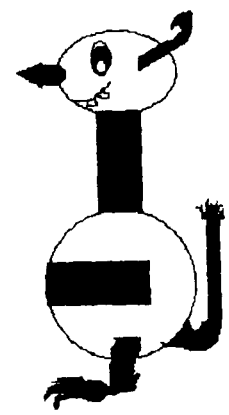


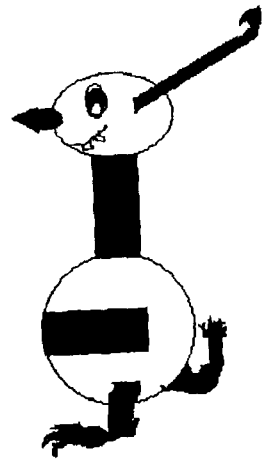


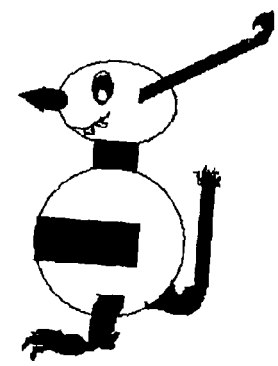


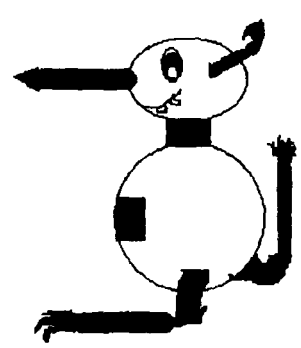
Monster category

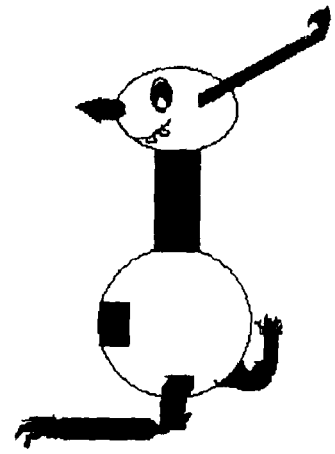


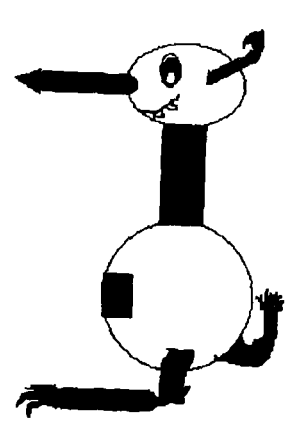








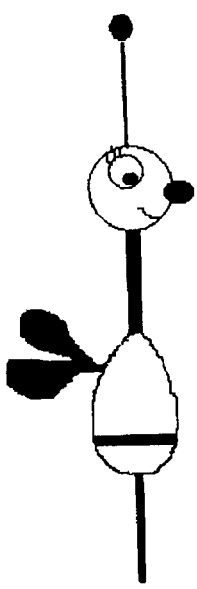


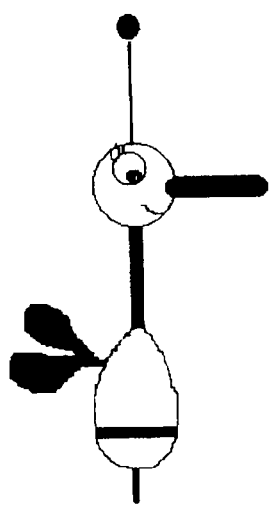


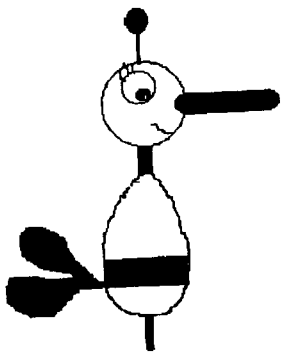
Appendix G: Prototype effect test – average test stimuli

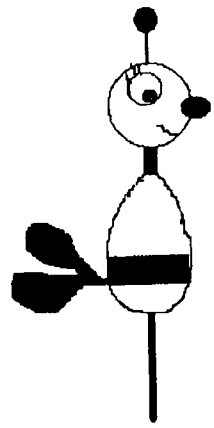
INSECT CATEGORY

Old medium FR items

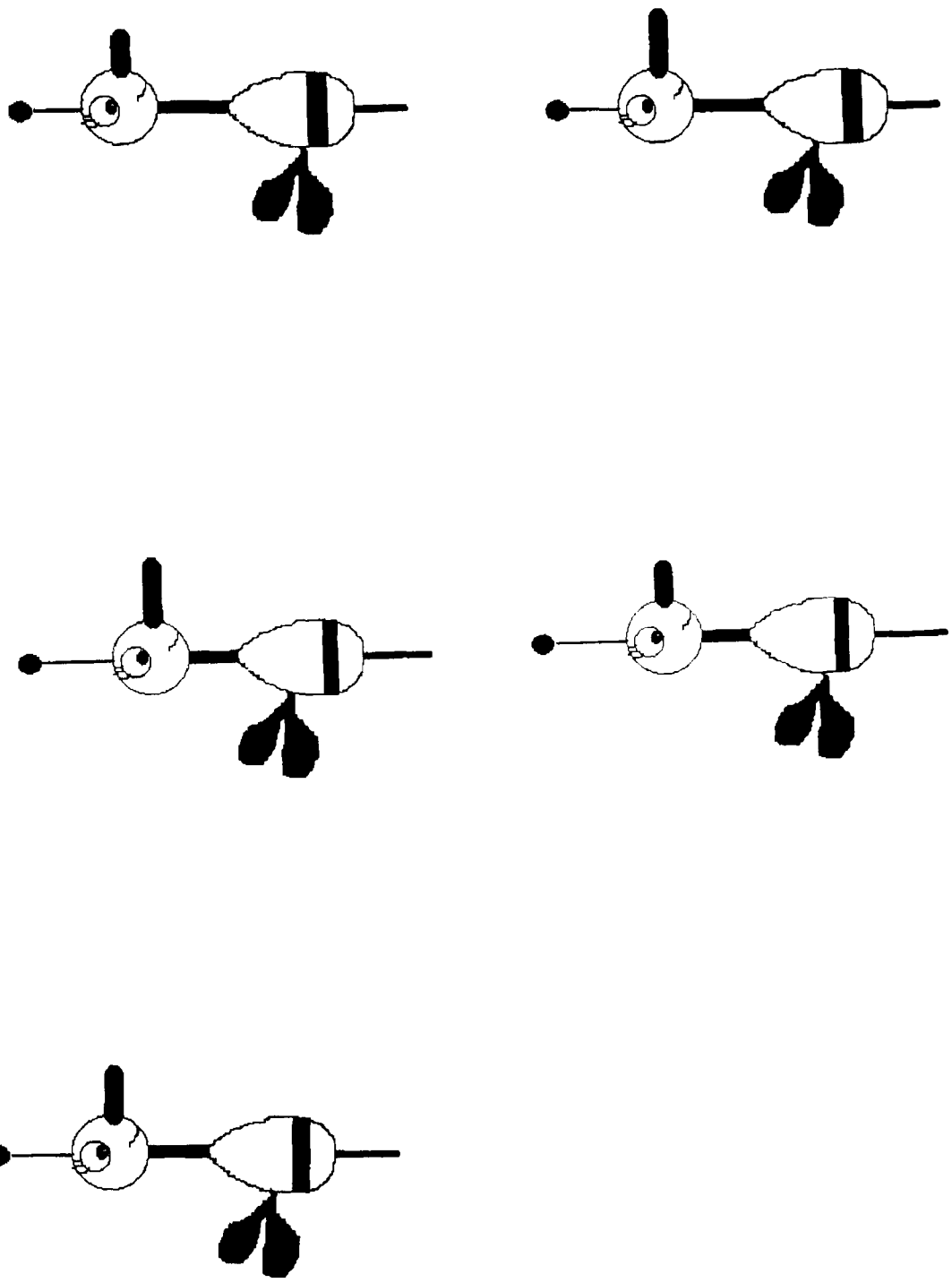




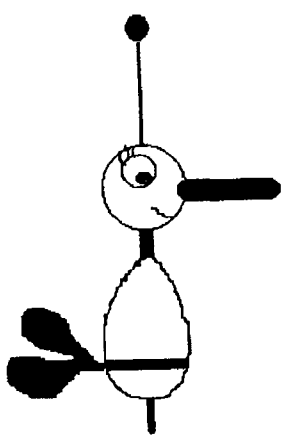


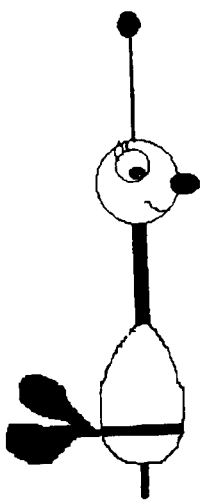


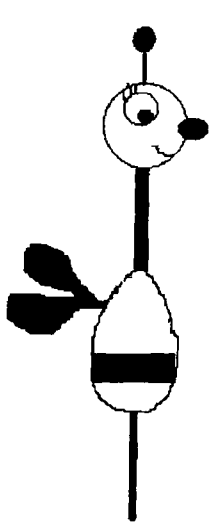
Bottom: prototype; remainder: high FR items

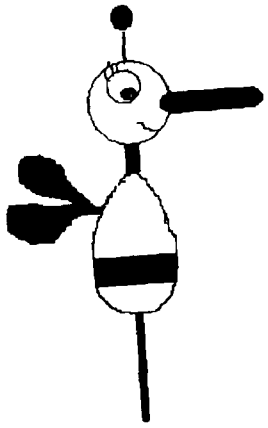


New medium FR items

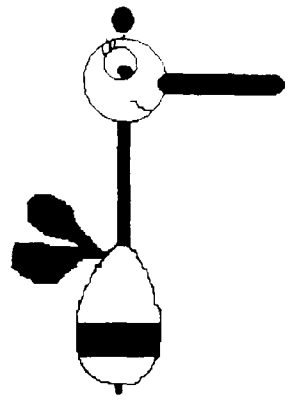


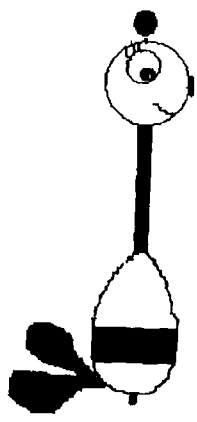


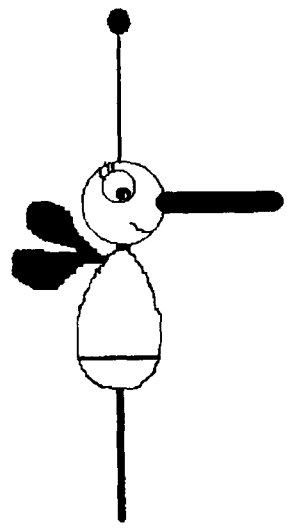




Low FR items

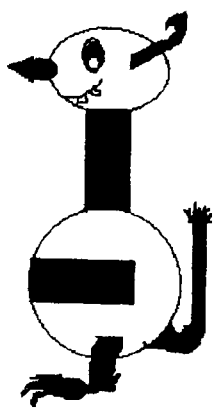


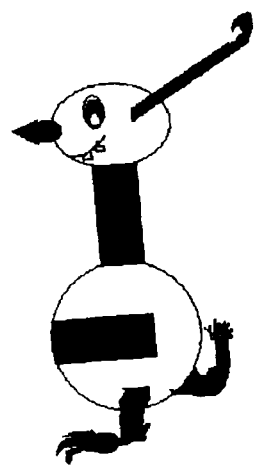


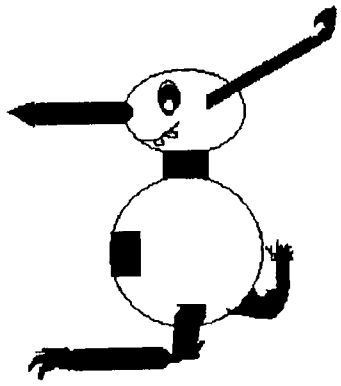


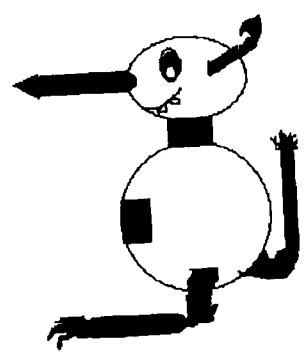
MONSTER CATEGORY

Old medium FR items

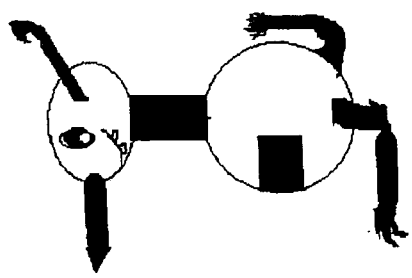


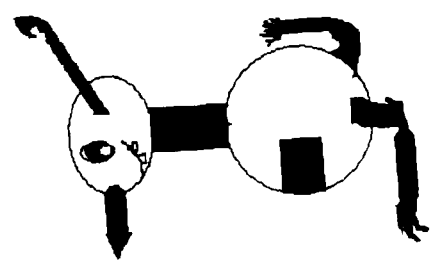


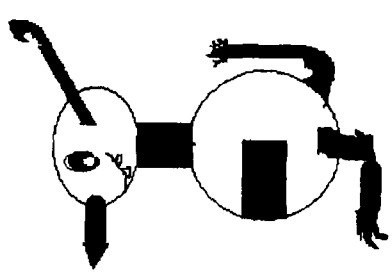


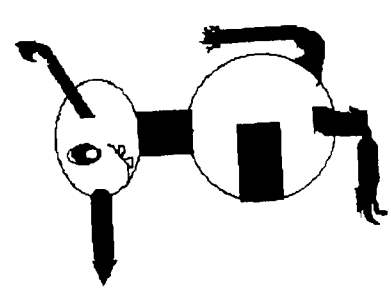


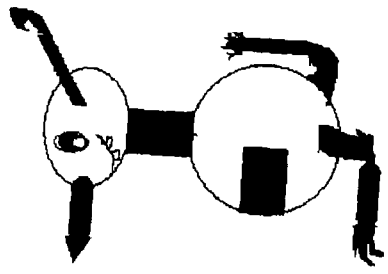
Bottom: prototype; remainder: high FR items



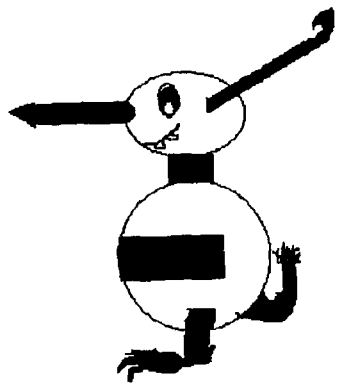


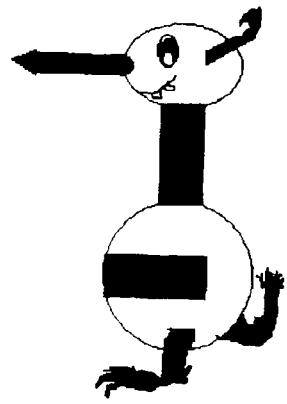


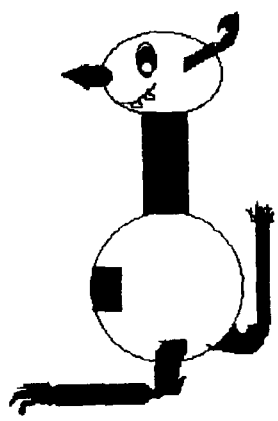


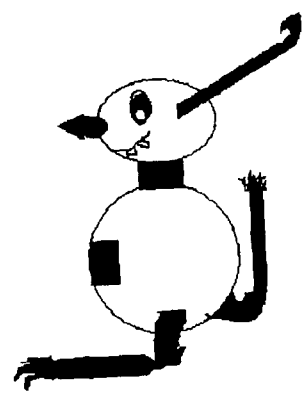


New medium FR items

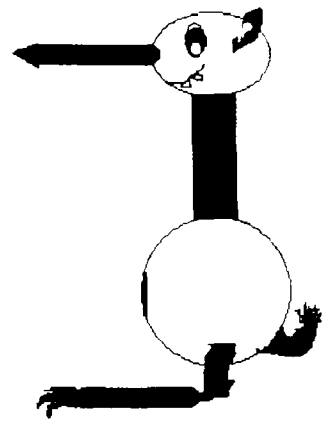


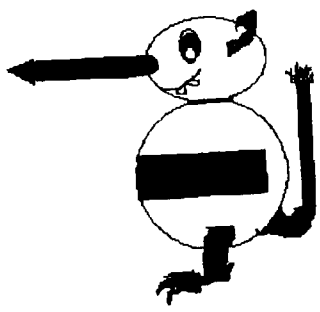


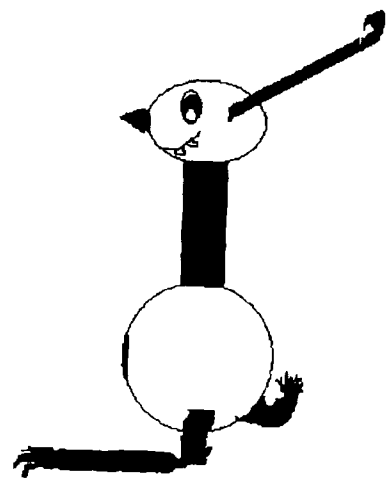




Low FR items





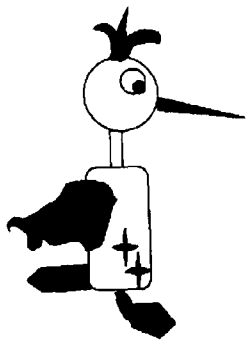


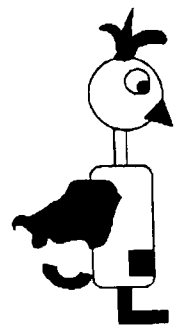
Experiment 3.3

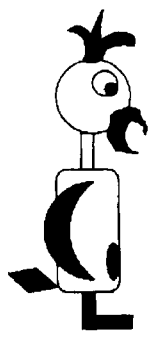
Appendix H: Prototype effect test – modal study stimuli

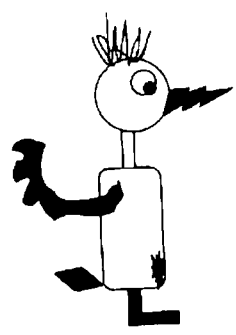
MEDIUM FR ITEMS

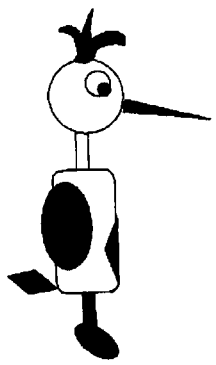
Bird category

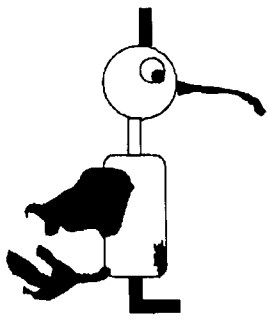


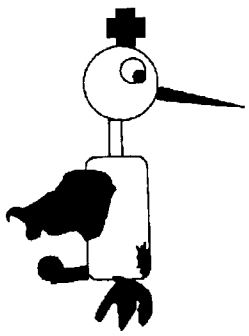


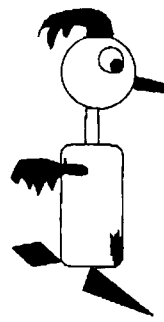




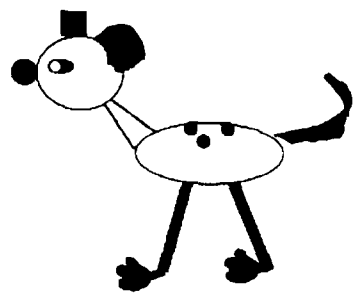


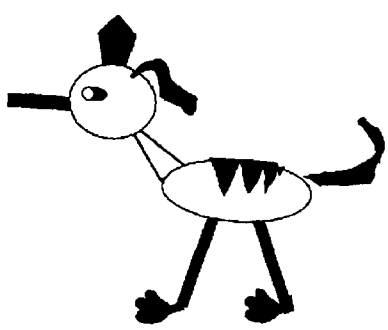


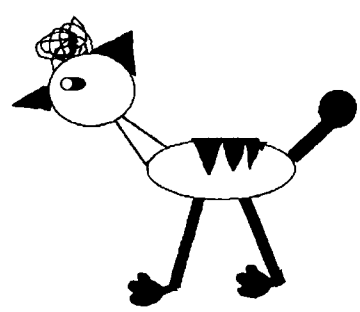


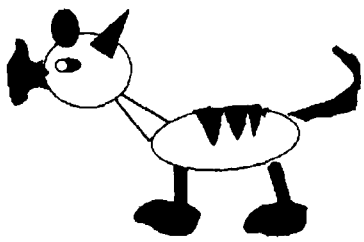


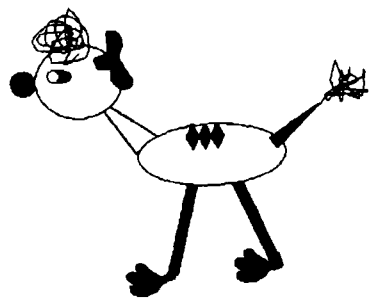
Animal category

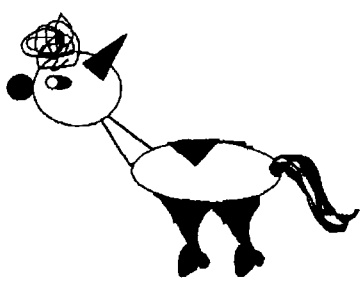


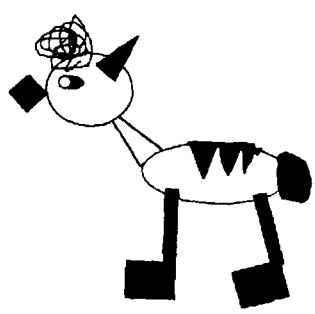








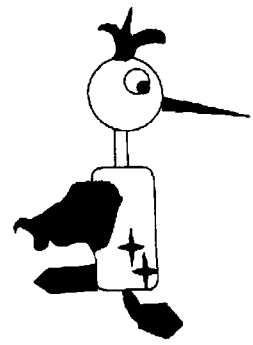


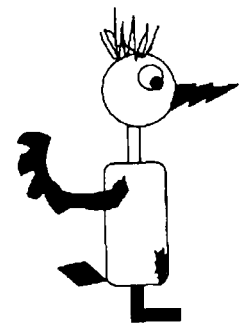


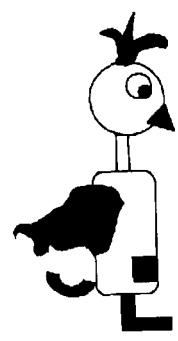
Appendix I: Prototype effecttest – modal test stimuli

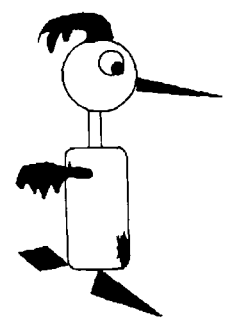
BIRD CATEGORY

Old medium FR items

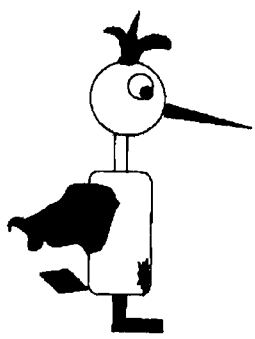


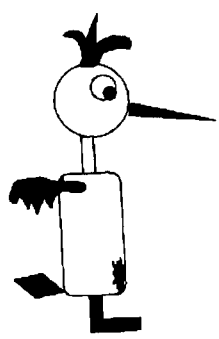


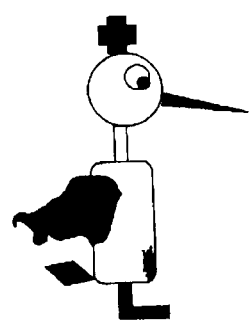


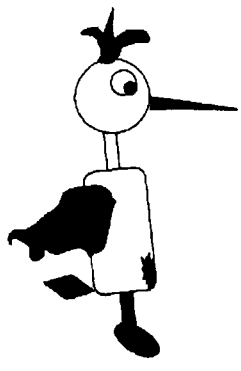


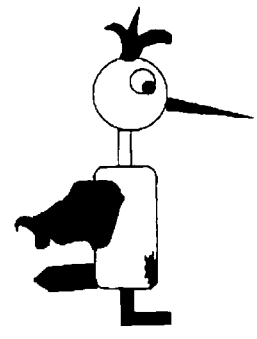
Top: prototype; remainder: high FR items



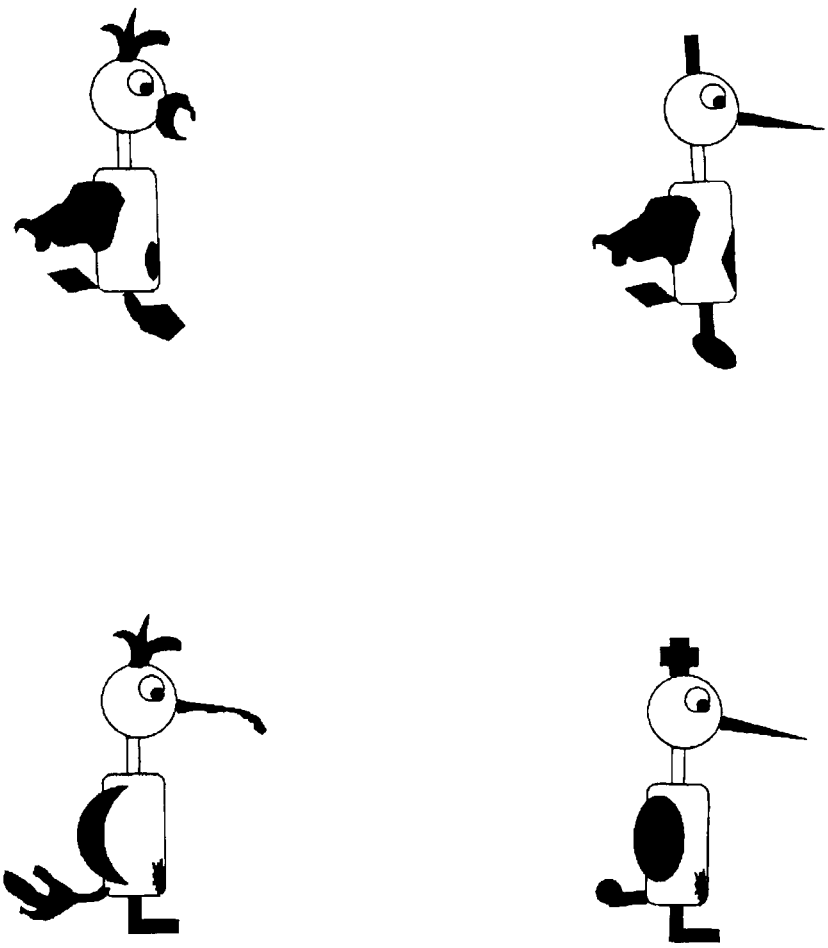




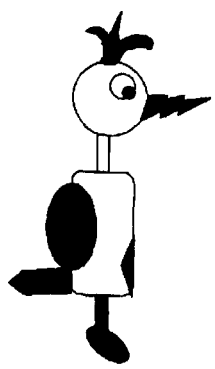


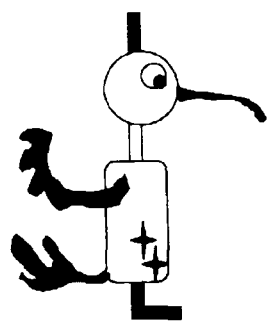


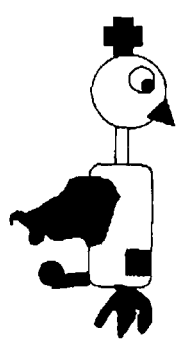
New medium FR items

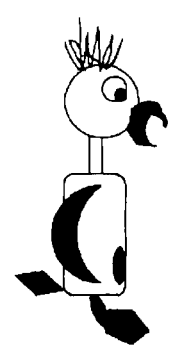


Low FR items



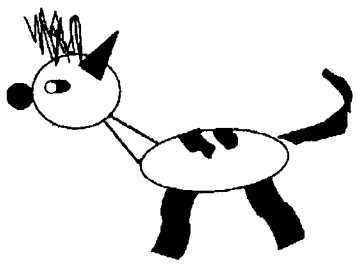


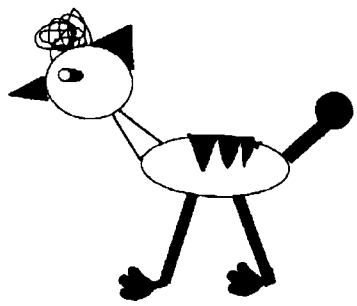


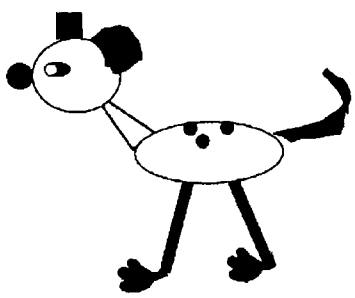


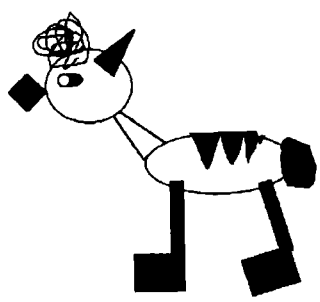
ANIMAL CATEGORY

Old medium FR items

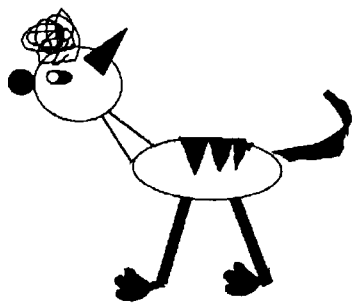


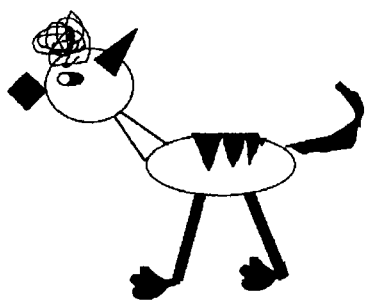


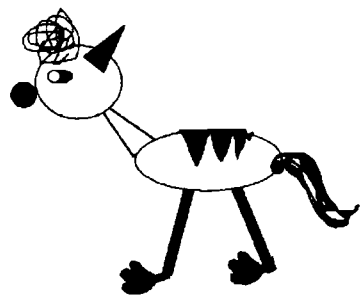


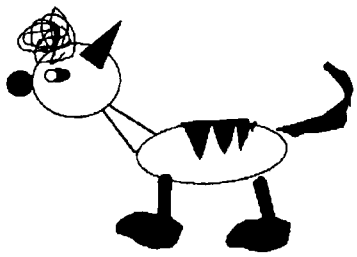


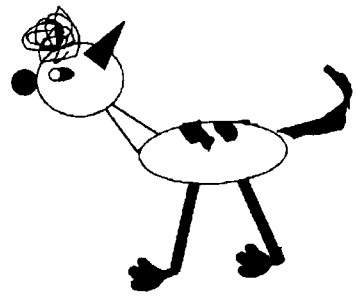
Top: prototype; remainder: high FR items



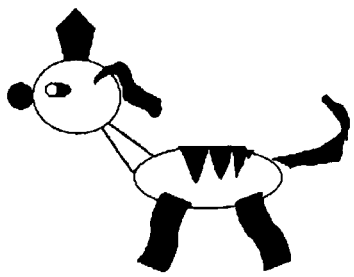


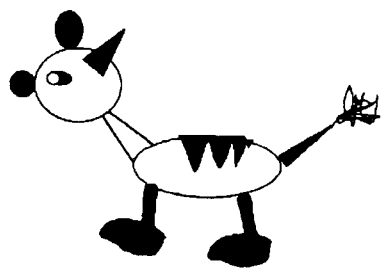


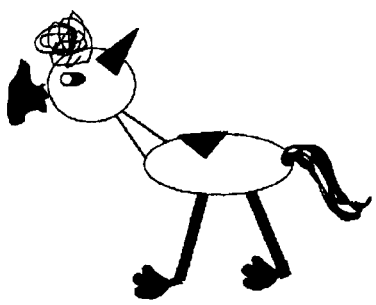


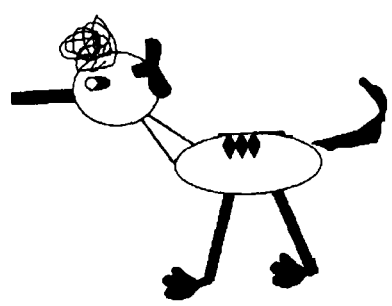


New medium FR items

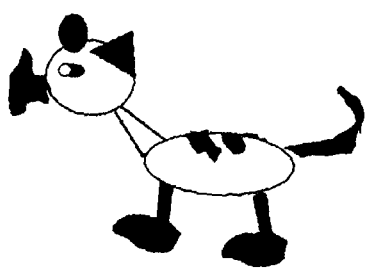


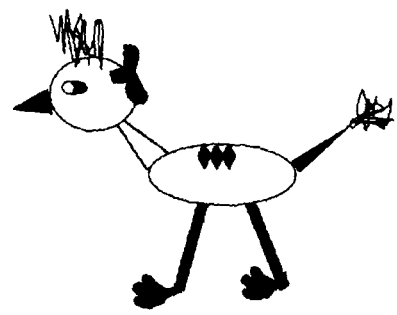


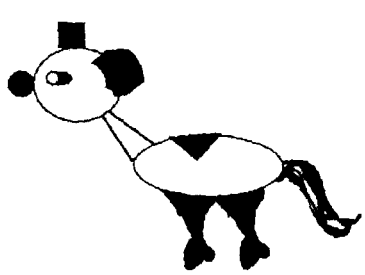




Low FR items







Appendix to Chapter 4

Appendix J: Participants' data from Experiment 4.1

KEY

Column heading	*Description*
Id	Participant identity number
Group	Participant group: 1 = autism; 2 = control
Diagnosis	Diagnosis of participants with high functioning autism: 1 = autism; 2 = Asperger syndrome
ca_yrs	Chronological age (years)
bpvs	Raw scores from the British Picture Vocabulary Scale (BPVS)
vma_yrs	Verbal mental age derived from BPVS raw scores (years)
rvns	Raw scores from the Ravens Progressive Matrices test
order	Presentation order of conditions: 1 = one-trial condition first; 2 = six-trial condition first
t1study_1	Proportion of correct categorisation responses (PCCR) during the one-trial study condition
	Proportion of positive recognition responses (PPRR) during the one-trial test condition
t1recmo	…mo = old medium family resemblance (FR) exemplars
t1rech	…h = high FR exemplars
t1recmn	…mn = new medium FR exemplars
t1recl	…l = low FR exemplars
	PCCR during the one-trial test condition
t1catmo	…mo = old medium FR exemplars
t1cath	…h = high FR exemplars
t1catmn	…mn = new medium FR exemplars
t1catl	…l = low FR exemplars
	PCCR during the six-trial study condition
t6study_1	…n = trial number
t6study_2	
t6study_3	
t6study_4	
t6study_5	
t6study_6	

KEY continued.

Column heading	*Description*
	PPRR during six-trial test condition
t6recmo	...mo = old medium FR exemplars
t6rech	...h = high FR exemplars
t6recmn	...mn = new medium FR exemplars
t6recl	...l = low FR exemplars
	PCCR during six-trial test condition
t6catmo	...mo = old medium FR exemplars
t6cath	...h = high FR exemplars
t6catmn	...mn = new medium FR exemplars
t6catl	...l = low FR exemplars

id	group	diagnosi	ca_yrs	bpvs	vma_yrs	rvns	order	t1study_1	t1recmo	t1rech	t1recmn
1	1.00	2.00	10.00	113.00	12.33	52.00	1.00	10.00	5.00	3.00	2.00
2	1.00	2.00	12.00	129.00	15.17	31.00	2.00	9.00	5.00	7.00	4.00
3	1.00	2.00	13.25	123.00	14.08	44.00	2.00	6.00	4.00	4.00	5.00
4	1.00	2.00	13.33	105.00	11.08	23.00	2.00	9.00	3.00	4.00	4.00
5	1.00	2.00	13.25	132.00	15.67	49.00	1.00	9.00	3.00	6.00	4.00
6	1.00	1.00	16.08	124.00	14.25	42.00	1.00	7.00	5.00	4.00	4.00
7	1.00	1.00	12.58	110.00	11.83	43.00	2.00	9.00	1.00	2.00	5.00
8	1.00	1.00	11.42	101.00	10.58	25.00	1.00	6.00	3.00	4.00	3.00
9	1.00	2.00	10.42	94.00	9.58	39.00	2.00	7.00	4.00	5.00	5.00
10	1.00	1.00	11.17	109.00	11.67	24.00	2.00	6.00	2.00	2.00	3.00
11	1.00	2.00	12.00	133.00	15.83	50.00	1.00	6.00	3.00	5.00	4.00
12	1.00	2.00	15.58	135.00	16.17	53.00	2.00	8.00	3.00	6.00	5.00
13	1.00	2.00	16.50	108.00	11.58	40.00	1.00	6.00	4.00	4.00	3.00
14	1.00	2.00	12.42	126.00	14.58	27.00	2.00	11.00	4.00	3.00	3.00
15	1.00	2.00	12.50	117.00	13.00	35.00	2.00	6.00	4.00	1.00	6.00
16	1.00	2.00	14.00	125.00	14.42	38.00	1.00	4.00	5.00	5.00	5.00
17	1.00	2.00	12.50	152.00	17.00	51.00	2.00	10.00	5.00	6.00	6.00
18	1.00	2.00	14.92	134.00	16.00	46.00	1.00	9.00	4.00	5.00	6.00
19	2.00		13.08	101.00	10.58	45.00	2.00	5.00	4.00	3.00	6.00
20	2.00		12.58	119.00	13.33	41.00	2.00	7.00	8.00	0.00	3.00
21	2.00		11.83	126.00	14.58	44.00	2.00	10.00	5.00	5.00	5.00
22	2.00		12.83	125.00	14.42	37.00	2.00	10.00	7.00	2.00	2.00
23	2.00		12.92	120.00	13.50	43.00	2.00	10.00	7.00	5.00	5.00
24	2.00		10.58	97.00	9.92	42.00	2.00	8.00	3.00	3.00	5.00

id	group	diagnosi	ca_yrs	bpvs	vma_yrs	rvns	order	t1study_1	t1recmo	t1rech	t1recmn
25	2.00		10.92	94.00	9.58	35.00	1.00	9.00	5.00	5.00	3.00
26	2.00		11.33	97.00	9.92	31.00	2.00	5.00	5.00	7.00	4.00
27	2.00		10.33	105.00	11.08	34.00	1.00	6.00	3.00	5.00	2.00
28	2.00		11.92	134.00	16.00	50.00	1.00	9.00	6.00	5.00	3.00
29	2.00		12.08	108.00	11.58	46.00	2.00	9.00	4.00	8.00	4.00
30	2.00		13.83	126.00	14.58	46.00	1.00	3.00	6.00	3.00	6.00
31	2.00		13.00	136.00	16.33	46.00	2.00	9.00	4.00	2.00	4.00
32	2.00		12.58	135.00	16.17	57.00	2.00	10.00	6.00	5.00	7.00
33	2.00		14.67	139.00	16.83	48.00	1.00	9.00	5.00	6.00	3.00
34	2.00		15.17	117.00	13.00	46.00	1.00	10.00	3.00	4.00	2.00
35	2.00		16.33	110.00	11.83	40.00	1.00	9.00	6.00	5.00	3.00
36	2.00		15.08	126.00	14.58	51.00	1.00	9.00	1.00	3.00	3.00

id	t1recl	t1catmo	t1cath	t1catmn	t1catl	t6study_1	t6study_2	t6study_3	t6study_4	t6study_5	t6study_6
1	4.00	6.00	8.00	8.00	6.00	8.00	9.00	9.00	12.00	10.00	10.00
2	5.00	5.00	5.00	6.00	4.00	6.00	8.00	11.00	7.00	12.00	10.00
3	4.00	8.00	7.00	6.00	4.00	8.00	10.00	10.00	12.00	12.00	11.00
4	3.00	5.00	4.00	6.00	4.00	10.00	10.00	12.00	11.00	12.00	11.00
5	3.00	5.00	5.00	6.00	4.00	5.00	11.00	10.00	10.00	11.00	12.00
6	5.00	4.00	5.00	3.00	6.00	7.00	11.00	11.00	8.00	12.00	12.00
7	0.00	8.00	8.00	7.00	4.00	7.00	8.00	12.00	12.00	12.00	12.00
8	6.00	3.00	3.00	2.00	3.00	4.00	7.00	5.00	8.00	5.00	6.00
9	3.00	3.00	5.00	4.00	5.00	8.00	10.00	5.00	5.00	9.00	8.00
10	0.00	4.00	3.00	2.00	3.00	8.00	11.00	12.00	12.00	11.00	12.00
11	3.00	7.00	4.00	2.00	7.00	9.00	2.00	11.00	11.00	12.00	12.00
12	5.00	7.00	5.00	3.00	1.00	5.00	11.00	10.00	12.00	12.00	12.00
13	4.00	5.00	4.00	2.00	7.00	7.00	4.00	7.00	6.00	6.00	4.00
14	4.00	5.00	6.00	5.00	6.00	7.00	7.00	12.00	12.00	11.00	12.00
15	0.00	6.00	2.00	4.00	3.00	5.00	6.00	7.00	7.00	6.00	7.00
16	5.00	3.00	5.00	6.00	5.00	6.00	4.00	3.00	4.00	3.00	7.00
17	0.00	8.00	7.00	8.00	5.00	7.00	11.00	11.00	12.00	12.00	11.00
18	4.00	3.00	2.00	1.00	2.00	8.00	10.00	11.00	11.00	10.00	11.00
19	3.00	6.00	5.00	1.00	5.00	6.00	3.00	10.00	12.00	12.00	12.00
20	1.00	5.00	4.00	2.00	6.00	5.00	10.00	8.00	11.00	11.00	12.00
21	3.00	5.00	6.00	7.00	4.00	8.00	11.00	10.00	9.00	5.00	6.00
22	2.00	7.00	8.00	8.00	6.00	9.00	7.00	11.00	11.00	10.00	9.00
23	4.00	5.00	6.00	6.00	4.00	8.00	11.00	11.00	12.00	12.00	11.00
24	4.00	7.00	7.00	4.00	6.00	8.00	5.00	11.00	11.00	12.00	12.00

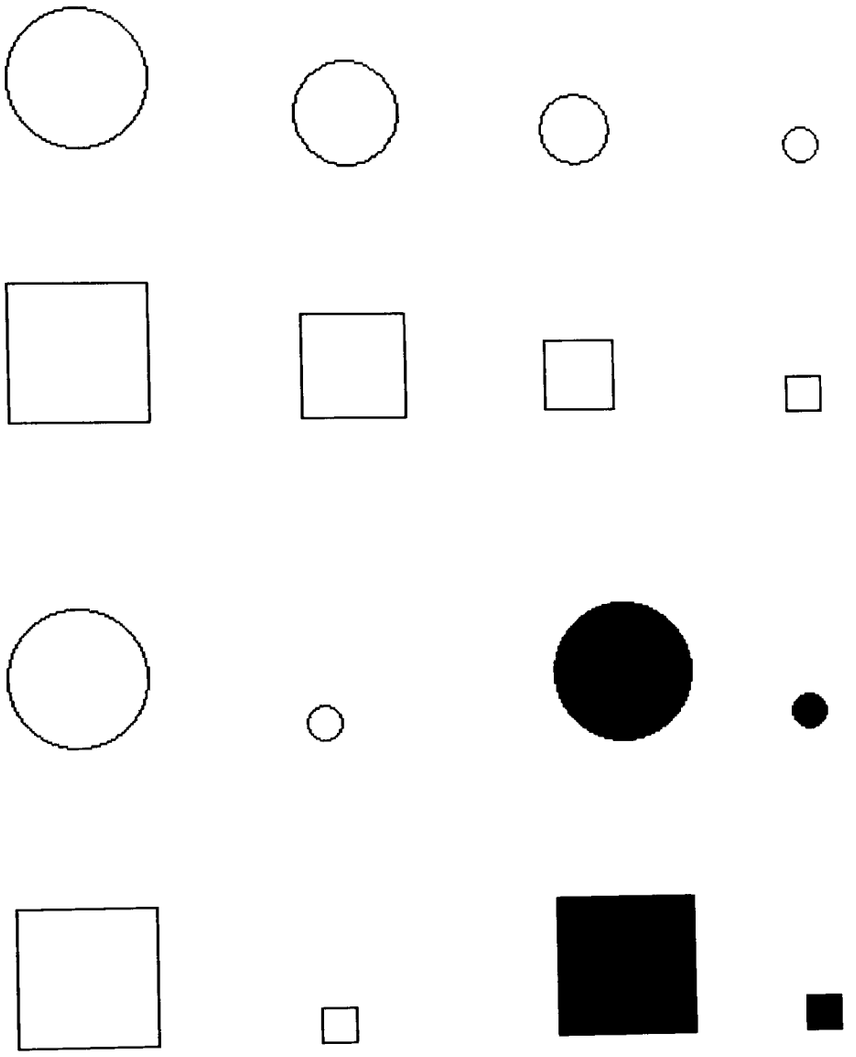
id	t1recl	t1catmo	t1cath	t1catmn	t1catl	t6study_1	t6study_2	t6study_3	t6study_4	t6study_5	t6study_6
25	3.00	6.00	4.00	2.00	4.00	4.00	6.00	4.00	3.00	8.00	9.00
26	6.00	4.00	6.00	5.00	2.00	5.00	3.00	7.00	8.00	9.00	7.00
27	5.00	3.00	1.00	3.00	3.00	3.00	7.00	8.00	7.00	10.00	9.00
28	2.00	6.00	7.00	5.00	6.00	12.00	11.00	11.00	11.00	11.00	12.00
29	0.00	7.00	8.00	8.00	5.00	10.00	12.00	12.00	11.00	12.00	12.00
30	2.00	8.00	6.00	7.00	5.00	9.00	8.00	11.00	9.00	12.00	12.00
31	2.00	7.00	6.00	6.00	5.00	7.00	12.00	12.00	12.00	12.00	12.00
32	5.00	2.00	1.00	2.00	1.00	7.00	12.00	12.00	12.00	12.00	12.00
33	1.00	0.00	0.00	0.00	3.00	7.00	8.00	11.00	11.00	12.00	12.00
34	3.00	5.00	8.00	6.00	7.00	5.00	7.00	6.00	3.00	1.00	2.00
35	2.00	6.00	3.00	5.00	3.00	6.00	4.00	8.00	9.00	11.00	12.00
36	1.00	5.00	6.00	7.00	5.00	5.00	6.00	10.00	11.00	12.00	11.00

id	t6recmo	t6rech	t6recmn	t6recl	t6catmo	t6cath	t6catmn	t6catl
1	4.00	4.00	3.00	4.00	8.00	8.00	6.00	4.00
2	4.00	2.00	0.00	0.00	5.00	4.00	6.00	4.00
3	5.00	4.00	5.00	2.00	8.00	7.00	7.00	6.00
4	8.00	5.00	6.00	0.00	8.00	7.00	7.00	6.00
5	7.00	4.00	6.00	4.00	6.00	6.00	6.00	6.00
6	4.00	3.00	5.00	2.00	8.00	7.00	7.00	4.00
7	4.00	1.00	2.00	1.00	8.00	7.00	8.00	6.00
8	4.00	5.00	7.00	7.00	2.00	3.00	3.00	3.00
9	6.00	5.00	5.00	3.00	4.00	5.00	5.00	0.00
10	4.00	0.00	2.00	0.00	5.00	6.00	7.00	7.00
11	6.00	4.00	5.00	3.00	8.00	8.00	7.00	6.00
12	8.00	7.00	5.00	3.00	8.00	8.00	8.00	3.00
13	5.00	4.00	3.00	3.00	3.00	5.00	3.00	5.00
14	6.00	6.00	7.00	2.00	7.00	8.00	8.00	6.00
15	6.00	3.00	2.00	0.00	6.00	3.00	7.00	5.00
16	3.00	4.00	2.00	4.00	4.00	4.00	3.00	5.00
17	7.00	7.00	2.00	0.00	8.00	8.00	7.00	7.00
18	6.00	7.00	5.00	2.00	7.00	7.00	7.00	6.00
19	8.00	8.00	4.00	1.00	8.00	7.00	7.00	5.00
20	3.00	5.00	4.00	0.00	8.00	8.00	8.00	6.00
21	4.00	3.00	3.00	3.00	4.00	2.00	3.00	4.00
22	7.00	3.00	5.00	3.00	6.00	7.00	6.00	6.00
23	6.00	7.00	7.00	2.00	7.00	8.00	8.00	7.00
24	5.00	5.00	4.00	3.00	7.00	8.00	8.00	7.00

id	t6recmo	t6rech	t6recmn	t6recl	t6catmo	t6cath	t6catmn	t6catl
25	2.00	7.00	1.00	0.00	2.00	5.00	3.00	3.00
26	3.00	4.00	5.00	2.00	6.00	7.00	7.00	6.00
27	5.00	4.00	7.00	3.00	5.00	8.00	4.00	5.00
28	7.00	4.00	3.00	3.00	8.00	8.00	7.00	7.00
29	6.00	5.00	3.00	1.00	8.00	7.00	6.00	6.00
30	6.00	6.00	4.00	3.00	8.00	8.00	8.00	8.00
31	7.00	4.00	2.00	0.00	8.00	8.00	8.00	5.00
32	4.00	4.00	4.00	2.00	8.00	8.00	8.00	6.00
33	5.00	3.00	4.00	2.00	8.00	8.00	6.00	7.00
34	3.00	5.00	3.00	3.00	5.00	6.00	7.00	2.00
35	4.00	2.00	6.00	6.00	3.00	5.00	5.00	3.00
36	3.00	4.00	4.00	2.00	7.00	6.00	8.00	6.00

Appendix K: Practice stimuli

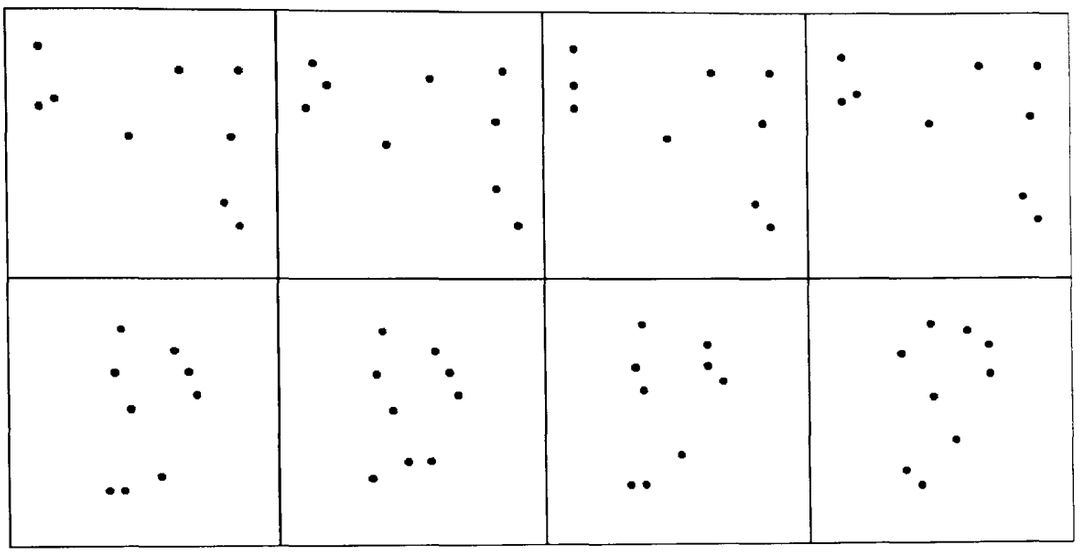
Top 2 rows – study session; bottom 2 rows – test session



Appendix L: Stimuli for instruction sheet

ALL ARE MEDIUM FR ITEMS.

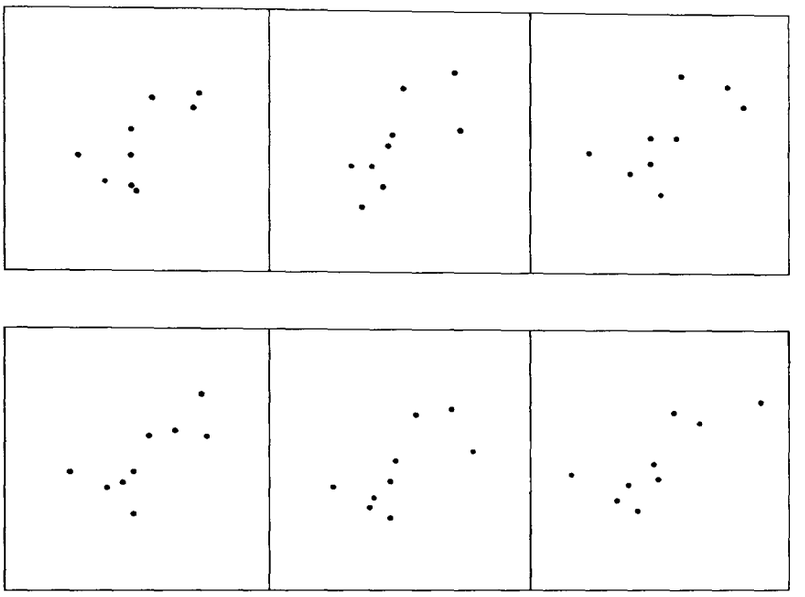
Top row: Category E; bottom row: Category F

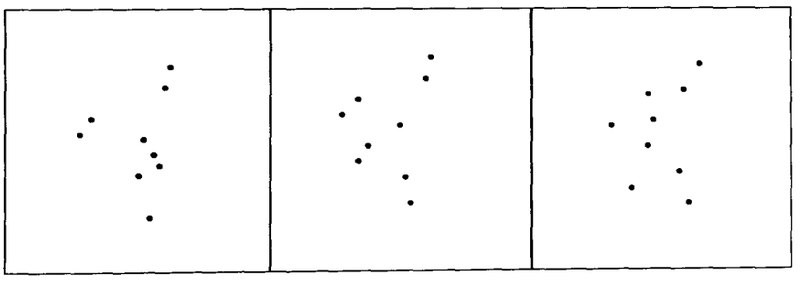


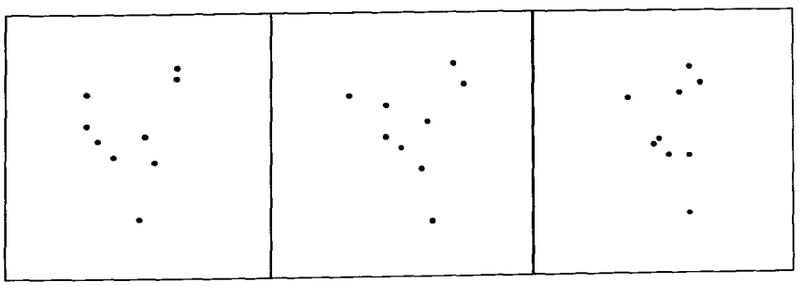
Appendix M: Study stimuli

ALL ARE MEDIUM FR ITEMS

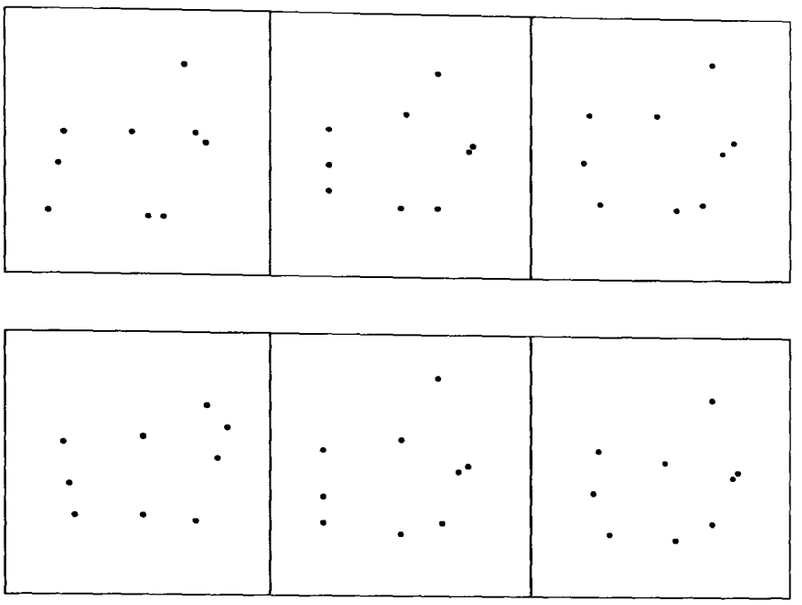
First two rows: Category A; second two rows – Category B

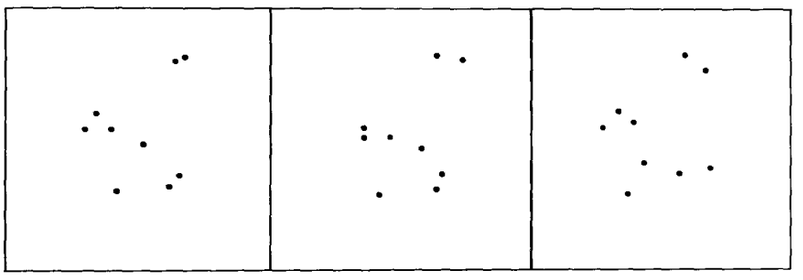


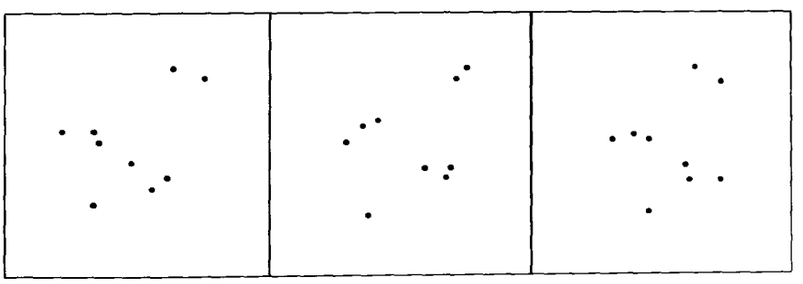




First two rows: Category C; second two rows: Category D



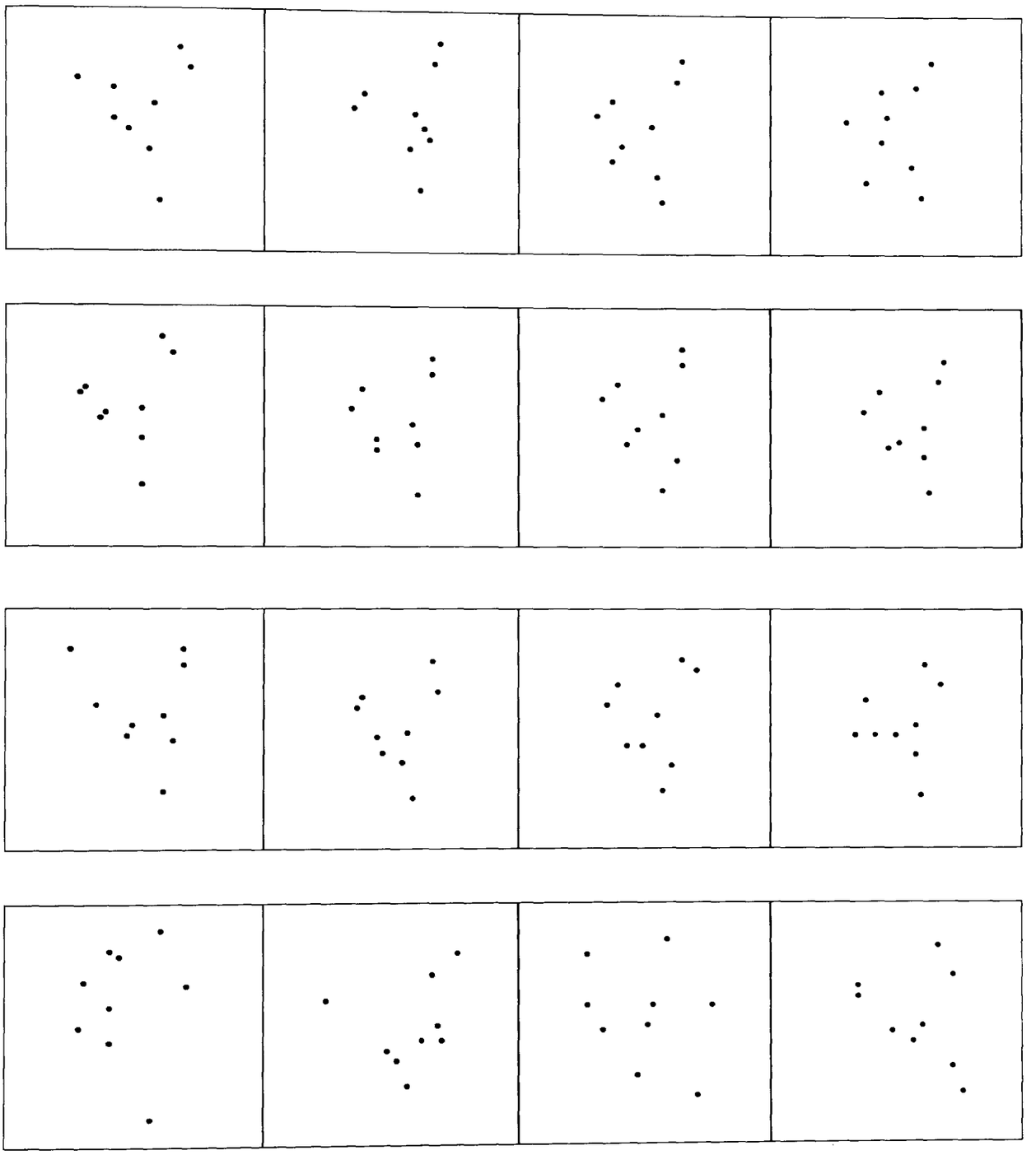




Appendix N: Test stimuli

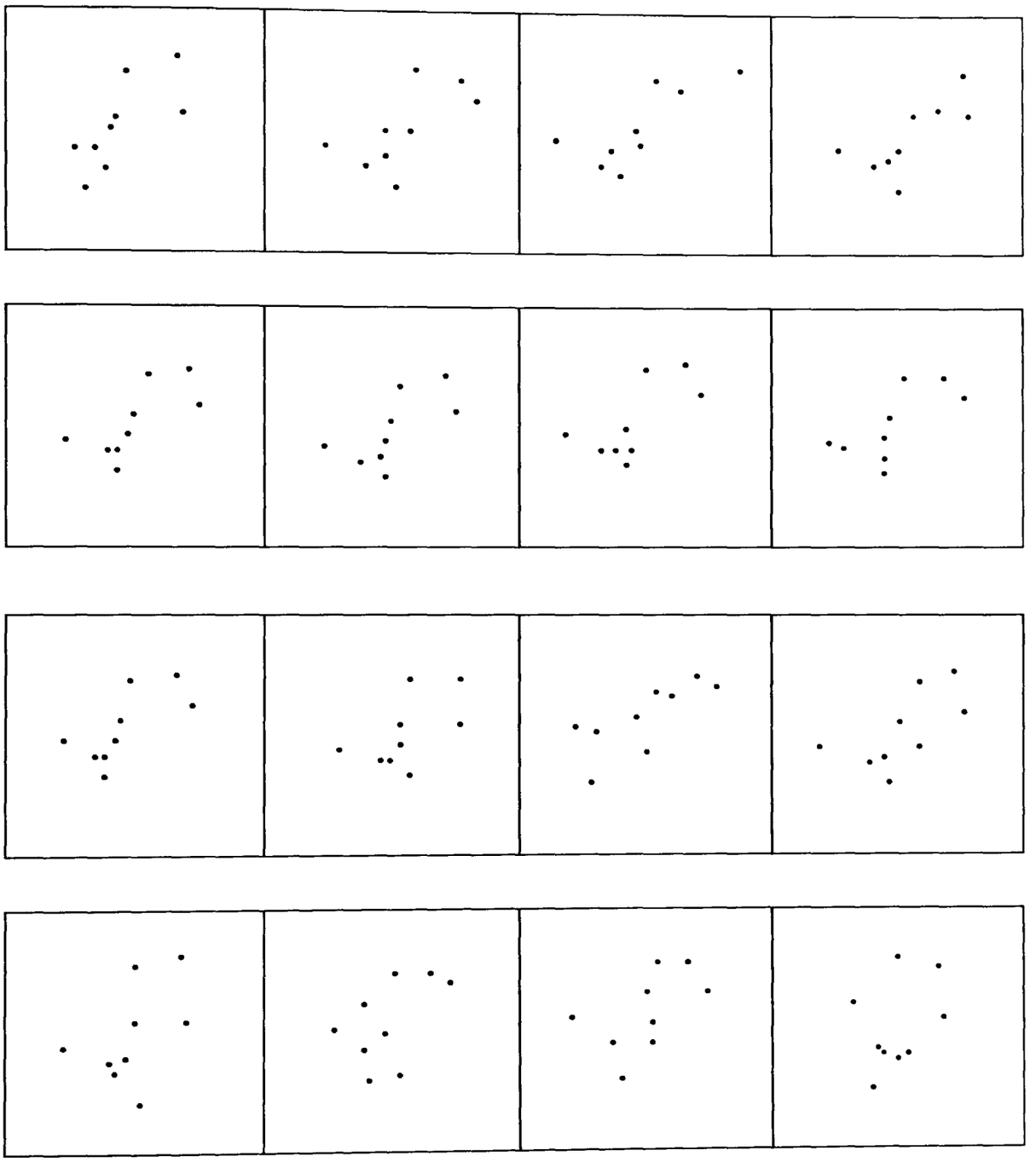
CATEGORY A

From top to bottom: 1st row – old medium FR items; 2nd row – high FR items; 3rd row – new medium FR items; 4th row – low FR items



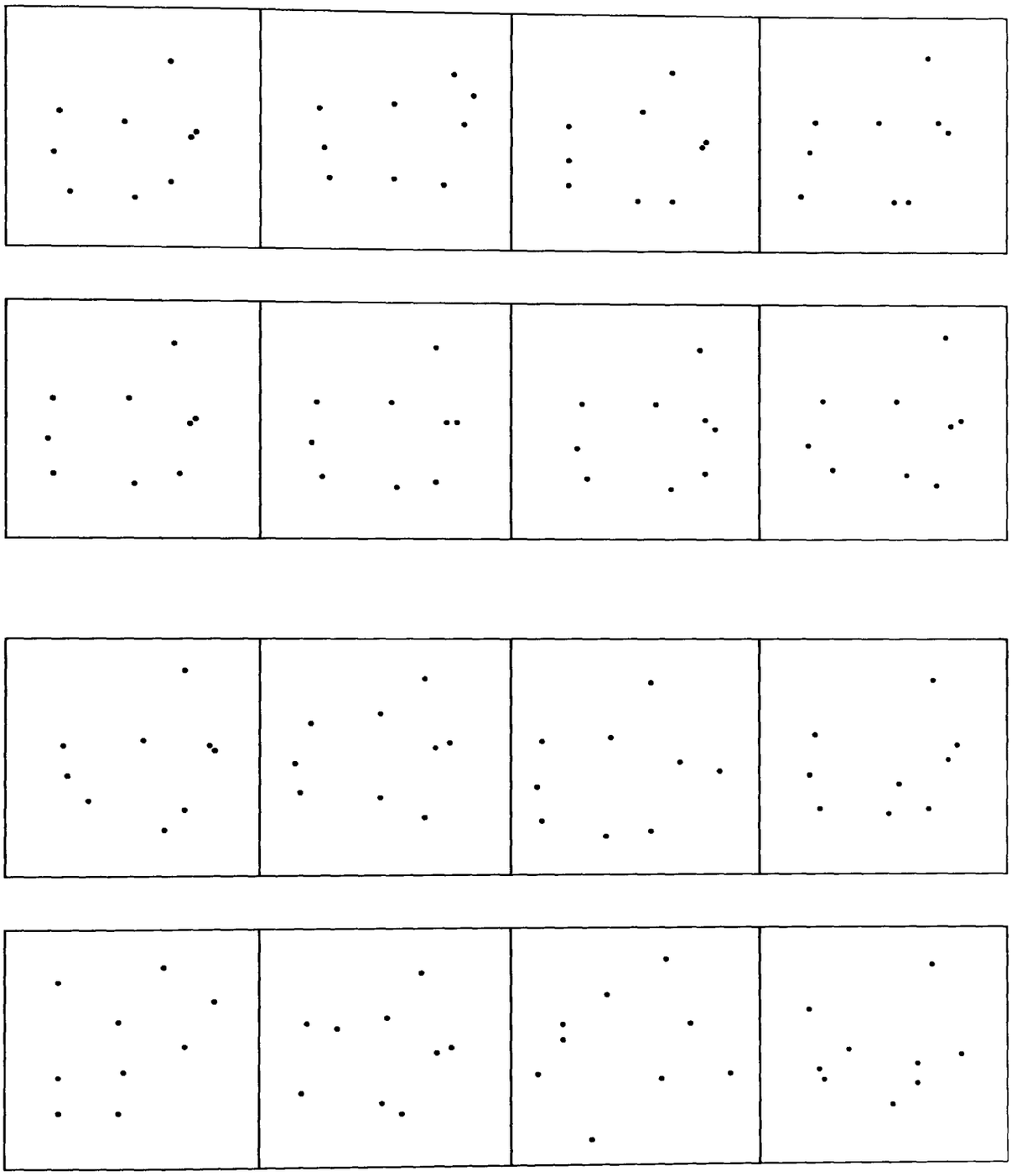
CATEGORY B

From top to bottom: 1st row – old medium FR items; 2nd row – high FR items; 3rd row – new medium FR items; 4th row – low FR items



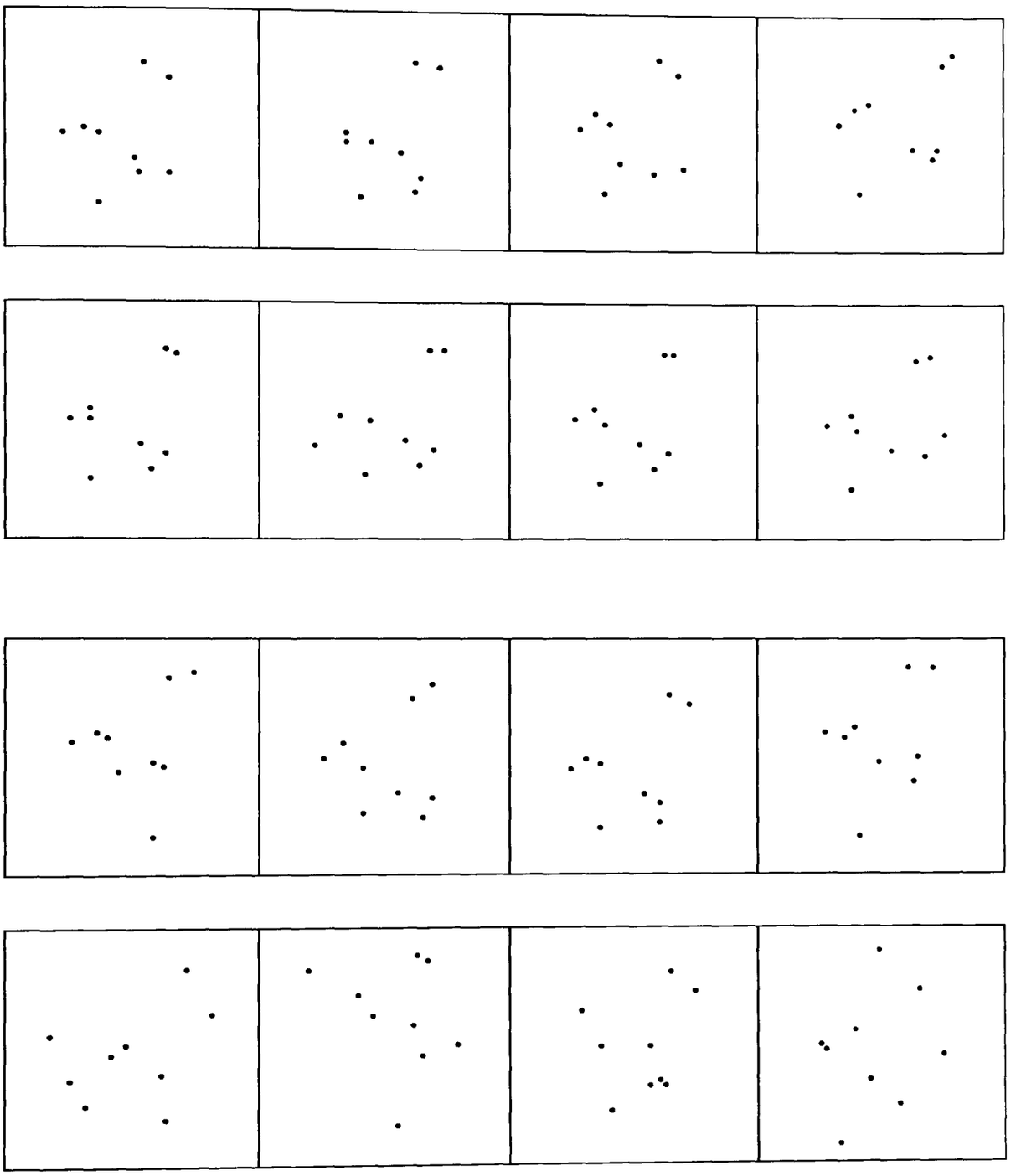
CATEGORY C

From top to bottom: 1st row – old medium FR items; 2nd row – high FR items; 3rd row – new medium FR items; 4th row – low FR items



CATEGORY D

From top to bottom: 1st row – old medium FR items; 2nd row – high FR items; 3rd row – new medium FR items; 4th row – low FR items



Appendix to Chapter 5

Appendix O: Participants' data from Experiments 5.1 – 5.3

KEY

Column Heading	*Description*
Id	Participant identity number
Group	Participant group: 1 = high functioning autism; 2 = control
Diagnosis	Diagnosis of participants with autism: 1 = autism; 2 = Asperger syndrome
ca_yrs	Chronological age (years)
bpvs	Raw scores from the British Picture Vocabulary Scale (BPVS)
vma_yrs	Verbal mental age derived from BPVS raw scores (years)
gender	1 = male; 2 = female
order	Presentation order of control tasks: 1 = shapes task first; 2 = numbers task first
prot	Prototype choice proportion
med	Medium family resemblance (FR) choice proportion
low	Low FR choice proportion
ps	Proportion of shapes scores
pn	Proportion of numbers scores
ca_yrs1	Chronological age (years) at start of Experiment 5.3
vma_yrs1	Verbal mental age (years) at start of Experiment 5.3
pmd_letc pmd_leth pmd_sqr pmd_ccl	Proportion of membership decisions for ...letc = the letter C target category ...leth = the letter H target category ...sqr = the square target category ...ccl = the circle target category
qwording	Question wording used in Experiment 5.3: 1 = one question per item in each array - for example: 'Is this a letter *C*?'; 2 = one question per array – for example: '...show me all the ones that are a letter *C* ...?'

id	group	diagnosis	ca_yrs	bpvs	vma_yrs	gender	order	prot	med	low	ps
1	1.00	1.00	9.42	69.00	6.75	1.00	1.00	0.50	0.17	0.33	0.88
2	1.00	1.00	9.92	92.00	9.08	1.00	1.00	0.50	0.00	0.50	0.96
3	1.00	2.00	10.92	84.00	8.17	1.00	1.00	0.33	0.33	0.33	0.88
4	1.00	2.00	15.67	135.00	16.17	1.00	2.00	0.33	0.50	0.17	0.92
5	1.00	2.00	12.58	116.00	12.83	1.00	2.00	0.33	0.33	0.33	0.92
6	1.00	2.00	12.83	102.00	10.67	2.00	2.00	0.17	0.17	0.67	0.96
7	1.00	1.00	10.58	73.00	7.17	1.00	1.00	0.17	0.50	0.33	1.00
8	1.00	1.00	14.42	103.00	10.83	2.00	1.00	0.67	0.17	0.17	1.00
9	1.00	1.00	13.67	131.00	15.50	1.00	2.00	0.50	0.50	0.00	1.00
10	1.00	2.00	14.33	103.00	10.83	1.00	2.00	0.67	0.33	0.00	1.00
11	1.00	2.00	10.50	89.00	8.75	1.00	2.00	0.50	0.50	0.00	1.00
12	1.00	2.00	13.25	107.00	11.33	1.00	2.00	0.33	0.33	0.33	1.00
13	1.00	2.00	15.00	145.00	17.00	1.00	2.00	0.33	0.33	0.33	1.00
14	1.00	2.00	13.92	117.00	13.00	1.00	1.00	1.00	0.00	0.00	1.00
15	1.00	2.00	15.17	97.00	9.92	1.00	1.00	0.83	0.17	0.00	1.00
16	1.00	2.00	15.33	151.00	17.00	1.00	1.00	0.83	0.17	0.00	1.00
17	1.00	2.00	14.00	123.00	14.08	1.00	1.00	0.00	0.33	0.67	1.00
18	1.00	2.00	14.92	145.00	17.00	1.00	2.00	0.83	0.17	0.00	1.00
19	2.00		11.50	87.00	8.58	1.00	1.00	0.50	0.33	0.17	1.00
20	2.00		11.08	117.00	13.00	1.00	2.00	0.83	0.17	0.00	1.00
21	2.00		12.83	115.00	12.58	1.00	2.00	0.83	0.17	0.00	1.00
22	2.00		13.75	134.00	16.00	1.00	2.00	0.67	0.33	0.00	1.00
23	2.00		9.92	92.00	9.08	1.00	1.00	0.50	0.00	0.50	1.00
24	2.00		10.67	76.00	7.42	1.00	1.00	0.33	0.33	0.33	1.00

id	group	diagnosis	ca_yrs	bpvs	vma_yrs	gender	order	prot	med	low	ps
25	2.00		10.75	102.00	10.67	2.00	2.00	0.33	0.50	0.17	1.00
26	2.00		10.67	85.00	8.33	1.00	2.00	0.17	0.33	0.50	1.00
27	2.00		13.08	107.00	11.33	1.00	2.00	0.17	0.67	0.17	1.00
28	2.00		9.58	88.00	8.67	1.00	1.00	0.50	0.33	0.17	1.00
29	2.00		14.17	103.00	10.83	1.00	2.00	0.67	0.33	0.00	1.00
30	2.00		14.25	113.00	12.33	2.00	1.00	0.83	0.00	0.17	1.00
31	2.00		15.42	138.00	16.67	1.00	1.00	0.67	0.33	0.00	1.00
32	2.00		14.00	113.00	12.33	1.00	1.00	0.67	0.17	0.17	1.00
33	2.00		15.58	118.00	13.08	1.00	1.00	0.50	0.50	0.00	1.00
34	2.00		14.17	141.00	17.00	1.00	1.00	0.50	0.50	0.00	1.00
35	2.00		15.50	144.00	17.00	1.00	1.00	0.67	0.33	0.00	1.00
36	2.00		14.92	150.00	17.00	1.00	2.00	1.00	0.00	0.00	1.00

id	pn	ca_yrs1	vma_yrs1	pmd_letc	pmd_leth	pmd_sqr	pmd_ccl	qwording
1	0.92	10.75	7.83	0.33	0.83	0.17	0.50	1.00
2	1.00	9.92	9.08					0.00
3	1.00	10.92	8.17					0.00
4	1.00	15.67	16.17					0.00
5	1.00	13.17	13.33	0.67	0.67	0.67	0.50	0.00
6	0.88	13.50	11.33	0.50	0.50	1.00	0.67	0.00
7	0.54	11.92	8.08	0.50	0.50	1.00	0.33	1.00
8	1.00	15.83	12.08	0.67	0.33	1.00	0.33	1.00
9	0.96	13.67	15.50	0.17	0.17	0.17	0.17	1.00
10	1.00	15.67	12.00					0.00
11	1.00	10.50	8.75					0.00
12	1.00	13.92	12.00	0.67	0.50	0.33	0.33	0.00
13	0.96	15.00	17.00					0.00
14	1.00	13.92	13.00	0.33	0.67	0.33	0.17	0.00
15	1.00	15.17	9.92	0.17	0.17	0.17	0.17	1.00
16	1.00	15.33	17.00	0.33	0.17	0.17	0.33	0.00
17	1.00	14.00	14.08	0.33	0.33	0.17	0.17	0.00
18	1.00	14.92	17.00	0.50	0.17	0.17	0.17	0.00
19	1.00	11.50	8.58	0.33	0.50	0.33	0.50	0.00
20	1.00	11.08	13.00	0.83	0.67	1.00	0.17	0.00
21	1.00	12.83	12.58	0.67	0.50	1.00	0.33	0.00
22	1.00	13.75	16.00	0.33	0.17	0.67	0.17	0.00
23	1.00	9.92	9.08	0.50	0.33	0.67	0.50	0.00
24	1.00	10.67	7.42	0.67	0.50	0.50	0.17	0.00

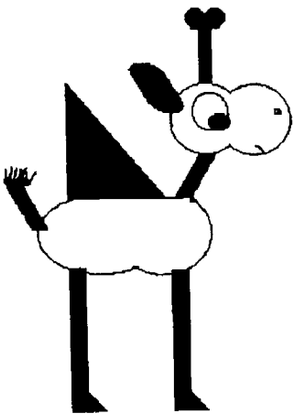
id	pn	ca_yrs1	vma_yrs1	pmd_letc	pmd_leth	pmd_sqr	pmd_ccl	qwording
25	0.96	10.75	10.67	0.50	0.50	0.50	0.33	0.00
26	1.00	10.67	8.33	0.50	0.50	0.67	0.50	0.00
27	1.00	13.08	11.33	0.50	0.83	1.00	1.00	0.00
28	1.00	9.58	8.67	0.33	0.17	0.17	0.33	0.00
29	1.00	14.17	10.83	0.67	0.50	1.00	0.17	0.00
30	1.00	14.25	12.33	0.67	0.17	1.00	0.33	0.00
31	1.00	15.42	16.67	0.50	0.33	1.00	0.17	0.00
32	1.00	14.00	12.33	0.83	0.83	0.83	0.33	0.00
33	1.00	15.58	13.08	0.50	0.50	1.00	0.17	0.00
34	1.00	14.17	17.00	0.33	0.17	1.00	0.17	0.00
35	1.00	15.50	17.00	0.83	0.50	1.00	0.17	0.00
36	1.00	14.92	17.00	0.83	0.83	1.00	0.33	0.00

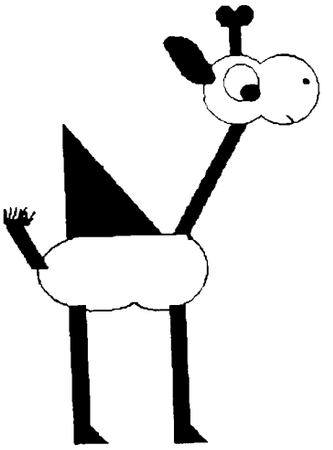
Experiment 5.1

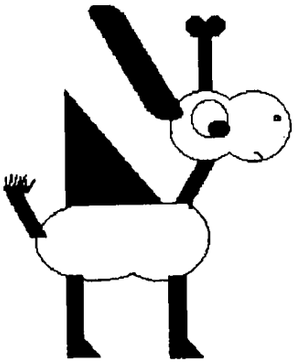
Appendix P: Prototype effect test Study stimuli

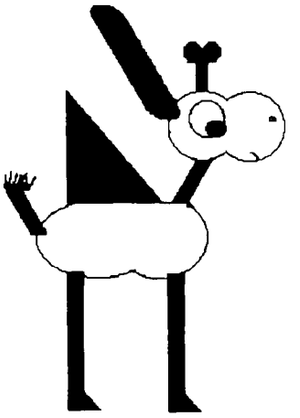
ALL MEDIUM FR ITEMS

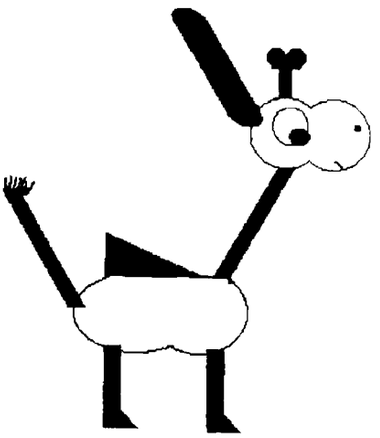
Hov category

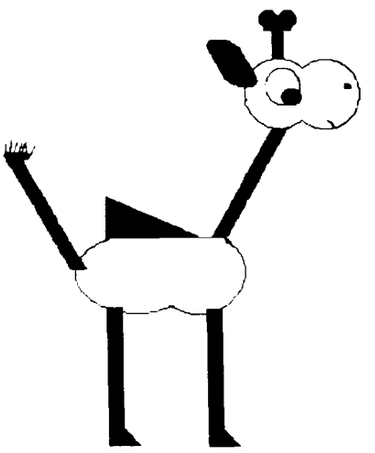


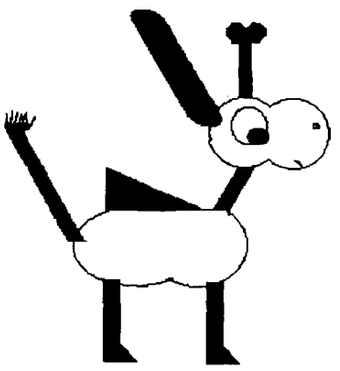


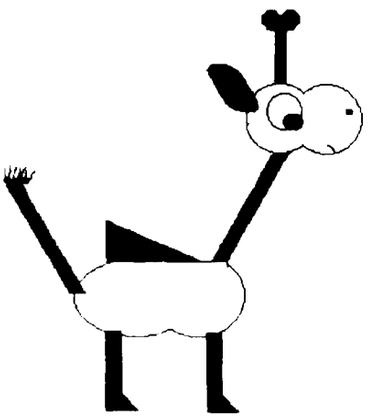




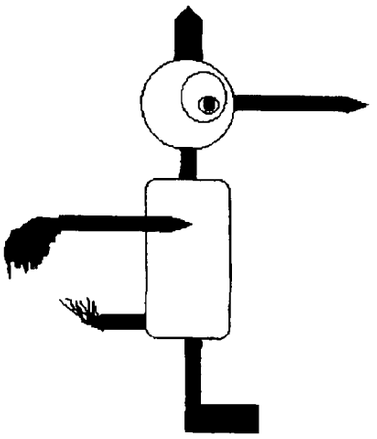


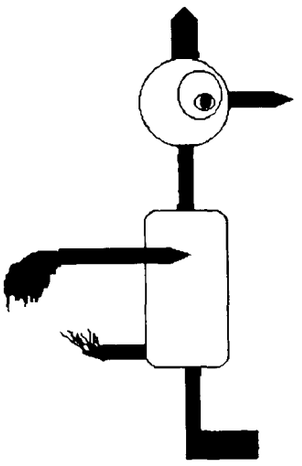


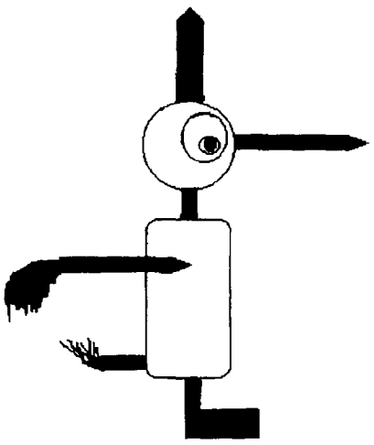


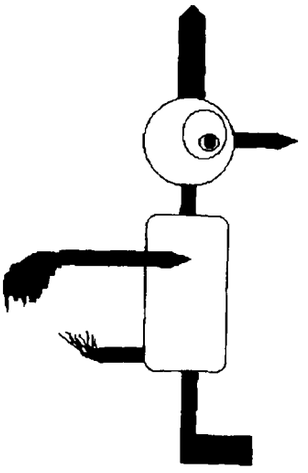


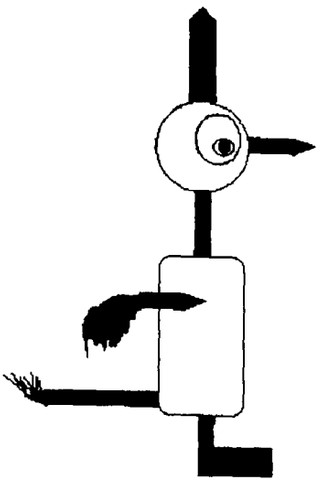
Raz category

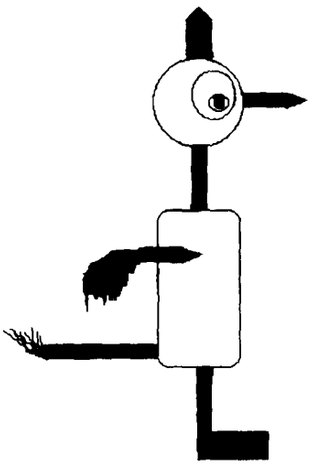


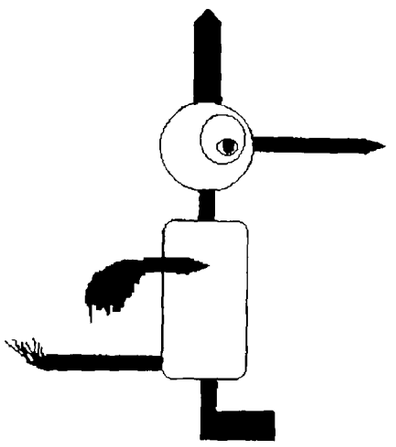


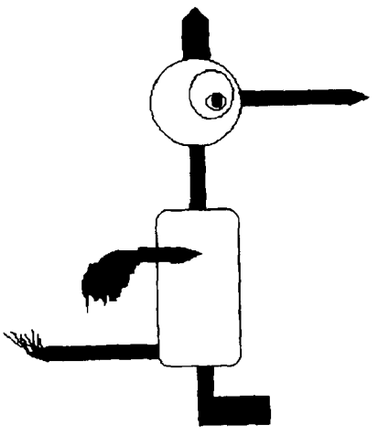




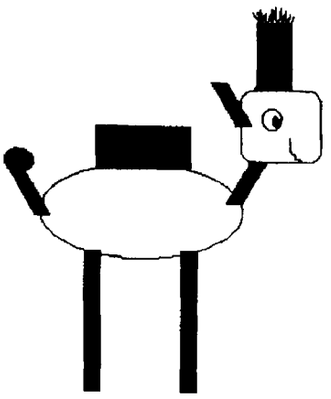


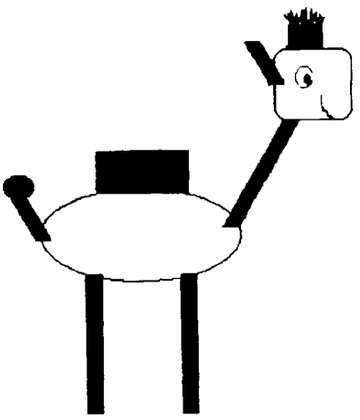


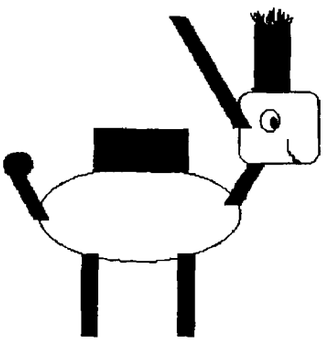


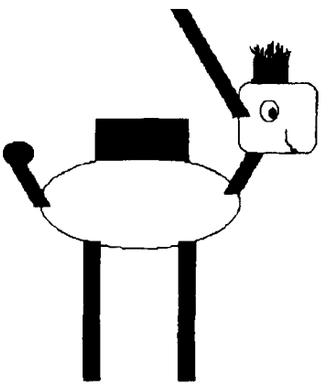


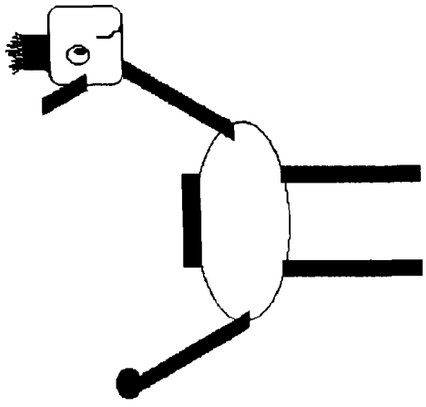
Mek category

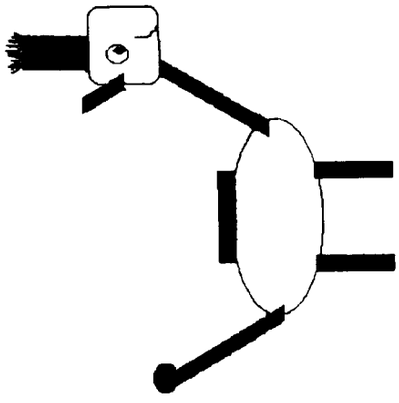


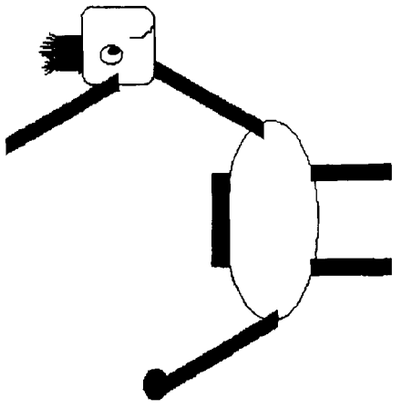


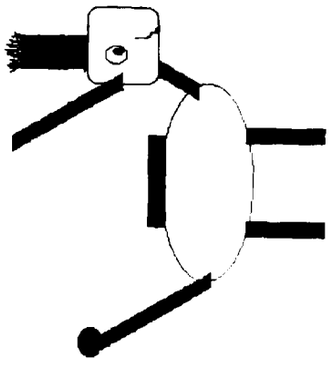




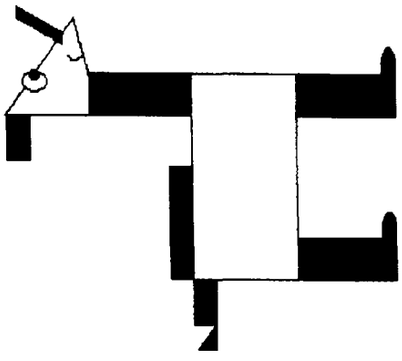


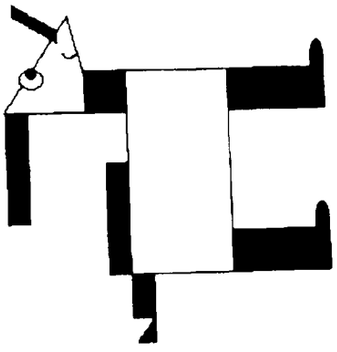


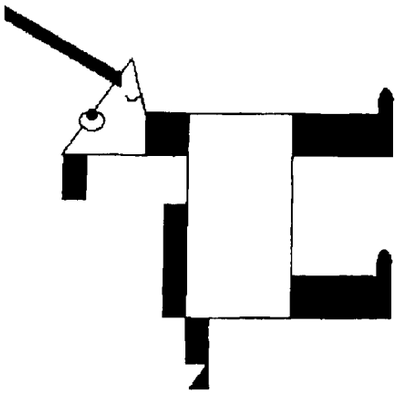


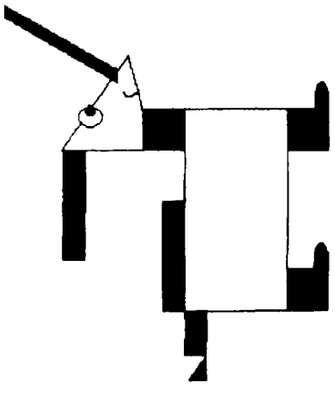


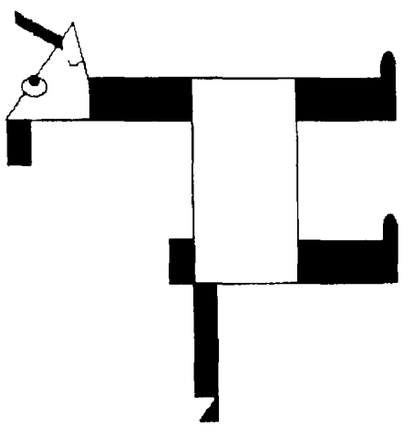
Gip category

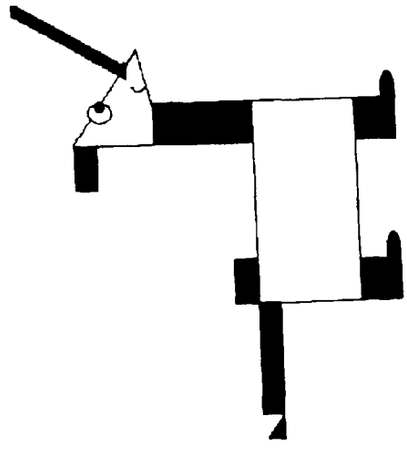


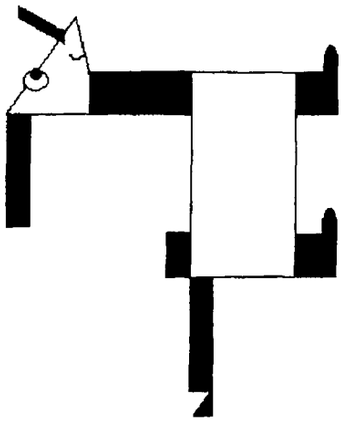


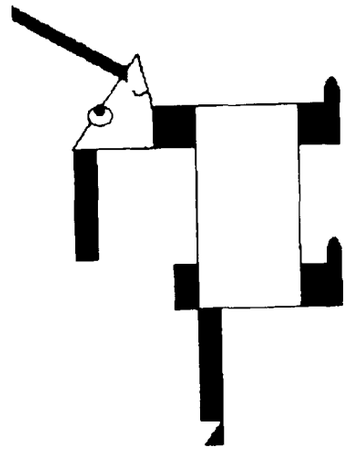




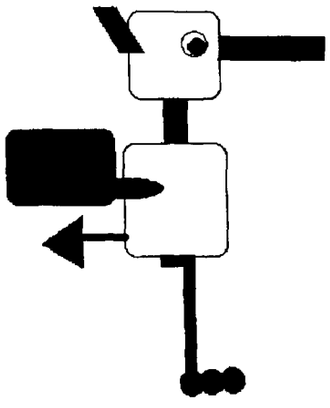


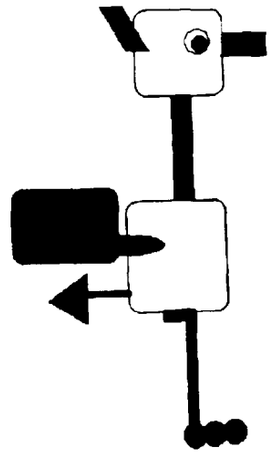


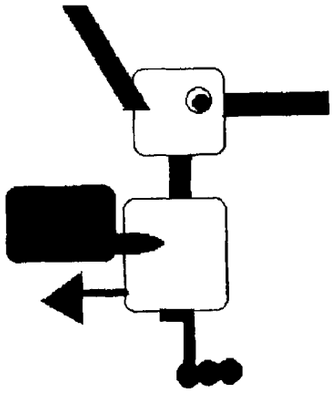


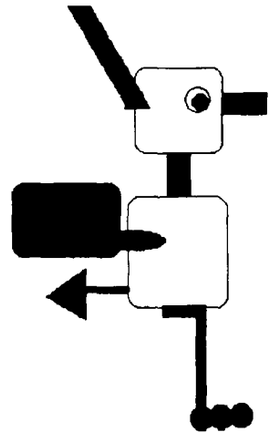


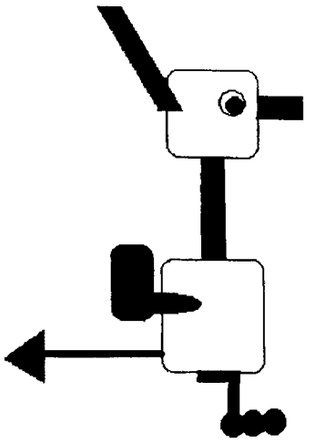
Dut category

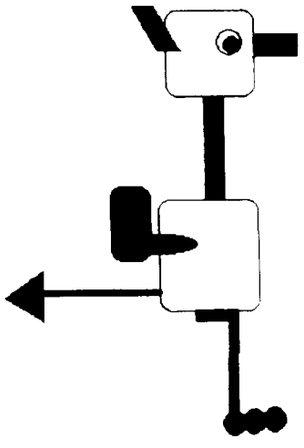


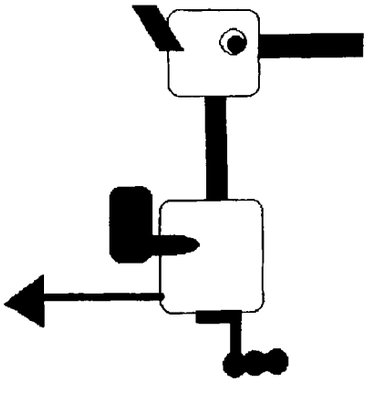


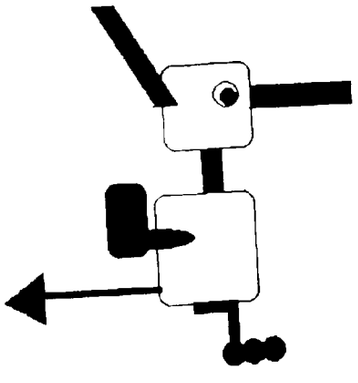




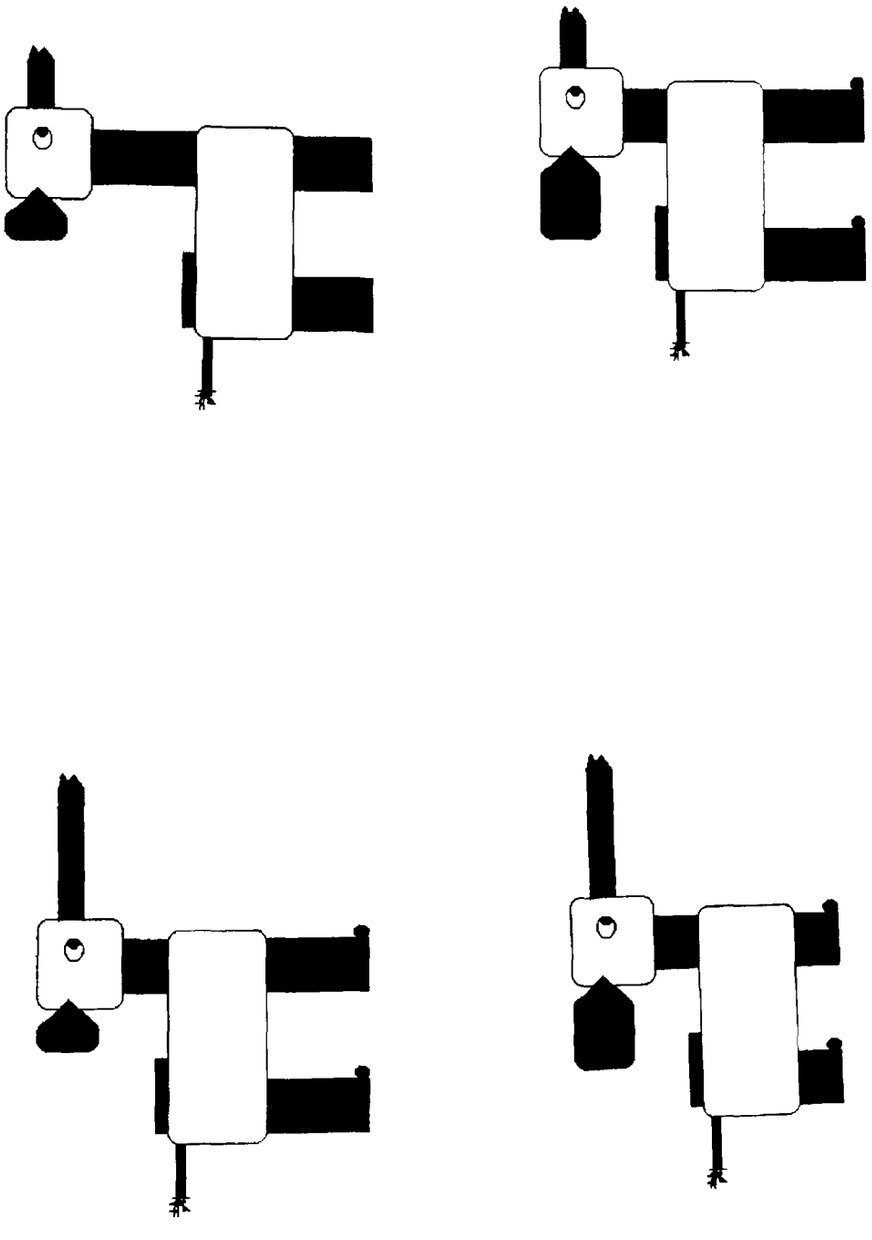


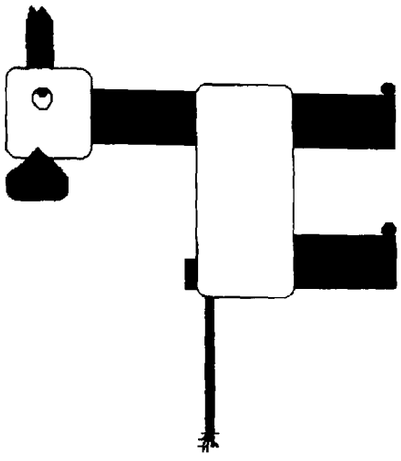


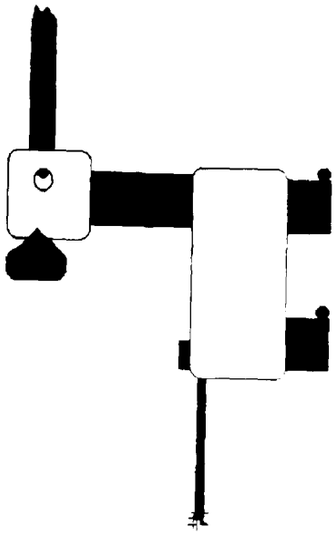


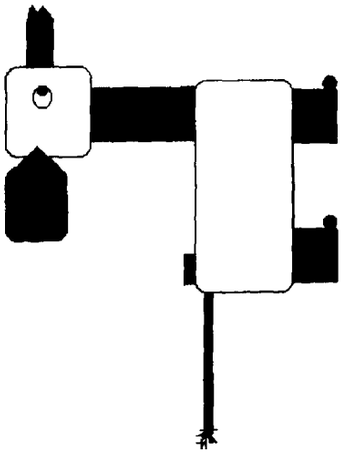


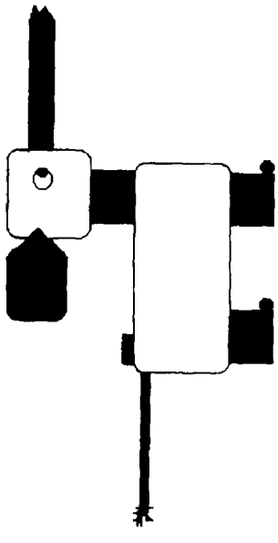
Bef category









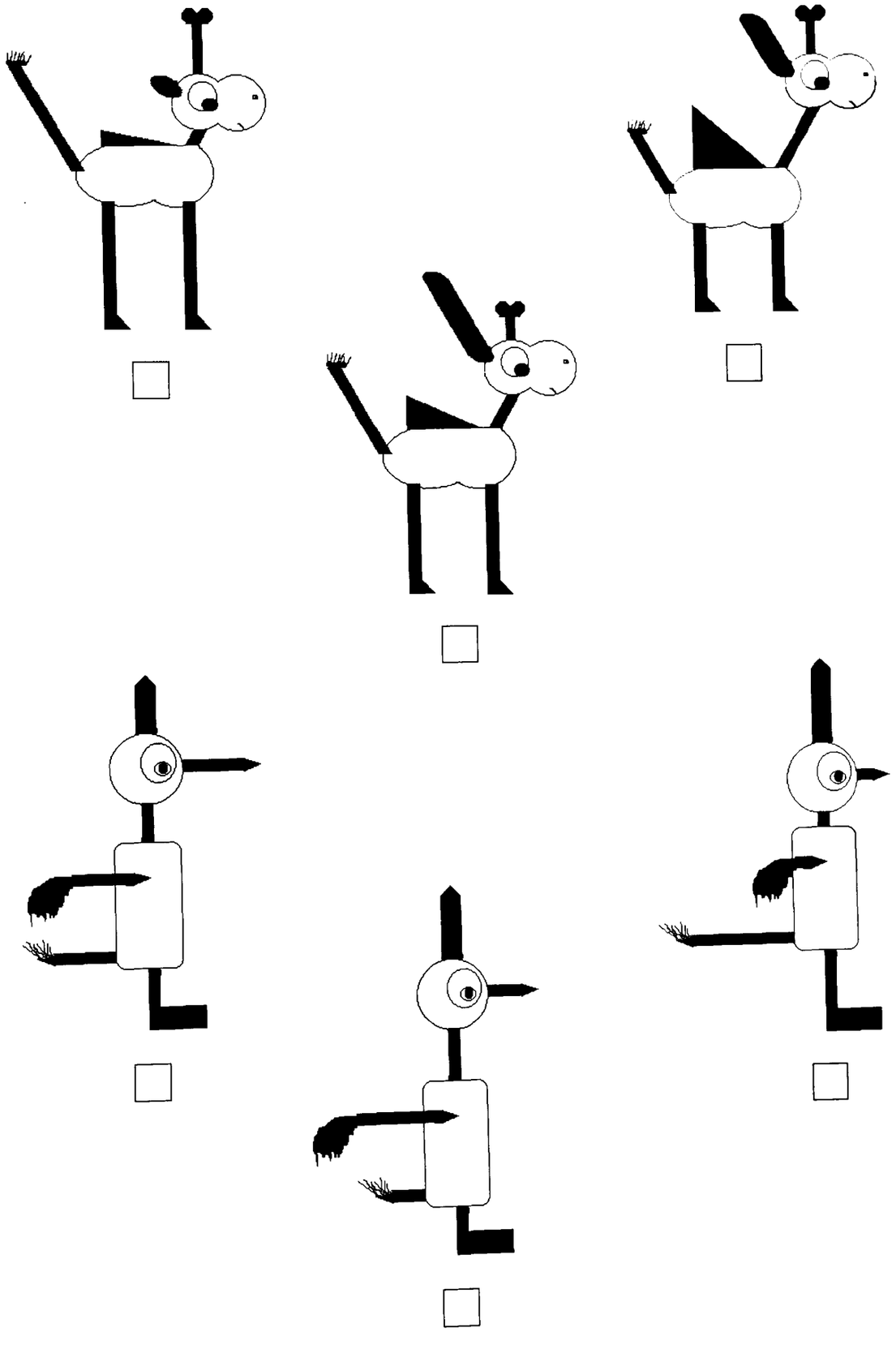


Appendix Q: Prototype effect test Test stimuli

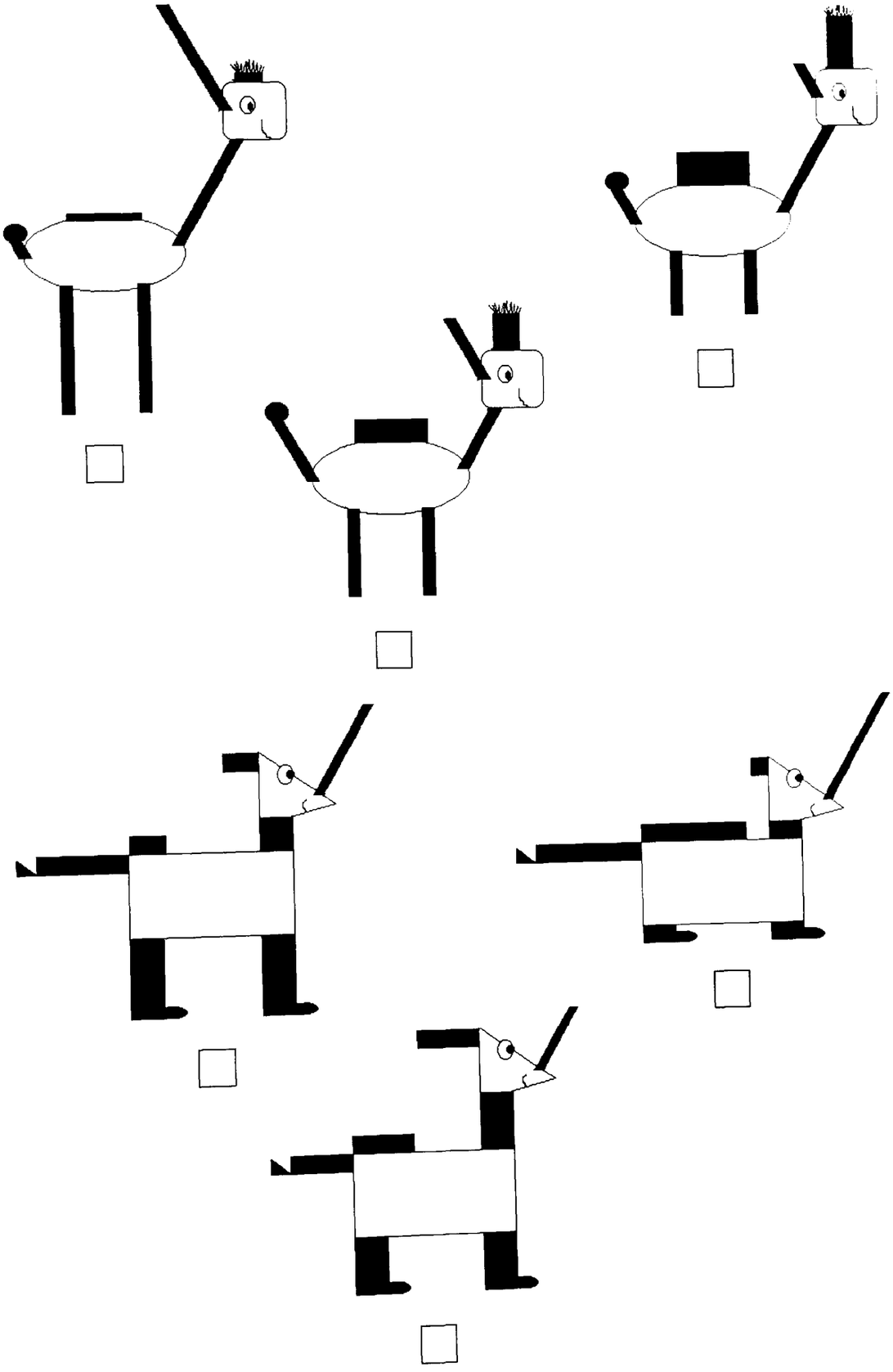
ALL FROM SET A

Top: Hov category: From left to right – low FR, medium FR, prototype

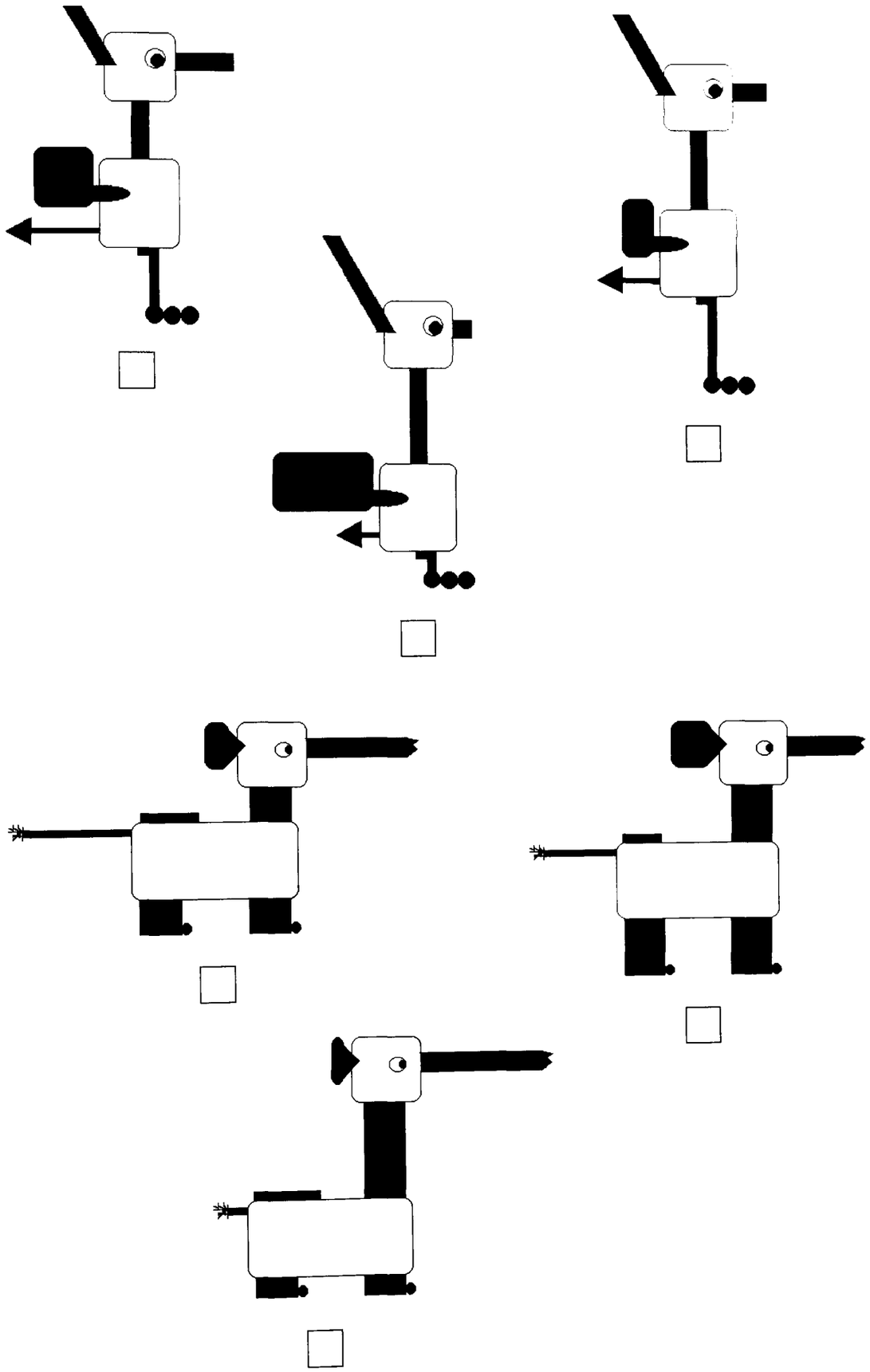
Bottom: Raz category: From left to right – prototype, medium FR, low FR



Top: Mek category: From left to right – low FR, prototype, medium FR
Bottom: Gip category: From left to right – medium FR, prototype, low FR



Top: Dut category: From left to right – prototype, low FR, medium FR
Bottom: Bef category: From left to right – medium FR, low FR, prototype

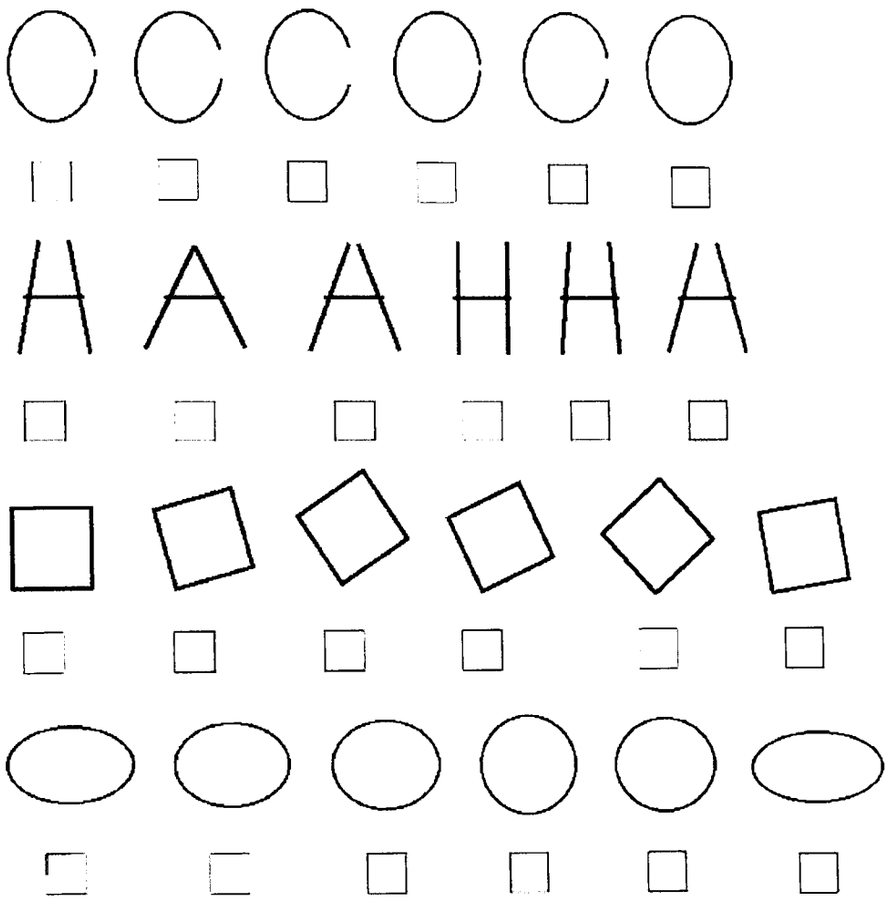


Experiment 5.2

Appendix R: Shapes test materials

ALL SET A

Arrays from top to bottom: letter C to letter O, letter H to letter A, square to diamond, and circle to oval



Appendix S: Numbers test materials

ALL SET A

English					
Mark	John	Mary	Ian	Sue	David
18	80	29	86	88	10

Maths					
Sarah	Mike	Kate	Anna	Stuart	Will
69	84	24	17	70	37

Science					
Rob	Sally	Alan	Flo	Vera	David
14	27	99	36	53	100

French					
Jenny	Jordan	Jerry	Alice	James	Claire
59	56	58	94	3	32