Introduction

Autism is a pervasive developmental disorder that features impaired social interaction and communication and a restricted repertoire of activities and interests (American Psychiatric Association Diagnostic and Statistical Manual 4th Edition, DSM IV-TR, 2000). When Kanner (1943) identified the behavioural pattern of autism in a group of children, he also observed that they were more interested and adept with objects than with people. Since then, it has generally been assumed that autism results from impaired social functioning.

Two important strands of research into autism in recent years emanated from the models of Leslie (1987) and Frith (1989). Leslie (1987) proposed that autism reflects the absence of processing that evolved to facilitate the understanding of mental states, which is referred to as theory of mind. Deficits have been found in autism groups, compared to appropriately matched control groups, on theory of mind tasks, while deficits were not found on 'control' tasks that tested the understanding of the underlying physical state aspects of the main tasks (Baron-Cohen, 2000). One type of theory of mind task tests the understanding of false belief, which is considered to be a good indicator of whether a theory of mind has been acquired because subjects have to attribute a mental state to someone else that is different from their own. There is a severe delay, relative to verbal mental age, in autism in passing false belief tasks (Happe, 1995).

Frith (1989) proposed that gestalt perception, where the perceived whole is more than the sum of the parts, is weak in autism. Subsequent research supports the theory that at least some gestalt perceptions, including a number of visual illusions, are weak in autism (Happe, 2000). Could weak gestalt perception lead to problems for theory of mind development? Michotte (1946) claimed that the launching effect, where one object is seen to push another object, is gestalt perception. Therefore, the launching effect may be weak in autism but why would this even impair theory of mind development, let alone lead to what seems like greater difficulty in understanding mental states than physical states?

As Leslie (1987) noted, a theory of mind involves understanding how mental states work within the general causal fabric; that is, mental states are represented as forcing or forced with respect to physical states. The normally rapid and reliable development of a theory of mind suggests that there is an innate basis for the idea of force and the launching effect potentially fills that role. If launching does fill the role, weak launching would not necessarily mean that the individual would not understand all interactions between all states. Rather, deficits should reflect how difficult it is to acquire the given understanding through associative learning alone. Behaviourism has demonstrated that associative learning should allow a basic understanding of physical interactions. However, mental state causality must be attributed across gaps in space and time to unseen states that can be false, pretending, deceiving etc. It would be extremely difficult to rapidly develop this ability with associative learning alone as a basis for causal reasoning.

Asperger syndrome is another pervasive developmental disorder with similar symptoms of social impairment. Family studies suggest that it has a strong genetic link to autism (Bailey, Phillips and Rutter, 1996). However, while subtle deficits are found in adolescents and adults with Asperger syndrome in identifying given mental states (Baron-Cohen, Jolliffe, Mortimore and Robertson, 1997), there is no evidence that children with Asperger syndrome have particular difficulty in passing false belief tasks (Ziatas, Durkin and Pratt, 1998). The evidence suggests though that gestalt perception is weak (Jolliffe and Baron-Cohen, 1997), so, if the launching effect is weak in autism, it should also be weak in Asperger syndrome. If this is the case, a challenge is to explain why weak launching leads to difficulty acquiring a theory of mind in autism but not in Asperger syndrome.

The first section of Chapter 1 outlines the key features of autism and Asperger syndrome. The second section summarises the theory of mind approach and discusses the strengths and limitations of various models, particularly Leslie (1987). The third section discusses perception in autism and argues that weak gestalt perception results from reduced input from the magno perceptual stream (Livingstone and Hubel, 1988). The fourth section describes the launching effect and proposes that reduced magno input could weaken launching. The research program tested autism, Asperger syndrome, neuro-typical and mild intellectual disability groups on their perception of illusion displays (Chapter

2), on various aspects of launching perception (Chapter 3) and on a temporal integration task that is (arguably) sensitive to magno stream functioning (Chapter 4).

Chapter 1: From Theory of Mind to the Launching Effect

1.1 Autism and Asperger Syndrome

Autism is a pervasive developmental disorder that features markedly impaired development of social interaction and verbal and nonverbal communication and a markedly restricted repertoire of activities and interests. Disturbance in at least one area must be apparent before 3 years of age for diagnosis (DSM IV-TR, 2000). Kanner (1943) noted that isolated abilities are also common; for example, children with autism can be surprisingly good at drawing, calculations or solving jigsaw puzzles and such abilities can extend to savant skills, at all levels of general functioning (Frith, 1989).

Asperger syndrome is another pervasive developmental disorder (others are Rett's disorder, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified, DSM IV-TR, 2000), which also features impaired social interaction and a restricted range of interests. However, unlike autism, there is no clinically significant delay or deviance in language acquisition (DSM IV-TR, 2000). Whereas autism occurs in about 5 in 10,000 (DSM IV-TR, 2000), Asperger syndrome is more prevalent, occurring in about 30 in 10,000. There are more males than females in both disorders, at a ratio of around 4:1 (Happe and Frith, 1996).

Bailey et al (1996) noted that evidence of neuropathology in people with autism suggests that the disorder is biologically based. They also noted that there is a much higher concordance of autistic irregularities in monozygotic twins than in dizygotic twins, which suggests that there is a genetic vulnerability for the disorder. Happe and Frith (1996) noted that there is a much higher than normal concordance of autism and Asperger syndrome within families, which suggests that the disorders have a common genetic vulnerability. However, it does not necessarily follow that the disorders always arise without any influence from environmental hazards like disease.

Kanner (1943) and Asperger (1944) independently described the behavioural pattern of some children as autistic (Frith, 1991). However, Kanner (1943) observed a lower functioning group and, perhaps as a result, produced a more rigorous set of criteria for diagnosis and a less optimistic prognosis. Kanner's (1943) criteria had greater influence in English-speaking countries and, as such, Asperger syndrome was not recognized in DSM until 1994.

Asperger syndrome has a lower rate of intellectual disability and symptoms tend to be milder than in autism (Happe and Frith, 1996) but it is not simply high functioning autism. Happe (1994) noted that some high functioning people experienced considerable language delay (they have autism), while others within the range of intellectual disability did not experience such a delay (they have Asperger syndrome). Throughout this thesis, 'autism' will be used to denote only those who experienced language delay.

Asperger syndrome is often not diagnosed until advanced ages because there is no language delay and it can be difficult to distinguish from disorders such as attention-deficit/hyperactivity disorder (DSM IV-TR, 2000). There has been particular interest in early development in autism. Given that, plus that DSM only recognised Asperger syndrome quite recently and that Asperger syndrome may not be diagnosed until relatively advanced ages, there has been much less research into Asperger syndrome than into autism. This effects several strands of research that will be described, including early theory of mind development, joint attention, pretend play, IQ profiles and perception. Two exceptions are the 'advanced' theory of mind (Happe, 1994a) and 'eye reading' (Baron-Cohen et al, 1997) strands, which are relatively new and test adolescents and adults.

Symptom presentation can vary markedly with developmental and chronological ages (DSM IV-TR, 2000). For example, Frith and Happe (1994a) suggested that lower functioning people are socially aloof, while higher functioning people tend to be socially active but odd. They also suggested that there are three levels of impaired verbal communication. The first is (virtual) muteness, while there is some language in the second but with very limited ability to engage in conversation. The third level features reasonably normal vocabulary and syntax. There is certainly much greater conversational ability at this level but with a limited understanding of pragmatic aspects, such as integrating words and gestures, humour and implied meanings. There is also limited understanding that conversation requires give and take (DSM IV-TR, 2000) and, as a result, it tends to be focussed on the restricted interests. People with autism who are high functioning progressed through the levels, whereas the third level is typical for children with Asperger syndrome (Frith and Happe, 1994a).

Other communication symptoms include unusual gestures and eye gaze and decreased use of facial expressions and decreased intonation (DSM IV-TR, 2000). Social symptoms include failure to develop friendships or interest in the activities of others, while symptoms reflecting the restricted interests and activities include obsessive interest in one activity, inflexible adherence to routine and preoccupation with parts of objects (DSM IV-TR, 2000).

Frith (1989) noted that autism groups produce an uneven, but characteristic, IQ profile. On a test such as WISC, verbal IQ is generally lower than performance IQ and often markedly so. The highest subtest score is almost invariably in Block Design, a performance subtest, while the lowest score is generally in Comprehension, a verbal subtest (Rumsey, 1992). However, Gilchrist, Green, Cox, Burton, Rutter and Le Couteur (2001) found that verbal IQ was higher than performance IQ in an Asperger group, Block Design was the highest score only among performance subtests and Comprehension was the lowest score only among verbal subtests. Klin, Volkmar, Sparrow, Cicchetti and Rourke (1995) found that autism and Asperger syndrome groups differed on 11 out of 22 neuropsychological tests, which the authors claimed reflected the differences in the relative strengths of verbal and performance IQ described above.

Therefore, while there are similarities in the profiles of autism and Asperger syndrome and the likelihood of a common genetic vulnerability, the difference in language acquisition may be indicating an important distinction. Accounting for this distinction may be as important as accounting for the common features. In this endeavour, it should not be assumed that findings with one disorder can be generalised to the other. Therefore, the current research tested separate autism and Asperger syndrome groups.

1.2 Theory of Mind in Autism

Leslie (1987) proposed that a module that evolved to facilitate theory of mind development is absent in autism and that this one abnormality accounts for the specific nature of the disorder. However, there are important features of autism, such as the savant skills, that are simply beyond the explanatory power of such an abnormality (Frith and Happe, 1994). Even though Leslie (1987) inspired a wave of informative research, its influence has diminished in recent years because it cannot fulfil its original promise to fully account for autism

The current thesis predicts that there is an autism-specific weakness in launching perception and, if the research supports this prediction, it would give reason to think that the proposal that a theory of mind module is absent in autism was incorrect. However, Leslie (1987) contains an important insight into autism that should not be lost. Rather, the approach should be to identify and address the flaws in the model.

1.2.1 The Metarepresentation Model of Autism

When Premack and Woodruff (1978) suggested that chimpanzees may have a basic understanding of mental states, the question that their suggestion raised was what would constitute definitive proof that a genuine theory of mind has been acquired. Pylyshyn (1978) suggested that the individual would have to demonstrate an ability to represent representational relationships, or to metarepresent. Dennett (1978) suggested that the individual must correctly assess a belief that is 'false'; that is, inconsistent with the current physical state and the individual's own belief.

Leslie (1987) fused these suggestions into a model of autism. He assumed that evolution provided a system of primary representation that has literal tracing between perception and stored information in order to represent the environment as accurately as possible. He noted that functional and pretend play, which emerge spontaneously before 24 months, have distinct processing needs. Functional play is reality-based, for example pushing a toy train while making a train-like sound, and could conceivably be represented through primary representation. Pretend play though is acting 'as if' an object is something else, as if a banana is a telephone or as if an empty cup is a full cup. As it is not acting in error, children must have double knowledge of the object's real state and its pretend state. However, if the pretend traces occurred within the primary system, it would lead to ideas such as 'this object (a banana) is a telephone'. Leslie (1987) proposed instead that the pretend traces are quarantined, or decoupled, from the primary system.

Leslie (1987) noted that young children can engage in pretend play in groups, so they must also be able to represent others as pretending in order to trigger decoupling; that is, they can metarepresent. Leslie (1987) suggested that pretend play could be represented through a structure, **agent**- information relation - *anchor*- "expression", or M-representation. The *anchor* is the literal representation in primary representation (this object is a banana) and the inverted commas indicate the decoupled trace (this object is a telephone). If a child sees his mother acting as if a banana is a telephone and detects some similarity, between the shapes of the banana and telephone receivers in this case, he is not confused by her actions. Instead, he understands her behaviour because the event has been represented as **mother** pretend *banana* "it is a telephone".

Leslie (1987) also claimed that the fact that one can anticipate that another person has a false belief (i.e., there is a discernable reason for their error), while maintaining one's own belief about the true state, suggests that the false content must be decoupled. He suggested that a module that evolved specifically to facilitate the development of theory of mind generates M-representation. As there was evidence that children with autism do not engage in pretend play (Sigman and Ungerer, 1984), Baron-Cohen, Leslie and Frith (1985, 1986) predicted that there would also be deficits in autism groups on theory of mind tasks but not on tasks that require primary representation capacities only.

Infants at around 12 months begin to use imperative and declarative gestures. An example of an imperative gesture is pointing at an object to request that someone brings the object, while an example of a declarative gesture is pointing at an object to initiate joint attention to the object with another person. Leslie and Happe (1989) claimed that the meaning of imperative gestures could be acquired through associative learning, as they are rewarded. In contrast, declarative gestures are ostensive communication, in that the gesture grabs and directs attention for the purpose of communication. Given that the meaning of declarative gestures depends on understanding their communicative intent, they argued that they require an ability to metarepresent. Therefore, if autism reflects an inability to metarepresent, there should be deficits in autism for declarative gestures but not for imperative gestures.

Given that the Leslie (1987) model accounts for joint attention gestures, it had the potential to link the three primary impairments to a single common cause, an inability to metarepresent. At that time, it was assumed that the primary impairments described the specific nature of autism. Difficulty in acquiring a theory of mind would severely constrain engagement in reciprocal social relations, as well as verbal communication, such as using propositional attitudes and following conversational intent, and nonverbal communication, like joint attention gestures. The constraint on imagination, seen with pretend play, would restrict the range of interests and activities.

Frith, Morton and Leslie (1991) suggested that the actual abnormality might be the lack of a sub-mechanism of the theory of mind module that decouples second order representations, or representations of representations. However, Leslie and Roth (1993) later argued that only an inability to metarepresent, as originally defined by Pylyshyn (1978), accounts for the results of research. The evidence that is taken as being support for the model is firstly described, to give a basis for the reason that Leslie and Roth (1993) rejected the second order model, before the implications of the strong version are discussed.

1.2.2 Support for the Metarepresentation Model

As noted, Dennett (1978) suggested that passing false belief tasks (FBT) would indicate that theory of mind has been acquired. Wimmer and Perner (1983) found that neuro-typical children do not pass FBT until around 4 years of age. In one FBT, Sally places a chocolate in a basket and leaves the room; Ann then moves the chocolate to a box and leaves before Sally re-enters. Subjects are asked either “Where does Sally believe the chocolate is?” or “Where will Sally look for the chocolate?” (pass rates are similar with either question). Actors or dolls play the scenario, while the experimenter uses comments and questions to ensure that the subjects are following the storyline.

Where Sally-Ann uses a misleading location to create a false belief scenario, ‘Smarties’ uses a misleading appearance. Subjects are first asked what is in a Smarties box before it is opened and they answer "Smarties". The experimenter then shows them that there are pencils in the box. The subjects are asked what the next person who comes in will expect to be in the box, which tests their ability to attribute a false belief.

Baron-Cohen et al (1985) tested neuro-typical, Down's syndrome and autism groups on the Sally-Ann task. The neuro-typical group with a mean age of 4 years 5 months had an 85% pass rate, the Down's syndrome group with mean age of 10 years 11 months and mean verbal mental age (vMA) of 2 years 11 months had an 86% pass rate, the autism group with mean age of 11 years 11 months and mean vMA of 5 years 5 months had only a 20% pass rate. Perner, Frith, Leslie and Leekham (1989) found that only 4 out of 26 in autism group with mean age of 13.6 years and mean vMA of 6.3 years passed the Smarties task, while 11 out of 12 passed in a language disorder group with mean age of 8.8 years and mean vMA of 6.9 years. As vMA is usually lower than performance mental age (pMA) in autism, control groups are matched via vMA to test whether the deficits on the theory of mind tasks in autism groups are simply reflecting the delay in language acquisition.

When subjects sequenced pictures to make stories from mechanical, behavioural and intentional categories in Baron-Cohen et al (1986), the only deficit in the autism group was on the intentional stories. Since then, research has used control tasks to test if deficits on theory of mind tasks were due to non-mental state aspects. For example, when Baron-Cohen and Goodhart (1994) found a deficit in an autism group with a 'seeing leads to knowing' task, they applied a control task that tested the ability to represent the visual perspective of others. In that study and others, autism groups performed as well as control groups on the control tasks, while almost always producing deficits on theory of mind tasks (Happe and Frith, 1995). Also, high functioning people with autism have difficulty following conversational intent. They also have limited use of propositional attitudes but use terms expressing emotion or physical causality more readily (Tager-Flusberg, 1993). Following Leslie (1987), learning the normal use of propositional attitudes depends on M-representation, whereas the use of emotional terms could be acquired without that structure.

Happe (1995) analysed performance on both FBTs over several studies. Neuro-typical children had 50% probability of passing both at 4 years 2 months and 80% at 4 years 6 months. No autism subject passed both with vMA below 5 years 6 months, 50% passed at vMA of 9 years 2 months, while all passed with vMA of 11 years 7 months. A 'meta-analysis' by Yirmiya, Erel, Shaked and Solomonica-Levi (1998) found deficits in other developmental disorders but none as severe as in autism. Therefore, there is a delay in autism in reliably passing FBT, the severity of which specific to autism. If FBT is a conclusive test of theory of mind acquisition, many people with autism will not truly understand mental states until a successful intervention is discovered.

People with congenital sensory impairments have difficulty in passing FBT. Peterson, Peterson and Webb (2000) and Peterson and Siegal (1998) found that people with congenital visual and auditory impairments do not reliably pass FBT until around 12 years of age, while they pass control tasks at a much earlier age.

This is similar to the pattern in autism. However, while there is interest in any common elements in the performances of autism groups and sensory impairment groups, there are almost certainly important differences. For example, Peterson and Siegal (1998) found that most of the people in the auditory group who failed FBT did not have a conversational partner in their early years who could sign propositional attitude sentences.

One challenge to Leslie's (1987) model is that autism persists after FBT is reliably passed, even though it was designed to conclusively test acquisition. Baron-Cohen (1989a) found that FBT passers failed a 'belief about a belief', theory of mind task, which led Frith et al (1991) to suggest that they had solved FBT without actually acquiring a theory of mind. However, Tager-Flusberg and Sullivan (1994) found that most FBT passers solved a belief about a belief task when the general information processing demands in the original task were reduced.

The strong correlation between FBT performance and vMA in autism (Happe, 1995) does suggest that those who reliably pass FBT have acquired a theory of mind, at least of sorts. Tager-Flusberg (2000) suggested that it is acquired through a language-based strategy; that is, theory of mind is so strongly built into language that sufficient language skill compensates for the impairment to whatever non-linguistic precursor(s) causes the delay with FBT. This method though is slow and inefficient and leads to ongoing social difficulties and Happe (1994a) found that adults with autism had difficulty in inferring contextually appropriate mental states in a 'strange stories' task. Ongoing difficulty with theory of mind is also consistent with the reports of high functioning people with autism (eg Grandin, 1992), who report continuing difficulty in working out how others think.

Following Leslie (1987), there should be deficits in autism with declarative gestures but not with imperative gestures and with pretend play but not functional play. Baron-Cohen (1989) found that an autism group had severe deficits in using and understanding declarative pointing but not in using or understanding imperative pointing. Other research has found that the severe deficits found by Baron-Cohen (1989) generalise to other declarative gestures (Sigman, 1998). Research has also found that children with autism rarely initiate pretend play (Jarrold, Boucher and Smith, 1993).

Milder deficits have been found in functional play and imperative gestures (Sigman, 1998). The deficits in the number of imperative and functional play acts or in the time engaged in functional play though are slight and it would have been surprising if these behaviours had exactly matched Leslie's (1987) categories. Children with autism can be taught to engage in pretend play (Lewis and Boucher, 1988) and declarative gestures (Mundy and Crowson, 1997), albeit very slowly, but they may have been simply imitating their teachers, rather than demonstrating an ability to metarepresent. Therefore, the pattern found across the theory of mind, language, pretend play and joint attention strands is broadly consistent with Leslie (1987). Also, the severe deficits on false belief tasks and pretend play are consistent with the proposal that at least children with autism cannot generate M-representations.

However, the next section summarises a finding that presented a problem for the original model.

1.2.3 'False' Photographs

The strong correlations between FBT performance and vMA show that neither 3-year-olds nor children with autism are simply guessing when they answer incorrectly. However, it is likely that they have different reasons for the incorrect answer and accounting for this difference should help to understand autism. The 'false photograph' task (FPT) is considered the control task for the misleading location FBT. In FPT, Sally takes a snapshot of the basket when it contains the chocolate and lays it face down on a table before Ann moves the chocolate to the box. Subjects are asked where the chocolate is in the photograph. Zaitchik (1990) found that most 3-year-olds, but not 4-year-olds, failed both FBT and FPT, while Leslie and Thaiss (1992) found that an autism group, who performed at near ceiling on FPT, still did poorly on FBT.

Leslie and Roth (1993) suggested that 3-year-olds fail both FBT and FPT because they do not inhibit the pre-potent act, Ann moving the chocolate. In a 'partial true belief' task, Ann does not move the chocolate but puts another in the box, so assessing Sally's belief still requires inhibition of the pre-potent act. An autism group improved from 31% pass on FBT to 50% on partial true belief in Leslie and Frith (1988), while 3-year-olds improved only minimally (26% to 28%) in Roth and Leslie (1998). In a 'search' task, Ann goes to the kitchen and gets a chocolate from a cupboard. When Sally sees Ann with the chocolate, she goes to the kitchen but, after looking in a tin and finding none, says, "Ann must have taken the last one". Subjects are asked where Sally believed the chocolates were when she entered the kitchen. If the performance on FBT is due to difficulty in inhibiting pre-potent information, subjects should improve in the search task, where the false belief is indicated by pre-potent information. Roth and Leslie (1998) found that a 3-year-old group improved markedly from FBT to search (10% to 65%), while improvement was less pronounced in an autism group (35% to 50%).

On the surface, this strand seems to support Leslie (1987). Inhibiting pre-potent information is considered to be an executive function (Russell, 1997) and autism groups continue to perform poorly on FBT, despite demonstrating that domain-general ability in FPT. Moreover, 3-year-olds showed greater improvement in attributing false belief when the executive function aspect was removed in the search task. This suggests that 3-year olds do have a theory of mind but that the ability is not ready to be demonstrated with FBT because of domain-general demands in the FBT structures. It followed from Leslie (1987) that understanding pretend play demonstrates an ability to metarepresent, so 3-year-olds should fail FBT due to domain-general aspects.

However, Perner (1993) pointed out that subjects cannot have a primary representation of the photograph in FPT without seeing it, while Ann moving the chocolate meant that subjects cannot have a primary representation of chocolate being in the basket. As such, passing FPT requires a second order representation of the basket at the time the photograph was taken. Therefore, it is difficult to reconcile the performance of autism groups on FPT with Frith et al's (1991) proposal that their performance on FBT reflects an inability to decouple second order representations.

1.2.4 Mental State Causality

Leslie and Roth (1993) rejected the second order model on the basis of the FPT results and argued that autism can only be explained in terms of the full M-representation structure; that is, in terms of agency representation. The difficulty in acquiring theory of mind in autism is not due to an inability to represent unseen representations per se, because autism groups have demonstrated that they can do this with photographs (the result of Leslie and Thaiss, 1992, has been replicated on several occasions). Pylyshyn (1978) claimed that a theory of mind requires an ability to 'represent the representational relationship itself'. This requires an understanding of how mental states work, that is, how they cause, or are caused by, physical states. As Leslie (1987) recognised, mental states become embedded within the general causal fabric, so some level of causal attribution is a necessary precursor to the ability to metarepresent and, following the reasoning of Leslie and Happe (1989), it must be in place by 9 to 12 months for declarative gestures to emerge.

Mental state causality cannot be assumed away as an issue simply because causal attribution is not specific to mental states. Hume

(1739) pointed out that necessary connections, or forces, are not detectable, either externally or internally. For example, he argued that we do not directly experience the causal relations between our mental states and our action states, only priority (one event always precedes before the other event), contiguity (the events are proximal in time and space) and constant conjunction (the events occur together reliably). Following Hume's (1739) argument, a child must attribute causal force to unperceived states of others across gaps in space and time, without even experiencing their own mental state force.

Recognizing the need to address agency in greater detail, Leslie (1994) proposed that there are three, hierarchically ordered, agency modules: 'theory of body' represents agents and objects in a mechanical sense in terms of causality and goal direction through 'force representation', 'theory of mind system 1' represents agents and actions and the third module is the theory of mind module that generates M-representation. Hume (1739) suggested that associative learning is the basis of the idea of force but the rapid and reliable development of theory of mind gives a powerful reason to reject that proposal. Leslie (1994) suggested instead that input from launching events triggers force representation.

Michotte (1946) showed that with events where one moving object (A) collides with a second, stationary, object (B) and displaces it, the perception is of A pushing B. Therefore, we can see at least one causal relation in the launching effect. Given Hume's (1739) argument that forces cannot be detected, how is this perception possible? Michotte's (1946) theory (and supporting evidence) will be detailed in Section 1.4 but a brief summary is given now. Michotte (1946) claimed that we do not see two independent movements onto which causality must be imposed. Instead, the event structure creates an anomaly at the point of impact between the gestalt laws of proximity (object A before impact is A after impact) and continuity (A's movement continues into B's movement; i.e., A before impact is B after impact). The resolution is a gestalt perception where A's movement extends, or 'ampliates', into B's movement (Figure 1.1b).

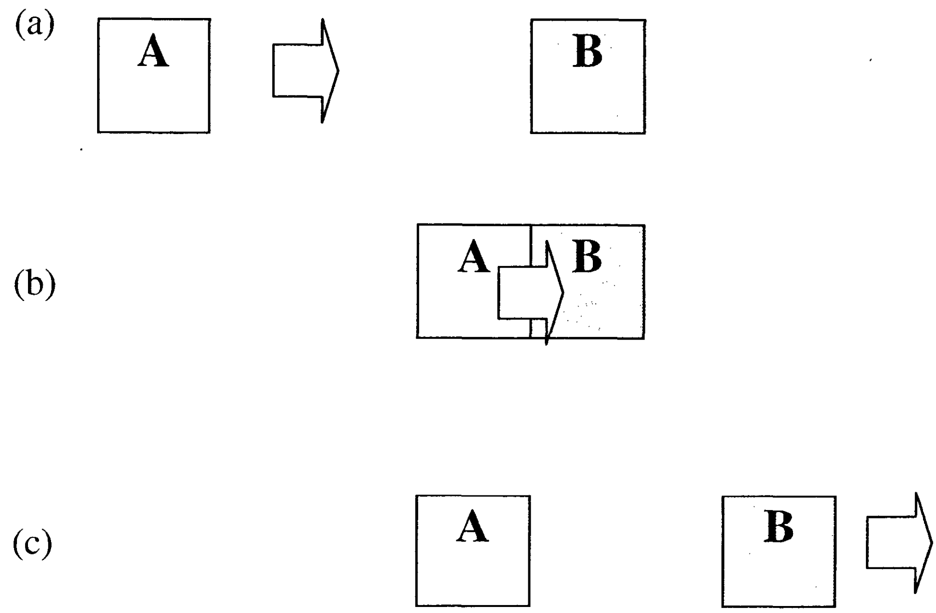

Figure 1.1: The launching effect. Michotte (1946) claimed that the movement of A is extended, or 'ampliated', into B at the 'point of impact' (b).

Frith (1989) proposed that gestalt perception is weak in autism. Combining that with Michotte (1946) suggests that the launching effect might be weak in autism (this will be argued over Sections 1.3 and 1.4). Marr (1982) claimed that a system of representation should make important information explicit and weak launching would mean that the causal relation does not stand out, so the system is less able to make this information explicit and the idea of force is delayed.

Baron-Cohen (2000a) presented a different model of causal attribution to Leslie (1994). Leslie and Keeble (1987) showed that 6 month olds are sensitive to differences between events where adults do and do not perceive launching. Research shows that 6-month olds are sensitive to other aspects of physical laws, such as one solid object should not violate the space of another solid object (Baillargeon, Kotovsky and Needham, 1995). Baron-Cohen (2000a) argued that sensitivity to agents though does not appear until around 12 months, which suggests that there are two distinct domains of causal attribution, 'folk physics', applied to interaction between objects only, and 'folk psychology', applied to interactions between agents and objects.

Michotte (1946, experiment 11) found that the launching effect has a 'radius of action' within which B's movement continues to be connected to A. Michotte (1951) demonstrated the radius of action by introducing an intermediate object (I) between A and B. If I is sufficiently close to B, A's movement is seen as the cause of B's movement, with I's movement being only a passive conveyor of A's extended movement. That is, only one launch can be perceived relations between objects that are beyond the limited range of the tool effect and allow such events to also be represented in terms of agency. The extension of agency across space and time would then provide a basis for the leap in imagination to represent the mind as causal. Therefore, abnormal perception in autism could weaken a necessary precursor for both the Leslie (1994, the ability to represent force) and Baron-Cohen (2000a, the ability to represent an agent as a cause across a gap in space and time) models of causal attribution.

The lack of an innate basis for the assumption of force would not mean that an individual would be unable to reason causally. Rather, deficits should reflect how difficult it is to develop behaviours or acquire language on the basis of associative learning alone. It will be argued in the next section that the results from the various strands of the theory of mind research are consistent with what might be expected from weak launching.

1.2.5 Reassessing the Theory of Mind Research

As noted, Kanner (1943) observed that children with autism are more interested and adept with objects than other people and, on that basis, a general assumption developed that the central impairment is social. However, other animals can acquire skill and interest with objects and this learning is adequately explained by associative learning. Therefore, Kanner (1943) was comparing intact capacities that may be acquirable through association against severe impairments to capacities that depend on causal reasoning.

Have the major strands of research into theory of mind in autism repeated this comparison?

a) pretend play and joint attention

Williams, Costall and Reddy (1999) suggested that the development of object use in autism might not follow the normal path. They noted that neuro-typical children near the end of the first year begin to combine objects in a way that reflects functional properties and, soon after, begin to use objects in conventional ways; for example, use a hair brush to brush their hair. DSM IV-TR (2000) notes that people with autism may be attached to a single object or a single movement such as spinning, there is a preoccupation with parts, rather than the whole object, and also stereotyped and ritualistic ordering of objects. If this object use in autism is present early in life, it could inhibit development of functional object use.

As noted, research had found only slight deficits in functional play in children with autism when the number of acts and time engaged are used as measures. Williams, Reddy and Costall (2001) compared children with autism to neuro-typical children and children with Down syndrome and found no significant deficits with those measures. However, qualitative analysis showed that the functional play of the autism group was less elaborate, integrated or varied than either control group. In fact, the autism group spent almost all their play time engaged in simple acts with single objects, such as pushing a toy car, which suggests that unusual object use does inhibit development of functional object use. Therefore, Williams et al (2001) demonstrated that it is unlikely that children with autism follow the normal developmental path in functional object use.

It is likely that children with autism can decouple second order representations (Perner, 1993) and they can be taught by modelling to engage in pretend play (Jarrold et al, 1993). However, there is nothing clever in noticing the similarity between the shapes of a banana and telephone receivers, by itself. What makes this pretence clever, and rewarding, is the understanding of the functional use of a telephone. It is possible that the simple acts of object use demonstrated by children with autism could arise through associative learning alone, whereas the rapid, untaught, development of functional object use in neuro-typical children suggests something more drives their development. Therefore, quantitative comparison of pretend play and functional play in autism, without distinguishing simple and complex play acts, had only compared capacities that require metarperesentation, at least according to Leslie (1987) against capacities that could be acquired through associative learning alone.

Leslie and Happe (1989) pointed out that imperative gestures could be acquired by associative learning, while declarative gestures require an ability to metarepresent. Following their reasoning, the joint attention research has this problem.

b) language and FBT

The feature that distinguishes autism from Asperger syndrome is a severe delay in language acquisition. It is possible that the delay is due to the lack of a concept of communicative intent, which, in turn, could be due to an inability to metarepresent. It was noted earlier that people with autism are more inclined to use physical causality terms and emotional terms than propositional attitudes compared to control subjects (Tager-Flusberg, 1993), which has been taken as support for there being a specific theory of mind impairment. However, if the severe delay in language acquisition results from inability to metarepresent, then the residual pattern must be reflecting compensatory processes.

Emotion words may be relatively easy to learn through one's own feelings without a strong idea of emotions as causal and Wellman and Lagattuta (2000) noted that people with autism rarely offer explanations for emotions. Similarly, basic physical state terms, like 'push' or 'hit', should be relatively easy to learn, as objects that are causes and the objects that are effects and their motions are perceivable. In contrast, it would be extremely difficult to learn mental state terms through association alone because mental states are not perceived.

All members of the autism group in Leslie and Frith (1988) who twice demonstrated an understanding that Sally did not know that the chocolate was in the box, passed the partial belief task. In the partial belief task, the chocolate was not moved but another chocolate was put in the box. Half of those subjects went on to fail

FBT (see Roth and Leslie, 1998). What made FBT (misleading location) more difficult than the partial belief tasks for those people? To solve the task, the subject must reason something like, "Sally should look in the box if she wants the chocolate but she will look in the basket because she does not know the chocolate is in the box". The subjects had to compare Sally's knowledge state against her desire state in FBT, whereas in the partial belief task, applying an awareness of Sally's knowledge state alone leads to the solution. Therefore, it would appear that learning how to compare underlying states is the last step in the compensatory process before people with autism can reliably pass the misleading location FBT.

Talmy (1988) argued that force representation underlies agency language and not only effects direct causal terms but, because it represents force and resistance, it provides a basis to compare the strength of forces. Therefore, a person may have learnt direct causal terms without knowing how to apply them appropriately. If Talmy (1988) is correct, this difficulty could result from weak launching. Alternatively, it could also be that force representation is present in autism but the children struggle to apply it to mental states because the leap in imagination requires help from specific theory of mind processing, as Leslie (1994) suggested. Does the comparison between the theory of mind and control tasks resolve these possibilities?

FPT does not because it does not present a need to compare forces. One does not have to understand electricity or reason causally to learn that if you press a certain switch, a certain light will come on. Similarly, one does not have to understand how a camera works or reason causally to learn the relationship between the camera, the given physical state and the consequent photograph. Section 1.2.3 showed that FPT is a control task for second order representation but it does not control the level of causal reasoning that is required to pass FBT.

In Baron-Cohen et al (1986), the cards were sequenced in the following order to make one of the mechanical stories: a man is standing over a rock on top of a hill, he kicks the rock, the rock is halfway down the hill, the rock is at the bottom of the hill. The remaining mechanical stories were similar; that is, they were all launching-type stories. As the autism group had little difficulty with these stories, should not this be considered reliable evidence of a strong launching effect? The significance of the launching effect is that it provides a perceivable causal relation, which is not tested by sequencing cards. A person who did not perceive launching would still see the see the objects and the motions. As Perner (1993) noted, the mechanical stories could all have been readily solved using spatial relations as a guide, whereas solving the intentional stories above chance depended on attributing a false belief.

c. 'folk physics'

Baron-Cohen (2000a) suggested that people with autism and Asperger syndrome might have superior folk physics, which he defined as understanding interactions between objects, and impaired folk psychology, which arises from the ability to understand agents and actions. Baron-Cohen, Wheelwright, Spong, reason causally to learn the relationship between the camera, the given physical state and the consequent photograph. Section 1.2.3 showed that FPT is a control task for second order representation but it does not control the level of causal reasoning that is required to pass FBT.

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Baron-Cohen (2000a) suggested that people with autism and Asperger syndrome might have superior folk physics, which he defined as understanding interactions between objects, and impaired folk psychology, which arises from the ability to understand agents and actions. Baron-Cohen, Wheelwright, Spong, Scahill and Lawson (2001) tested an Asperger syndrome group and a neuro-typical group, both with mean age near 13 years, on their 'intuitive' reasoning in physics. The Asperger syndrome group, with mean IQ just below 100, averaged 16 correct answers out of 20 multiple-choice questions, while the neuro-typical group averaged 10 correct answers. In contrast, the Asperger syndrome group performed significantly worse than an 8 to10 year old neuro-typical group on a theory of mind task.

In a case study, Baron-Cohen, Wheelwright, Stone and Rutherford (1999) found that a mathematician, a physicist and a computer scientist with Asperger syndrome performed poorly on a theory of mind task, while performing at near ceiling on a folk physics test. Baron-Cohen's (2000a) logic can be seen in this study. There are three very high achievers, their ability at physics shows that their domain-general causal reasoning is excellent but they are still poor at theory of mind. Therefore, there are separate physics and mental domains. However, it is likely that those three people have another common feature, besides Asperger syndrome, which is that they are all excellent at mathematics.

If you want to increase the output force of a hydraulic brake system, you decrease the size of the input cylinder. If there is not enough power in electrical circuit to light a globe, you can light the globe by adding another globe to the circuit; that is, you can increase power by adding something that takes power away. These are just two examples of physical relationships that most people would find counter-intuitive but follow from mathematical formulae. It is hardly a coincidence that many great physicists, like

Archimedes, Newton and Einstein, were also great mathematicians, even though the laws that they discovered are relatively simple. The genius of the theory of relativity, for example, is not revealed in the famous formula but in the geometric manipulation that led to its discovery.

In Baron-Cohen et al (2001), the Asperger syndrome group performed similarly across the items but the neuro-typical group varied from as high as 90% correct to as low as 13% correct. The consistent performance of the Asperger syndrome group suggests that some capacity could be used to solve most questions, while the performance of the neuro-typical group suggests that some answers followed from their intuitive understanding of physical relations but others did not. If it is assumed that taking a mathematical or geometric stance could solve most of the problems and that there was no difference in such ability between the groups, then it could be that the superior performance of the Asperger group was reflecting an ability to detach from a force mode of causal reasoning, rather than their capacity for folk physics is superior.

None of the control tasks in any of the strands of research (play, joint attention, language or theory of mind development) rule out the possibility that there is a domain-general impairment that effects development of causal attribution. The next section describes two other aspects that Leslie (1987) has difficulty explaining.

1.2.6 Social Deficits and Asperger Syndrome

Hobson (1990) pointed out that very young infants perceive and respond to the affective expressions of their caregivers, such as smiles, frowns and prosody. He suggested that impaired 'affective' perception in autism inhibits development towards the ability to metarepresent, not the lack of the lack of a theory of mind module. Hobson (1990) did not argue that there is not processing similar to what Leslie (1987) proposed. He argued that autism does not result from the lack of that processing. Deficits have been found in matching expressions to emotions, discriminating emotions, sorting photographs by expressions of emotion (Hobson, 1993), labelling emotions by prosody (Van Lancker, Cornelius and Kreiman, 1989) and in early behaviours such as reaching out to be picked up (Klin, Volkmar and Sparrow, 1992).

Leslie and Frith (1990) suggested that these deficits might not be specific to autism or could be due to difficulty in representing, rather than perceiving, affective states. If it was the latter, the deficits could result from the lack of a theory of mind module. However, Davies, Bishop, Manstead and Tantam (1994) found deficits in both high and low functioning autism groups in detecting affective states from faces and detecting facets in similar, but non-social, structures. It is unclear how such a deficit would result from an inability to metarepresent, as defined by Leslie (1987)

Baron-Cohen (1995) attempted to overcome this limitation by suggesting that a shared attention module, rather than a theory of mind module, is absent in autism. He claimed that the shared attention module builds on input that represents eye movements and volition, for example movement towards a desired goal, to represent triadic events. Triadic events are where person 1 and person 2 jointly attend to an object but the joint attention is not necessarily initiated by a child's declarative gesture. He suggested that this module provides input to the theory of mind module.

Baron-Cohen (1995) predicted that there would be deficits in other triadic capacities besides declarative gestures; that is, where understanding communicative intent is not a necessary requirement. Baron-Cohen, Baldwin and Crowson (1997b) found a marked deficit in a young autism group in monitoring eyes to detect referents of novel words. The model also predicted that problems in reading eye language would persist after FBT is passed. Baron-Cohen, Wheelwright and Jolliffe (1997c) found that most adults reliably inferred complex mental states (thoughtful, arrogant, etc) from photographs of both whole faces and only eyes. They also found that adults with autism or Asperger syndrome, who passed FBT, were less able to make such inferences, particularly in the 'eyes only' condition (also, Baron-Cohen et al, 1997). Baron-Cohen and Hammer (1997) found that parents of children with Asperger syndrome were less accurate than control subjects at inferring mental states from eyes only, which suggests that this strand has tapped into the genetic vulnerability.

As noted earlier, people with Asperger syndrome do not experience significant language delay and it seems that language delay in autism is linked to the difficulty in passing FBT, whatever the causal direction might be. Deficits have been found in Asperger syndrome groups on Baron-Cohen's (1989a) belief about belief task (Ozonnoff, Pennington and Rogers, 1991), detecting facial information (Davies et al, 1994), following eye language (Baron-Cohen et al, 1997) and inferring mental states that are contextually appropriate (Jolliffe and Baron-Cohen, 1999). However, compelling evidence of inability to metarepresent has to come from lack of pretend play or a severe delay on FBT. Ziatas et al (1998) found 75 % passing FBT in an Asperger syndrome group with vMA below 7 years, which is not only considerably in advance of autism groups but it matched a language disability group. A literature search found no studies of pretend play in Asperger syndrome based on direct observation but clinical observation suggests that the play of children with Asperger syndrome is unusual but not lacking in imagination (Attwood, 1998). Also, parental recall suggests that children with Asperger syndrome are more likely to initiate pretend play than children with autism (Gilchrist et al, 2001).

Therefore, there is no direct evidence suggesting that Asperger syndrome results from the lack of a theory of mind module. One possibility is that the underlying abnormality in Asperger syndrome is less pronounced than in autism and acts only on the shared attention module, whereas people with autism lack both modules.

1.2.7 Summary

It was stated at the outset of this discussion that Leslie (1987) contained an insight that should not be lost. This was that the M-representation structure links pretend play and the ability to appreciate that the beliefs of others may be different to one's own. An inability to generate this structure remains the best explanation for the severe deficits in those capacities in children with autism. This remains the case even if the primary cause of this inability is not the lack of a theory of mind module. The challenge for any precursor model is to explain why impairment to the precursor(s) would cause an inability to generate M-representation.

There is reason to doubt that impaired affective perception (Hobson, 1990) alone can do this. Neuro-typical children display 'positive affect' in joint attention and this is reduced in autism but to the same level for both imperative and declarative gestures (Mundy, Sigman and Kasari, 1993). Therefore, the model seems unable to account for the severe deficits at what may well be the critical link to the ability to metarepresent. While the lack of a shared attention module (Baron-Cohen, 1995) accounts for problems in eye reading, the model, as yet, does not distinguish between autism and Asperger syndrome. Leslie (1987) also does not explain the difference between the disorders but it at least explains the severity of autism at a cognitive level, which Baron-Cohen (1995) does not do. Therefore, while it is unclear how Leslie (1987) accommodates the social deficits, the alternatives do not sufficiently account for the severe theory of mind deficits in autism.

The problem with understanding the data that has been described is partly historical. The picture of autism presented to Leslie (1987) was Kanner's (1943); that is, that 'physical relatedness' is unimpaired in autism, while 'social relatedness' is severely impaired. As such, Leslie (1987) described autism in terms of a social impairment, even though pretend play is object use. The notion that the primary impairment must be social seemed to be supported so obviously by both research and observation that it went virtually unchallenged until Williams et al (1999). Leslie (1987) suggested that some functional play might be acquired through primary representation, which does not mean that neuro-typical children do acquire these behaviours without representing themselves as agents. One consequence is that the idea that theory of mind is domain-specific was not adequately defined, which is clear from the results of Williams et al (2001).

To accommodate recent findings, Baron-Cohen (2000a) suggested that 'folk psychology' is anything that involves goal-directed actions of agents, which is the essential mode of 'physical relatedness' for homo sapiens. It seems almost certain that our species evolved and survived because of tool design, which would have required goal purpose and an ability to see properties in objects that were not really 'there'; for example, that a piece of wood could be an axe handle. Therefore, tool design would have required M-representation. That pretend play seems to require different capacities is because so many tools are now 'there'. In order to be tool designers, evolution firstly had to guarantee that our species would use objects as tools and the ability to see 'force' in basic physical events might have been one aspect that could guarantee such behaviour.

This section has argued that the results of the theory of mind research are what might be expected if the launching effect is weak in the disorder. The launching effect is potentially the basis for the idea that forces mediate cause and effect, which, as Leslie (1994) said, is "the central organising principle in the core domains of object mechanics and theory of mind" (p121). It was argued in Section 1.2.4 that the lack of a notion of causality would place a severe constraint on the ability to metarepresent and, hence, to generate M-representation. Frith (1989) proposed that gestalt perception is weak in autism and it will be argued over the next three sections that the findings from the subsequent research suggest that the launching effect is likely to be weak in autism.

1.3 Perception in Autism

1.3.1 Central coherence

People with autism report that they can, at times, find seemingly innocuous odours or minute noises overwhelming, yet, at other times, be oblivious to having been called loudly by name (Grandin, 1992, Frith, 1989). DSM IV-TR (2000) notes that other unusual sensory responses include a high threshold of pain, exaggerated reactions to light and fascination with certain stimuli. Frith and Baron-Cohen (1987) summarised early research into perception as showing that parts are favoured over wholes and that there is hyper- and hyposensitivity across modalities. They noted though that the theories that drove this research, such as stimulus over-selectivity (Lovaas, Koegel and Shreibman, 1979), had not made major inroads towards providing a complete account of autism. Happe (2000) noted that one reason for this was that most theories predicted deficits only, whereas autism also features isolated abilities. A breakthrough came when Frith (1989) realized that some gestalt perceptions are weak in autism and that this might account for the isolated abilities.

Shah and Frith (1983) found that an autism group outperformed controls on the Embedded Figures task (EFT), while autism groups have consistently produced their highest IQ subtest score on the Block Design task (BDT, Rumsey, 1992). EFT and BDT are similar in that subjects must identify parts within master displays. They are asked to find a figure (for example, a triangle) that is embedded within a more complex figure in EFT, while they are asked to use blocks with simple markings to construct the more complex figures in the master displays in BDT.

Frith (1989) noted that both types of masters are perceived with the gestalt quality, figure/ground. Goldstein (1984) defined the properties of figure/ground as: the figure is seen as being in front of, and more 'thing-like' than, the ground, which is seen as unformed material. Frith (1989) suggested that weak figure/ground perception of the BDT master displays would make it easier to see how the parts (the markings on the blocks) fit within the overall figure, thus facilitating a bottom up strategy that readily solves the task. Shah and Frith (1993) confirmed this proposal when they found that high and low functioning autism groups outscored control groups on the standard BDT but the control groups performed as well as the autism groups when the masters were presented in a segmented form that weakened figure/ground. Jolliffe and Baron-Cohen (1997) found that an autism group and an Asperger syndrome group were both faster at EFT than a neuro-typical group matched for both chronological and mental ages.

As noted earlier, there is a high incidence of savant abilities in autism, while Kanner (1943) observed that even low functioning children show isolated abilities. Frith (1989) pointed out that the uneven, but characteristic, pattern across IQ subtests of autism groups (Rumsey, 1992) suggests that isolated assets are a universal feature of autism. Perfect pitch is a savant ability found in about 1 in 20 with autism (Sacks, 1995). Heaton, Hermelin and Pring (1998) and Mottrom, Peretz and Menard (2000) found that pitch detection in non-musical autism groups was superior to control groups and Heaton et al (1998) also found that pitch detection correlated to BDT scores in the autism group only. This suggests that the savant ability does reflect a more widespread asset and that a common factor may underlie at least some of the assets.

Frith (1989) proposed that weak gestalt perception facilitates a bottom up style with BDT. Happe (2000) summarised other research showing that autism groups produce assets on tasks that could favour a bottom up style (for example, memory for unrelated word strings and solving jigsaws by just the shapes of the pieces) and deficits in similar tasks that may suit a more global approach (for example, memory for sentences and solving jigsaws by a picture).

Frith (1989) claimed that weak gestalt perception results from a weakness in central coherence, a prefrontal function that pools information from divergent sources (Frith and Frith, 1991). There were four parts to her argument. Firstly, she claimed that global organization reflects relatively high order, 'meaningful' processes[1] and global functions are impaired in autism. Secondly, she claimed that input processing describes parts and research has shown that functions that she claimed reflect input processing, such as visual and auditory acuity, object constancy and object recognition, are unimpaired in autism (Frith and Baron-Cohen, 1987). Thirdly, she argued that, given that there is impairment to 'meaningful' global organization at both perceptual and cognitive levels, it is more likely to be reflecting abnormal cognitive processing than abnormal perceptual processing. Finally, she claimed that, multi-sensory impairments could only result from a central abnormality because sensory processing is grossly modular.

Leslie (1988) argued that it is unlikely that illusions reflect central processing because they persist even when the perceiver knows that they are wrong. Therefore, Frith (1989) proposed that only 'strong', meaningful gestalts, like the BDT and EFT displays would be weak and that 'weak' illusions would be perceived normally. However, Happe (1996) found that an autism group were less susceptible than controls to 5 out of 6 illusions. Reduced

[1] The use of 'meaningful' is Frith's. It has never been clear to this author what was intended by its use within the context.

susceptibility was found to the Kanizsa, Titchener, Ponzo, Poggendorff, and Hering illusions but not to the Muller-Lyer illusion. For example, only 32% of the autism group said that the centre circles in the Titchener display (Figure 1.3) were different sizes, compared to 61% of a learning disability group and 71% of a neuro-typical group.

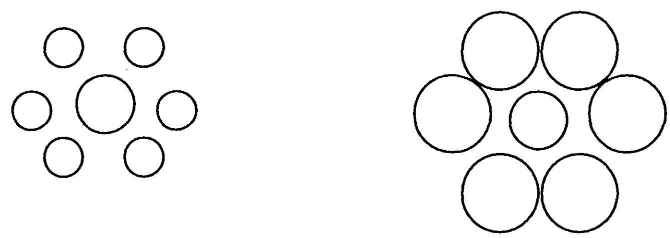


Figure 1.3: The Titchener circles illusion. Most subjects report that the centre circle in the left field looks bigger than the centre circle in the right field. Happe (1996) found reduced susceptibility to this illusion in an autism group but Ropar and Mitchell (2000) did not.

While Happe's (1996) findings did not support the original prediction from the weak central coherence theory, she argued that the results might still result from weak central coherence. Illusions have inducing and induced parts; for example, the different sizes of the surrounding circles induce different perceptions of the size of the middle circles with the Titchener display. She suggested that central coherence integrates the inducing and induced parts and that, as such, weak central coherence reduces susceptibility to illusions. She also suggested that the autism group was susceptible to the Muller-Lyer illusion because the physical connection between the wings (the inducing) and the shafts (the induced) compensates for the weak integration.

Despite not following Frith's (1989) prediction, Happe (1996) is the most direct evidence that gestalt perception is weak in autism. However, Ropar and Mitchell (2000) found that neither an autism group nor an Asperger syndrome group showed reduced susceptibility to the Ponzo and Titchener illusions. Happe (1996) used a judgment method, whereas Ropar and Mitchell used a performance method. Happe (1996) presented a display and asked a question that was relevant to the given illusion, for example, "Are these two circles the same or different sizes?" with Titchener. In contrast, Ropar and Mitchell (2000) asked subjects to adjust one circle on a computer screen until it appeared to be the same size as the other. The latter method may have encouraged relatively strong fixations on the inner circles, rather than a focus on the whole display. This could have artificially deflated the illusion effects in the control groups, with the consequence that there was no difference between those groups and the autism group.

BDT did not produce a relatively a high score for oppositional or dysthymic groups in a study by Lincoln, Courchesne, Kilman, Elmasian and Allen (1988) or for a dyslexia group in a study by Rumsey and Hamburger (1990), while an autism group outperformed a learning disability group matched for pMA in Shah and Frith (1993), that was described earlier. BDT was the highest score for a dysphasic group in Lincoln et al (1988) but it was only marginally above other subtest scores, whereas the BDT score in autism groups is generally well above all other scores except

Object Assembly, a somewhat similar task. Fathers of children with autism or Asperger syndrome have also produced superior performance to control subjects on BDT and EFT and show reduced susceptibility to the Titchener illusion (Happe, Briskman and Frith, 2001, Baron-Cohen and Hammer, 1997). These findings suggest that weak gestalt perception is specific to autism and Asperger syndrome and may be reflecting the common genetic vulnerability.

The next section describes perceptual streaming before it is proposed that reduced magno input underlies weak gestalt perception in autism, rather than weak central coherence.

1.3.2 Perceptual Streaming

Livingstone and Hubel (1988) claimed that magno perceptual stream has a specialist role in figure/ground discrimination and illusory contours. This thesis argues that Livingstone and Hubel's (1988) theory of how some gestalts arise, particularly in light of recent findings (Bullier, 2001), provides a feasible alternative to the central coherence model (Frith, 1989). As noted in the previous section, it appears that unusual perceptual functioning in autism occurs across all the senses. Selective staining procedures show that heavily (magno) and lightly (parvo) myelinated pathways are apparent for all senses (Livingstone, 1993). The focus, though, will be mainly on the visual system.

The current understanding of the primate visual system is that magno, parvo and konio cells are apparent in the ganglion cells in the retina and the lateral geniculate nucleus. There are three cortical pathways, the magno, the parvo inter-blob and the blob streams (Bear, Connors and Paradiso, 2001). The blob stream receives projections from parvo and konio cells, while magno and parvo neurons project respectively to the magno and parvo inter-blob streams in separate layers of area V1 in the primary visual cortex. It appears that the blob stream is specialised for colour analysis, as its cells lack orientation selectivity (Bear et al, 2001) and the stream does not extend far beyond V1 (Livingstone and Hubel, 1988). The main focus here is on the distinct magno and parvo projections.

Some ganglion cells project to the superior colliculus, which appears to be dominant for perception before 2 months of age, when the parvo cells begin to mature and the cortical pathways start to dominate. Magno cells do not begin to mature until the fourth month (Colombo, 1995).

Parvo cells in the lateral geniculate nucleus mainly respond to differences in frequency input, whereas magno cells mainly respond to differences in intensity input. Although both streams receive input from cones and rods, the magno stream receives greater input from rods in the periphery than the parvo stream (Livinsgstone and Hubel, 1994). As magno neurons are thicker and more heavily myelinated than the parvo neurons, the transfer of information is much quicker in the magno stream (Bullier, 2001).

The properties of the cells in the geniculate of monkeys are summarised in Table 1.1.

Table 1.1: Properties of subcortical parvo and magno cells in the lateral geniculate nucleus.

	Parvo	Magno
cell size	small	large
receptive field	small	large
stimulus	frequency	intensity
myelin	light	heavy
firing	slow, sustained	rapid, transient
acuity	high	low
temporal resolution	low	high

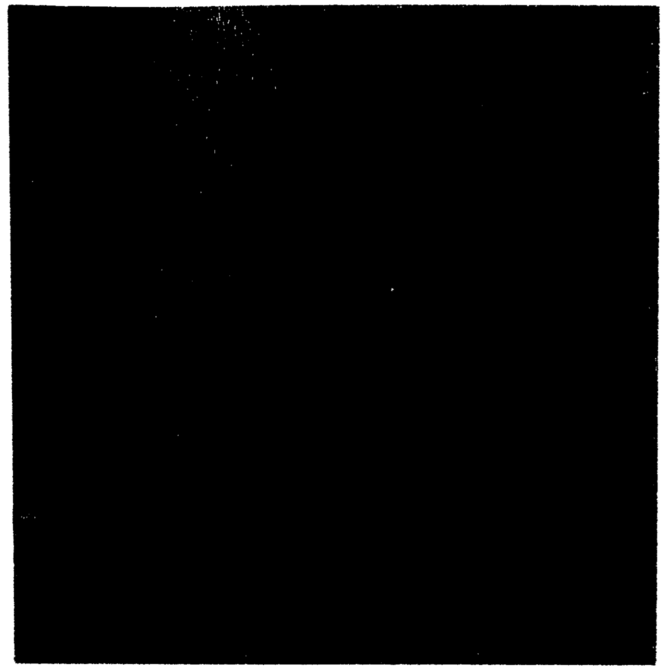
Livingstone and Hubel (1988) claimed that the high level of segregation in the geniculate continues in the magno and inter-blob pathways in the cortex. The inter-blob streams in V1 have small receptive fields and surprisingly little colour contrast, except at borders. They suggested that the inter-blob stream is mainly concerned with form detection. The magno cells in V1 are orientation selective and have little colour selectivity.

Livingstone and Hubel (1988) also claimed that aspects of human perception reveal functions of the magno stream. They suggested that distinct functions should be apparent due to the properties of the magno and parvo geniculate cells in colour selectivity, contrast sensitivity, speed and acuity. For example, given the high contrast sensitivity and low colour selectivity of the magno stream, magno properties should be constrained in isoluminant conditions, where there is no difference in contrast in the colours across the display. Also, given its low spatial resolution, the magno stream should also be constrained with high spatial frequencies. They pointed out that research had found that motion perception is impaired in both isoluminant conditions and high spatial frequencies. They also noted that stereopsis is not perceived with random dot stereograms when the colours are isoluminant or there are high spatial frequencies. Therefore, they suggested that the magno stream is dominant in movement and depth perception.

Illusory contours and figure/ground discrimination disappear or become unstable in isoluminant conditions (see Figure 1.4). Livingstone and Hubel (1988) suggested that the global properties of the magno stream make it suited for 'linking by co-linearity', linking across a gap when the input prescribes such linkage; for example, an object can still be seen as a whole, even if part of it is occluded by another object. Such linking can create 'good continuation', where organizational processes preserve smooth continuity, rather than produce abrupt changes (Bruce et al, 1996). Koffka (1935), one of the Gestalt school, anticipated many of the properties of perceptual streaming. He claimed that perception of the whole precedes the part, which could be due to the heavy myelination of the magno stream conveying global information faster than the slow, local parvo stream. He also claimed that visual organization does not depend on colour information and that the periphery is the 'ground sense' and the fovea is the 'figure sense'.

Ungerleider and Mishkin (1982) proposed that a ventral pathway extends from the primary visual cortex to the temporal cortex and is responsible for object recognition ('what' specialization), while a dorsal pathway from the primary visual cortex extends to the parietal cortex and is responsible for localizing objects in space ('where' specialization). Livingstone and Hubel (1988) suggested that the inter-blob stream is the ventral pathway, while the magno stream is the dorsal pathway (Figure 1.3).

Two main objections were raised against Livingstone and Hubel's (1988) theory. Firstly, the magno stream is not completely colour-blind and, as such, Zeki (1993) doubted that isoluminance is the right method to distinguish specialist functions. Secondly, there is evidence of considerable integration between the streams and 'cross talk' as they progress to the later cortical areas. Moreover, neither single cell nor lesion studies have found isomorphism between the properties of the cells in the geniculate and the cells in the later areas (Merigan and Maunsell, 1993). There are eight times as many parvo cells as there are magno cells, so the population of parvo cells might transcend any advantages that single magno cells seem to have, for example in early receptive field size for global perception (Bruce et al, 1996). As such, most authors (e.g., De Yoe and Van Essen, 1988) proposed models where perceptions are constructed though integration of the pathways as they progress through areas with increasing ability to process complex properties.



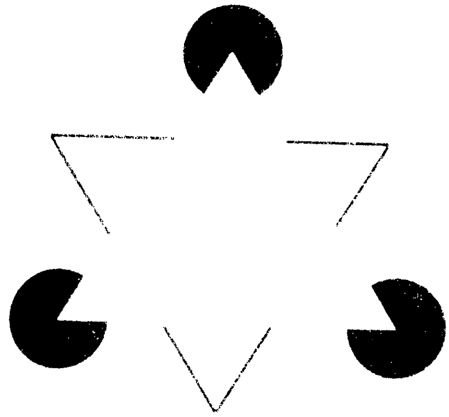


Figure 1.4 (previous page): The Kanizsa illusion: Conditions are ideal in Figure 1.4b (at the bottom) to perceive the illusory triangle, while Figure 1.4a has an unsaturated green, which means that the display is approximately isoluminant. In the latter condition, the illusory contour is weak.

However, Bullier (2001) pointed out that such hierarchical models face major problems. For example, he claimed that the conduction times of parvo neurons, in both the feedforward and the horizontal projections, are much too slow to provide integrated, global perception in the time from stimulus onset to perceptual experience.

Bullier (2001) suggested that the early cortical areas, V1 and V2, provide a 'backboard' for given perceptions. He noted that, due to heavy myelination, magno inputs arrive at V1 on average 20msecs before parvo inputs and, with the heavy myelination and thickness of the feedforward and feedback neurons of the dorsal stream, this input could project to the parietal cortex and back to V1 and V2 in time to provide global organization for the incoming parvo input. He also noted that these feedback neurons cascade across V1 and V2, which could eliminate having to rely on slow horizontal connections across the areas for global integration.

Bullier and colleagues have provided evidence of the influence of feedback projections on gestalt perceptions. They cooled area MT in the magno/dorsal stream in monkeys, greatly reducing physiological activity in that area. They measured responses in V1 and V2 to displays where illusory contours (Seghier, Dojat, Delon-Martin, Rubin, Warnking, Segebarth and Bullier, 2000) and figure/ground (Bullier, Hupe, James and Girard (2001) are perceived. They found great reductions in the strength of the responses of many cells in those areas. These reductions were compared both to responses when MT was not cooled and to responses under cooling to similar displays that do not produce gestalt perceptions. These differences were particular large when the displays had low contrast differences between the parts and the background. These results support the contention that feedback connections do influence V1 and V2 and also support the proposal that the magno stream is particularly significant for these aspects of gestalt perception.

Livingstone and Hubel's (1988) theory is more in keeping with the findings of the Gestalt school than Frith (1989). Day (1993) noted that gestalt and illusion perceptions are resolutions of anomalies between underlying input processes. It has already been suggested that the global properties of the magno stream should favour the law of good continuation. The more local properties of the parvo stream should favour the 'law of proximity', things that are close together get grouped together. The word 'favour' is used because it is not being suggested here that either stream is absolutely specialised in those functions. Rather, it is suggested that the laws describe interactions between structures within given optical arrays and the neurological properties of the streams.

When one object is occluded by another object, there is information of good continuation but over a spatial discontinuity. The global magno stream is better equipped to extend over spatial and temporal gaps than the parvo stream. However, it is only when one stream coheres to one law and the other stream coheres to another law that resolution is necessary. The broader that given spatial or temporal gaps are, the more good continuation should be reflecting magno properties. Magno cells have small centre firing and large surround inhibition, so, if there is a large gap and sufficient contrast information, an illusory contour is perceived, as with the Kanizsa illusion. As such, illusory contours and figure/ground either disappear or become unstable in isoluminant conditions (see Figure 1.4).

Therefore, according to Livingstone and Hubel's (1988) theory, it is possible that weak figure/ground perception could result from reduced magno input. However, not all gestalts would depend equally upon magno stream input nor is it necessary that the key aspect of all gestalts reflect magno functioning. For example, Zucker (1980) argued that the Muller-Lyer illusion is an example of local contexts, the wings, acting over global aspects, the perceived lengths of the lines. He cited a case with the variation of Muller-Lyer where both wings are on the same line. When it is presented over a rapid sequence of images, rather than one static display, the overall image is that, at one instant, the structure moves away from the observer and is blurry, and, at another instant, it moves towards the viewer and is sharply focused. However, the centre wing remains sharp throughout and is not perceived to move. This independence from apparent motion suggests that the 'wings effect', the key aspect of Muller-Lyer, may be dominated by parvo processing.

Some people with developmental dyslexia have impaired global perception that could be due to reduced magno input (Lovegrove, 1996). It appears though that gestalt perception is not weak; for example, dyslexia groups do not produce high scores with BDT (Rumsey and Hamburger, 1990). It appears that the abnormality is subcortical, as neuropathology has been found in the geniculate (Galaburda and Livingstone, 1993). Livingstone (personal communication) did not find a similar neuropathology in autism. Impaired perception that mimics the effects of isoluminance could only result from a severe subcortical abnormality but one that reduces cortical magno input in the cortex. Therefore, it is proposed that people with autism and Asperger syndrome have normal subcortical magno input but reduced magno input into the primary visual cortex (whether by feedforward or feedback projections). It is also assumed that a similar reduction to magno input occurs in all the senses.

1.3.3 Reassessing Central Coherence

As noted in Section 1.3.1, Frith (1989) claimed that central coherence is a prefrontal function that makes sense of information from divergent sources. She also suggested that the global processes of central coherence are more meaningful than the simple, feature organization processes than the Gestalt school stressed. As noted, Frith (1989) made a four-part argument that central coherence is weak in autism.

The first part was that global organization requires relatively high order processes. However, it is not necessary that weak gestalt perception must result from weak central coherence. Frith (1989) suggested that only relatively meaningful gestalts would be weak, but not illusions. It is not clear why the BDT masters are particularly meaningful but, nonetheless, Happe (1996) disproved this hypothesis. Moreover, the illusion to which the autism group were least susceptible (only 2 out of 25 subjects) was Kanizsa, which is readily weakened by reduced contrast distinction (Figure 1a). The illusion to which the autism group were most susceptible was Muller-Lyer (22 out of 25 subjects), which, following Zucker (1980), may be more a local illusion.

The second part of Frith's (1989) argument was that input processes are unimpaired, as seen in intact visual and auditory acuity, object constancy and object recognition. As reduced magno input is an alternative to weak central coherence, streaming must also be taken into account when considering this issue and intact object constancy and recognition suggest only that the inter-blob pathway is functioning normally.

As Frith (Frith and Baron-Cohen, 1987) pointed out, visual and auditory acuity are not normal but are enhanced in autism. Hyper- and hyposensitivity occur together in people with autism; for example, Grandin (1992) has perfect pitch but difficulty following rhythm. This is consistent with the general picture that auditory acuity is an asset (Heaton et al, 1998) and that temporal resolution is a deficit (Gillberg and Coleman, 1992). This suggests that frequency processing is unimpaired, while intensity processing is impaired, as expected from reduced magno input. Auditory N100 event related potentials measure neural activity in sensory cortices 100ms after stimulus presentation and are sensitive to changes in both frequency and intensity. Lincoln, Courchesne, Harms and Allen (1995) found reduced N100s in an autism group for changes to intensity but not for changes to frequency.

Other research has found 'tunnel vision' (Rincover and Ducharme 1987), a narrow 'spotlight' of attention similar to people with parietal insults (Townsend and Courchesne, 1994), difficulty directing attention towards laterally presented stimuli (Wainwright-Sharp and Bryson, 1993) and saccadic eye movements that are consistent with an abnormality in the parietal attention network (Kemner, Verbaten, Cuperus, Camfferman and van Engeland, 1998). As Plaisted (2000) noted, weak central coherence does not readily explain these findings.

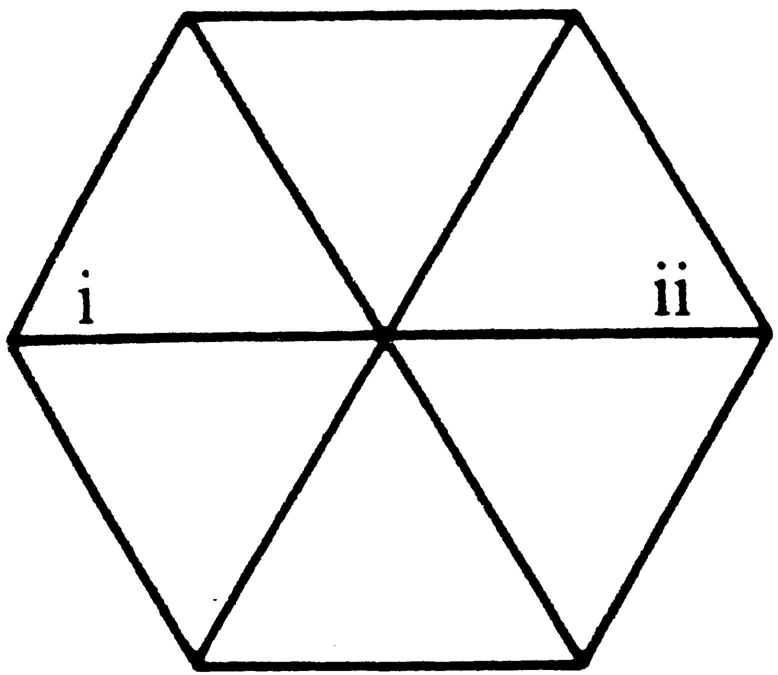
The third part was that impaired global organization in both perception and cognition is likely to be due to abnormal cognitive processing (see Frith and Baron-Cohen, 1987). According to Frith's (1989) theory, given a task that taps organisational processes at both levels, any divergence in autism groups from normal should not be due to feature processing only. In the 'Navon task', subjects are presented a large letter that is made up of smaller letters (for example, a big 'H' that is made up of little letters). The small letters may be the same as the large letter (compatible) or different from the large letter (incompatible). Neuro-typical subjects show 'global advantage' in that they are quicker and more accurate in identifying the large letters than the small letters in compatible conditions. They also show 'global interference' in that they are slower and less accurate in detecting a target letter when it is a small letter in incompatible conditions.

There are two organisational aspects in this task, perception of the large object and recognition of the letters. Plaisted, Swettenham and Rees (1999) found that an autism group showed the normal levels of global advantage and global interference when the experimenter primed them to attend at a global level. When the autism group were not primed, they showed 'local interference'; that is, they made more errors identifying the large letters than the small letters in incompatible conditions. Whereas the autism group showed global effects only when primed, they showed cognitive interference in both situations. The interference was in the opposite direction to normal (i.e., they showed local interference to global feature detection) when they were not primed. The autism group should have shown reduced global effects in both conditions, if a reduction in imposed meaningfulness is the reason for abnormal perception.

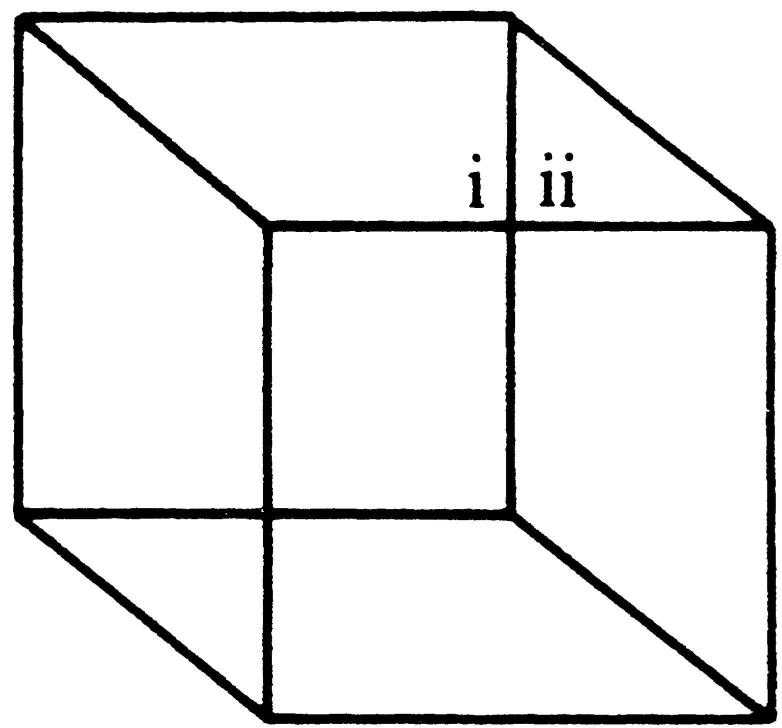
The fourth part of the argument was that multi-sensory impairments require a central abnormality, which is the hardest to answer. One possibility that there is analogous wiring in all senses and the 'trigger' of the necessary wiring is multi-sensory. Alternatively, there might be a 'set point' mechanism that controls the balance between the streams that is multi-sensory to provide consistency across senses. Abnormalities that constrain either function could lead to multi-sensory impairments. Although these proposals are speculative, the evidence favours a relatively low order abnormality, once perceptual streaming is considered. Moreover, there is no persuasive evidence that central processes play a direct role in gestalt perception or even that there is such a function. In contrast, Livingstone and Hubel (1988) showed that the magno stream has an important role in the type of gestalt perceptions that are weak in autism.

1.3.4 Weak Gestalt Perception?

Figures 1.4b and 1.5b are standard Kanizsa triangle and Necker cube displays respectively while Figures 1.4a and 1.5a are examples of how these illusions can be weakened for the neuro-typical system. The contrast distinction of Figure 1.4b is reduced in Figure 1.4a and with that, the illusory contour is considerably weaker. Also, the contour disappears far more readily in Figure 1.4a if a part is fixated, that is, if a local perspective is taken, than with Figure 1.4b. Figure 1.5 (from Gregory, 1987) shows how the Necker cube is weakened with a change to the underlying structure, which, as Gregory (1987) noted, alters the relationship between the Gestalt laws. In Figure 1.5b, the edge at i-ii (proximity) makes it difficult to see the display as anything other than three-dimensional. However, focusing attention across the line i-ii in Figure 1.5a creates good continuation and leads to a two dimensional perception. Therefore, at least three factors are important for weak gestalt perception: distinctions between frequency and intensity processing, the processing of structure and the focus of attention.



a



b

Figure 1.5 (previous page): The Necker Cube (from Gregory, 1987). Conditions are ideal to perceive the cube in Figure 1.6b (at the bottom) but Figure 1.6a can be perceived as a cube or a hexagon.

It has been proposed here that reduced magno input underlies weak gestalt perception in autism, which should reduce contrast distinctions between the parts. As such, standard displays should be perceived in a way that is similar to what is perceived by the neuro-typical system in isoluminance. Illusory contours would be perceived weakly, if at all, while displays that are perceived as figure/ground by the neuro-typical system, like the BDT masters, would be perceived unstably but with the parts more prominent. This could facilitate the bottom up strategy that Frith (1989) proposed underlies the superior performance of autism groups on BDT. The extent that reduced magno processing weakens other gestalts would depend on relationships between streaming, the processing laws and the given structure. Therefore, no matter what abnormality is proposed, whether it should weaken a perception must be considered on a case-by-case basis.

Happe (1996) tested illusions that are frequently displayed in psychology textbooks. The editors base those presentations on an assumption that they are universally perceived, at least in the neuro-typical population. There may be some theoretical significance in the fact that there was always some in the neuro-typical group in Happe (1996) that gave answers that were not based on illusion perceptions but it is not necessarily critical here.

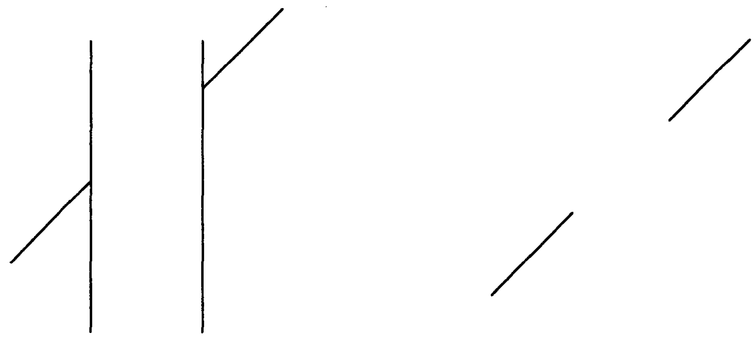
Also, some of the autism group showed susceptibility to each illusion but this it is not necessarily critical for the proposal that weak gestalt perception is universal in autism. As Figures 1.4a and 1.5a show, weak gestalt perception does not necessarily mean that the given gestalt aspect would not be perceivable. There is already strong evidence from BDT performance over numerous studies (Rumsey, 1992) that weak gestalt perception is universal in autism. The extent of the underlying abnormality, the given display structures and the manner of attention prompted by the questions are all factors that could have influenced the answers of the autism group in Happe (1996). It is more important that the autism group showed reduced susceptibility to most of the illusions in Happe (1996).

1.3.5 Testing the Alternative Models

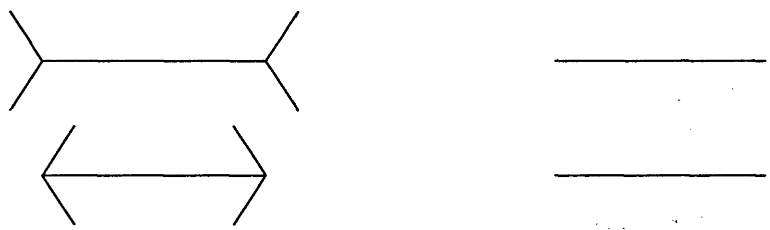
It has been argued that it is more likely that weak gestalt perception results from reduced magno input than weak central coherence but, of course, this must be resolved empirically. As noted, Happe (1996) found that an autism group were less susceptible than control subjects to the Poggendorff illusion but not the Muller-Lyer illusion. She suggested that reduced susceptibility reflected weak integration of inducing and induced parts, due to weak central coherence, but that the physical connection between inducing (the wings) and induced (the length of the shafts) parts in Muller-Lyer compensates for the weakness.

The current research measured the illusion effects with the Poggendorff, Muller-Lyer and Brentano displays by comparing the magnitude of error with those displays to error on appropriate control displays (Figure 1.6 a, b and c, respectively).

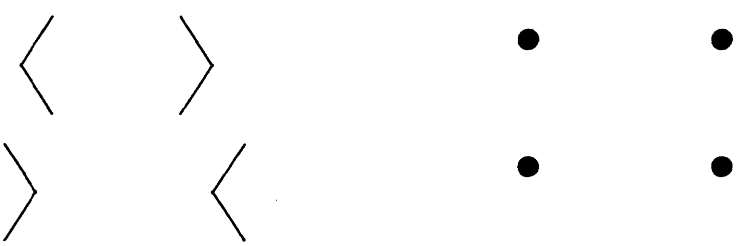
Brentano has the same wings as Muller-Lyer but without the shafts. As the shafts are the proposed connections between the inducing and induced parts, according to Happe (1996), the autism group should be as susceptible as control groups to Muller-Lyer but less susceptible to Brentano and Poggendorff. The current thesis proposes that wings effects result from local processes and that, therefore, the autism group would be susceptible to Brentano. It also proposes that a reduced Poggendorff illusion effect, if found, would reflect reduced misalignment (Day, Jolly and Duffy, 1987) and argues that misalignment reflects global processes. These alternatives are outlined in greater detail in the summary of the Illusions experiment in Chapter 2.



(a) Poggendorff Poggendorff control



(b) Muller-Lyer Muller-Lyer control



(c) Brentano Brentano control

Figure 1.6: The Poggendorff, Muller-Lyer and Brentano illusions. Chapter 2 summarises the experiment that measured the illusion effects in each group.

As noted, Ropar and Mitchell (2000) did not replicate Happe's (1996) finding that an autism group showed reduced susceptibility to the Ponzo and Titchener illusions. A difference between the studies was that Happe (1996) used a judgement method, whereas Ropar and Mitchell (2000) used a performance method. The current research also uses a performance method, which may help to resolve whether the different results were due to the different procedures.

Even if the predictions of the current thesis are supported by the Illusions experiment, it would only be indirect evidence that there is reduced magno input in autism. Temporal integration tasks (Hogben and Di Lollo, 1974) are arguably sensitive to the distinct properties of the magno and parvo streams. Two displays are presented rapidly in sequence in the same spatial location; if there is no interval between the presentations, two dot matrices are perceived. At some pause between the two presentations, apparent motion is perceived, rather than two stable matrices. It is argued that the perception of the stable matrices mainly reflects the parvo stream, while the apparent motion reflects increasing dominance of the magno stream as the temporal gap increases. If so, reduced magno input should mean that the two matrices are perceived at greater temporal gaps than normal. The Temporal Integration experiment is described in Chapter 4.

Difficulty in acquiring theory of mind obviously does not result from a weakness in perceiving the static displays that have been discussed thus far. However, the next section proposes that weak magno input could weaken perception of the launching effect.

1.4 The Launching Effect

As noted in Section 1.2.4, Hume (1739) claimed that causal reasoning is based on the idea that forces mediate cause and effect but that such forces cannot be directly observed. For example, he claimed that only two independent movements can been seen in billiard ball collisions. He noted that what is available to be detected over repeated experience is that object A arrives beside object B before B immediately moves on every occasion; that is, such events have detectable priority, contiguity and constant conjunction. He claimed that general causal reasoning reflects these properties and that, therefore, the idea of force arises from associative learning.

If Hume (1739) was correct that associative learning, by itself, is the basis of the idea of force, then the sense of seeing object A push object B should be reflecting repeated experience only and not an actual perception. However, Michotte (1946) studied the perception of collision events and claimed A pushing B is perceived in the launching effect. This raises two important questions. Firstly, is the launching effect an innate basis for the causality assumption? Secondly, how can the effect be perceived?

The first question certainly has not been answered but Leslie and Keeble (1987) found that six-month-olds are sensitive to the launching effect, which at least supports the possibility that it arises from innate processes. As for the second question, Michotte (1946) claimed that the event structure creates an anomaly that is resolved as a direct gestalt perception where A's movement extends, or ampliates, into B's movement. 'Direct', in this instance, means unmediated by high order processes. In contrast, Leslie (1994) claimed that his research showed that the launching effect involves mediation by modular processes. These theories are described over the next two sections.

1.4.1 Ampliation of Movement

Michotte (1946) built a machine to simulate collision events. In what will be referred to as the standard launching event, object A moves from one side of the viewing area towards object B in the middle. When A arrives beside B, A stops and B moves off immediately in the direction that A was travelling and at a similar speed. Michotte's (1946) research can be broken into two types of experiments. The first type tested numerous subjects and the second tested a small number of trained subjects. Almost all subjects reported seeing A *push* B in the standard event.

There were reliable patterns with variations to the standard event. Most subjects reported seeing A *trigger*, rather than *push*, B if the speed of B was markedly faster than A. The trained subjects reported seeing *delayed launching* at a pause of around 90ms between A stopping and B moving (i.e., the impression of pushing persisted even though they detected the pause between the movements), which in turn gave way to *two independent movements* at around 150ms. Also, launching was reported until there was a substantial spatial gap between where A stopped and B started. A seemingly impossible perception of A *tunnelling* through B occurred if the event was viewed with peripheral vision, if the viewer looks directly at the event through semi-transparent paper, if it was viewed directly but at a distance or if the squares moved at high speeds.

Joynson (1971) criticised Michotte's (1946) methodology, in particular, the use of trained subjects and the lack of statistical analysis. However, the core findings have been replicated in studies that used naïve subjects and applied statistical analysis: for example, 'temporal pause' (Schlottmann and Anderson, 1993), 'spatial gap' (Day, Stecher and Gordon, 1990) and 'tunnelling at speed' (Wilson, 1991).

Michotte (1946) argued that the standard event is not perceived as two movements that are unified by imposed causality. He claimed that his research shows that the structure of the standard event creates an anomaly at 'the point of impact' (i.e., where A and B meet) between the gestalt laws of proximity (A before impact is A after impact, likewise for B) and good continuation (A's movement continues into B's movement; i.e., A before impact is B after impact) that is resolved in a gestalt perception where A's movement is perceived to extend, or to ampliate, into B's movement. Therefore, he claimed that the resultant launching effect is a direct perception of a causal relation.

Wilson (1991) argued that, with the parvo and magno streams respectively favouring proximity and good continuation, the parallel processes in perceptual streaming should create such an anomaly with launching events, which, according to Livingstone and Hubel's (1988) theory, could be resolved in a gestalt perception. Tunnelling is induced if peripheral vision is used; that is, when increased rod reception strengthens the magno stream. It is also induced if the event is viewed through semi-transparent paper; that is, when the effect of edge detection, an inter-blob function, is reduced. Therefore, ampliation, which Michotte (1946) claimed is the key to the launching effect, should depend heavily on magno input. Given that gestalt perception is weak in autism and that it was argued earlier that this results from reduced magno input, the launching effect may also be weak in autism.

1.4.2 Imposed Causality

Piaget (1969) and Leslie (1994) agreed with Michotte (1946) that pushing is perceived in 'billiard ball' events, rather than two independent movements, as expected from Hume (1739). However, they posited alternate theories to Michotte (1946) for how the effect is perceived. Piaget (1969) did not accept Michotte's (1969) concept of ampliation. He proposed instead that tactile sensitivity with collision events creates a top down representation that organises input, so that by the end of the second year, children can represent objects as causal.

However, Leslie and Keeble (1987) showed that 6-month-olds have greater sensitivity to the standard launching event than non-launching events. As this is before the age that Piaget (1955) suggested that infants actively initiate collisions between objects, Leslie and Keeble (1987) had disproved Piaget's (1969) theory. Unlike Piaget (1969), Leslie (1994) accepted that the event structure creates an anomaly that results in ampliation and presented a similar account of this to Wilson (1991). However, he did not accept that the launching effect is a gestalt and, instead, claimed that the input from launching events triggers the theory of body module, described earlier, which then imposes force representation.

In Leslie (1984), one group of infants were assigned to a standard launching event and another group was assigned to an event with only one object moving continuously across the screen, although it changed colour at B's position. In Leslie and Keeble (1987), one group was assigned to a launching event and another group assigned to an event with a 500ms pause between the movements of A and B. In both studies, infants were habituated to one event before they were presented the same event but played in the reverse direction. Only the two launching groups renewed interest in the reverse condition. Leslie (1988) argued that habituating the infants to their events first and then reversing the events had controlled the temporospatial changes to the launching event. The delayed reaction controlled proximity and the single movement event controlled continuity. As such, Leslie (1994) claimed that the specific sensitivity to launching shows that modular processing imposes force representation on the input processing.

1.4.3 Controlling Continuity

Leslie's (1994) argument about whether his research shows that there is a theory of body module that imposes force representation, rather than Michotte's (1946) contention that the launching effect is a gestalt, depends on whether his research had adequately controlled the parameters of the standard event. The point of impact in launching events is represented diagrammatically in Figure 1.7.

A→ B	just before impact
A1 B1→	just after impact

Figure 1.7: The anomaly between proximity and good continuation. Proximity says that 'A is A1' but good continuation says that the movement of A extends into the movement of B; therefore, 'A is B1'.

The event could be processed as 'A is A1, B is B1' or 'A is B1, B is A1'. It is not being suggested that A 'becomes' A1 or B1 at any instant; the notation is used to show the competition between the two ways that the event could be perceived. If only 'A is AI, B is B1' (proximity) is processed, two independent movements would be perceived. Michotte (1946) argued instead (although not in these terms) that good continuation of movement ('A is B1') is processed in parallel and, therefore, that the interaction between the event structure and the processing laws creates an anomaly. Only when proximity is strengthened by substantial temporal or spatial gaps does 'A is A1, B is B1' totally dominate. When continuity is strengthened, for example, at high speeds, 'A is B1, B is A1' dominates and tunnelling is perceived. 'B is A1' can also be perceived in high-speed events. If the squares are different colours, a 'flipping back' movement is perceived, along with tunnelling.

Another way to look at this is that there is spatial discontinuity from the front edge of A to the front edge of B in the standard launching event and Michotte (1946) was arguing that good continuation acts over this spatial discontinuity. Therefore, 'A is B1' is the appropriate control event for continuity in launching events. This can be simulated with an event where B is not present initially and A moves until it reaches the point of impact, where it disappears and B immediately appears moving to the right. Adults report that they see A *flip or jump* into B in this event (Wilson, 1991); that is, there is an illusory movement across the spatial discontinuity. The illusory movement is a powerful demonstration that ampliation is likely to be a gestalt perception, as Michotte (1946) argued. The problem with Leslie's (1994) argument is that his research had used only one continuous movement as the control for continuity and, therefore, he had not adequately controlled the temporospatial structure of the standard event.

Infants around 6 months not only recover from habituation to launching events, they also recover from habituation to static displays where adults perceive illusory contours (Campos and Stenberg, 1981). Therefore, Leslie's research (Leslie and Keeble, 1987 and Leslie, 1984) did not disprove Michotte's (1946) contention that the launching effect is a gestalt. Instead, it supports the possibility that the effect arises from innate processes.

As noted above, Leslie (1994) recognised the need for ampliation of movement and he suggested that it results from a 'Michotte module'. Given the problem in controlling continuity, the findings of his research were more compatible with a Michotte module than a theory of body module. Interestingly, he suggested that the Michotte module is in the magno stream. Magno cells do not begin to mature until 4 months (Colombo, 1995), which could be the reason that younger infants are not sensitive to launching. What would such a module have to do?

Michotte's (1946) research showed that the launching effect is of the input but, like other gestalts, the perception is more than what is actually 'there'. Michotte's (1946) research suggests that is it is not the case that anything is added beyond what the event structure prescribes. Rather, it would seem that good continuation input is amplified into ampliation of movement when there is anomaly with proximity that cannot be resolved by the input alone.

If the launching effect is the basis of the idea of force, the perception would normally have to be impervious to individual differences in input, yet be able to extend across a broad temporospatial range. As there is no 'little man in the head' guiding the processes, any optical array that creates a similar anomaly between the streams might lead to amplification of magno input. This may be the reason that we see illusions like Kanisza and Poggendorff and also figure/ground. Given this interpretation, Leslie's (1994) notion of a Michotte module is compatible with Michotte's (1946) theory, in that it still provides a 'direct' perception of launching, and with what the current thesis proposes.

As it has been argued that weak gestalt perception in autism is consistent with reduced magno input, it is imperative to test the launching effect in autism. Reduced magno input should mean that good continuation is difficult to maintain over gaps between the movements of A and B. Therefore, the first hypothesis of the Launching research (Chapter 3) was that the autism group would have a lower pause threshold than the other groups for the change in reports of seeing A *push* B to A *did not push* B.

1.5 Overview of the Research Program

The research program featured three experiments: Illusions, Launching and Temporal Integration. Chapter 2 summarises the Illusions experiment, which measured the illusion effect from the Poggendorff, Muller-Lyer and Brentano displays. The Launching experiment, summarised in Chapter 3, had three parts. The first measured the size of temporal gaps (or pause thresholds) between the movements of objects A and B at which the participants' reports changed from launching to two independent movements. The second measured pause thresholds for the continuity control event that was described above. The third measured spatial thresholds for the tool effect, which is perceived when there is a third object between A and B (Michotte, 1951). Chapter 4 summarises the final experiment where a temporal integration task (Hogben and Di Lollo, 1974) was used to measure the strength of magno processing.

There were 4 groups, Autism, Asperger Syndrome (AS), Mild Intellectual Disability (MID) and Neuro-typical (NT). Participants were at least 13 years old, as Brian and Bryson (1996) noted that there is development that may effect gestalt perception until 13 years of age. No significant effects of age or gender were found in any of the experiments. The lack of a gender effect is important, as there are more males than females with autism and Asperger syndrome. The MID group was included in the research to ensure that weak launching, if it was found in the Autism group, is not a general effect of developmental disability. The Autism and Asperger groups were relatively old and high functioning and should not have found FBT particularly difficult. As such, the participants were not tested on FBT.