INVESTIGATING THE EARLY PERCEPTUAL BASIS OF SOCIAL COGNITION

THE PERCEPTION OF SOCIAL AND PHYSICAL CAUSALITY IN HIGH FUNCTIONING CHILDREN WITH AUTISM

by

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Introduction

This work is about perceptual causality abilities in children with autism: typical adults, children and even 6 months old infants show perceptual causality phenomena in response to at least two types of motion display, launching (Michotte 1946/1963) (figure a) and reaction (Kanizsa and Vicario 1968) (figure b).

Figure a: Launching event. A reaches B, stops upon contact with B while at the same time B moves upon contact. As if A hits B and sets it into motion.

Figure b: Reaction event. A starts moving, after a while B starts moving too therefore the two shapes move both towards the same direction for a while, as if A chases for B while B escapes.

Perceptual causality is in place very early in typical development and it is supposed to allow the infants to learn about the causal structure of the world without the need for previous knowledge or experience, perceptual causality abilities could help infants to parse the visual flow into meaningful parts. It has been suggested that the perception of contact causality (figure a) can promote learning about mechanical interactions of material bodies (Leslie 1988; Schlottmann 1999) and that analogously the perception of non-contact causality (figure b) could promote learning about the social interactions of intentional agents. In this sense, it has been suggested that it would be a precursor to theory of mind (Schlottmann and Surian 1999; Baron Cohen 1991). The early ability to distinguish between physical and social causality would promote learning about the different behaviours of inanimate objects and animate agents.

Perceptual causality in development emerges before other early social behaviours that have shown to be impaired in autism, like response and initiation of joint attention which are believed to be at the basis of later understanding of intentional beings, a problem in reaction
perception could have important effects as well. Thus previous studies have investigated perceptual causality abilities in children with autism principally driven by the idea that perceptual causality could be impaired in autism and that this impairment could concur to later social deficits (Bowler and Thommen 2000). Other studies instead have investigated the ability to individuate the social elements present in schematic more complex animations similar to those used by Heider and Simmel (1944) and to make social attributions (Klin 2000).

Studying perceptual causality in children with autism is of interest also because the ability to extract causality from the spatial and temporal features of schematic animated events could be impaired in this population due to perceptual peculiarities characterising the syndrome. While problems with the perception of reaction events could be related to specific difficulties in the perception of social features and theory of mind, the tendency to process visual information at the local rather than global level especially with short duration events, and problems in rapid attention shifting could give rise to problems in the perception of causal events in general, (Ray and Schlottmann 2007).

An impairment in the perception of causality could be a characteristic of autism since an early age, it could possibly persist during childhood and it could hinder the child’s understanding of mechanical and social interactions and consequently her understanding of the behaviour of inanimate objects and intentional agents. According to this hypothesis a problem in perceptual causality would contribute to produce the social impairments characterising children with autism.

Perceptual causality in autism

Previous studies about perceptual causality in autism have used different methodologies and have come to different conclusions. While some have found no impairment with launch and reaction stimuli but a problem in the verbal description of interactions at a distance in complex animations in a sample of high-functioning children (Bowler and Thommen 2000), others report deficits only in the individuation of the social elements of actions and interactions at a distance in a sample of adolescents and adults (Klin 2000), or in launch perception in a sample of young children (Ray and Schlottmann 2007).

Many methodological differences characterising these studies can account for the diversity in results: the stimuli, the answer procedure used, the design of the experiment, the characteristics of the subjects tested.
There is a great difference between perceptual causality animations (Michotte 1946/63; Kanizsa and Vicario 1968) which are short and simple and represent one interaction at a time, and more complex animations similar to those used by Heider and Simmel (1944) which represent a sequence of various interactions. Either physical and social causality interactions are embedded in longer complex animations that represent multiple interactions between two or three animated geometrical shapes, however simple causal animations produce an impression of causality in the observer, while complex ones can elicit spontaneous attributions of intentions, mental states and emotions to the shapes. Moreover the motion of the shapes involved in simple animations can be defined through a reduced number of parameters (i.e. straight trajectory, uniform speed, continuous motion) and this makes possible to control these parameters in experimental designs in order to understand their influence on the impression of causality, while more complex animations have many parameters to control (i.e. irregular trajectory, variations in speed, discontinuity of motion, animacy features) therefore it is more difficult to understand how each of them influences the impression of intentionality.

Either Bowler and Thommen (2000) and Klin (2000) used a verbal answer procedure and this factor can be problematic. The verbal answer method may not be the optimal procedure neither to assess perceptual causality in children with autism, nor to reveal potential problems with perceptual causality. In fact it has been reported that also typically developing children (5 to 12 years old), in verbal reports, mainly describe launch and reaction events in terms of their spatial and temporal features and not in terms of causal features (Thommen et al. 1998). While on the other hand as we have already pointed out, experimental evidence shows that typically developing preschoolers are able to differentiate these events according to causality when a non-verbal answer procedure is used (Schlottmann et al. 2002). Moreover, since the narrative competence of children with autism is usually related to the cognitive level of the child and to his verbal abilities, and children with autism can tend to give minimal answers instead of complex accounts, a bad performance could be due in part to the answer method used. Verbal responses might not be sensitive enough to reveal potential problems or to assess perceptual causality in children.

On the basis of this evidence, in a recent study, Ray and Schlottmann (2007) investigated perceptual causality in children with autism and mental age matched children with learning difficulties and typical development. In order to reduce the demands of the test and to overcome the language problem, a non-verbal answer procedure was used, the same procedure had been already successfully used with typically-developing preschoolers.
(Schlottmann et al. 2002). The task required the children to watch the stimuli and then choose between three images displaying mechanical causality, social causality or a non-causal interaction. Moreover the experimental design used by Ray and Schlottmann (2007) allows to rule out the hypothesis that the performance of the children is not due to a simple contact/non-contact matching strategy because the design includes non-causal launch and reaction events (where causality is destroyed by means of a temporal gap). The experiment run by Bowler and Thommen (2000) lacked such a control measure, therefore while the results tell us that the children were able to distinguish between launching and reaction events it is not clear if they were distinguishing the two events on the basis of causality or rather on the basis of another criterion. In Ray and Schlottmann’s (2007) study children with autism had an impaired performance in the perception of launching events while their performance with reaction events was in the norm.

These two previous studies about perceptual causality in children with autism have produced controversial results and raised new questions. Bowler and Thommen’s study with the verbal answer procedure and the lack of control stimuli doesn’t provide an ultimate answer to the question of perceptual causality in children with autism as it is not clear if the children were categorising the events according to causality. Ray and Schlottman’s study on the other hand raises some questions about the reasons of the impairment in the perception of launching events. It is not clear if there is a problem with physical causality in general, if the tendency to process information at the local level could affect the children’s performance with launch but not reaction events because of a duration factor of the critical information that is very short in launching but not in reaction events. It could also be the case that since the critical information in launching events is very short lasting, the children could miss it because of an attentional problem. Finally, the different characteristic of the children in the two samples in terms of chronological as well as verbal mental age, could account for the different results. The present study aims to provide an original contribution to the debate. Following a procedure similar to that already used to investigate perceptual causality in young typically developing children and in children with autism (Schlottmann et al. 2002; Ray and Schlottmann 2007), a group of 20 children with high functioning autism and a group of 22 verbal mental age matched controls with typical development was tested on perceptual causality. Each child saw 14 computer animations representing different causal interactions and delayed control events, and matched each of them with one of three pictures representing physical and social causality, and non-causality.
The present study investigates perceptual causality in high-functioning and older children with autism, therefore it allows to observe differences due to age and cognitive functioning, and it reduces the possible influence of mental delay on the performance of the children. Moreover, as already pointed out, the test was designed in order to reduce the verbal demands and to attempt to answer some specific questions raised by Ray and Schlottmann’s (2007) study in which children with autism showed an impairment in the perception of launching events. More stimuli were created and shown to the children in order to address different questions, first of all the “event duration” hypothesis proposed by Ray and Schlottmann (2007) who suggested that the impairment in launch perception could be an effect of the enhanced local processing in short (launching) but not long (reaction or entraining) interaction between the geometrical shapes. Secondly whether children failed to process crucial information because of an attentional problem (through the introduction of an attentional cue), and finally whether they manifested a preference in their interpretation of ambiguous events (combining reaction and launching).

In the present study, like in Ray and Schlottmann (2007) the stimuli involved either rigid geometrical shapes or agents characterised by an animacy feature and this allowed to test if the influence of animacy on the answers of the children differed between the two groups.

The thesis is structured so as to provide the reader with background information about autism, about perceptual causality, and about the relevance of a study of perceptual causality in a population of children with autism, in order to explain the results of the experiment within the framework that originated the experimental research.

Autism

Autism is a developmental disorder characterised by an abnormal development in three domains: qualitative impairments in social interaction, in communication intended as verbal and non-verbal abilities, and restricted and repetitive patterns of behaviour, interests and activities (DSM IV, 1994). Moreover, particular skills in areas such as drawing, music, calculation, and memory are 10 times more common in people with autism than in other people with intellectual disabilities, occurring in about 1 on 10 individuals (Miller 1999).

The study of a developmental disorder like autism leads to important knowledge about mind development and, vice-versa, the study of typical developing children is fundamental to understand autism.

Although it is widely accepted that autism is a genetical disorder that causes dysfunctions in the functioning of the central nervous system, the diagnosis of autism is still
made on a behavioural basis as it is not yet possible to make a diagnosis on the basis of biological correlates, therefore psychological theories and methods of investigation have had a great part in driving the research on the syndrome in the past 60 years (Volkmar and Klin 2005).

Several theoretical approaches have been proposed in order to explain the potential causes of autism and of its wide pattern of symptoms. Among them three approaches have been the most influential ones:

1. the theory of mind account (Baron Cohen et al. 1985; Baron Cohen 1995) that was proposed in order to explain the social and communicative deficits of autism;
2. the executive functions approach (Russell 1997; Ozonoff et al. 2005) that focuses on the rigid and restricted pattern of behaviours and interests;
3. the weak central coherence theory of autism, that tries to explain not only the deficits of autism but also the islets of abilities that characterise the syndrome (Frith 1989; Happé 2005; Happé and Frith 2006).

These three theories were initially proposed as explanations for all the behavioural symptoms of autism in a single core deficit approach. While the first focussed on specific social-cognitive mechanisms, assuming that problems in the social domain are the primary disability in autism, the others studied perceptual and cognitive learning mechanisms with the assumption that the social disability depended on a more generalised impairment (Klin et al. 2002; Volkmar et al. 2004).

The early Theory of Mind account of autism (Baron Cohen et al. 1985) explained the syndrome as the result of the incapacity to meta-represent other people’s mental states such as beliefs and knowledge. In typical development such an ability is considered mature between the third and fourth birthday, while children with autism have been systematically described as having a very low performance in tasks requiring theory of mind. The lack of a theory of mind has been initially proposed as being causative and explicative of autism. However, the recent findings in the research about early diagnosis have shown that infants with autism follow already an abnormal developmental trajectory long before the three years of age and this is not compatible with the view that autism can be caused and explained with a meta-representational deficit (Chawarska and Volkmar 2005).

The term Executive Functions indicates goal directed behaviours like planning, inhibition of responses, flexibility, use of working memory, that are thought to be mediated by the frontal lobes (Shallice 1990). Although early studies on executive dysfunction in autism were relatively imprecise, further work has managed to measure specific executive
processes and their associations with autism (Ozonoff et al. 2005). These studies suggest that not all the executive functions are compromised in the syndrome, in fact inhibitory control and working memory are relatively spared while mental flexibility like in set shifting or in attention shifting appears compromised (Hill and Russell 2002). There is also evidence of significant correlations between executive functions and core symptoms of autism, and important associations between executive functions and other characteristics of autism like theory of mind problems, IQ, language and repetitive behaviour, even if the causal direction and specific nature of this relationships are not completely understood.

Finally, the Weak Central Coherence (WCC) account (Frith 1989) proposed to explain not only the deficits characterising autism, but also its assets. Central coherence is intended as the common tendency to process information trying to extract higher level meaning, at the expense of memory for details; weak central coherence instead is characterised by a focus on details at the expense of global meaning and was proposed as the information processing strategy common among people with autism. Individuals with autism often show a bias for local rather than global visual processing, they don’t benefit from meaning in verbal memory tests, don’t discriminate homographs on the basis of contextual information and show a good performance in tasks requiring segmentation, focus on details, and in which the contextual information can interfere. WCC was initially proposed to account not only for the non social symptoms of autism but also for the theory of mind impairment (Frith 1989). It was defined in terms of a detail-focused processing in which features are perceived and retained at the expense of global configuration and higher level meaning. According to this view theory of mind deficits were considered a consequence of the inability to process social information coherently in order to extract higher level representations of the thoughts underlying behaviour. Frith and Happé (1994) then modified this view and proposed that weak central coherence and theory of mind impairments were independent but interacting manifestations of autism. On the basis of new experimental evidence (Plaisted 2001; Mottron and Burack 2001) the original hypothesis of WCC has been later reformulated in terms of a local bias in processing rather than a deficit in global processing (Happé 2005; Happé and Frith 2006). Peculiarities in the perceptual processing of visual information could influence perceptual causality abilities.

More recently another theoretical approach to the understanding of autism prevails, it focuses on early social motivation. On one hand the hypothesis of a single core deficit and the search for a unique and global explanation for all the symptoms characterising the syndrome doesn’t seem to be compatible with neurobiological and neuroimaging findings that point to
the involvement of broader and developmentally interrelated neural systems (Volkmar et al 2004). Moreover, although the difficulties intrinsic in the process of early diagnosis, the research has shown that very early diagnosis of autism is possible and is fundamental either for research and for treatment, therefore it points out the need for a truly developmental account of the syndrome with the individuation of early skills emerging throughout infancy, that can be linked to later patterns of deficits such as those affecting communication social behaviour and the representation of other’s mental states that become evident during childhood. In fact, it is widely accepted that individuals with autism have an impaired intuitive understanding of their and other people’s mental states (Hill and Frith 2004), but it could still be the consequence of very early and fundamental perceptual and social deficits. A perceptual causality impairment could hinder early social perception experiences in children with autism and contribute to their social difficulties.

The sensitivity to physical and social perceptual causality has been shown in infants as young as six months and it is supposed to have strong developmental influence (Leslie 1982, 1984; Leslie and Keeble 1987; Schlottmann and Surian 1999) as it could help infants to learn about the causal structure of the world in absence of previous experience and causal knowledge. Moreover the early distinction of causal domain could orient the infants in the process of attribution of agency and intentionality, a problem in the perception of mechanical or social interactions involving people and objects would reduce the possibilities to pay attention to causal interactions in these two different domains, and consequently to learn and gain an expertise about specific characteristics and differences of intentional agents and inanimate objects. A difficulty with perceptual causality could characterise infants with autism and it could still be present during childhood or even later. Such a difficulty would mean the lack of a powerful perceptual instrument that normally allows typically developing infants to learn about intentional agents and objects in absence of previous knowledge.

The hypothesis of a problem with perceptual causality is compatible with recent findings about impairments in early social motivational aspects. Recent studies about autism focus on the problems in very early social motivational processes that cause deficits in the orientation towards socially relevant aspects of the surrounding environment and in engagement in social interactions. Abnormalities in the orienting to social stimuli and in social interactions have been found: infants with autism are less sensitive to social stimuli, they are less likely to orient to their mother’s voice, to respond to their name, to follow another person’s eye gaze and to engage in reciprocal interactions (Dawson et al. 2004; Carter
et al 2005). A problem with perceptual causality would contribute to decrease the amount of social information available to the child.

The use of the eye tracking made possible to observe the patterns of attention in naturalistic social situations. This showed that adults and toddlers with autism focus more on non-relevant elements of social scenes, like the background or the mouth region, rather than on highly socially informative ones, like the eyes (Klin et al. 2002; Klin et al. 2005b), moreover Klin (2000) has shown that adults and adolescents with autism have great difficulties in the recognition of the social elements present in complex animations similar to those ideated by Heider and Simmel (1944). These studies reveal the discrepancy between the performance of normative-IQ individuals with autism in solving explicit social cognitive problems and their ability to respond to the demands of everyday social situations.

The lack of sensitivity to social stimuli is supposed to influence the social and linguistic development of children with autism. The developmental process is twofold, on one hand infants with autism are characterised by a lack of sensitivity towards social stimuli, on the other hand this lack of sensitivity limits their experiences and their opportunities to learn about the social world. The research on autism thus benefits much from recent studies in developmental psychology that tell us relevant information about the infant’s mind. Through the habituation paradigm the researchers can investigate infant’s perceptual and conceptual capacity on the basis of attention patterns. For instance, by means of this experimental paradigm it has been possible to gain knowledge about early preferences and abilities characterising very young typical developing infants long before complex social behaviours like joint attention and pointing appear.

Since birth, typically developing infants orient preferentially towards social stimuli like faces and voices (Mehler et al 1978), at three months of age they show sophisticated perceptual abilities like the identification of body movements shown by means of light points (Berthental et al. 1987). Moreover, infants between 6 and 9 months of age are sensitive to higher order features like goal-directedness of human action (Woodward 1998) and perceive goal-direction in the behaviour of computer animated shapes (Gergely et al. 1995; Csibra et al. 1999; Schlottmann et al. 2006).

Perceptual causality

Michotte (1946/1963) defined perceptual causality as a Gestalt property emerging by specific motion patterns and providing an innate foundation for the idea of cause, independent of learning and reasoning. Even if it has not been proven that perceptual causality abilities are
innate as suggested by Michotte, it has been shown that they appear very early during development.

Adult subjects describe the launching event as a collision in which A hits B and sets it into motion, and describe reaction events using goal-directed language, as B escaping from A that is chasing for it (Michotte 1946/1963; Schlottmann and Anderson 1993). Children as young as three can reliably associate animated causal events, with corresponding pictures representing causal interactions, moreover they discriminate the causal domain associating physical causality to the launch and social causality to the reaction events (Schlottmann et al 2002; Watts et al. 2007).

If on one hand the origin and nature of perceptual causality is still object of debate, on the other hand there is agreement on the fact that the ability to perceive causal interactions characterises infants since an early age, and therefore its good functioning could support development and could be at the basis of successive knowledge of the behaviour of inanimate objects and animate agents.

Perceptual causality could allow the identification of events in order to permit a causal analysis without the need for previous experience. The causal domain distinction could orient the infants in their understanding of the domain of object physics and that of social interactions (Ray and Schlottmann 2007).

The perception of causality in the motion display of events like launching and reaction could be assimilated to other early social perceptual skills that characterize typical development and that are believed to be essential for social development since infancy. Perceptual causality in fact allows the perception of socially relevant information: typically developing infants, contrary to infants with autism, naturally orient their attention toward socially relevant stimuli and features and they are particularly attracted by intentional behaviour characterising animate agents, but we also know that infants perceive goal-direction even in the behaviour of non-familiar and non anthropomorphic objects like simple geometrical shapes (Gergely et al. 1995; Csibra 1999; Schlottmann et al. 2006).

Since perceptual abilities are supposed to allow the infants to extract socially relevant information from visual stimuli and to pay attention to it and gain experience and knowledge, vice versa an impairment in perceptual causality would correspond to an impairment in the perception of important information about the behaviour of animate agents versus that of non animate objects.
1 Autism

1.1 Early accounts of autism

The word autism, from Greek autós that means “self”, was initially used by E. Bleuler in 1911 to indicate the extreme withdrawal from the social world characterising schizophrenic patients. Thirty years later, almost at the same time but independently one of the other, Leo Kanner in 1943, in Baltimore and Hans Asperger in 1944, in Vienna, utilised the same term to describe some of their patients.

In his paper Kanner describes the characteristics of 11 children whose condition differs so markedly and uniquely from anything reported so far, that each case merits [...] a detailed consideration of its fascinating peculiarities (Kanner 1943).

Kanner recognised that although the high degree of variability the children observed presented many characteristics in common, therefore he suggested to consider autism as a unique syndrome. Most of his acute observations are still actual and some of them are at the basis of the contemporary diagnostic criteria for autism.

The American psychiatrist individuated the fundamental characteristics of the syndrome and suggested that autism affects children since birth. He recognised and described the social withdrawal that characterises every child with autism, the desire for sameness, the attachment to daily routines, the repetitiveness, and the communicative and linguistic deficits, the scarce interest in people and social interaction and the infrequent spontaneous eye contact.

He, described the communicative problems in spite of excellent rote memory and the presence of the capacity to articulate, learn and repeat words (echolalia), he also noted the scarce flexibility in the use and in the prosody of language and the pronoun reversal problem. Finally he reports that some of the children were completely non verbal. Another important observation was the sensitivity to loud noises, or as we would define it nowadays a sensitivity to excessive sensory stimulation of different kind, not only auditive.

In 1944 Hans Asperger a Viennese paediatrician (independently from Kanner) described a group of patients showing symptoms that resembled those described by his American predecessor, for instance both of the authors used the word autism to describe the children’s difficulties in social interaction.

Moreover Asperger hypothesised that this pathological condition affected only males, that it relatively spared language and cognitive skills, and that it was hereditary. Among the
characteristics identified by Asperger there were the impairment in non verbal communication, the idiosyncrasies in verbal communication, uncommon idiosyncratic interests, the intellectualization of affect, marked by poor empathy, and absence of intuitive understanding of other people’s affective experiences. Moreover, clumsiness and poor body awareness, the conduct problems like aggressiveness and non compliance and finally an onset that could be not recognised in early childhood.

The main difference between the children observed and described by Kanner and by Asperger was that while both authors described children with low ability and poor language, Asperger observed also patients that presented high intellectual abilities and a precocious acquisition of language. In this sense the cases reported by Asperger reflected better the wide spectrum of autism (Wing 2000).

A recent retrospective analysis of 74 clinical case records of children diagnosed by Asperger between 1950 and 1986, verified that the children in the sample represented a restricted subgroup with very high intellectual functioning, circumscribed interests and talents, but with impairments in communication, social development and motor skills, 68% of the sample met ICD-10 criteria for Asperger Syndrome, while 25% responded to the diagnostic criteria for autism (Hippler and Klicpera 2004).

The term Asperger syndrome became more popular after Lorna Wing’s paper (1981), that introduced Asperger’s theories to the English-speaking world. The main heredity left by Asperger consists maybe in his insights about the importance of understanding autism and the Asperger disorder in order to educate these children appropriately, and in the conviction that Asperger individuals could be successful in their professions and of high value to the society (Frith 2004).

1.2 Diagnosis and definition of autism

Pervasive Developmental Disorders (PDDs) or Autism Spectrum Disorders (ASDs) are a group of five neuropsychiatric disorders composed by Autism, Asperger Syndrome, Pervasive developmental disorder NOS (non otherwise specified), Childhood Disintegrative Disorder, Rett Syndrome (DSM IV). Although the inclusion of Rett Syndrome in DSM IV was the object of some debate because of its slight relation with autism, all pervasive developmental disorders (PDDs) have in common a series of phenomenological features, namely a pattern of both delays and deviances in multiple areas of development, an onset in the first months of life, an association with mental retardation, delay or impairments in language acquisition.
Autism is a developmental disorder caused by one or more congenital alterations of the development and functions of the brain, it is a behavioural syndrome, reflecting a neurological deficit due to different medical aetiologies.

After sixty years there has been a great increase in research and knowledge about autism, its causes, its etiology, the genetical basis of the disorder, but many questions remain still unsolved.

For instance it is well established that the disorder has a genetical origin. Taking a narrow definition of autism, if one of the twins in a monozygotic couple has autism, then in 36% of cases the other twin has it too, but with a wider definition, the concordance rate is 90% for monozygotic twins and 10% for dizygotic twins (Hill and Frith 2004; Bailey et al 1995), though autism can’t still be diagnosed on the basis of genetical markers. Moreover, in most of patients with autism the structure of the brain (with the exclusion of some particular condition like tuberous sclerosis) is normal, the disorder is therefore invisible to neuro-images as it pertains to the level of the functional organisation of the brain. Consequently, in spite of the important progresses in the process of knowledge of the syndrome, the diagnosis of the autistic disorder is still made exclusively on a behavioural basis.

Consensus on autism as a diagnostic category has been reached relatively recently with the convergence of two major diagnostic systems, the fourth edition of the Diagnostic and Statistic manual of mental disorders (DSM IV, APA, 1994), and the tenth edition of the International Classification of Diseases (ICD-10, WHO, 1993), this has brought to international guidelines for the diagnosis of autism which is now considered the developmental disorder with the best empirically based, cross-national, diagnostic criteria (Volkmar and Klin 2005).

Autism causes several impairments in three domains: social interaction, verbal communication and stereotyped and reiterative behaviours (DSM IV).

The impairments in social interaction comprehend the inability to use eye contact, facial expressions and gestures in order to regulate the interaction with other people, an abnormal interaction with peers, the lack of initiative and response to sharing of attention, the lack of sharing of interests or pleasure with others, and the inability to understand others and have social reciprocity with them.

The communication problems concern verbal language, that can be absent and accompanied by the lack of attempts to compensate with gestures. Even when language is present, there is scarce initiative and inability to sustain the conversation, verbal children take part in the conversation in inappropriate or awkward ways, the language used can be
repetitive, echolalic or there is an idiosyncratic use of words and phrases that result inappropriate to the context and that are difficult to understand for people who are not familiar with the child.

The play behaviour is abnormal both in the absence of the social component of imitation that in the lack of make-belief play. Some of the children with autism engage in spontaneous symbolic play but even in this case their play lacks creativity and flexibility and it is usually not coordinate in a social way with other children.

The repetitive, restricted and stereotyped interests comprehend the preoccupation with abnormal activities or objects. Many children with autism have restricted and stereotyped interests such as spinning things or playing with laces, these behaviours are merely linked to self-stimulatory sensory needs. The more cognitive able children can have fixations for special subjects like cars, cartoon characters, or soccer players at the point that they can become real experts and talk persistently about these same topics. These interests are uncommon both in their focus and in their intensity and they can last for long.

The repetitiveness of behaviour is associated also to a strong attachment to daily routines or rituals both in the organisation of the environments and in the daily schedule of activities. Moreover children with autism show often a persistent preoccupation for parts of objects and stereotyped, repetitive motor mannerisms such as hand flapping, jumping and finger flicking.

The focus on detail, and a restricted and repetitive pattern of activities can be partially due to perceptual and sensorial characteristics present in autism. People with autism experience the world in a different way and this emerges either in their auto-biographical accounts (Grandin 1996) and from experimental results. The differences concern either the sensorial and the perceptual level. There can be hyper or hypo sensory sensitivity, and these features are reflected in avoiding or in the active seek of particular stimulations (Koening et al. 2000). In case of vestibular hyposensitivity the child can actively search for an extra-stimulation by spinning around or rocking. Vice-versa a tactile hypersensitivity will produce a general intolerance for stimuli like a itch caused by a certain fabric or a hug. Moreover there can be very often a problem with sensorial integration, this can be at the tactile (sensations like pain, temperature and pressure), vestibular (balance and head position) or proprioceptive (awareness of the body’s position) level. The integration of these sensorial systems is fundamental for the survival of an organism. Another sensorial feature is sensory overload due to the inability to process the amount of information that comes from the environment, for instance in a crowded situation the presence of both continuous movement (visual
stimulation) and sound (auditory stimulation) can produce an overload that can cause a temporary shut-down of the sensory system. Moreover some individuals with autism can have difficulties in filtering different information coming through one sense like in distinguishing a conversation from the noise in the background, while others can find it difficult to perceive simultaneously auditory and visual information like for example in listening to a person talking while seeing her at the same time (Grandin 1996).

The diagnosis of autism and the other PDDs is now greatly standardised and the identification of the defining deficits of the syndrome is easier thanks to the agreement between DSMIV (APA, 1994) and ICD10 (WHO, 1993) for autism and most of the autism-related categories, and to the standardized diagnostic methods such as the ADI-R (Le Couteur, Lord and Rutter, 2003) and the ADOS (Lord et al. 1999) that offer the possibility to quantify diagnostic characteristics allowing great progresses in the research.

However, one of the main problems concerning autism is the difficulty of early diagnosis. Although the strong progresses in diagnostic tools, it is difficult to diagnose children under the first three years of age in case of classic autism (often defined also Kanner Autism), and paradoxically even later for less cognitively impaired forms of autism (High functioning autism or Asperger Syndrome), especially in verbal children, as the presence of good language skills can mask the social disabilities during early childhood.

The individuation of infants and very young children is also difficult because many of the criteria already present in diagnostic systems originated from the observation of children older than three and are less adapt to the diagnosis of younger children. Moreover, many of the deficits become more evident and are better perceived by the parents, as well as by the paediatrician and the teachers as the child enters kindergarten and is exposed to a prolonged contact with peers, but it can take a considerable amount of time before the child receives a diagnosis (Carter 2005).

Although mental retardation is not universally present in autism, autism is strongly correlated with mental retardation. The cognitive functioning of individuals with autism can be thought on an ideal continuum. The extremes go from high mental retardation in the 70% of the cases, a 50% of which has an IQ<35, to a normal or even higher than normal level of intelligence (Lord & Schopler, 1989). The cognitive profile of individuals with autism is usually characterised by a disharmony in the levels of the various abilities. Furthermore, the syndrome is characterised by an high frequency (1 on 10) of special abilities, the so-called ability islets, like drawing, visuo-spatial imagination, calculus, processing of details in a context (Happé 1999).
The autistic disorder is characterised by an high variability in terms of severity of the symptoms both among different individuals, and in the same person during a life-span.

This high variability makes autism particularly difficult to define in diagnostic terms, and if on one hand the definitions of the DSM-IV and of the ICD-10 constitute certainly very important steps towards an international agreement and standardization of the definition of the syndrome, and provide important guide-lines for diagnosis and research, they are still strongly debated and criticised.

As Autism is part of a spectrum of disorders it becomes very important to define the boundaries that allow to discriminate between the various conditions of the spectrum. Among the main sources of current debate are the individuation of subtypes of the syndrome and the diagnostic definition of very similar conditions, like higher functioning autism (HFA) and Asperger Syndrome (AS). Children with Asperger Syndrome share the key symptoms of autism but they can differ in terms of higher cognitive and language abilities. The label high functioning autism refers to an higher cognitive level, accompanied by problems in language acquisition early in life. Generally children with a good cognitive functioning and language are frequently less isolated from other people (Prior and Ozonoff 1998).

1.3 Asperger Syndrome

Asperger syndrome (AS) first official recognition is in the DSM IV (APA 1994), where it was included as one of the PDDs.

It’s inclusion in the DSM-IV derived from some degree of evidence that it could be differentiated from the condition of HFA (higher functioning autism – or autism without mental retardation).

Asperger syndrome, is closely related to autism and PDD-NOS, together these disorders form part of the continuum of autism spectrum disorders (ASDs). Although Asperger and autistic disorders have two distinct diagnostic definitions they are very similar conditions, therefore the continuity of Asperger syndrome and autism is still a topic of debate. The nosological status of Asperger syndrome is not clear, in part because of the adoption of varying diagnostic schemes in the research literature, and because of the significant limitations of the DSM-IV definition (Miller, Ozonoff 1997).

Frith (2004) presents the possibility that Autism and Asperger syndrome could have the same aetiology, this hypothesis is in fact supported by three types of evidence, genetic, in
the outcome and neuro-anatomical. The genetic evidence is based on the fact that Asperger syndrome and autism may occur in siblings, this signals the possibility that the same genetic predisposition gave rise to both disorders. It would mean that the biological cause could be similar even if the disorders can have very different manifestations. There are moreover analogies in the outcome as older Asperger and HFA individuals tend to become very difficult to distinguish from each other. For instance Howlin (2003) found that individuals with HFA and with Asperger syndrome were really similar in their outcomes in terms of language comprehension, and cognitive functioning. Furthermore Frith underlines that in autism and in Asperger syndrome there are neuro-anatomical similarities at the level of mini-columnar organisation. According to these facts the Asperger disorder would be in strong continuity with autism, even if situated at the milder end of the spectrum.

The inclusion of AS in the DSM-IV was intended as a common starting point for research, but this definition has been often criticised as overly narrow, and making the diagnostic assessment of AS improbable if not virtually impossible (Klin et al. 2005; Howlin 2003).

Although the diagnostic criteria for AS are still evolving, the “official” definitions provided in the ICD 10 (WHO, 1992), and in the DSM-IV (APA 1994), distinguish it from autism on the basis of relative preservation of linguistic and cognitive capacities occurring in the first three years of life, which often means the use of words by 24 months of age and phrases by the age of 33-36 months as specified in the ADI-R, (Howlin 2003) and on the precedence rule that excludes individuals from having Asperger syndrome if they have ever met diagnostic criteria for autism (Volkmar et al. 2004).

However, both in practice and in research studies, AS has been used to refer to individuals with different manifestations of the ASDs, including autism without mental retardation (HFA higher functioning autism), forms of autism characterised by higher cognitive and linguistic abilities, and more socially motivated even if socially vulnerable adolescents and adults with odd and socially interfering restricted interests. In spite of the agreement about the definition of Asperger syndrome in the diagnostic manuals, there are many more different definitions of Asperger syndrome, which are difficult to operationalize and have probably little agreement with each other (Volkmar et al 2004). The use of the term Asperger Syndrome has originally been justified to bring more attention to individuals with autism with higher verbal abilities, or to less disabled but still socially inadequate individuals, with a good cognitive level and a learning style disposed towards technical knowledge or skills (Wing, 1981; 2000).
The nosological status of Asperger Syndrome as a discrete condition separate from autism is far from being certain (Frith 2004; Volkmar & Klin, 2000). Autism and Asperger syndrome don’t have the same level of detail and diagnostic description. The description of the two disorders is not comparable in terms of behavioural features and early history, the diagnosis of Asperger syndrome is actually an afterthought that is applied only when the diagnosis of autism is not apt to define the child and this is seen as a limitation (Volkmar et al 2004).

Nevertheless researchers and clinicians consider AS an early-onset social disability that impairs the capacity to be independent in everyday life. Asperger syndrome can be considered either as a disorder entirely separate from autism, or as a variant of the same disorder, but in any case Asperger syndrome is not a mild disorder. Having a diagnostic label independent from autism can be useful as it allows to distinguish verbally and more cognitively-able children, this allows to provide an adequate education to these individuals that can be able to study, have a job and live near to normal lives (Frith 2004; Grandin 1996).

Differently from children with autism, children with AS don’t show clinically significant delays in language acquisition, cognitive development, or self-help in the first years of life. Actually, language acquisition, in terms of vocabulary and sentence construction may be precocious in some cases, and parents may even report that their child begun to talk before learning to walk. However, vocabulary acquisition may be unusual as these children may learn complex or adult-like words, (typically associated with a special interest), prior to learning more typical, child-like vocabulary usually associated with social play. Parents report a pedantic quality of the speech of the child, in terms of the choice of words, in sentence construction, in the tone of voice (often defined informally as similar to that of a small teacher).

These children seem more incline to orient to others, although they use others more instrumentally than reciprocally. For instance the child uses other people to speak to them rather than truly engage in a shared interaction. The social disability is more evident when the child is outside the home environment, particularly in situations that involve the contact with peers. For instance, as children with Asperger syndrome have usually a good language competence, good cognitive skills, and seek the contact with others, their parents and relatives can perceive them as “bizarre”, but the differences emerge especially as the child enters the kindergarten. Children with Asperger Syndrome have usually a social initiative and seek the contact with others, but they usually approach others in inappropriate or awkward ways.
1.4 Asperger Syndrome (AS) and High Functioning Autism (HFA)

The label *Asperger syndrome* emerged in order to distinguish it from *autism without mental retardation*, but the question if these two conditions should be considered as the same or distinct is still debated, and different studies suggest different conclusions.

As already observed, some studies support the idea that individuals with HFA tend to have greater impairments in language and verbal comprehension, while exhibiting relative strength in non-verbal areas. Several studies have empirically demonstrated significant distinctions between these two groups.

In one study (Klin et al. 1995), a group of individuals with AS and HFA matched for chronological age and IQ were compared in several domains of neuropsychological function. Individuals with AS exhibited a significant Verbal IQ to Performance IQ differential with stronger verbal abilities, while individuals in the HFA group tended to have comparable verbal and performance abilities.

11 areas of ability were shown to discriminate between the two groups. Some neuropsychological skills represented areas of strength in AS and weakness in HFA, and the converse was true for other domains of ability. While six areas of psychological deficit were associated with a diagnosis of AS: fine and gross motor skills, visual motor integration, visual-spatial perception, nonverbal concept formation, visual memory, other Five areas of psychological deficits were negatively correlated with a diagnosis of AS, namely: articulation, verbal output, auditory perception, vocabulary, and verbal memory.

All but three subjects with AS had a neuropsychological profile consistent with a *non-verbal learning disability* In contrast, only one subject in the HFA did so. These results indicate an overlap between AS and non-verbal learning disability but not between HFA and non-verbal learning disability, suggesting an empirical distinction between AS and HFA based on neurocognitive profiles.

Another study comparing results on an intelligence test across groups with AS and autism (Ehlers et al. 1997), found that individuals with AS exhibited stronger verbal abilities with a weakness in subtests measuring visual-spatial organization and grapho-motor skills (WISC-R object assembly coding subtests). In contrast, individuals with autism displayed an isolated skill in the Block design subtest, a measure of visual *parts-to-whole* reasoning.

Lincoln and colleagues (1998) carried out a meta-analysis of several studies addressing neuropsychological profiles differentiating AS from HFA. The results indicated that individuals with AS showed a pattern of stronger Verbal IQ relative to the Performance
IQ. In contrast, individuals with HFA exhibited the reverse pattern, with stronger non-verbal abilities and weaker verbal skills. The authors concluded that autism is characterised by impaired verbal skills, which are intact in AS.

Miller and Ozonoff (2000) also compared groups with HFA and AS obtaining similar results: the AS group had higher VIQ and Full-scale IQ and exhibited a greater difference between verbal and nonverbal abilities (verbal abilities were stronger). This study observed also better visual-perceptual skills in individuals with AS.

Although Asperger Syndrome has its place as a distinct disorder among the others in the spectrum, it is still described as a variant of autism, typical of high-functioning individuals, and not as a truly separate disorder (Frith 2004). One of the problems is that the impairment in social communication might be difficult to identify in infancy, and it could be still covert by compensatory learning in adulthood. Moreover, experimental evidence suggests that Asperger individuals although socially impaired in their ability to intuitively gain knowledge about other people’s mind, can still acquire an explicit theory of mind.

Klin et al (2005a) examined the research implications of the use of three competing systems for the diagnosis of Asperger syndrome, and demonstrated that the comparison across studies using different diagnostic systems for the syndrome is virtually impossible as the different systems have very poor agreement one with the other. Moreover the authors of the study claim that from the comparison of the IQ levels it emerges no significant difference across diagnosis in the three diagnostic schemes and therefore Asperger syndrome can’t be considered as an high-IQ variant of autism. However the differential between VIQ and PIQ was significant in the comparison between autism and AS. Confirming the result already reported (Lincoln et al 1998; Klin et al 1995).

1.5 Psychological theories about autism

To date, genetic and structural brain findings have not been specific enough to allow consistent progress in the knowledge about neural or psychological systems involved in autism. The individuation of genetic markers is still a long term goal, but in the future it will certainly inform the debate on affected neural mechanisms which will eventually constrain the discussion of psychological constructs involved in the pathogenesis (Volkmar et al. 2004).

Having models of autism resulting from the integration of knowledge about genetic, brain research and behavioural studies is still a goal for the future. However the psychological
models of core deficits of autism are very important for the search for factors involved in the etiology and development of the disorders of the spectrum.

The search for core psychological factors has been required by the lack of established etiologic factors and psychological features are essential in order to diagnose autism. Furthermore, so far no specific biological markers are known and psychological features are fundamental as they can be used as heuristic models for neuroimaging research, and as group phenotypes in genetic research.

Early psychological research from the origins to the ’70 (i.e. Hermelin and O’Connor 1970) has focused on disruptions of symbolic and conceptual development in autism. The following research has been oriented to the study of specific social cognitive mechanisms, inspired by the hypothesis that the primary disability of autism concerned the social domain. On the other hand it has tried to study more general perceptual and cognitive learning mechanisms with the alternative assumption that the social disability could be just an instance of a more generalised learning impairment (Volkmar et al 2004; Happé 2006).

Several psychological models have reached a prominent position in the field since the early 1980s. The prevailing tendency until recently has been that to construct a theory adapt to explain all the symptoms of the syndrome in a “single core deficit” framework. However to date none of the theories proposed can adequately account for the whole triad of symptoms. The three main theoretical approaches have explained the social symptoms of autism either as the origin for all the problems observed in multiple developmental domains, or as a result of deficits occurring in another developmental domain. Social accounts of the syndrome are not adequate to explain the non-social symptoms, and vice-versa non social accounts can hardly explain the social symptoms. Such models were built around the constructs of “theory of mind skills”, a cognitive drive for “central coherence” and a group of neuropsychological skills that are identified with the term “executive functions”. More recently the research about the social aspects of the syndrome is based on an approach centred on the hypothesis of a deficit in early social motivation (Dawson et al. 2004). This approach is linked to research about the precursors to theory of mind like gaze following, joint attention, pointing (Mundy et al. 1995; Charman 2003) and to research on face processing (Schultz et al. 2005). On the other hand the Weak central coherence theory has been revised (Happé and Frith 2006) and new hypothesis about enhanced local functioning, rather than problems in global perception, have been formulated on the basis of new experimental findings (Mottron et al. 2006).

Investigating perceptual causality in autism has implications either for theories focussed on the social deficits and for those on perceptual aspects. Distinctive predictions
have been made on the basis of these different theories however previous work on perceptual causality in subjects with autism has produced controversial results.

**Theory of mind**

The dominant theory in the field of social development in autism has been for a long time the “theory of mind” hypothesis. Theory of mind interprets autism as a consequence of dysfunctions in the social domain. According to this theory the social deficit in autism is due to the disruption in processes that should lead to the acquisition of the capacity to conceive other people’s and one’s own mental states (Baron Cohen, Leslie, Frith 1985; Baron Cohen 1995).

In their seminal paper Baron Cohen, Leslie and Frith (1985), suggested a developmental model of meta-representation with the purpose to explain the social impairment affecting children with autism. They claimed that children with autism had a specific impairment with a basic meta-representational capacity called “theory of mind”, (following Premack and Woodruff 1978), intended as the capacity to meta-represent other people’s mental states. The lack of pretend play, common among young children with autism, was seen as an early sign of the incapacity to form second order representations *decoupled* from reality (Leslie 1987).

The classic theory of mind test (since Baron Cohen et al. 1985) is the False Belief test or Sally and Anne test. In this test the child has to attribute a belief to a character in the scene. Particularly the character has a “wrong” belief due to a lack of knowledge about a changing occurred in the environment during her absence. The plot is generally the following: there are two characters i.e. Sally and Anne, one object and two possible positions for the object. Sally puts her marble in the basket and goes away, when she is not there Anne puts Sally’s marble in the box. The child has to figure out where Sally is going to look for her marble when she comes back.

The child has to predict where Sally will search for her marble given that she doesn’t know that Anne changed its position, therefore he has to attribute a false belief to Sally. Several replications of this test, and several variants made on its basis (i.e. Perner et al. 1989; Perner et al. 1987) have brought to claim that four years old children with typical development pass the test without any difficulty, while three years old children don’t (Wimmer and Perner 1983).

In the first study of 1985, the 80% of the children with autism with a mental age of at least 4 years of age wasn’t able to pass this same test, by contrast 86% of the children with
down syndrome, with similar cognitive level, was able to pass the test. Successive studies have attributed the poor performance of younger children to limited processing resources rather than to a conceptual problem. Vice-versa the scarce performance of children with autism was attributed to a deficit in a domain specific cognitive mechanism dedicated to the development of folk psychological notions (Leslie and Thaiss 1992; Surian and Leslie 1999). This strong result brought to the conclusion that the deficit in the meta-representation of mental states was specific to autism.

Other evidence of the difficulty of children with autism with the attribution of mental states came later from reports of a reduced production of mental state terms in the spontaneous speech and in verbal descriptions of stories (Baron-Cohen et al. 1986; Tager-Flusberg 1992), in the recognition of mental state terms (Baron Cohen 1994), and in the scarce understanding of pretence, deception and figurative speech like jokes, metaphors and sarcasm (see Baron Cohen 2000 for a review).

The hypothesis of a modular system for understanding agents and mental states was later formalised separately by Leslie (1994) and Baron Cohen (1995).

Leslie (1994) talks about a domain specific processing stream that has the function to understand the behaviour of agents. He names the highest module of the hierarchy ToMM2 (Theory of mind mechanism2). It is the module that interprets the agents’ behaviours in terms of mental states, while ToMM1 is the second module that has the function to encode the agent’s actions in terms of goals. The third basic element in this tripartite theory of agency is the ToBy (theory of body mechanism) which is the seat of the child’s theory of physical bodies. The system corresponds to a hierarchy of separate modules in which each level corresponds to a separate subsystem necessary to understand agents at different levels, and only the last module is concerned with the representation of the agent’s mental states and how they produce the agent’s behaviour.

Baron Cohen (1995) proposes an alternative hierarchy that he calls the mindreading system and is composed firstly by the ability to recognise agents on the basis of their movement and to attribute them goals and desires (ID-intentionality detector). Secondly there’s the ability to understand that the eye gaze links the agent to an external thing and that the gaze corresponds to seeing (EDD-eye direction detector). Through ID and EDD the agents can construct dyadic representations of the link between an agent and something else. Finally there is the ability to share one’s own focus of attention with other people, (SAM, shared attention mechanism). This step corresponds to the capacity to conceive triadic
representations of two agents attending to the same thing. Finally the process terminates with Leslie’s ToMM2 that Baron Cohen simply calls ToMM.

The system proposed by Baron Cohen is supposed to be modular and to develop hierarchically. In this hierarchy the last components gather input information from the output of the preceding ones, and the system is also divided into developmental phases. From birth to 9 months the infants possess ID and EDD. They are able to individuate agents (on the basis of self propelled motion) and attribute goals and intentions to them, moreover they can monitor another person’s eye gaze and know what she is looking at. In the second phase from 9 to 18 months the children develop SAM and acquire the ability to make triadic representations that make joint attention possible. This stage is similar to what Trevarthen (1978) calls “secondary intersubjectivity”. Finally in the third phase from 18 to 48 months ToMM develops and is preceded by the capacity to engage in pretend play. At this point the child is able to build meta-representations of his own and other’s mental states.

While Leslie (1994) doesn’t specify which parts of his modular architecture are supposed to be compromised in autism, (we can hypothesise that he thought of only the ToMM2), Baron Cohen (1995) claims explicitly that SAM and ToMM but not ID and EDD are disrupted in the syndrome.

According to the theorists of the theory of mind model of social development, the abilities of theory of mind, intended as the capacity to attribute mental states such as beliefs, intentions and desires to other people and to the self and to interpret behaviour accordingly, is a cognitive mechanism at the basis of social interactions.

The lack of a theory of mind has been originally proposed to be causative and universal in autism, being responsible for the social and communicative deficits characterising the syndrome, as well as for the lack of pretend play and the pragmatic problems. Baron Cohen (1995) has provided an account of autism as mindblindness, the inability to represent mental states.

Several critics have been moved to the validity of the Theory of Mind tests as measures of the social abilities of children with autism. For instance, the fact that a failure in these tasks is not specific for autism and that it is strongly associated to the general linguistic and cognitive level of the child (Happé 1995). Language is supposed to be an important variable influencing also the performance of young typical developing children in theory of mind tests. In fact the representation of mental states is encoded in mental verbs, but also in the syntax of complementation that is used with these verbs. As a consequence if the child doesn’t master the connection between syntax and semantics of mental states verbs and of
their arguments he would not be able to interpret the embedded proposition in a sentence like *Sally thought the marble was in the basket* (deVilliers and Pyers 2002). In addition, there is evidence that theory of mind skills even when explicitly taught to children with autism don’t improve the child’s capacity to interpret other people during real life situations. Finally, the main critic to theory of mind tests comes from the fact that many individuals with autism are able to pass false belief tests in spite of their difficulties in real life social competence because in false belief tests the problem is presented in a totally explicit fashion that has not much in common with the complexity of everyday life social situations (Klin 2000).

Critics to the theory of mind hypothesis as causative of autism come instead from the fact that children with autism show social disabilities that precede even the earliest precursors of theory of mind skills such as joint attention, therefore the lack of ToM could still be the consequence and not the origin of early and basic social disabilities (Klin et al. 1992).

Thus the practice of ToM testing through false belief and similar tasks has proven not to be reliable. But in spite of the critics, it is widely accepted that individuals with autism have an impaired intuitive understanding of their own and others’ mental states (Hill and Frith 2004). Therefore there’s the need of new explicative models and of new ways to assess the capacity to make social attributions in autism.

A main problem is represented by the discrepancy between the good performance of individuals with autism in explicit tasks of social reasoning, where all the elements are presented verbally, and their poor performance in everyday social situations, when they need to use spontaneously their social reasoning abilities to make sense of the continuous flow of social information. One of the possible explications for this discrepancy is thus in the difference between the nature of these two tasks (Klin 2000).

On one hand the deficit in implicit social reasoning is universal among individuals with autism with different degrees of severity, on the other hand, especially those individuals with an high cognitive level can solve complex, but explicit, social reasoning tasks. This implies that it is possible to teach better social reasoning skills to these individuals but this explicit teaching may have little impact on their social-communicative abilities in everyday life (Ozonoff and Miller 1995). Also high functioning individuals like Temple Grandin acknowledge this problem in their autobiographical accounts, confirming the fact that even if they have been able to acquire an explicit theory of mind, they still lack the intuitive mentalising ability required by the normal process of communication (Grandin 1996).
Executive functions

The executive function theory represents an attempt to explain autism as being in part the result of developmental consequences not affecting directly the social domain.

Problems with executive functions have been observed both in individuals with autism and their family members across many ages and functioning levels (Ozonoff et al 2005).

Executive functions are high level functions necessary to control goal-directed behaviour like movements, planning and monitoring of actions, inhibition of responses, self-monitoring and use of working memory. They are supposed to be localised in the frontal lobes of the Brain (Shallice 1990).

Some of the behavioural problems of children with autism can be explained through the theory of the executive function deficit. The EF theory aims to explain the restrictive and repetitive interests, the scarce initiative of new actions, the tendency to get stuck in “set shifting” tasks, and the attachment to the routines.

The earliest study about executive functions in autism was that of Rumsey (1985) who administered the Wisconsin card sorting test (WCST), a measure of cognitive flexibility, to adults with high functioning autism, finding a significant tendency to perseveration. A study with the WCST was later made also with children (Prior and Hoffmann 1990), like adults the children made more perseverative errors than controls.

However the tasks used in early studies of executive functions in autism were imprecise as they usually measured several executive operations at a time with no possibility to analyse the variance in individual skills.

For instance the WCST which is supposed to be a measure of cognitive flexibility requires also the ability to discriminate among stimuli and to categorise them according to abstract principles. It requires to use working memory, to sustain attention, the inhibition of previously reinforced answers and to use verbal feedback to change behaviour, therefore a poor score on the WCST could be due to the malfunctioning of one or more of these cognitive operations.

Further work has been more precise and suggests that inhibitory control and possibly working memory are relatively spared functions in autism, while mental flexibility of a variety of types like set shifting and attention shifting appear compromised (Hill and Russell 2002). Rigidity and perseveration are symptoms analogue to those of patients who have had an injury in the frontal lobes, moreover deficit in executive functions characterise also
Schizophrenia and Tourette Syndrome, but the problem in action planning and “set shifting” is supposed to be typical in autism and it is at the basis of the perseveration problems (Russell 1997).

Abilities mediated by the frontal lobes include processes such as concept formation and inferential reasoning. The EF system coordinates the behaviour allowing the use of cognitive abilities in a variety of contexts and flexibly. Considering for instance the conversational rules and the context in which every conversation takes place, it seems plausible that an intact EF system should be necessary in order to feel the motivation necessary to engage appropriately in social interaction and communication. Engaging in a conversation with another person requires reasoning abilities, working memory, planning, the ability to shift attention and sensitivity to the changeability of the context. These abilities can lack because of an EF deficit (Surian 2002).

However, later studies have shown that the EF deficit is not a core deficit in Autism, and as a consequence it seems unlikely that it can explain or be at the origin of the symptoms of the syndrome and especially of the social problems. Besides that EF are observed in many other disorders (Pennington and Ozonoff 1996) and there is not a straightforward correlation between EF and the degree of social impairment (Ozonoff et al 2005).

Yet, EF can have a fundamental role for language and the communication abilities especially in the process of inference of meaning from the context.

**Weak central coherence**

The weak central coherence (WCC) account has been originally formulated (Frith 1989) to explain both the deficits and the assets of autism as originating from the difficulty to integrate information in meaningful wholes.

At the basis of the WCC theory there are those behaviours that can be interpreted as striking abilities. Among them there are not only the renown areas of excellence like drawing, music or calculus that occur about in 1 on 10 individuals with autism (Miller 1999), but also skills like making puzzles, or being distressed by minute changes in a familiar room, a behaviour that reveals the presence of an unusual attention and memory for details.

The non social features of autism are characterised by strengths and weaknesses and they have been less understood and studied than the social aspects of the syndrome. The insistence for sameness and a restricted repertory of behaviours coexist with an uneven cognitive profile characterised by excellent rote memory, visuo-spatial construction and
attention for detail, but also low level performance in common sense, strategic task planning and working memory (Hill e Frith 2004).

Central coherence was the term used by Frith to indicate the everyday tendency to process information in order to obtain meaning and global form at the expense of details. Such a tendency was defined as “drive for meaning”, by Bartlett (1932) who showed how people retain the essential meaning of a story, while the surface form is quickly forgotten. Frith proposed that the drive for central coherence was disturbed in autism and that instead people with autism process details at the expense of global meaning.

The WCC account predicts a good performance on tasks that require attention to local elements, and a bad performance on tasks requiring the recognition of global meaning or the integration of stimuli in the context.

The theory was based on empirical evidence that showed good local processing and impaired global processing at various level, namely the verbal-semantic one, the visuo-spatial construction one and the perceptual one.

At the verbal semantic level the first evidence came from an old study demonstrating that people with autism didn’t show the usual benefit from meaning in memory tests (Hermelin and O’Connor 1967): while control subjects recalled sentences better than unconnected word strings this advantage was diminished in autism. Frith and Snowling (1983) used homographs, (words with one spelling but two pronunciations and two meanings) to examine the use of the sentence context in the discrimination of meaning, finding that either adults and children with ASD failed to use the contextual information to decide how to pronounce the homograph.

The demonstration of WCC at the visuo-spatial construction level was demonstrated on the basis of the observation of the superiority of people with autism in the Wechsler block design task (figure 1). Shah and Frith (1993) showed that such a well documented facility is due specifically to segmentation abilities, in fact while typical developing controls took advantage from the pre-segmentation of the global configuration, individuals with autism did not. This fact was interpreted as the demonstration that the latter processed already the figure in terms of the constituent blocks without the need of pre-segmentation. Individuals with autism excel also in the embedded figures test in which a small shape must be found within a larger design (Shah and Frith 1983; Joliffe and Baron Cohen 1997).

WCC theory is non-specific in terms of the underlying neuro-physiological processes, but it alludes to poor connectivity throughout the brain between basic perceptual processes
and top-down modulating processes, a possible cause of this characteristic could be the failure of neural pruning.

The WCC theory was originally formulated also as an explanation for the theory of mind deficits, since understanding behaviour in mental state terms obviously requires coherent processing of the information in the context. Later, the link between weak central coherence and theory of mind has failed to be proven empirically. For example the WCC that emerges in the incapacity to disambiguate the homographs, seems to be characteristic of even those individuals who show mentalising abilities and pass the theory of mind tests. The early version of the theory hypothesised that individuals with autism experienced the world in a fragmented way, and that this processing style could have a crucial role in their poor understanding of social stimuli and meaning.

The WCC theory has been recently revised and limited to the perceptual level (Happé 1999) because of controversial experimental evidence. Other studies (Plaisted et al 1999) have found evidence of local advantage and interference from local to global in the Navon task (figure 2) when participants were required to divide attention between local and global levels, but not in a selective attention task. Besides that, in another study individuals with autism seemed to be subject to some visual illusions like normal individuals, failing to replicate Happé’s previous findings about the scarce susceptibility of individuals with autism to visual illusions (Ropar and Mitchell 1999).
The most recent version of the weak central coherence account (Happé and Frith 2006) suggests that the idea of a core deficit in extraction of the global form and meaning has been challenged. In fact the same results could be interpreted as an outcome of the superiority in local processing, or with the concept of a local processing bias characterising Autism Spectrum Disorders. Besides that weak coherence characterises people with autism but it occurs alongside the social deficits rather than explaining them.

Other studies (Mottron and Belleville 1993; Plaisted et al. 1999; Mottron et al. 2000a; Plaisted 2001) have in fact demonstrated that there is not a deficit in global perception of stimuli but rather a superiority in the ability to discriminate individual elements. Mottron and Burack (2001) proposed an “enhanced perceptual functioning framework” in which there is over-developed low-level perception and atypical relationships between low and high-level processing.

Jolliffe and Baron Cohen (1997) suggest that central coherence is weak in autism because of the slow speed at which central processes are activated and operate. They argue that duration can be a crucial difference between stimuli presented in Navon tasks. In different Navon Task studies when the subjects were required to name the large letter of an incongruent stimulus, before naming the small letters, it was found a local precedence with stimuli having a duration of 10-25 ms (Mottron and Belleville 1993), but global precedence was observed with stimulus duration of about 1000 ms (Ozonoff et al. 1994). Enhanced local processing but intact global processing has been shown also with musical stimuli (Mottron et al. 2000b; Heaton 2003).

Thus both local and global processing have been found in autism, meaning that the weak coherence is more appropriately explained with the notion of enhanced local processing

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1 in which the small letters were different from the large one
and intact global processing abilities rather than being a deficit in global processing (Plaisted 2001; Mottron and Burack 2001; Mottron et al., 2006).

1.6 Beyond the single core deficit explanation

The idea of a unique explanation for all the symptoms underlying the syndrome in the three different domains has dominated the research in the last 2 decades, but it has proven not to be very promising and presents several problems. The symptoms of the syndrome can be hardly explained with a unique theoretical model: the accounts centred on the social aspects, that were developed so far, were not adequate to explain the non-social ones and vice-versa those centred on the non-social symptoms failed to explain the social ones. For instance the rigid and repetitive behaviour and interests, emerge later than social and communicative difficulties, therefore it is hard to provide a unitary account of all these symptoms (Happé et al 2006). Moreover, the notion of “single core deficit”, which was at the basis of the three main psychological theories just described, is not compatible with neurobiological and neuroimaging findings that point to the involvement of broader and developmentally interrelated neural systems (Volkmar et al. 2004). It is also possible that different aetiologies underlie the different phenotypes present in the syndrome (Carter et al 2005).

The explicative limits of these early theories as well as the use of new technologies and the possibility to observe very young children with autism have brought to modifications in the approach to autism research.

In this view the abnormal trajectory of the social development in autism spectrum disorders originates from a problem in social motivation processes, that lead to deficits in orientation and engagement in the social aspects of the surrounding environment. This model is closely related to other developed areas of research like face and social stimuli processing, joint attention and imitation.

Spontaneous orienting to socially relevant stimuli and the sensitivity to particular features of agents and social interactions are supposed to be hard-wired and necessary for an optimal adaptation to the social environment. Early social development is based on the strong interrelation of these processes and developmental and neuro-scientific evidence suggest that the study of social development as composed by modular and unrelated skills is problematic and potentially misleading.

Behavioural dysfunctions such as those related to the orienting to social stimuli and joint attention are likely to originate from abnormalities in brain development and to cause a drastic reduction in the flow of social information processed by the child. This is supposed to
contribute to the subsequent disorganization in the neural as well as in the behavioural
development of children with autism (Mundy and Burnette 2005).

One of the limits of traditional computational models of the social mind (i.e. Leslie
1994; Baron Cohen 1995; Frith 1989) is represented by the fact that they were often
suggested to be modular in a sense derived by the adult model of modularity, and as such their
model contemplated that some mature aspects of social functioning could be preserved, while
others could be disrupted. If this can be partially true, it is also true that early social
perception and experience determine the course of successive development, therefore a
developmental account needs to consider that different aspects of social functioning are
extremely interwoven during development.

The modular view based principally on an adult model of the cognitive architecture
can be problematic for the explanation of a developmental disorder like autism. The
traditional modularity model doesn’t take fully into account the fact that the trajectory of
maturation in developmental disorders is dramatically different from the typical one.
Therefore the neuropsychological model based on the characteristics of the adult brain is not
adapt to understand the complex dynamics of development that can become evident at the
level of gene expression, brain development, cognitive and behavioural processes. The
classical computational models are not adequate to explain the processes involved in
intersubjective behaviour because even if they can describe the details of the real-time
processing of social information, they don’t provide an explanation for the developmental
changes occurring in the child’s behaviour (Marraffa 2001).

While the strict nativist approach based on the model of typical development seeks
impairments to domain-specific cognitive modules, the neuroconstructivist approach proposes
to search for indirect and lower-level causes of abnormality. This model supports a
modularisation hypothesis according to which the innate starting points are domain relevant
rather than domain specific, becoming domain specific only later in development. The
concept of modularity in order to be useful in the explanation of developmental disorders
should better be thought as a concept of modularisation as suggested by Karmiloff Smith

Some concepts are central in the current psychological research about autism which is
centred on early social motivational problems, rather than on later emerging problems, in the
belief that an early abnormality in social perceptual processes can produce severe effects on
later development.
For instance the belief that the social dysfunction is the defining aspect of autism, although the syndrome is characterised also by non-social symptoms, the importance of early diagnosis and of the individuation of early symptoms, as well as the need for a developmental account of these behavioural symptoms.

The social dysfunction, characterised by the inability to establish a reciprocal relationship and communication is believed to be the defining core of autism. Although other disorders, like deficits in language acquisition, and restricted and repetitive behaviour affect children with autism, it is likely that the social disorder is central in autism and affects the development and the expression of these other skills (Klin et al 2002). Perceptual peculiarities are also likely to affect social development, for instance poor processing of eye gaze and faces have been linked to problems in low level perception (Dakin and Frith 2005). Even if the new research trends are still not part of an organic psychological model like the dominant ones, it is possible that the common focus on social motivation and orientation will lead to an alternative psychological model (Volkmar et al 2004).

Since autism has an onset during the first two years of life there is the need to search for early signs of the syndrome that can either allow early diagnosis, already in toddlers, and can lead to understand the developmental course of the syndrome since its very early phases. This is believed to be of crucial importance for treatment and for research.

Research, theories and diagnosis of autism have been shaped by the rather late average age of diagnosis of the syndrome, earlier theories attempted to provide an explanation for evident symptoms observed in older children adolescents and adults with autism, but it is now widely accepted that autism could be diagnosed at 18-24 months of age (unfortunately, as already underlined, this is not the norm yet) and these early theories are not adequate to explain the manifestation of the syndrome in very young children. Analogously diagnostic criteria were based on the observation of older children while the direct observation of infants and toddlers was virtually impossible.

A good theoretical model of autism should offer a developmental account and with it the individuation of skills and processes that appear early on and that could be linked to later emerging deficits, like for instance those in theory of mind, in perceptual functioning or in executive functions. Besides that one important characteristic of a good theoretical model that indicates the cause of the social dysfunction in the disruption of a particular skill, should be the possibility to establish a predictive relationship, and a proportional relation between the levels of disruption of one skill and the level of social competence in real life behaviour, however this last characteristic is often lacking.
Finally, the comparison between the typical developmental pattern and the developmental pattern of a child with autism is indispensable and useful in order to better understand the architecture of the human mind, but it is not simple to come to conclusions. In experimental research the focus on results intended as the performance in the tests can miss that on processes defined as the developmental pattern that brought to the achievement of these good performances (Karmiloff Smith 1998; Volkmar et al. 2004). The fact that a particular ability is present in a child with autism is not sufficient to allow a comparison between that ability and the analogue ability in a typically developing child, in fact it is always important to consider that the developmental trajectories followed by these two children are radically different. The same ability or behaviour observed either in typical development and in autism could be qualitatively different: children with autism can achieve “intact” performances in some tasks through different cognitive processes, through compensatory mechanisms of acquisition. The performance on explicit tasks for instance is often correlated to the level of the verbal ability.

Clinical features of infants and young children with ASD: the importance of early diagnosis

The core social and communicative symptoms of autism emerge during the first three years of life. Although some parents may report the recognition of developmental abnormalities in their children already in the first or second year of life, until recently the early history of children with autism has been reconstructed mostly through retrospective parent’s reports because the majority of the children still receives a diagnosis after the age of three years or even later, in early school age.

More recently the advances in early diagnosis research and the knowledge about the efficacy of early intervention supported the development of the study of autism in the first three years of life. It is now widely recognised that autism can be diagnosed in toddlers as young as 18 to 24 months, and the evidence that the diagnosis is stable from this age onward has pushed many researchers to search for early developmental trajectories of symptoms (Chavarska 2006).

The early diagnosis is particularly important as it allows to study the disorder before other factors intervene (like treatment, compensatory strategies, comorbid disorders). In the past the early behaviour of children with autism has been studied principally through parent’s retrospective reports. An improvement to this kind of research came initially from the study of family video-tapes of young children later diagnosed with autism (Osterling and Dawson
Parents report that children with early onset autism during the first 6-8 months of age show reduced visual attention to people. These children seek others less frequently and are less likely to engage in early social communicative exchanges including eye contact, smiling at others and vocalizing. However, they don’t seem to differ from typically developing children in their explorative behaviour of objects. In addiction, parents often report of difficulties in sensory sensitivities, arousal regulation, motor difficulties and impaired vocal and motor imitation, however none of these factors was reported as a result of the analysis of the videotapes. This could either mean that such symptoms are not unique to infants with autism but it could also be due to the fact that such symptoms were not taped.

More recently important data come from the observation of high-risk populations like younger siblings of children previously diagnosed with autism (Chawarska et al. 2003; Klin et al 2004). The observation of very young children with autism has produced great improvement either for diagnosis and for research.

One of the main questions for early identification of autism regards both sensitivity and specificity in the diagnostic instruments and procedures that have been originally created for older children. The current diagnostic criteria in DSM-IV give the best results when the diagnosis regards children of four years of age and older (Chavarska and Volkmar 2005), but the same criteria can be less adequate for the diagnosis of the youngest population of children with autism (Lord 1995).

Thus one of the main issues concerning early diagnosis is that the diagnosis in very young toddlers, must be based on different features since some of the DSM-IV criteria may not be valid yet. For instance the lack of imaginative play, or unusual qualities of language can’t be observed in toddlers. Moreover global developmental delays complicate the process of identification of early symptoms of autism. Stereotypic movements are non-specific and emerge later in development while behaviours typical at one stage of development become clinically significant only later, like sensory exploration, or features of nonverbal communication.

The definition of diagnostic criteria for infants and toddlers is an intrinsically challenging task as many changes can occur in the manifestation of the syndrome at an early age. In the course of development a behaviour or its absence in a narrow period of time can be significant and adaptive under a certain age, while it becomes indicative of abnormal development a few months later. In example, the explorative play behaviour is typical of children under the age of 12 months, but its extension in the second year of life, accompanied by the absence of other forms of symbolic and creative play, can be the sign of a
developmental difficulty or of a delay. Similarly, the use of physical gestures like reaching, and grasping in order to obtain a desired object is typical in children younger than 9 months of age. In typical development (after the 9 months) the same behaviours coordinated with eye contact are an index of the emerging intentional communication (Bates 1979), while the absence of such an organization of gestures and eye gaze during the second year of life can become the sign of a disorder affecting social communication.

In conclusion the recent studies based on parental reports, on the analysis of videotapes and diaries, and on the studies on younger siblings of children with autism which are at high risk of developing the syndrome have allowed the identification of diagnostic criteria valid for infants and toddlers under three years of age.

The early symptoms affect social reciprocity and non verbal communication skills and the profile of toddlers with autism appears already composed by strengths and weaknesses. Abnormal eye contact, lack of response to, and initiation of joint attention, lack of response to name and lack of pointing and other communicative gestures are diagnostic features of autism in toddlers younger than 2, specific areas of functioning result systematically affected. (Chawarska and Volkmar 2005).

This profile is coherent with the hypothesis of the early disruption of social development in autism even if it is not sufficient to determine whether the scarce social orientation in the first months of life is unique to autism or whether it is common also to other developmental disorders. It can signify limited salience of social stimuli and little interest in the social environment and it obviously limits the child’s possibility to learn about his social environment.

**Attention to social stimuli**

The very first social behaviour that characterises human development is the attention to social stimuli. Infant’s behaviour is intrinsically social since the first phases of development, as infants are typically part of a social environment and are naturally attracted by social stimuli rather than by non-social ones.

There is an innate preference for faces, for the eye gaze (Farroni et al. 2002; Bryant 1991) and for voices (De Casper and Fifer 1980). Newborn babies recognise their mother’s voice since birth and are able to coordinate auditory and visual information to recognise her face before the age of three months on the basis of the sound of her voice (Burnham 1993). Infants direct their attention preferentially towards an object characterised by eyes, nose, and mouth, spatially arranged like in a human face, rather than to a scrambled version of the same
stimulus (Morton and Johnson 1991). The first social interactions of newborns consist in the spontaneous engaging in the mimesis of facial expressions and face gestures of the caretaker (Meltzoff and Moore 1977). Infants are subject to the *emotional contagion*, this means that they are naturally influenced by the emotional state expressed by the people around them (Hatfield et al. 1994). Moreover infants as young as three months can individuate a human form on the basis of movement information (Berthental 1987).

As we have already underlined, the social dysfunction is a core diagnostic feature of autism independent of the cognitive and verbal level. The low number of studies about social development of children with autism younger than three reflects the difficulties intrinsic in the diagnosis of young children as well as the fact that even when the parents manifest a preoccupation about their children (usually about the age of 18 months) there is a significant time lapse before the child receives a diagnosis (Carter 2005).

Several studies have found that children with autism fail to orient spontaneously to social stimuli, that the voice, appearance, and behaviour of other people don’t seem to be salient enough among all the stimuli present in the environment (Klin 1992; 2002). It is widely recognised that spontaneous imitation as well as intersubjective communication are very poor in the behaviour of children with autism (Zappella 1996). The basic ability to orient to social stimuli is believed to be at the basis of later social development. Basic shared attention skills such as following another person’s eye gaze, and declarative pointing, as well as communication can’t develop appropriately without an adequate ability to attend to social stimuli.

An early impairment in the spontaneous orienting to other people and the scarce responsiveness to name are among the behaviours that characterise toddlers with autism at the age of 12 months as it has been reported with studies on the videos of their first birthdays (Osterling and Dawson 1994; Osterling, et al. 2002).

The attention to social and non-social stimuli as well as the response to joint attention are part of the items of the ADOS (Lord et al. 1999) used for the diagnosis of young or non-verbal children. During the ADOS the clinician has to test the child’s response to name and his response to other non-social stimuli like the noise of a plastic frog. Moreover there is also the responsiveness to joint attention, (the clinician has to direct the child’s attention calling him and pointing towards an object). It is in the everyday experience of many clinicians the fact that many children with autism usually fail to orient to the experimenter when called by name, especially if they are handling an attractive toy (non-social stimulus) that literally absorbs their attentional resources. However, in the same situation they can respond to
another competing non-social stimulus like the whistle of the toy frog. This shows that the non-social stimulus is often more salient than the social one. Usually the responsiveness to joint attention is also absent in young children with autism.

Dawson and colleagues (1998) tested young children with autism, with Down syndrome and typical development in order to analyse their abilities to orient to naturally occurring social and non-social stimuli. They found significant abnormalities in the responses of children with autism compared to those of the other children. The social stimuli provided to the children consisted of clapping hands and calling the child’s name. The non social controls consisted of playing music with a toy and shaking a rattle. In a second part of the study the shared attention abilities of the children were also tested. Children with autism generally failed to orient to all kind of stimuli and especially to social ones, in addition the responses of children with autism where slower respect to those of the children in the other groups. Children with autism were also impaired in their shared attention abilities, and a correlational analysis showed a connection between shared attention performance and the ability to orient to social stimuli but not with the ability to orient to non social ones. Thus shared attention impairments in autism may be in part the consequence of the inability to attend to social stimuli. This is not surprising as shared attention skills require first of all the ability to orient to social stimuli like the other person’s eye gaze and voice and to coordinate one’s own attention with the other’s attention and direct it towards the same focus.

In a more recent study (Osterling et al 2002) the social skills of children with autism were compared with those of children with mental retardation (MR), confirming that children with autism can be distinguished from those with mental retardation already at the age of one year, since they are less likely to orient to social stimuli, to orient to their name and to look at other people. Other kind of behaviours were instead common to children with autism and MR. They were less likely to look at objects held by other people (precursor of joint attention) and to use gestures to communicate, while they were more likely to engage in repetitive behaviours than typical developing peers. Thus these last behaviours at the age of one year appear to be linked to MR rather than to autism in itself.

Recent descriptions of very young children with autism suggest that the diagnosis of autism can be made before the two years of age and that it is likely to remain stable over time. Klin and colleagues (Klin et al. 2004) report the profile of a 15 months old girl who received an early assessment with standardised diagnostic instruments as well as follow up with the same instruments 8 and 19 months later. The child was characterised by an uneven profile of strengths and weaknesses. Higher non-verbal cognitive functioning and motor skills
accompanied by lower receptive and expressive language on the Mullen scales of early learning (Mullen 1995), and higher levels of ability in motor and daily-living skills with delays in communication and socialisation on the Vineland Adaptive Behaviour Scales (Sparrow et al. 1984). Although her early age the child manifested also stereotypic behaviours (particularly in response to sensory stimuli), therefore she met criteria for autism also on the Autism Diagnostic Interview (ADI, Le Couteur et al. 2003) and on the Autism Diagnostic Observation Schedule (ADOS, Lord et al. 1999).

Follow-up assessments confirmed the profile with some progress only in the non-verbal cognitive functioning and motor skills. This suggests that the developmental trajectory followed by the child was the result of a complex interaction between biological and experiential factors. The poor attention to social stimuli limits her social experiences and the limited vocal and motor imitative skills limit her ability to learn through observation and imitation.

**Attention to faces and eye gaze**

In typical development, as early as the second month of age the eye region becomes the most scanned of the face, this fact is of great developmental importance as this part of the face displays a great amount of social information.

It has also been found that very early, by the age of 4 months, face processing of an upright face is enhanced when accompanied by direct gaze (Farroni et al 2004). This is consistent with the results of an fMRI study on adults in which it was observed a greater activation of the Fusiform Gyrus, usually active in response to face stimuli, when the face was directed towards the subject. This could mean that a direct gaze automatically triggers a deeper encoding of the face.

Motor mimesis with the reproduction of seen facial gestures characterises infants since their first hours of life (Meltzoff and Moore 1977; 1983). Thus, the child possesses this innate imitative ability for facial gestures before learning has occurred, and this suggests also a strong link between movement perception and production. It has been suggested that this automatic reproduction of the other person’s gesture could be the way in which infants come to understand that gesture, by executing it in first person. Analogously, in the adult brain particular neurons of the pre-motor cortex activate during perception of particular goal-directed actions like grasping, chewing and kicking (Buccino et al. 2001). It has been suggested that a function of these neurons could be that of making action recognition possible (Gallese 2002; Rizzolatti et al. 2001). And it has been hypothesised that abnormalities in the
mirror neuron system could be responsible for some of the social abnormalities characterising autism (Ramachandran 2003; Gallese 2006). New experimental findings seem to support these hypothesis, for instance a recent study (Dapretto et al. 2005) reports an absence of neuron mirror activation in the brain of children with autism during a task of imitation of facial emotional expressions and anatomical differences have been found in the mirror neuron system of adult individuals with autism (Hadjikhani et al. 2006).

By 4 months of age infants perceive a shift in gaze as a directional cue to some object in space, and their attention is attracted towards the direction indicated by the eyes of the adult. Hence, at an early age infants can already follow the direction of the gaze of another person (Farroni et al. 2004). In an analogue way adult subjects, in attention cueing experiments, show a reflexive orienting towards the direction indicated by the eyes of a static photograph, responding faster to targets situated in a position consistent with the direction of the eye gaze of a presented face (Driver et al. 1999). By 10-11 months of age infants can spontaneously follow head turn and gaze shift, but only from 18-19 months they can engage in spontaneous gaze monitoring. It has been suggested that spontaneous gaze monitoring signals the understanding that gaze shift corresponds to the other person’s shift in attentional focus (Tomasello 1995).

**Expertise in the processing of Face and eye gaze**

A great amount of social information is conveyed by faces, particularly by emotional expressions and eye gaze: early communication processes like joint attention, shared enjoyment or interest and social reference require the child to have some understanding of the social information displayed through the face and the eyes of the other person.

The early lack of interest for social stimuli reduces the amount of social information perceived by the infant. The lack of social stimulation is supposed to influence the ability to process social stimuli, not only in infancy, but also later in life. For instance older people with autism spectrum disorders (ASD) may lack the expertise for faces that is normally achieved by other people. This because the preference for faces normally begins very soon after birth, while this preference is absent in autism.

Typically-developing individuals process faces in an holistic way, conversely it has been suggested that individuals with autism don’t process face-stimuli holistically but in terms of their isolated features (Grelotti et al. 2002). Holistic processing usually characterises expertise, therefore an upside down stimulus causes an impairment in holistic-expert processing because the inversion affects the local relational information between the
individual features, therefore in typical individuals it produces a slower recognition of the global stimulus. This happens for instance with inverted face stimuli. Even if they are able to discriminate between faces, individuals with autism show a diminished inversion effect for faces and this is a sign of their lack of expertise with these stimuli. Nevertheless, when the task is more demanding, or it includes elements like emotional expressions, individuals with ASD have an impaired performance, and in this case the differences in face processing are likely to originate because of the reduced social interest and expertise characterising individuals affected by the syndrome (Klin et al. 1999).

Joseph and Tanaka (2002) have recently analysed face perception in children with autism testing the hypothesis of the deficit in holistic processing. Their data support the idea that the face recognition problems in autism are not linked simply to processing strategy of isolated features. In fact this population has deficits in the recognition of other’s faces from the eyes, while the mouth region receives much greater attention, therefore the theory of a deficit in holistic processing is not sufficient to explain how individuals with autism perceive face stimuli.

It has been hypothesised that social stimuli for people with ASD have the same salience as any other object, and that people with autism process faces like people without social disabilities process non-social objects, experimental data support this hypothesis. Schultz et. al 2000, in an fMRI study have recorded a greater activation of the inferior temporal gyrus (associated to object processing) during a task of face discrimination in adult individuals with autism respect to normal controls. Conversely this same area was the most associated to object perceptual discriminations in the control group. Furthermore the autism group didn’t show an activation of the fusiform gyrus during face perception, while the controls did, consistently with previous studies about face perception (Kanwisher et al. 1997) and objects of expertise (Gauthier et al. 1999). Problems in the recognition of people from faces are also in autobiographical reports of high functioning individuals like Gunilla Gerland who writes:“... the boys who were nasty to me on my way back from school. I didn’t recognise them. They had empty boy faces that simply flowed into each other. I thought they were different boys each time” (Gerland 1997).

Evidence of an enhanced processing of the mouth region and a scarce processing of the eye region of the face was found already in the pioneering study of Langdell (1978), where children with autism were shown pictures of their classmates in which different features were occluded by a mask. Young children with autism resulted more able in recognising their classmates from the mouth while they were more impaired in recognising
them from the upper part of the face including the eyes. Another finding is also interesting, in fact, older children with autism were as good as their typically developing peers in recognising their classmates from their eyes, probably thanks to the development of compensatory strategies for face identification (Grelotti et al. 2002; Klin 1999).

These data have found recent confirmation thanks to the eye tracking technique. Klin and colleagues (2002) have measured the visual fixation time of high functioning adult individuals with autism viewing social scenes extracted from a movie. The individuals with autism focussed their attention on the mouths of the characters while the controls were more likely to focus on the eyes and follow their eye gaze. A similar study involved also toddlers with autism who showed results consistent with those of adult subjects as their attention was attracted by inanimate details of the background rather than to the social elements (Klin et al. 2005). Although toddlers with autism fail to follow other people’s eye gaze in naturalistic situations, two years old toddlers with autism have shown to be sensitive to the directional cues signalled by eye movement but not to a non-biological directional cue. However the data suggest also that toddlers with autism might process gaze information differently from matched typical developing peers as these last were more likely to attend for a longer time to the eye than to the non-eye cue (Chawarska et al. 2003).

On the basis of these data about the spontaneous visual monitoring of social situations in children and adults with autism Klin (2003) has recently proposed a new working framework, the Enactive Mind, in which two ideas are fundamental: the role of motivational predispositions to respond to social stimuli, and a developmental process in which social action is at the basis of social cognition. This last point underlines how social perception affects the cognitive development of the child.

The failure to orient to the eyes when processing faces could be due to a lack of sensitivity to the social information that comes from them, moreover it hinders the construction of an expertise in this sense. On the other hand, the great amount of attention for the mouth could signal either that during dialogues the movement of the mouth as well as the verbal information are more salient for individuals with autism, this would suggest a compensatory strategy consisting in a verbally-mediated access to the social information.

Thus, in the end, since observing the mouth doesn’t provide enough social information, individuals with autism fail to receive relevant social information when they observe other people’s faces.

Typically-developing people usually mature an expertise for social stimuli and in particular for faces. From such an expertise cortical face specialisation develops in a
particular area called the *fusiform face area*, FFA (Kanwisher et al. 1997). It has been shown that this area is not specialised for faces but rather for the recognition of objects of expertise (Gauthier et al. 1999) and that people with ASD are not expert in face recognition and lack a specialised face area (Schultz et al. 2000; Grelotti et al. 2002). Therefore it is believed that some organising principle is at the basis of human motivation for social interest and that this principle might be disrupted in autism. The amygdala is a sub-cortical structure responsible for salience detection and because of its rich network of connections with the ventral-temporal cortex it is situated in an ideal position to influence the acquisition of face expertise (Schultz et al. 2005).

The role of the amygdala could consist in making social stimuli salient for people’s attention, it could signal a face as something meaningful that needs special processing. The amygdala has a role in early stages of processing of emotional expressions: it reacts quickly and automatically signalling the importance of a stimulus to the cortical areas devoted to its elaboration. The development of face perception and social cognitive skills could depend on the amygdala–fusiform system, and problems in this network could produce social symptoms of autism.

Abnormalities in the functioning or in the structure of the amygdala have been found in individuals with autism. In this population the perception of emotional expressions produces a reduced activation of the amygdala respect to that of typical individuals (Baron Cohen et al. 1999), moreover postmortem studies have found structural abnormalities in the amygdala as well as in other areas of the limbic system of some individuals in the autism spectrum (Bauman and Kemper 2005).

Recently Schultz and colleagues (2003) have shown that the FFA is activated not only during face perception but also during the observation of animated geometrical shapes similar to those used by Heider and Simmel (1944). A group of normal volunteers were fMRI scanned during a task of social attribution to geometrical moving shapes the so called “SAT” (Social Attribution Task, Klin 2000), it was found that a part of the Fusiform Gyrus was activated by the SAT, and that the portion of the FFA activated, in the same subjects, during a face perception task overlapped (for 50%) with the FG area activated by the SAT. Therefore the FFA rather than being only specific for faces (or other objects of expertise) is likely to be part of a larger circuit for social cognition. The same cortical area is activated either in tasks of social attribution to non-face geometrical figures or to judgments about greyscale pictures of faces, thus these visual perceptual areas seem to be involved in the representation of more abstract social properties.
Social perception is linked to social cognition during the normal course of development and the growth in social-perceptual skills could provide important elements for the development of social skills. The activation of the FFA in tasks of social judgment not involving faces is an example of how the brain areas involved in perception are also implied in knowledge about the same perceptual properties confirming the deep relationship between perceptual and conceptual processes.

**Early social interactions and the emergence of joint attention**

Until about the age of 6-9 months the infants engage only in dyadic interactions (Trevarthen 1979; Reddy et al. 1997; Tomasello et al. 2005). This means that they either interact with a person in an expressive reciprocal relationship, in which the two parts are emotionally involved and concentrated one on the other in an affective exchange, or engage in sensorial exploration of an object. The relationship with the caretaker doesn’t involve communication about a third entity, and the infant concentrates his or her attention on the object without driving the adult’s attention on the same object.

The dyadic adult-infant interaction is pervasive and it consists in the reciprocal emotional syntony and contingent communication characterised by vocalising, turn-taking, eye contact, emotional expressions. Bateson (1975) named the early mother-infant interactions proto-conversations, the observation of these early exchanges between infant and caretaker suggested that the infants possess an active and immediately responsive appreciation of the adult’s communicative intentions, and this was defined primary intersubjectivity (Trevarthen 1979).

The information conveyed by the face is fundamental in the first interactions between infant and care-taker, very early the infant will focus his attention mostly on the eyes of the communicative partner. At the age of 4 months (Farroni et al. 2004) the perception of a shift in gaze-direction automatically orients the infant’s attention, however until 6-9 months of age the infant is not able to actively coordinate his attention with that of another person towards an external object.

The successive phase of development with the emergence of joint attention is characterised by what Trevarthen names secondary intersubjectivity and Tomasello calls triadic interactions. It is only at this point that the infant starts to follow intentionally other people’s eye gaze to the object of attention, and successively to coordinate his eye gaze with that of another person and to use gestures in order to attract the other person’s attention towards an object (Scaife and Bruner 1975).
Joint attention consists basically in the coordination of the child’s visual attention with that of a partner in a social interaction. This implies the ability to follow the line of visual regard of a partner and later the ability to initiate joint attention with the eye-gaze or with gestures like showing or pointing. Therefore the term comprehends either the behaviours indicating responsiveness to joint attention, like gaze and point following and behaviours that indicate an initiative of joint attention like showing and pointing.

When the ability to monitor another person’s eye gaze develops, the infant begins to understand that other people can help him or her to obtain a desired object. Around the 10 months the infant will express his or her needs with pre-linguistic intentional communication based on gestures (Camaioni 1995). When the child can coordinate the attention towards a person, with that towards an object, he will be able to communicate his desires intentionally. In fact, at about the age of 10 months, the child will begin to actively direct the other person’s attention towards an object. The typical basic intentional communicative sequence is made of an alternation of the eye gaze towards an object (this can be accompanied by a pointing gesture), to the eyes of the person and again to the object. In joint attention sequences the infant and the adult share a common focus of attention while maintaining a reciprocal social relationship (Camaioni and Perrucchini 2001).

The joint attention deficit in autism emerges clearly at the age of 12 months and can become manifest first of all in a lower frequency of looking at objects held by others (response to joint attention), this same symptom is very reliable during the second year of life and beyond.

Children with autism have a deficit with these as well as with related social-orienting skills (Loveland and Landry 1986; Mundy et al. 1986). This disturbance is problematic for development as joint attention is considered to be central in social learning during the first years of life (Baldwin 1995; Charman 2003). It has been suggested that the most harmful aspects of the joint attention impairment are linked to the inability to initiate social sharing with other people (Mundy 1995).

The individuation of the joint attention dysfunction in young children with autism has contributed to enrich the description of the social-communicative deficit typical of autism. While the act of showing an object to the social partner can involve simply the coordination of overt aspects of visual attention as it happens in early infancy, joint attention will later become important in the intentional coordination of covert aspects of attention, like ideas, intentions or emotions (Tomasello 1999).
Pre-linguistic communication

Children with autism have a qualitative impairment in communication that becomes manifest in the following ways (DSM IV):

1. Delay or lack of the development of verbal language, not accompanied by an attempt to compensate through alternative modes of communication such as gestures or mime;
2. In individuals with adequate speech there is an impairment in the ability to initiate and sustain a conversation;
3. The language can be repetitive or idiosyncratic;
4. There is a lack of varied and spontaneous make-belief play and of social-imitative play adequate to the developmental level.

Toddlers with autism don’t manifest a large range of pre-verbal communicative behaviours that are usually seen in children of about one year of age: moving the head to mean yes or no, pushing an object away to mean rejection, reaching with the hand accompanied by gaze monitoring in order to request an object, pointing towards an object to call attention to it. These same communicative behaviours in typical development will be later substituted by speech with the same communicative functions, such as rejecting or requesting objects, orienting attention to objects or events, and commenting on their appearance.

Not all the communicative functions are absent in the behaviour of children with autism, in fact they can complain or make requests in order to obtain something, however they are likely to do it in a qualitatively inappropriate fashion.

Since the age of 9-12 months, infants and toddlers can use eye contact, gestures and vocalisations to attract the other person’s attention on an object in order to communicate a need. For instance they can ask for the object, or can ask for help, through the coordination of a series of behaviours: vocalisations and eye gaze directed towards the communicative partner, gestures like pointing or proto-pointing (stretching the arms trying to reach the object). In this way the child is communicating that he wants something to happen. These kind of communicative behaviours are defined proto-imperative acts as they are used for imperative purposes (Bates 1976), such as, making the other person doing something.

On the other hand the spontaneous initiation of joint attention, through eye gaze alternation, showing, or pointing, can represent a proto-declarative act without imperative purposes, which is the first step towards a process of communication about something.
Typically-developing children, before the 12 months of age, master the ability to attract another person’s attention on an object maintaining at the same time the social engagement, by searching the eye contact, monitoring the other person’s eye gaze, pointing, and vocalising. Children with autism are likely to perform inefficient gestures like standing nearby the desired thing but not attempting to attract the other person’s attention in an adequate way. The behaviour of children with autism suggests an important impairment in the child’s knowledge of mechanical and social interactions and probably a poor understanding of the distinction between the domain of inanimate objects and that of animate agents and their ability to engage in interactions at a distance. These children don’t respond nor engage adequately in social sharing sequences, and, contrarily to typical children, they often seem to treat the other person as an instrument. Many young children with autism, make use of the other’s body to communicate, this means that they don’t coordinate their eye gaze with that of the other person but rather take her hand and put it on the object if they want her to perform an action, this behaviour is an evident sign of the impairment in social interaction.

The communication impairment in autism seems to be strongly linked to the social impairment, indeed specifically the social aspect of communication appears to be strongly limited. This is not surprising as early developmental phases of social and communicative behaviours are almost indistinguishable.

Ostensive actions, like showing or pointing without the intention to obtain something, accompanied by vocalisations or by the denomination of the object, are communicative gestures very common among typically-developing young children. The capacity to respond and initiate joint attention sequences is fundamental in order to respond to, or to initiate a proto-declarative act. A typical sequence of joint attention initiation can be when the child shows an object to the caretaker, this behaviour will be coordinated alternatively looking at the object and at the face of the caretaker. Another example can be that of a child who sees a flying airplane, points towards it, and alternates his gaze between the object and the eyes of his communicative partner while pointing. These are behaviours that have as a unique goal the sharing of attention with the partner on a common object, and have therefore a proto-declarative function, children with autism are severely impaired in the use of this communicative function.

This is particularly interesting as it is not the gesture that is absent, but rather the communicative function underlying it. The dissociation between the gesture and its function is coherent with the studies about typical development showing that pointing for request
develops earlier than pointing for declarative purposes, and suggesting a delay in the communicative behaviour of the child with autism (Camaioni 1995).

Furthermore, the proto-imperative pointing that emerges in autism could be substantially different from the analogue behaviour present in typical development. A simple conditioning mechanism could influence the reinforcement of this behaviour. The infant can learn that through pointing he can obtain a desired thing. The reinforcement of this sequence can bring the child to learn the proto-imperative pointing. However this same mechanism doesn’t work in case of proto-declarative pointing as no concrete reinforcement originates from this behaviour (Vivanti et al. 2006).

The difference between the proto-imperative and proto-declarative behaviours is crucial as the first involves the communication of a need but only with the second the child manifests to understand that the other person is an entity with attentional states. Moreover, given the different nature of the two types of gestures it seems that only proto-declaratives can be considered as precursors of language. In particular, proto-declarative gestures, contrary to the proto-imperative ones represent a referential act towards an object in the world, in proto-declaratives the gesture points to an object similarly to a verbal expression, while in proto imperatives the communication is about the child’s needs. The message communicated through an imperative gesture can be interpreted only through an inference about the child’s needs. On the contrary proto-declarative pointing has a purely communicative goal, the child makes a comment about a third object and he directs the communication to another person. Moreover, the joint attention sequence is a true communicative exchange as the communicative partner provides an answer to the child, either verbally or just expressively.

The interest for the other person’s reaction to a stimulus, and the ability to monitor the other person’s reaction to a stimulus and to behave according to the reaction of the other person is called social reference. This behaviour emerges actively in typical toddlers around the age of 12 months and is typically performed by the child in order to orient his or her own behavour in situations of uncertainty (Sorce et al 1985). Children with autism on the other hand show to be less sensitive to the emotional state of another person and don’t engage in social reference (Kasari et al., 1990; Sigman et al., 1992; 1999).

The use of proto-declarative gestures represents a progress in social and communicative development. Proto-imperative gestures don’t require the child to coordinate appropriately his attention with that of the other person, proto-declaratives instead are truly social as they require necessarily social coordination and can be considered as precursors of linguistic reference.
As already underlined, the joint attention deficit is a characteristic feature of children with autism, and has an important role in the successive development of language and social communication (Mundy et al 1990; Mundi 2003; Charman et al 1997; Charman 2003). Several studies have examined the longitudinal association between joint attention in the pre-school years and later linguistic and social development, Mundy et al (1990) found such a correlation at 45 months of age. Furthermore there is evidence that intervention approaches that place emphasis on the development of non-verbal social communicative skills like joint attention are successful in promoting language and social development (Lord 2000; Paul and Sutherland 2005).

The deficit in joint attention has been hypothesised to be a precursor to ToM disabilities in autism. The preferential orienting for social stimuli and the innate inclination to social engagement are believed to be essential precursors to any subsequent social development.

During the second and third year of age the symptoms become more evident, most of the parents of children with autism begin to recognise and seek medical or psychological advice about their children’s developmental disturbances around this age (Chavarska et al. 2005). The main concern is always triggered by the lack of progresses in language acquisition, the loss of skills (like loss of, acquired words, response to name, interest in others) and the emergence of abnormal behaviours (like sensory interests, motor mannerisms, tendency to spin things).

During the second year, at the age in which typical infants undergo a fast growth process in social interaction, imaginative play, verbal and non verbal communication, infants with autism begin to show specific difficulties exactly in these areas.

The social domain behaviour includes diminished eye contact, limited interest in peers, in social games and in turn taking, scarce social reference and preference for being alone. Moreover, at this age the children show a delay in motor and vocal imitation. Finally, most of the children show also a limited range of facial expressions directed to others, and a limited sharing of affect and enjoyment.

The problems in the area of communication concern the difficulties with conventional gestures, the absence of pointing in order to show and the difficulties in understanding and responding to these gestures when made by others. The absence of response to the name continues. In general the communicative behaviour is globally affected as the children manifest difficulties in the communicative use of gestures and vocalizations. Verbal children can be echolalic, and at the same time stereotyped and reiterative behaviours, (like hand and
finger mannerisms) can appear, especially around the age of three, together with unusually sensory interests and sensitivity. Generally in children with autism these symptoms intensify and become more evident, while at the same time autistic-like symptoms in children with developmental delays of a different nature diminish allowing for a clearer discrimination. Parents prospective reports are reliable and can be compared with direct clinical observation more than retrospective accounts that can be affected by selective recollection.

1.7 Language acquisition

In the DSM IV (APA, 1994) language development is included among the communication impairments and is strongly linked to them.

Contrary to children with specific language impairments, children with autism don’t attempt to compensate the lack of verbal language trough alternative modes of communication such as gestures or mime. This means that not only verbal language, but the communicative intent is often very reduced in non verbal children with autism.

Moreover, even when a certain degree of linguistic development has been achieved, these children still don’t show the capacity to develop peer relationships that would be appropriate to their developmental level.

Although language problems are a defining feature of autism, delays in language expression in the early preschool years are not specific to the syndrome. Abnormalities and delays in language and communication are a core feature of autism, but problems in language acquisition are not necessary nor sufficient for a diagnosis of ASD (Tager-Flusberg et al. 2005). Children with Asperger Syndrome for instance don’t have a history of early impairment in language acquisition.

Some children with autism never acquire a productive language (i.e. they only produce echolalic speech), many of these children have also a very low non verbal IQ. There is a significant correlation between IQ and language outcomes, but higher levels of non-verbal IQ are not always associated with higher level language skills (Howlin et al. 2004).

The emergence of language before the 5 years of age is positively correlated with a better outcome for children with autism, and those children who acquire language before the age of 5 are usually the most represented population in studies about language (Tager-Flusberg 2001).
Earlier studies focussed on communication deficits that are universal among children with autism, and identified problems with pragmatics and discourse skills. These studies usually analysed verbal high-functioning children with autism or Asperger Syndrome.

Pragmatics is the use of language in context for the purpose of communication, children and adults with autism have a problem in the conversational use of language. They have problems in understanding the communicative intentions of other people, in understanding the non-literal use of language, like in metaphors and humour. Difficulties in turn taking behaviours and in sustaining a conversation as well as violation of Gricean maxims of quality, quantity, relevance and manner (see Lord and Paul 1997; Tager-Flusberg et al. 2005 for recent reviews). Moreover some form of impairment is always present in the language of people with autism and Asperger Syndrome, at least in suprasegmental aspects. The intonation can be monotonous or exaggerated, the stress patterns can be unusual, the rate of speech can be excessively slow and there can be poor volume modulation (Klin et al. 2005).

The use of language concerns the speaker’s intentions, desires, beliefs and depends on higher level computational systems. The ability to communicate is based on the integration of different knowledge about the world, the communicative partners and the overall communicative context. The knowledge about the context and about language must be integrated in order to produce new specific inferences for every communicative act. One of the aims of the study of pragmatics is to explain how, in particular communicative situations the meaning (or part of it) can be derived from the social context.

In autism there are signs of an abnormal pattern of language acquisition as the language of subjects affected by the syndrome is often stereotyped, repetitive and there is use of idiosyncratic words or sentences. This means that children with autism with limited verbal abilities are often able to learn language in a non-flexible way, associating whole sentences to particular events in an arbitrary way, or repeating previously-heard sentences and words. In this case the communicative attempts made by the child will be inefficient as it is difficult to understand the child for people who don’t know him or her very well.

Echolalia is an immediate or delayed repetition with similar intonation, of words or sentences previously heard by the child. It can be present also in the speech of typically developing children, however in autism is present at a greater degree and for longer periods of time. In fact much of the early speech of children with autism is characterised by echolalia (Prizant and Duchan 1981).
Examples of immediate echolalia are linked to the immediate verbal exchange, for instance when the child repeats a question, or the last words of a question (reply to do you want some juice?, echoing do you want some juice? or reducing the sentence to want some juice?). Delayed echolalia instead is the repetition of a sentence, that the child has learnt in the past, and that can be associated to a particular context. For instance the sentence “it’s time to tickle you!” can be used by the child to signal that he wants to be tickled because this is the sentence that he has heard from his parents in the past in the context of tickling. Or the sentence “don’t be afraid, it’s only a toy, it won’t hurt!” can be spontaneously repeated by the child in order to reassure himself.

In the past echolalia has been considered only as a dysfunctional element (Lovaas 1977), but even if the function of echolalia in the acquisition of language is not well understood, other scholars have considered it as an important social behaviour. Echolalia often can be the sign of a communicative intent, and it can have a function in the successive process of language acquisition (Prizant and Duchan 1981). Prizant and Duchan individuated several communicative functions underlying echolalic behaviours, it is the case of turn taking, declaratives, answers and requests.

The communicative intent of the child can be interpreted only in the context in which the child has uttered the echolalic sentence.

It has been suggested (Prizant 1983) that the acquisition of language in the population of children with autism could vary along a continuum going from analytic to holistic elaboration as occurring also in early phases of language acquisition in typically developing children (Peters 1983). According to this view the holistic learning would be typical in children with autism and the memorisation of multi-word utterances without deeper elaboration of the underling syntactic structure would be just the initial step towards the process of inductive segmentation into smaller grammatical units.

The personal pronoun inversion (i.e. the use of You instead of I and vice-versa), is frequent in the speech of many children with autism, even if it is present in the speech of children with other language disorders or in blind children (Fraiberg and Fraiberg, 1977) and it can be present for a short period in the speech of typical children (Chiat 1982), it is more common in autism.

The difficulties in the use of pronouns is defined as part of a more general difficulty with deixis. This suggests a general difficulty with the aspects of language that code the shifting of reference between the speaker and the listener. Deictic terms are particularly difficult because while the shifting of reference doesn’t affect names like “Mary”, it affects
personal pronouns, but also determiners like “this” or “that”, the choice of verbs like come and go, and the verb tense.

The difficulties with pronouns manifested by children with autism can be explained as a sign of the difficulties in conceptualising the notion of self and other as they are embedded in the shifting of discourse roles of speaker and listener (Lee et al. 1994; Tager-Flusberg et al. 1994). It has been suggested that this particular difficulty could depend on the more general social and communicative impairment (Tager Flusberg et al. 2005).

**Word learning**

In typical development, around the first year, children begin to understand words. At the same time the conventional use of language with the first words begins and by the 18 months of age the vocabulary size reaches the 50 to 100 words in production and even the 300 words in reception. Then the acquisition of language progresses in a very fast way (Tager-Flusberg et al. 2005).

Also non-linguistic contextual mechanisms have a role in the process of acquisition of language in typical development. For instance around the 18 months toddlers are able to follow the adult’s eye gaze to make distinctions about the named object and other objects eventually present (Baldwin 1991), therefore the understanding of other’s intentions is fundamental also in the context of language acquisition. The acquisition of verbal language in autism is useful to show that early social abilities play a great part in language acquisition.

Before the 24 months of age children begin to combine words to form their first sentences, the first language is concentrated mostly on objects, animals, people and actions.

The process of language acquisition towards a full use of grammar is in the preschool period between 2 and 5 years of age, during this period of time not only the vocabulary increases at a high rate, but the first telegraphic sentences of the child evolve into complete grammatical sentences. The child acquires a rule-governed system, and makes rule-governed achievements and mistakes, the length of sentences increases and the child begins to use different sentence forms with different functions, like questions and negative sentences.

The use of grammatical structures allows the child to articulate his thoughts and to convey them in a form that is understandable for everyone. Moreover, at this point the language becomes less linked to the actual context and can be referred to things that are far both in time and space.

Pragmatic capacities develop together with linguistic ones: the ability to maintain and add new information to conversational topic, to clarify and request clarification of
misunderstood sentences, and adapt their speech to the knowledge and characteristics of their interlocutor (Bates 1976).

Language development in children with autism is characterised by a great inter and intra-individual variability. Even if variation characterises the acquisition of language also in typical development this variability doesn’t resemble the patterns of communication delay typical of autism. The development of language in children with autism has peculiar features that differentiate it from typical development.

The linguistic problems of children with autism can be situated on a continuum going from a total lack of verbal language to a pervasive disorder that spares syntax but affects the individual’s capacity to communicate with appropriate pragmatic and conversational rules. A minority of children usually diagnosed with Asperger Syndrome don’t show any significant delay in the onset and in the process of language acquisition, but a majority of children with autism begin to speak late and develop speech at a slower rate respect to typically developing children, with the production of the first words at an average age of 38 months (Howlin 2003). As the diagnosis of autism is still made on average after the three years of age, still much remains unknown about language in very young children with autism.

Psycholinguistic studies suggest that the lexical semantic develops also thanks to sensitivity to the communicative intentions of the speaker. According to this point of view the acquisition of the meaning of words would be driven by meta-representational hypothesis about the intentions of the communicative partner in a particular context.

Children with typical development acquire language also by means of some semantic and pragmatic constraints. The whole object constrain (Markman and Wachtel 1988; Baldwin and Markman 1989), brings the child to assume that a new name refers to the whole object rather than to its parts, the mutual exclusivity constrain brings the child to exclude that an object already known with a name can also have another name.

Markman and Wachtel (1988) studied how typically developing children aged 4 to 5 years apprehend the names of object parts. They showed that in this process the two constraints combine and the first can be inhibited by the second. In the study the children were shown either familiar or unfamiliar objects. In both cases the children were exposed to a new word that could also be a non existent word (i.e. “fendle”). The children had to show what they thought the word referred to, and the data show that in case of unfamiliar objects the whole object constrain prevails, while for familiar objects the mutual exclusivity constrain prevails and the children point to parts of the objects rather that to the whole object.
The same kind of experiment was replicated with children with autism (Surian 2002, p. 44). It seems that these children don’t follow the same semantic or pragmatic constraints of children with typical development. The whole object constraint wasn’t applied by the children with autism. This could signal that the acquisition of language in these children depends on attentive processes oriented more to local processing of particulars. Besides that these children are not able to monitor the other person’s eye gaze in order to understand the referential relation of the naming act and this would hinder the acquisition of language and favour anomalous idiosyncratic processes of acquisition. However the children demonstrated to be able to use the second type of constraint.

High functioning children and adolescents with autism can have a good performance in standard vocabulary tests. This indicates an unusually rich knowledge of words (Fein and Waterhouse 1979; Tager-Flusberg 1985; Eigsti et al. 2006), however it was also found that children with autism, when asked to recall words of unrelated lists or to use cues to recall words, don’t use knowledge of words in a normal way to facilitate performance on retrieval or organizational tasks (Tager-Flusberg 1991).

Other studies have suggested that some word categories are underrepresented in the language of children with autism. Tager-Flusberg 1992 in a longitudinal language study found that children with autism used mental state terms very rarely, particularly those terms indicating cognitive states like know, think, remember and pretend. This same result was replicated also with older children (Tager-Flusberg and Sullivan 1994). Children with autism have also difficulties in understanding social-emotional terms measured on vocabulary tests such as the PPVS (Dunn and Dunn 1997). This means that while word acquisition can represent a strength in the language of many children with autism, the acquisition of words that map onto mental state concepts may be specifically impaired.

**Language deficits in autism**

Nowadays it is widely recognised that the language deficit in children with autism is pervasive and not unitary. It can affect different aspects in different ways, it can be phonological, lexical, syntactic morphological or semantic and with a great variability in the degree of severity.

An account of language disorders in ASD has to explain the high variability that can be found among different individuals. The identification of autism sub-types on the basis of language is considered useful also as an heuristic that can be used in genetic research as different aetiologies are likely to underlie the different impairments.
A main distinction is that between completely non-verbal children who never acquire language during their life, and the group of those children who understand and produce language with different degrees of fluency and complexity.

A large part of children with autism never acquires verbal language. It is possible that some of these children are affected by specific problems like verbal apraxia, a neuro-motor deficit that hinders the ability to produce speech sounds, sound sequences and prosodic features. Another sub-group could be affected by verbal auditory agnosia, (VAA), an inability to distinguish syllable and word boundaries in rapid streams of speech, that has been identified as an underlying problem in some children with autism (Rapin 1997; Rapin and Dunn 2003).

However, although some children with autism can have also other specific pathologies that affect their capacity to perceive or produce language, a part of them has an intact capacity to learn language. Recent reports suggest that the diffusion of early intervention on communication abilities has reduced the overall number of non-speaking children with autism (Goldstein 2002). This means that among non-verbal children there is also a sub-group that can learn language if appropriate treatment focused on the development of communication as a necessary precursor to speech production is provided. Therefore the poor attention to verbal stimuli and the poor ability to engage in social interactions hinders linguistic development in these children.

Still not much is known about the linguistic skills of non-verbal children with autism because of a scarcity of research on this population (Tager-Flusberg et al 2005).

Subgroups can be individuated also analysing the abilities of verbal children. The ability to use language fluently and in a flexible way accounts for the distinction between high-functioning and low-functioning autism.

In the past the grammatical aspects of language in children with autism have been analyzed in few studies and with diverse findings. For instance Bartolucci et al. (1980) found that English speaking children with autism were more likely to omit certain morphemes like articles, auxiliary and copula verbs, past tense, third person present tense and present progressive. Other early studies of sentence form have found that children with autism have a delay in the acquisition of syntax (Bartak et al. 1975). On the other hand Tager-Flusberg and colleagues (1990) in their longitudinal study have found that these children followed the same developmental path as matched children with Down Syndrome and typically developing children in terms of the growth curve in the length of their utterances MLU (mean length of utterance), which is usually considered a gross measure of grammatical development. They
came to the conclusion that there were not specific deficits in phonology, syntax or lexical knowledge because the performance of children with autism either in spontaneous production or in experimental tests was comparable to that of the control groups.

However, these studies included small, and probably unrepresentative, samples of children with autism, another important fact is that MLU might overrate language development if the child produces echolalic speech. Furthermore, they did not provide a systematic evaluation of the profile of abilities or deficits across the different domains of language, therefore much remained unknown about the language impairments that may be present in the majority of children with autism (Kjelgaard and Tager-Flusberg 2001).

Recent studies suggest the presence of syntactic anomalies in subgroups of individuals with autism. Kjelgaard and Tager-Flusberg (2001) tested a group of 89 verbal children with autism of various ages and functioning levels with a battery of standard tests in order to measure their phonological (Goldman Fristoe test, Goldman and Fristoe 1986), lexical (Peabody Picture verbal test, Dunn and Dunn 1997), semantic (EVT, Williams 1997), and grammatical (CELF, Wiig et al. 1992) abilities. Only half of the children were able to complete all the tests in the battery. These 44 children were subdivided in three groups according to their CELF scores (a measures of morphology, syntax, semantics and working memory). The first group had abilities in the norm (85-100), the second had a score of 1 standard deviation below the mean (70-85) and the third had a score of 2 standard deviations below the mean (below 70).

The results show that the performance of the group with normal abilities was balanced on scores between 90 and 100, while that of the two impaired groups had an unbalanced profile of deficits with basic articulation abilities in the norm. Moreover the children had also problems in a phonological test of non-word repetition that is considered highly sensitive to the diagnosis of SLI (Bishop et al. 1996).

Kjelgaard and Tager-Flusberg (2001), and Tager-Flusberg and Joseph (2003) suggest that there are at least two different phenotypes among verbal children with autism. A subgroup of children having linguistic abilities in the norm (in terms of phonological skills, vocabulary, syntax and morphology) and a subgroup of children having a profile similar to that of children with SLI. They suggest that there could be a significant overlap between these two developmental disorders in a subgroup of children with autism.

They also found that the sub-group of impaired children, like children with SLI made errors in the use of finite verb morphology, with omission of morphological marking on the verbal stem of the past tense, as well as the omission of the marking of the third person of the
present tense (i.e. he help-s). This finding was recently replicated in a study with a consistent number of subjects (more than 60) who were given tasks to elicit both the past tense and the third person tense (Roberts et al 2004). The sample was divided into children with scores within the normal range on standardised language tests, and those who reported scores significantly below the mean, only these last had a poor performance in the tense task. Roberts et al. (2004) interpreted these findings as evidence of a subgroup of children with autism having a grammatical deficit similar to those reported among children with SLI (Rice 2004). On the contrary the absence of symptoms of impaired reciprocal social interaction or restriction of activities (diagnostic criteria for ASD) is among the criteria for a diagnosis of SLI (Leonard 2000).

**Speech perception and comprehension**

Parents of children with autism usually recognise the absence of communication in their child around the second year of age when typically developing children of the same age begin to have a consistent vocabulary of several words, use already first word combinations, and show an evident communicative intent.

However early speech perception is unusual early on in development and early speech perception skills are good predictors of future language abilities either in typically developing children and in children with autism (Kuhl et al. 2005).

Typically developing infants not only show a preference for speech but are sensitive to minimal differences characterising phonetic units of speech either in their native speech and in foreign language contrasts. 4 days old infants prefer their mother language respect to a foreign one showing also to be particularly sensitive to the prosodic aspects of the language (Mehler 1990). On the contrary there is evidence about a lack of preference for speech sounds even in very young toddlers and children with autism (Osterling and Dawson 1994; Klin 1991).

Furthermore experimental work suggests a scarce interest in listening to speech and the lack of preference for typical examples of spoken language. In a recent study (Kuhl et al 2005) young children with autism differed from typically developing peers in two ways: they were not sensitive to a syllable change as measured through ERP (event related potentials) and showed a preference for non-speech sounds respect to typically developing peers who preferred motherese speech sounds.

It is also interesting that one of the behaviours that allows an early individuation of infants with autism is their infrequent response to name (Baranek 1999; Osterling et al 2002).
Between the age of 6 to 12 months, typically developing infants begin to respond in a different way to verbal stimuli, and in particular to the sound of their own name. Children with autism at the same age don’t show such a sensitivity, this deficit is typical of autism and persists throughout the early preschool years (Lord 1995).

Between 6 and 9 months of age infants with autism are less responsive and pay less attention to people in their environment, at this same age, in the typical developmental pattern the infants become capable of integrating their interactions with people, with their exploration of objects, and begin to engage in visual joint attention behaviour (Trevarthen 1979, Bruner 1981).

Scarce attention to speech, in young children with autism, is believed to be predictive of later problems with language expression, as well as with the reception of language and with the adaptive use of language for communication. Consistently with the infants’ data, abnormal response to speech sounds has been reported also in children (Ceponiene et al. 2003) and adult individuals with autism (Gervais et al. 2004). In the first case, through an ERP study, it has been reported that high-functioning children with autism although not impaired in the sensorial perception of speech stimuli failed to reflexive orienting to changes in speech sounds (vowels) but not to changes in other simple and complex tones. In an fMRI study on a small group of adult subjects with high functioning autism it has been found that voice processing didn’t activate the Superior Temporal Sulcus voice-selective regions that were activated in typical control peers.

As we have already underlined, communicative and social behaviours characterise early infancy since the first weeks of life and lack in the behaviour of infants and toddlers with autism: the recognition of the mother’s voice, the turn taking in reciprocal vocalisations between infant and caretaker, the eye contact and the ability to follow the eye gaze of the communicative partner.

The general lack of interest in social stimuli characterising children with autism is likely to be present from birth and to be at the basis of their impairments in social and communicative behaviour. For instance it can be linked to early abnormalities in pre-verbal and verbal communication. Recent studies have shown that children with autism manifest a deviance in preverbal vocalisations as well as little pre-verbal communication. Pre-verbal reciprocal vocalisations between infant and caretaker are important for social development. Even before the acquisition of language, typically developing infants are sensitive to elements of speech like tone and pitch, this long before they are able to respond differentially to the content of speech (Carter et al. 2005).
The majority of studies about language in children with autism focalises on verbal children and on their capacity to produce language. However lack of response to speech stimuli is one of the defining features of autism in young children and it is a direct precursor of later comprehension as well as production abilities.

In the typical pattern of language acquisition understanding precedes production of speech and young children can understand more words than they produce.

Children with autism can often seem to have language comprehension skills not adequate to their production capacities and this seems to be strongly linked to their limited possibilities to learn the meaning and use of language in social situations as well as their use of delayed echolalic speech. The comprehension delay in autism can linger during later development and this characteristic allows to distinguish high functioning autism from specific language impairments (Rutter et al. 1992). Paul et al. (2004) claim that in general the gap between understanding and production of language is present around the two years of age but it gradually reduces during the third and fourth year.

A sign of the importance of taking part in social situations for the understanding of language is that, in children with autism, imaginative play skills, in which the child has to invent plots involving dolls, as well as skills in social interaction with other people, are correlated to receptive language skills (Sigman and Ungerer 1981).

Children with autism are generally less expert of social situations and have a limited ability to integrate real world knowledge with the linguistic input in order to achieve a better language understanding. The gap between production and understanding of verbal language can also be the result of the presence of echolalia.

**Poor attention to speech produces linguistic impairments**

Although delays in expressive language in the early preschool years are not believed to be specific to autism, the language delay is often the most evident symptom that worries the parents of a child with autism.

It is difficult to provide a theoretical model and a universal explanation of the particular patterns of language acquisition present in autism, it is likely that different mechanisms may be impaired in different children.

However we can hypothesise that language problems, at least in a sub-group of children with autism, represent a good example of the cascade of negative effects caused by the lack of salience of social and linguistic stimuli early on in development. The problems in the perception, acquisition and use of verbal language in many children with autism are likely
to be linked to the early lack of attention for social stimuli and social interactions. Functional use of language is related to better long-term outcomes in autism (Paul and Cohen 1984) and attention to social stimuli during infancy and later on is likely to correlate positively either with social development and with language acquisition.

Very early diagnosis allows early treatment focalised on communication enhancement, and early treatment produces great improvement in language acquisition (Chawarska, 2006). This suggests the existence of a strong link between attention to social and particularly linguistic stimuli, the development of communicative abilities and the acquisition of speech in young children with autism. These findings are very important in orienting intervention strategies and probably tells us much about early phases of language acquisition in typical development.

The intervention in early phases of language development attempts to increase attention to and understanding of language. Secondly it will try to enhance joint attention skills which have been shown to be a significant predictor of language outcome in children with autism. Third since communicative behaviours are reduced in rate and the communicative functions are usually restricted to protests and requests, the aim of intervention will be to increase the rate, expanding the functions and providing more conventional forms of communication. Finally, language is not the only symbolic behaviour impaired in children with autism. Lack of pretend or imaginative play and limited abilities in imitation are another core deficit area. These are the primary manifestations of a symbolic deficit at the prelinguistic level, therefore early intervention programs aimed at improving communication skills need to incorporate also these forms of symbolic behaviour (Paul and Sutherland 2005).

The process of language acquisition in some children with autism could be limited similarly to what happens in cases of social or sensorial deprivation. These children have problems in the acquisition of the grammatical and pragmatic aspects of language while they can acquire a good lexical knowledge.

The best documented example of abnormal language acquisition in case of total lack of appropriate stimuli is the history of Genie, a girl who grew up in total isolation from social and linguistic stimuli until the age of about 13 years. She missed linguistic stimuli during the critical period of language acquisition, usually indicated as going roughly from 0 to 12 years. After many years of re-education Genie acquired good lexical and semantic knowledge, but she never acquired a good grammatical knowledge and showed a very poor use of pragmatics. Her language was very poor in terms of morphology, in the use of complementizers,
determiners, and other functional elements, and it was characterised by important omissions of fundamental elements like auxiliaries and problems in word order (Curtiss 1977; 1988; 1989).

The prototypical case of sensorial deprivation is represented by deaf people who can’t perceive spoken linguistic stimuli. This affects the way the children in this population acquire spoken language but not sign language. This because they have a sensorial but not a specific cognitive or linguistic impairment. Nevertheless deaf children who don’t have early access to verbal stimuli will produce non-standard verbal language similar to that of Genie and partly similar to that of SLI children although with important differences. Deaf children who don’t have an optimal access to linguistic stimuli are often poor in some grammatical aspect like the use of functional elements such as determiners, clitics, inflectional morphology, complementation/relativization constructions and verbal thematic requirement satisfaction (Chesi 2006).

Unfortunately no systematic comparison between the language abilities of children with ASD and sensorially impaired children has been attempted as far as I know. Such a comparison would be of interest in order to better understand how poor attention to speech can influence successive development of spoken language.
2 Perceptual Causality

2.1 Causality

The concept of causality is at the basis of the ability to interpret the events in the world as causally linked to each other in a coherent flow, in a chain of causes and effects, as well as of the causal interpretation of intentional actions and of the agent’s capacity to cause changes in the world. Furthermore the understanding of human action requires a representational account of the causal structure of the world, and since a goal directed action performed by an individual requires that individual to have some knowledge or expectation about what the consequences of that action are, we could say that goal directed behaviour requires a knowledge of causality.

Thus, causality is a concept that permeates our life and our thoughts. Both common sense and scientific thought, have at their origin the ideas of cause and effect that link the events of the world in a coherent way. At a certain extent we can’t help to reason on the basis of this principle and it’s hard to imagine a world where the notion of causality wouldn’t exist. Causality is in fact not only one of the categories that we commonly use to describe the relationship between objects and events, the behaviour of animate agents, and the interactions between animate agents and objects in everyday life, it is also at the basis of scientific reasoning, in fact the identification of the causes of phenomena is one of the main goals of science.

Philosophers and psychologists have tried to understand how people come to master the concept of causality.

One current view has its origin in the work of the Belgian psychologist Herbert Michotte (1946/1963) about perceptual causality. Through a series of experiments Michotte claimed that adult subjects perceive physical/mechanical causality in schematic motion events.

Successively Kanizsa and Vicario (1968), inspired by Michotte and Heider and Simmel’s work about apparent behaviour proposed that not only physical but also social causality can be perceived in simple schematic events. They studied a schematic event similar to Michotte’s launch and showed that adult subjects perceive social causality in such an event.

Although Michotte interpreted the reports of social causality made by the subject in his own studies as the result of an interpretive rather than perceptual process and later
criticised the validity of Kanizsa and Vicario’s construct, recent developmental work with infants and children (Schlottmann and Surian 1999; Schlottmann et al. 2002; Schlottmann, Surian and Ray, submitted) has significantly strengthen the hypothesis of a perception of social causality in reaction events.

The experimental data regarding adults and infants suggest that minimal perceptual information is linked to the complex notions of mechanical or social causality.

Michotte theorised that perceptual causality in motion events was independent of other forms of causal understanding and he claimed that it was at the origin of the notion of cause. While this perspective is difficult to consider for adults as perceptual causality can be easily confounded with causal knowledge, and the existence of two separate processes would seem redundant (Schlottmann et al. 2006), the ability to perceive causality and goal directed actions could be fundamental in development. It could help the infants in the process of categorisation of various entities as objects or animate agents, on the basis of the characteristics of their motion, without prior knowledge or understanding.

It has been suggested that the perception of contact causality can promote learning about mechanical interactions of material bodies (Leslie 1988; Schlottmann 1999) and that analogously the perception of non-contact causality could promote learning about the social interactions of intentional agents and in this sense it could be a precursor to theory of mind (Schlottmann and Surian 1999; Baron Cohen 1991).

Developmental studies show that the sensitivity to the causal structure of perceived events begins very early in infancy, for instance around the age of 6 months the infants show to perceive the actions of other people as goal-directed (Woodward 1998) and show to perceive mechanical causality and goal-directed behaviour in simple schematic animations (Schlottmann et al. 2006b; Schlottmann et al 1999).

Two different mechanisms are likely to underlie the grasping of causality in these two situations, while the first is based on knowledge the second is based on perception.

On one hand in their perception of causal events infants can integrate top down information about the agents involved in the interaction, and can make implicit predictions about the events they perceive, in fact there’s evidence that infants have different expectations about the behaviour of objects and that of animate agents, and they seem to know that while direct physical contact and transmission of force is usually linked to objects, both people and animals can communicate and interact at a distance.

But on the other hand causal interactions can also provide information about the nature of the entities involved in them, in fact infants perceive causality either in events in which an
unfamiliar object (i.e. an animated geometrical shape) A collides with another object B, and in events in which A and B interact at a distance, these same events in adults produce impressions of physical and social causality respectively. Therefore infants don’t need to see real agents in order to perceive causality and goal-directedness of actions. The causal structure of schematic events can be extracted through visual perception.

Several questions originate from these facts, the principal question in development concerns the origin of infants’ understanding of causality, whether it is a top-down inference made on the basis of knowledge about non-animate objects and animate entities behaviour, or a bottom up perceptual process triggered by particular features in the motion of objects. Another question is about the adaptive function of such a perceptual ability.

Further questions concern what allows infants to identify and distinguish non animate entities from animate ones. What is at the basis of the ability to attribute intentions and perceive actions as goal-directed.

Therefore the study of perceptual causality is highly interwoven either with the research on social development, on the perception of animate agents, on intentionality and animacy and with that on knowledge of physical objects and their behaviour.

2.2 The origins of the debate

In order to understand the modern scenery of studies about causality it is useful to go back to what is commonly reported as the history of the debate.

The origin of the idea of causality has had an important place in modern philosophy and this is not surprising given the relevance of this question in the natural sciences, in psychology and philosophy in general. Michotte himself contrasted his own view with an empiricist approach that he attributed to the philosopher David Hume2. According to Michotte, the first problem faced by philosophers like Hume and Kant, was substantially an epistemological one; their speculation was aimed to discover what could justify the necessity and universality in causal relations (Michotte 1963 p.270), why some events are correctly judged as causally related and not simply as covariant. Moreover, the classical debate on causality with the contrast between Hume and Kant’s thought has been the common reference for much of the research on causal reasoning in infancy.

2 Although later many commentators of Hume read him differently (Saxe and Carey 2006), and Michottes’ reading can be in some sense not up-to-date or inaccurate, in the psychological debate others (i.e. A. Leslie and L. Cohen) refer directly to Michotte’s reading of Hume, therefore it is useful to expose such a point of view.
Hume investigated causality in “An enquiry concerning human understanding”. The principal goal of his research was that of understanding the origins of the concept of causality. He expressly asserted that people can’t perceive the influence exerted by one physical event on another, and this claim has been so widely accepted that it was taken almost as an universal assumption still expressed by contemporary thinkers like Durkheim for instance (Michotte 1963, p.6).

The main idea in the Humean (Hume 1740) view is that people can’t have actual evidence of causation through perception.

On one hand some modern commentators of Hume report that he distinguished between an innate “causal sense” and “causality” which is projected onto the world by the mind, on the other hand, Michotte and other contemporary thinkers report that, according to Hume the idea of causality is derived from the learned regularity in the succession of phenomena. It is based on anticipation, on the expectation (based on experience) that when one event occurs, another event which usually follows it, will do so again. In other words, the only thing that people perceive is a regular sequence of events or one event following another.

In this view three special features (the so called Humean Indices) allow people to infer causality from perceptions: X causes Y when X is temporally prior to Y, when X is contiguous with Y in space and time and when such contiguity is regular across time. Causation for Hume is therefore something that we infer from these indices, in other words it is an inference based on information about features of contiguity and regularity of the events of the world.

People can only perceive the spatial and temporal arrangement of events and not their causal connections. Since there is no evidence for causation, our belief in the causal world is produced by our imagination: causality is projected onto the world by the mind, it is only a response of our mind to the events that occur constantly together and are closely connected in time and space. In line with this view, a belief in causality would arise only through prolonged exposure to events that are regularly conjoined.

On the other hand Kant (1783), believed that causal connections exist in the world and are not mere inferences of the human mind, in fact as a consequence of this, only some of the regular contiguities in the world, and not all of them, are deemed as causal by people. According to his thought individuals can come to know causality because they possess an *a priori* notion of causation (an *a priori* form) within which, sequences of events in the world can be interpreted. We could say that Kant’s view was nativist in his attribution to people of such an ability to perceive the causality that is intrinsic to phenomena in the world. In Kant’s
philosophy the concepts are fundamental for experience, and the fact that every event can be linked to its cause is not simply part of experience, it is in the end what allows experience itself.

Causality is defined as an *a priori* concept and therefore people don’t abstract the concept of causality from perception since causality is a category (of relation) that is applied to perception. The application of a category to perception produces a synthetic a-priori judgement and allows people to recognize physical objects as capable of causal relations and interactions with other objects. According to Kant synthetic a-priori judgements are the origin of objective experience.

### 2.3 The perception of causality

#### The first studies

Heider and Simmel (1944) with their experiments on the perception of apparent behaviour and Michotte (1946 / 1963) with his experiments about the perception of physical causality represent the first studies about perceptual causality. Later Kanizsa and Vicario (1968) considered these studies as the empirical and theoretical background for their work on the perception of intentional reaction.

During the Fourties with Michotte’s book *The perception of causality* and Heider and Simmel’s article on apparent behaviour, the attention of many psychologists was attracted by this kind of events that, although perceptual in nature, produce in the observer impressions such as causality, that are typically associated with higher-level cognitive processing. According to modern theories this evidence would suggest that the visual system operates to recover the causal and social structure of the world by inferring properties such as causality and animacy from the spatial and temporal characteristics of visual stimuli (Scholl and Tremoulet, 2000).

The experiment about apparent behaviour (Heider and Simmel 1944) represents a pioneering study in the field. The experiment consisted in showing an animation, (lasting about 2 minutes), in which three geometrical shapes (a small and a big triangle and a small circle) moved in an expressive way that made them look similar to hypothetical human agents interacting in various ways. The background was white with a big rectangle in which a small part opened and closed like a door (figure 3). The subjects had to watch the animation and
provide a verbal account of what they saw. In the first experiment only one on 34 subjects tested provided a geometrical explanation of the animations. In a second experiment all the 36 subjects were prompted to consider the shapes as if they were people. The most remarkable result is not only that almost all the subjects spontaneously described the animation as if it represented the actions of people, but also that the descriptions of the sequences of the animations were largely similar among the subjects.

Heider and Simmel further analysed the reports trying to understand the characteristics of the stimuli corresponding to the different interpretations. They distinguished four main types of movements: the contiguous movements with instantaneous contact where the impression is that object A hits object B and launches it, the simultaneous movements with prolonged contact where the impression is that A pushes B along for a while, simultaneous movements without contact in which the movement of B is caused by A at a distance like in a chase interaction, and contiguous movements without contact in which the movement of A and B are independent.

It is widely accepted that adult viewers generally offer a social interpretation of this kind of animations and provide narratives characterised by social attributions in order to describe the relationship shown and the agents involved. Similar stimuli have been used in research since then (Abell et al 2000; Castelli et al. 2002).

Almost contemporarily to Heider and Simmel through a series of experimental investigations with adult subjects Michotte (1946/1963) stated that particular event sequences are directly and spontaneously perceived as causally connected, moreover he claimed that the direct perception of causality can occur in a single event without any specific prior experience.
and that the perception of physical causality in schematic events is at the basis of people’s notion of cause.

Collecting verbal reports Michotte found that adult subjects perceive causality in animations displaying the motion of two small projected shapes. In the interaction the two shapes A and B appear static on the screen, than A moves towards B until it touches it, at this point, A stops while at the same time B starts moving (along the same direction) as if pushed. This event named launch event is perceived as a collision between the two shapes in which A causes the motion of B by means of a mechanical interaction. Adult subjects perceive the launch event as A hitting B and causing its motion (figure 4).

Another interesting effect of physical causality was elicited by a different event that Michotte named the entraining event. In this case A doesn’t stop upon contact with B, the effect obtained is that A continues pushing B for a certain amount of time until it stops, while B continues moving alone for a while (figure 5).

Michotte observed that the subjects tested described the situations in anthropomorphic terms attributing intentionality (“pushing”, “following”) to the shapes. The spatial and temporal contiguity are essential features in these causal events, therefore the presence of a spatial or a temporal gap destroys the physical causal impression.

Figure 4 Launching event

Figure 5 Entraining event

Michotte hypothesised the existence of a mental mechanism with the function to transform particular inputs, like visual sequences of motion having specific spatio-temporal parameters, into a causal impression. For Michotte such a mechanism had the characteristics
of a perceptual process rather than those of an inference based on knowledge, and was supposed to emerge early on in development.

Some of Michotte’s claims are difficult to deny, as adult subjects clearly see causality in the actions of objects under particular conditions (Palmer 1999 p.513). It is however difficult to decide at what extent this perceived causality is truly direct and unmediated by experience as perception of collision events could still involve interpretation, and knowledge could influence the judgments of causality provided by the subjects.

The influence of knowledge and experience has been recently documented in the answers of adult subjects (Schlottmann et al. 2006b). Michotte’s argument that causality in other domains is generalised from the prior representation of causality in schematic motion events is still strongly debated (White 2006; Saxe and Carey 2006).

On the other hand the fact that very young infants and children already perceive causality in schematic events gives new strength to Michotte’s nativist arguments, and can lead us to revalue Kant’s explanation of an *a-priori notion of causality* that could predispose infants to the perception of causal relations among events. We can reinterpret this concept in modern terms as a natural disposition of our visual system to the extraction of causality from spatial and temporal information characterising moving stimuli. Finally, experimental evidence supports the idea that experience contributes to perception, the essential function of such a perceptual mechanism could consist in helping infants to learn about causality, but once this task is accomplished, in older subjects the perceptual information necessarily integrates with knowledge (Schlottmann et al. 2006b).

In an event representing the motion of two objects, we don’t simply perceive the physical structure of the single moving object, we see perceptually organised structures with important interrelations. One essential component of motion events is exactly their causal structure, that is, how the motion of one object appears to affect the motion of another object when it hits it, or interacts with it at a distance (Palmer 1999 pp.513).

Such a definition of “causal structure” of an event, provided by Palmer, is really close to Michotte’s one as it stresses that in order to have perceptual causality there has to be an interaction between two entities in which one affects the motion behaviour of the other in some way.

Adults’ disposition to the causal interpretation of the events of the world seems so pervasive that people can’t help to perceive many of the stimuli present in the surrounding environment according to causality.
In virtue of this perceptual principle, causality is attributed even to examples of schematic visual displays in which no naturalistic causal interaction occurs.

Kanizsa and Vicario (1968) define their work as a research on the perceptual aspect of expressiveness. They further investigated the process of perception of social causality in animated displays in which two shapes interacted at a distance. Their work is explicitly inspired to that of their predecessors, and if initially they investigated reaction in complex displays more similar to those of Heider and Simmel, they later chose to drastically simplify the number of factors present in the interaction and studied reaction in a display similar to those already used by Michotte.

The reaction event (figure 6) proposed by Kanizsa and Vicario differs from Michotte’s launching event because there is no contact between A and B and the movement of the two shapes is simultaneous and not contiguous. In this case A starts moving towards B, some time before A reaches B, B starts moving too, and at a certain point A stops while B continues moving by itself and than stops. Adult subjects perceive A as chasing after B while B escapes from it, and when asked use goal directed language to describe the event, like B is going away because A chases for it.

The movement of the second object is perceived by the majority of subjects as a reaction to the movement of the first, the chasing event constitutes the simplest schematic representation of a causal interaction at a distance.

![Figure 6 reaction event](image)

Although early studies on perceptual causality presented problems in methodology as especially Michotte did not report details of procedures, instructions, or even of the data obtained, later researchers used formal experimental methods confirming Michotte’s claims and results (see Schlottmann et al 2006b for a discussion).

After the early investigations with adult subjects (Michotte 1946 /1963; Kanizsa and Vicario 1968), analogue experiments were set up first with adults and later in a developmental key. In fact on the basis of the quite strong experimental evidence obtained with adults, various researchers have later investigated the question from a developmental point of view.
Developmental studies on perceptual causality are particularly interesting: while the evidence in adult subjects can always involve some interpretive rather than perceptual component, infant’s studies can be particularly useful in order to understand how causal perception, causal understanding and reasoning develop during infancy when the cognitive system is supposed to operate more likely on the basis of perception rather than on the basis of prior knowledge.

Since then, causal thinking has surely been one of the most important areas of research in developmental psychology. Causal cognition is supposed to have an important role in development because the understanding of events is largely possible when their cause can be individuated, and vice versa knowing the cause of an event can allow to explain, predict and even control that event (Schultz and Kestenbaum 1985). The experiments about the perception of causality in young infants have suggested that perceptual causality abilities could be at the basis of infants’ ability to distinguish social from non-social interactions.

The origins of the understanding of causality has long been a topic of speculation, despite traditional theories that defined young children as incapable of causal reasoning (Piaget, 1954; 1974), more recent experimental investigations with children have shown that even three year olds, master already some sophisticated ideas about mechanical interactions and also about social causality (Schlottmann et al. 2002). The origins of the notion of causality seem likely to lie further back in development, already in infancy, as it has been found that infants are sensitive to the causal structure in schematic motion events already by the age of 6 to 9 months (Leslie and Keebele 1987; Schlottmann and Surian 1999).

The questions at the basis of infant’s studies on perceptual causality concern the origin and development of this ability that is supposed to provide a unique foundation for the notion of cause (Michotte 1946/1963).

**Theories about the origin of causal representations**

As already underlined Michotte presents his theory of the perception of causality with an empiricist approach that he attributes to Hume.

On the basis of his experimental results Michotte proposed the existence of a mental mechanism that transformed inputs like visual sequences of motion with particular spatio-temporal features into causal impressions. He suggested that causality derived purely from perception in an innate and automatic way.

It has been suggested that Michotte anticipated the modularity theory later formulated by Fodor (1983). In fact it has been suggested that in Michotte’s view the perceptual
mechanism seems to satisfy the requirements of modularity being encapsulated from knowledge, data driven, fast and automatic (Scholl and Tremoulet 2000).

In developmental studies, Leslie (1984; 1987; 1995) approaches the phenomenon of causation following Michotte. According to him causality (mechanical causality) pertains to the relation between two or more objects external to the observer, like in the billiard ball collision proposed by Hume.

The theory that the notion of causality comes from perception is antithetical to the associationist view that it originates from the causal sense of one’s own actions on the objects of the world. The Piagetian (1954; 1974) sense of causality (physical causality) is distinct from Leslie’s one, and refers to the relation between the observer as agent and other objects as recipients of the action made by the observer.

According to Michotte (1946/63) this view although not completely coherent with Hume’s thought, is derived directly from Hume’s writings. In fact the philosopher denied the possibility that our idea of power can originate from a sentiment or consciousness of power within ourselves, when we move, or use our limbs, but at the same time, he admitted that the impression of effort against resistance can become part of the naive popular and inaccurate idea of power or cause.

This thought, amplified and adapted was later adopted by Piaget, who explained that a belief in the causality of the self is only an illusion, justified by two phenomena: the ability to predict the result of our action before it takes place and the presence of a feeling of activity.

Michotte notices that this opinion in its extreme form is expressed in the theory developed by the French philosopher Maine de Biran (Michotte 1963 p.11).

Then Maine de Biran’s view has become part of the contemporary psychological thought in Piaget’s work about the origin of the idea of causality in children. The best example of this concept comes from Piaget himself (1954) whose attention was directed towards the young child’s interactions with the environment, and his or her growing awareness of psychological causality. This notion of cause refers to the child’s intentions that bring consequences in the external world.

In this sense causality is defined by Piaget in terms of an inductive inference that comes from the proprioceptive sense of power over one’s own body as a mean to act onto the surrounding objects.

In Piaget’s original formulation (1954) there are several developmental stages from 0 to 18 months. In the first 2 stages (0-4 m.) the child doesn’t have a concept of the self or of the object, therefore he can’t understand neither psychological nor physical causality, there is
a mixture of the two kinds of pre-causality: efficacy and phenomenalism. In the next stage (4-8 m.) in which the child is supposed to have some sense of his power (efficacy) over the world he still has only some “magical” sense of this power to cause changes in the world, accompanied to a sense of phenomenalism intended as the feeling that temporal contiguity between two events means that one caused the other. Only later in development in the fourth stage (8-12 m.) when the child learns to distinguish between himself and his environment and acquires the notion of permanence of objects, he starts to differentiate between different sorts of cause and effect relationships, and to perceive causal relationships in situations in which he is not involved. Finally in the fifth stage (12-18 m.) infants begin to see the immediate universe as made up of causes that are independent from themselves. Both objects and people are seen as potential causes and infants understand the necessity of spatial contact between successive terms in a causal series. Later on, after 18 months of age with the emergence of the symbolic capacity the infant comes to infer causes on the basis of their effects. In conclusion, for Piaget causality has its roots in the sensory-motor components of action itself, the understanding of causality originates from the subject’s actions and is later applied to the relations between objects.

Most of Leslie’s criticism is directed against different aspects of Piaget’s theory of the slow development of causality.

As it is well known, Piaget’s work has strong methodological limitations since his theories were based on anecdotal evidence and on the observation of a limited number of subjects. Moreover developmental studies conducted successively demonstrate that this conception of the infant’s slow construction of the world reflects more on the limitations for planned and structured activity, like for instance in manual search tasks and not on infants capacity to represent physical bodies with mechanical properties (Leslie 1994).

The new approaches to infant cognition that take attention as a measure of infants’ ability to perceive and predict events, offer a different image of early abilities possessed by infants at birth or under the year of age when the manual search tasks are not adequate to the infant’s age and abilities.

Leslie (1995) criticises the limits of associationism and follows an alternative stream of research about specialised learning mechanisms, present in infants, and adapted to create conceptual knowledge of the physical world before higher cognitive structures are in place. Leslie’s view of mind development is that of a core modularity that provides a way to ensure a basis of knowledge in biologically adaptive domains. He refuses the conception of causality as originating from experience, by saying that infants come to life already equipped with a
“sub-module” that has the function to detect mechanical interactions in which there is a transmission of force.

Contrary to the classical associationist view of a core cognition consisting of statistical associative processing over elementary sensations. Core architecture is assumed to have a more differentiated character, in which core structure reflects specialisation for processing different kind of information as the result of an adaptive evolution.

According to Leslie the core cognitive architecture is represented by human information processing systems that form the basis for development rather than its outcome (Leslie 1988). Vision and language are examples of specialised sub-systems of this kind and the notion of cause and effect is supposed to be the central organizing principle in the domains of object interaction and people interaction, or as Leslie says “in the core domains of objects mechanics and theory of mind”. With Leslie the evidence and theories about perceptual causality have found a place in a broader theory of agency intended as the features that allow an observer to individuate an agent as such.

Leslie’s theory is aimed to demonstrate how perceptual causality is linked to the understanding of agency, therefore he suggests that understanding agency involves a hierarchy of processing modules (inspired to Marr 1982) that correspond to three distinct levels of comprehension. These modules are the foundation and not the product of development and mirror the fact that agents are defined as possessing a range of causal properties that allow to distinguish them among other entities.

Both Piaget and Leslie differentiate between mechanical (Physical) and actional (psychological) features of causality. But contrary to Piaget in his descriptive theory Leslie (1995) assumes the existence of two different mechanisms for the understanding of mechanical and actional causality.

Leslie (1995) states that the understanding of agency is in part the result of domain-specific learning. He introduces the concept of three different and task-specialised cognitive subsystems corresponding to three main classes of properties of agents, namely mechanical, actional and attitudinal agency.

Leslie considers agency as an enduring property of an object that doesn’t imply biologically connoted features of animacy. The notion of agency can emerge from domain-specific learning and reflects properties of the core cognitive architecture. Agents have mechanical properties as they possess force intended as a renewable source of energy, they possess actional properties since they act in a goal-directed manner and react to the environment in result of their perceptual abilities, moreover agents have cognitive properties
as they have mental states defined as “holding a certain attitude to the truth of a proposition”. This set of characteristics distinguishes agents from non-agents like for example physical objects.

The understanding of agency requires the activity of each of three different processing modules, the hierarchy in question is composed by ToBy, ToMM1 and ToMM2, (theory of body mechanism, and theory of mind mechanism). ToBy corresponds to the infants’ theory of physical objects and concerns the mechanical properties of agents as well as the capacity to distinguish agents from non-agents while the ToMM components pertain to the “intentional” properties of agents. The first of these two modules interprets goal-directed actions and the second one interprets the agent’s mental state and the behaviour that results from it.

Leslie’s theory is not only nativistic but also explicitly modular in a Fodorian sense (Fodor 1983, p.47), ToBy, the perceptual causality mechanism based on the notion of force postulated by Leslie, is part of the visual input system similarly to what Fodor sustained about colour perception or the mechanisms for the analysis of shape, but also for more task-specific “higher level” systems concerned with the recognition of human faces. ToBy is supposed to have a central role in the identification of agents, ToMM1 is the module that allows the perception of actions as goal-directed, and ToMM2 is supposed to be concerned with the attribution of mental states to agents, according to Leslie these properties of the information processing system, are hierarchically arranged and form the basis for subsequent development.

Leslie proposes that causality is not a concept that develops during time, on the contrary, he defines it as a core cognitive property which must be in place in order to allow subsequent development. Michotte himself excluded experimental effects when discussing perceptual causality. He claimed the universality of causal percepts as well as their encapsulation from higher order interpretations, and the high correlation between the character of the stimuli and the resulting percepts.

2.4 Developmental studies on perceptual causality

It’s due to notice that Michotte himself, in his book about the experimental research on perceptual causality in adults, anticipating the lines of research of the following decades, stated “it would clearly be very interesting if experiments as those described in this book could be tried out in children of different ages” (Michotte 1963 p. 255).

The research about causality during development can be divided into two main branches, on one hand are those studies about the origins of causality in the perceptual
causality abilities shown by infants, while on the other hand there’s the research about causal reasoning and understanding with older children of various ages. Moreover, the kinds of perceptual causality studied concern two different domains, and precisely the physical and the social one, that mean respectively, the contact interactions that affect the behaviour of objects and the non-contact interactions that affect the behaviour of people and animated agents.

We’ll focus on developmental studies about perceptual causality.

The perception of physical causality

Since the Eighties perceptual causality in infants has been studied principally through the habituation paradigm, recording infant’s reactions to causal events displaying both animated or filmed objects. Habituation experiments allow to test what kind of stimuli can be discriminated by the infants as well as to test their conceptual knowledge about the event through the violation of expectancy. In the first case infant’s dishabituation to the new event allows to test the ability to discriminate between events, in the second case the infants are more attracted by the unexpected events and therefore the attention pattern allows to infer what kind of representations underlie the expectation of the child.

The research about infants’ perception of physical causality has focused principally on mechanical causality implemented in the “launching event”.

The origins and development of infant’s sensitivity to causality are still investigated using this same kind of events and comparing infant’s reactions to them at several ages, versus their reactions to other similar events, in which the causality effect is destroyed by means of a small temporal or spatial gap. Since mechanical causality is assumed to be in the contact between two objects followed by the immediate movement of the second object, (in other words in the spatio-temporal contiguity of the movement), if one of the two contiguity elements is missing the event is generally defined as non causal.

These prototypical events were already described by Hume (1748) who proposed the example of one billiard ball striking another ball as the simplest model of a sequence of events characterised by particular features that give rise to the inference of causation.

The research on causality in infants has been explicitly guided by the ancient debate: using the same experimental settings psychologists of both Kantian or Humean inspiration investigate causality in infants, although with different predictions. The first expect that the causal (contact + immediate) condition should be given a special status and should be treated differently from the two other non causal (spatial gap or delay) conditions that are by definition considered equivalent in the sense that they are non-causal. Moreover the special
status attributed to the causal condition should be a tendency, a feature of the human mind similar to a modular capacity. Humeans instead predict that very young infants might initially process the launching according to its spatial and temporal features and only later come to infer causality on the basis of contact and immediacy. Along with this expectation, the two non causal conditions could be treated as non equivalent because the two different features have a different status as indicators of causality.

Today common accounts of infants’ perception of mechanical causality refer to their tendency, at least at some point in development, to distinguish between causal and non causal stimuli or to organise these sort of stimuli on the basis of causality rather than on some other basis (Leslie 1984; Leslie and Keeble 1987).

According to this principle an infant that reacts to the spatial or temporal gap event in the same manner, but who treats both of them differently from the direct launching event, is considered as responding on the basis of causality. However, the equivalence between the two types of non-causal events is often taken for granted even if it is not completely true. It is useful to underline that the variation in the spatial gap affects perceptual causality in a gradual way: small spatial gaps don’t destroy the impression of causality as it has been recently demonstrated through a study with adult subjects (Congiu et al 2005), this is likely to be true also for the temporal gap, however, the range over which the spatial and temporal gap work may seem different (Schlottmann and Anderson 1993).

The perception of social-psychological causality

Parallel to the studies about physical causality, a different set of studies investigated the perception of a second type of causality, not physical but social-psychological in nature. Action-Interaction at a distance (not based on the contact and transmission of force from one object to another) is supposed to be a defining feature of social exchanges contrary to the contact interactions that mark physical interactions in the object world.

Knowledge of physics and psychology are supposed to provide two different systems for understanding behaviour. We know that infants during their first year employ basic principles of contact mechanics (Spelke et al., 1995; Baillargeon et al., 1995), but less is known about their abilities in applying psychological principles.

Infant’s understanding of others as persons was traditionally considered to emerge from their early social interactions. One important developmental stage was seen in infants engagement in intentional action and triadic interaction by the end of their first year (Trevarthen 1978, 1979; Tomasello 2005).
It has been proposed more recently that triadic interactions are the signal of infant’s initial appreciation of others as intentional beings (Carpenter et al. 1998); others have argued for intersubjectivity from birth that lacks overt behavioural expression until this time (Trevarthen, 1979). Though, the observation of infant’s behaviour alone is not sufficient to understand whether they react to other’s behaviour, if they perceive the goals of the actions or if they are able to infer mental states that were at the basis of actions and their goals.

A growing body of research indicates that from at least six months of age, and possibly earlier, infants distinguish between animate and inanimate motion (for reviews see Rakison and Poulin-Dubois, 2001, Spelke et al. 1995; Meltzoff 1995; 2002).

Before showing the capacity to attribute mental states to agents (capacity that seems to be mature between the second and fourth year of age), infants show to be sensitive to certain features like the goal-directedness of actions in animated displays already at 9 to 12 months of age (Gergely et al 1995; Csibra et al. 1999) or even at 6 months (Schlottmann et al. 2006a).

Recent studies confirm the data about infant’s perception of action-reaction sequences at the age of 9 months (Schlottmann and Surian 1999; Rochat et al. 2004) and suggest to consider these facts as the effect of the crucial development in social cognition that takes place around that age. At the age of nine months the development of social abilities can affect the way infants perceive, construe and infer social scripts in animations representing moving shapes on a computer screen.

An alternative interpretation is that chasing events produce the perception of interactions at a distance and our visual system perceives them automatically, these kind of interactions are different from those characterising inanimate objects and give an impression of intentionality.

**Experimental evidence on infant’s perception of physical causality**

Infants’ reactions to the events previously described, already used in experiments with adults, are evidently of crucial importance for the debate about the origin and development of the notion of causality.

Current studies on infant’s perceptual causality use the habituation paradigm to investigate mental capacities on the basis of patterns of attention. Through this technique it is possible to analyse either the infant’s ability to discriminate among stimuli and the ability to categorise them according to particular features, or to investigate the infants’ expectations through the violation of expectancy paradigm.
The perception of physical causality in infants has been investigated mostly through the launching stimulus, contrasted with an analogue but delayed stimulus in which a small pause interrupts the temporal continuity between the movement of A and that of B and with it the causal effect.

At least two different developmental hypothesis have driven the research on perceptual causality in infants. Those scholars who intended to show that causality is an inference and is therefore a reasoning principle acquired through experience, have tested violation of expectations displaying occluded stimuli to the infants in order to test their expectations. On the contrary, those who wanted to investigate causal perception as an innate or early capacity of our visual system to extract causality on the basis of particular motion features of the stimuli have shown overt causal and non causal stimuli to the infants.

The situations shown usually represent the movement of 2 objects that can be either animated geometrical shapes, filmed objects, people or hands, and the experiments have included infants as young as 4 months.

**Occluded events, testing infants expectations**

In a study about the violation of expectancy Kotovsky and Baillargeon (2000) found that 7.5 months old infants expect that the motion of an object is caused by contact.

They familiarised infants to an apparatus in which an object A was put at the top of a ramp, while B was at the bottom of the ramp, between the two objects there was a barrier which could block the contact between A and B or had a gap that allowed contact between the two shapes. 7.5 months old infants were shown the apparatus and the consequent event, than the part corresponding to the bottom part of the barrier was hidden behind a screen. A group of infants saw a target sequence corresponding to A launching B, while a second group saw an event in which A disappeared behind the occluder but B didn’t start moving.

The results show that infants of the first group looked longer at the events in which B moves in the full-barrier case, that is when the contact between A and B is not possible, while infants in the second group looked longer in the gap-barrier case, that is when contact between A and B is possible, than when it is not possible. These results support the idea that 7.5 months old infants can use contact to form an expectation about causality.

Generally occluded causal events to which the child is habituated are direct launching events in which the contact between the two shapes is not visible as it happens behind a screen.
Ball 1973 introduced the method of the violation of expectancy to the field of infant research, testing the expectations of infants from 6 to 26 months old. The experiment proposed consisted in habituating a group of infants to an “occluded” event (figure 7), then the occluder was removed and half of the group was shown a direct launching (causal contact-event), while the other half of the group was assigned to a non-contact launching (non causal event). Ball reports that the contact but not the no-contact event was perceived as causal, and interpreted this result as a sign that the infants were treating the non-contact event as inconsistent with their expectation and were therefore looking at it for a longer time. On the basis of this result he suggested that infants perceive causal events in the same way as adults (Michotte 1946/1963).

![Figure 7 - The habituation event used by Ball (1973). A screen occludes the centre of the image and part of object B. A moves across the screen, disappears behind the screen and then stops. B immediately starts moving across the stage. During the test trials the occluder is removed and the infants can see the whole interaction. In contact trials B moves upon contact with A, in no-contact trials A stops before making contact with B. Infants tend to look longer at the impossible event.](image)

Although the many methodological problems present in Ball’s study it’s important that this same result of infants making an inference of contact from the relation between A’s and B’s motion in occluded events has been replicated by different research groups.

Kosugi et al. (2003) investigated 10 months old infants capacity to infer an invisible cause of an object motion in events with non-visible onset of motion.

Two groups of infants were habituated either to a ball moving or to a person moving in an occluded event in which the moment of the onset of motion was hidden behind a screen.

Then the children were tested with three different test events in which the occluder was removed and the object (either the ball or the person) moved. The first event showed an
hand pushing the object, the second one showed an hand not in contact with the object, and the third showed the object moving by itself.

The results show that in the *ball* events the infants looked longer at the “impossible conditions” in which either the hand didn’t make contact with the ball or the ball moved by itself, on the other hand the infants were not surprised to see a person starting to move by herself.

These data demonstrate that 10 month old infants infer that a non-animate object needs a physical cause to move while a human agent can move by itself.

On the basis of the paradigm ideated by Ball (1973) Muentener and Carey (reported in Saxe and Carey 2006) habituated 8 months old infants to causal events in which there was an agent (hand) and two potential effects (breaking vs. colour/music change). Habituation trials were occluded events in which the hand entered and an effect occurred on a box. During test the screen was removed, and infants were shown, in alternation, two events: the hand made contact with the box or the hand didn’t make contact with the box.

Infants looked longer at non contact events only when the hand was the agent, therefore the authors came to the conclusion that the agent’s dispositional features influenced infants’ causal representations and that infants represented the event as causal only when the agent was a hand.

In a previous and analogue experiment with 8 months old infants the same authors found that infants represented motion events (launch) but not ambiguous status events (braking or colour/music change) as causal, however in this study the agent was an inanimate block therefore they hypothesised that the result could be due to the fact that infants didn’t perceive that event as causal. On the other hand this result might support Michotte’s claim that perceptual causality is driven by bottom-up spatio-temporal features and therefore it can be perceived only in motion events.

Spelke, Phillips and Woodward (1995) have shown that already 6 months old infants have different expectations about the behaviour of objects or animate agents, expecting objects to move by effect of contact while animate agents can move by themselves.

From the description of this kind of experiments that used occluders it emerges clearly that the ability tested is not perceptual but instead it is an inference based on the knowledge about the behaviour of animate agents or inanimate objects.

On one hand there are infants’ abilities in the recognition of biological motion or hands as agents which are well known and appear very early in the infant’s life, on the other hand there is the bottom-up perceptual mechanism that allows the infant to attribute agency
and intentions to an unfamiliar moving object on the basis of the causal interaction in which it is involved.

It is not clear the reason why the occlusion should be employed in these experiments about causal perception instead of directly showing the event to the child (Cohen et al. 1998). In fact, in order for the perceptual ability to be activated, it would need to receive the appropriate input, and the problem is that in this case that appropriate input is precisely what is invisible because of the occluder. The violation of expectation paradigm with hidden causal events could not be appropriate to test perceptual causality rather than some more mature apprehended (associative) knowledge about the behaviour of physical objects.

Visible events, testing perceptual abilities

Showing to infants either causal and non-causal events allows to test their perceptual abilities. This experimental method is more coherent with the nativistic bottom-up concept of causal perception originally proposed by Michotte.

Habituation experiments on perceptual causality consist in habituating the child to a causal event and than testing his capacity to distinguish it from analogue but non-causal events. The goal is that of understanding whether infants are responding on the basis of causality, or rather on the basis of independent spatio-temporal features, therefore the exposure to causal (direct launching figure 4) events is usually contrasted with the exposure to non causal ones (either with a temporal delay or a spatial gap), and the amount of attention given to the different stimuli is recorded and compared. A decrease in the amount of attention that the infants dedicate to a stimulus indicates habituation, while an increase of attention after habituation means that the child is sensitive to the difference displayed in the new stimulus.

Leslie (1984) tested 6 and 1/2 months-old infants’ ability to differentiate causal from non causal events. The results show clearly that infants were able to distinguish the continuous motion of a direct launching from similar but (temporally or spatially) discontinuous events. When infants were habituated to a causal event and tested on a non causal event there was greater dishabituation than when the switch was from a non-causal or the other non causal event, however Leslie also found that the dishabituation from one non causal event (spatial gap) to the other non causal event (temporal gap) also produced dishabituation (even if to a smaller extent).

While Michotte didn’t address the question of how non-causal events are categorised by the infants, Leslie (1984) through a series of experiments excludes that they could be part of a unique class of noncausal. Moreover he claims also that there’s no evidence of infant’s
processing of independent spatio-temporal features in launching events and its non-causal equivalents although the infants distinguished each non-causal event from the other.

Even if Leslie already in 1984 excludes that the non-causal events can be considered equivalent as part of a unique category of non-causal events, and excludes that the dishabituation from one non-causal event to the other represents evidence of responses on the basis of independent features, in the developmental literature it is usually assumed that the two non-causal events in which either spatial or temporal contiguity is disrupted are equivalent being both non-causal (Cohen and Amsel 1997).

Thus the prediction commonly made is that if infants mentally organise the events according to causality, the direct launching should be individuated as the only “causal” event and it should be perceived differently from the other non-causal events.

In order to account for his data Leslie hypothesised the existence of a “spatiotemporal contiguity gradient” intended as a continuum indicating the degree of spatio-temporal continuity of the stimulus. The absence of spatial and temporal continuity corresponds to a non-causal stimulus, while the launching stimulus which is characterised by perfect spatio-temporal continuity represents the positive extreme of causality, in between there are the launching + temporal delay and the launching at a distance.

The gradient explanation has been controversial, some observe that the concept of a continuous gradient doesn’t seem to be suited to capture the notion of a non-continuous causation module in which the causal event is distinct from the non-causal events (Koslowsky and Masnick 2002). Others propose an alternative explanation claiming that perceptual causality in launching events develops through different phases in which the infants are not sensitive to causality but to the separate features like spatial and temporal continuity of motion (Oakes and Cohen 1994, Cohen and Amsel 1998). According to this view, before the 7 months of age the infants don’t perceive causality but respond differently to the separate spatial and temporal features of the event, and only later discriminate events on the basis of causal features. The prediction is that during development there should be a decrease in responding in terms of independent features, and an increase in responding in terms of causality.

Cohen sustains also that Leslie’s mixed results rise questions about the modularity of causal perception, because if infants responses were based upon an innate causal module, it is not easy to demonstrate how they could be based also upon an incompatible perceptual system in which the spatial and temporal features are perceived independently.
Cohen (1994; 1997) and Oakes and Cohen (1995) support an alternative explanation that they define an *information processing* view, opposed to a nativist one.

They argue that infant’s perception of independent spatial and temporal features is a developmental precursor to later causal perception. Leslie (1984; 1987) explained his data through the concept of “spatio-temporal contiguity gradient”, but this findings could be due to the fact that his sample of subjects comprehended younger or less advanced infants who were responding according to separate spatio-temporal features, and more developed infants who were already processing the stimuli in terms of causality.

Through a series of experiments investigating causal perceptual abilities in infants of various ages (7 to 4 months of age) Cohen and colleagues tried to challenge Leslie’s hypothesis of the innate module for the perception of causality as well as that of the spatio-temporal continuity gradient.

In the first of the experiments Oakes (1994), showed some simple events to 7 months old babies, the displays involved a red and a blue ball moving. Infants divided in three groups were habituated to a causal direct launching, to a non-causal delayed launching, or to a non-causal no-collision event. The infants were then tested on all three events. Oakes found evidence of responding on the basis of causality, but no evidence of responding on the basis of independent features as the infants habituated to the one of the non causal events didn’t dishabituate to the other non-causal event. This could mean that at 7 months of age the infants are finally responding on the basis of causality and not anymore on the basis of independent features.

Subsequently, a series of other experiments tested also 4 and 5 ½ as well as 6 ½ months old infants (Cohen and Amsel, 1998). According to Cohen and Amsel the results obtained could seriously challenge Leslie’s hypothesis that causality perception is innate and hard-wired. The data indicate in fact a developmental progression involving two distinct modes of processing, prior to perceptual processing in terms of causality. The authors suggest that the most primitive of the two can be mistaken for causal processing. The results replicated Leslie’s findings with children of 6 ½ months. It seems therefore that at this age there’s evidence of mixed responses, to causality but also to independent features. In fact, infants who habituated to the causal event dishabituated to the delay and gap events, and infants who habituated to delay or gap events dishabituated more to the causal event than to the other non-causal event.

The 4 months old infants regardless whether they were habituated to the causal event or to one of the non-causal events, looked longer at the causal one during the test
demonstrating to have a natural preference for the causal interaction. Moreover, looking at the first four habituation trials it can be seen that even prior to habituation the infants looked longer at the causal event than at either of the non causal ones.

At 5 ½ months, there still wasn’t any causality effect, the infants manifested a preference for causal events, in fact infants habituated to the causal event still looked longer at the causal one rather than to the non causal ones after habituation.

Moreover, the crucial development at 5 ½ months was that infants habituated to the delay or the gap event dishabituated significantly to the causal event (showing to be sensitive to causality), but also to the other non causal event, (demonstrating that the two non causal events are not perceptually equivalent).

Cohen and Amsel argue that analysing the data of the three experiments just described, it seems possible to obtain a developmental trend, showing evidence of causal perception at all three ages, with a systematic decrease in independent features perception from 4 to 7 months of age.

In order to explain his data Michotte (1963) suggested that the direct launching event presents the perceptual system with a conflict: the motion of the shapes is perceived as continuous, but at the same time the two distinct events are perceived separately as a movement performed by the first object and the movement performed by the second one. The Belgian psychologist argued that the perceptual system resolves this conflict by perceiving the direct launching as causal. Following Michotte, Cohen interprets his data about 4 months old infants as a preference for the continuity of motion, while the data about the 5 ½ months old would reflect the perception of two distinct events. Only later at around 6 ½ months of age the infant would become able to merge the perception of the single characteristics (spatiotemporal continuity of motion) in order to perceive causality. The information processing view of causality development hypothesises that the two perceptual aspects, continuity of motion and the perception of two distinct moving objects develop independently at first, and than combine later to form the perception of causality.

The problem is that all this debate about the development of perceptual causality in infants seems to originate from the presupposition that the two non causal events are equivalent being both non causal, at the same time however, it remains true that the two kinds of non causal events are not equal in terms of their spatio-temporal structure, therefore it is not clear why the infants shouldn’t perceive a difference between them.

Thus, the data previously described can be interpreted alternatively. The fact that 4 months old infants show a preference for causal events (longer looking time) could be
interpreted as a preference for stimuli that are salient and interesting for the infant, stimuli that attract his attention, contrary to the non causal ones. Such a preference could have an adaptive function, in fact preferences for particular stimuli can signal areas of their future expertise (i.e. let’s think to face-preference in young infants).

Infants younger than 6 months perceive the difference between causal and non causal events and between the different non causal events, which in fact are supposed to be equivalent from the point of view of causality but not in their spatio-temporal characteristics.

Later, after 6½ months of age, the most salient characteristic is that of causality (Oakes and Cohen 1994) and the difference between the non causal events seems to become less important for the infant.

Also in adult subjects, while a temporal pause, as little as 60 ms destroys inevitably the causal effect (Schlottmann et al. 2006b), the spatial gap maintains instead a more ambiguous nature. A launching event with a temporal gap is never perceived as causal, but a launching event with a small spatial gap can be still perceived as causal, in fact it is perceived as a launching at a distance (Yela 1952). This reveals a fundamental difference between temporal and spatial contiguity in the perception of causality, and underlines the importance of temporal contiguity in the perception of physical causality. While the introduction of a small pause in a launching event is sufficient to destroy the impression of causality, the launching at a distance can be similar enough to the standard launching. Moreover it has been shown that in adult subjects as the size of the gap increases the impression of physical causality decreases but at the same time the social causality impression increases (Congiu et al 2005), this means that a spatial gap event can still be perceived as causal.

The importance of temporal contiguity emerges also in studies about causal explanation in young children between 5 and 10 years of age. Schlottmann (Schlottmann 1999) investigated how children integrated perceptual causality with their knowledge about the causal mechanism that ruled the event shown.

In the experiment the children had to make a causal choice on the basis of the knowledge about a mechanism or on the basis of their perception of an event: one ball A was dropped into a box by a hole, after a pause another ball B was dropped in a second hole and a bell rang immediately. Children had to choose whether A-not contiguous or B-contiguous with the effect (the ring), made the bell ring. Two mechanisms one contiguous and one not contiguous were inside the box and the children responded after a familiarisation phase with the two mechanisms.
The children understood that the fast mechanism would have produced an immediate effect and vice-versa the slow one would have produced a delayed effect, and could reason on the basis of this knowledge, but they were not able to choose the delayed cause when perceiving a contiguous distracter. The result of the experiment was that 5 to 7 years old children chose temporal contiguity regardless of the mechanism hidden inside the box, this would suggest that temporal contiguity has a crucial role also in early judgements of causality. Therefore the causal continuity is a strong element that children find difficult to overcome and this suggests a link between perceptual contiguity and causality.

In the spatio-temporal continuity gradient hypothesised by Leslie the launch at a distance (temporal but not spatial continuity) is situated on the causal side while the launch delay is correctly more on the non-causal side, this is compatible with experimental evidence about the ambiguous role of spatial contiguity in the perception of causality.

On the light of this evidence it is necessary to wonder whether two events that have been traditionally considered as non-causal events, that is a launching event with a spatial gap and a launching event with a temporal gap are truly equivalent or if such equivalence is only supposed as these two events differ not only in their spatio-temporal features but also in the fact that spatial gap events can still elicit attributions of physical or even social causality at least in adult subjects, therefore the debate about the role of nature and nurture in perceptual causality abilities during infancy seems based on a false premise.

Last but not least, strong experimental evidence produced through reversed events supports the idea that infants truly categorise launching animations according to causality and not according to distinct spatial and temporal features.

Reversed events: the agent-patient distinction

Leslie and Keeble (1987), proposed that the most efficacious test of causal perception consisted in habituating infants to events that are either causal or non-causal, and then to test their reaction when the same familiarisation event is shown in reverse. Such a procedure allows to overcome all the controversy about the eventual spatio-temporal differences between causal and non-causal events.

This paradigm was first used by Leslie (1982) in order to investigate if infants perceived launching events as having an internal structure (causality), opposed to non-causal ones. The launch was compared with the movement of a single object that by definition has no internal structure but only a spatial direction, the findings show that the infants habituated
to the launching event and than tested on its reversal recovered their looking more than the group of infants habituated to the single moving object event.

The assumption is that if infants are sensitive to causality, those habituated to the causal event should show greater dishabituation to the reversed event than those habituated to the non-causal event.

This is the prediction because the reverse of the causal sequence reverses also the causal direction, that is the action roles of agent and patient, whereas in the non causal one there’s no reversal of causal roles in fact there is no causality and therefore there are also no roles. The reversed events allow to investigate if the child really perceives causality or rather the spatio-temporal subcomponents of the structure.

With this powerful series of experiments Leslie linked strongly the concept of causality with that of agency and demonstrated that infants as young as six months perceive causal interactions differently from the spatio-temporal properties of an event. Moreover the results go further as they push strongly towards a special status of causation and specifically of causal agency (Koslowsky and Masnick 2002).

Leslie and Keeble (1987), habituated infants aged 24 to 32 weeks, to a direct launching event (figure 8) or to a non causal, delayed event in which a 0,5 seconds delay occurred between the contact of the two objects and the movement of the second object. The interactions involved a red square and a green square, and in the test trial the animation was played in reverse in order to obtain a switch in causal roles, the results show that infants in the causal group dishabituated more than those in the non causal one. Therefore 6 to 8 months old infants resulted able to perceive the role reversal in causal situations.

Coherently with the prediction, the data show that the reversal of an apparently causal event (direct launching) produced more recovery of attention than the reversal of the corresponding non causal one.

Figure 8 Launching event (top) and reversed launching event (bottom)
Causal Inference and Causal Perception

The dissociation between causal perception and causal inference reflects a functional dissociation of the two hemispheres in the adult brain, usually not evident in typical adult individuals, but that seems to emerge in split-brain patients. Roser et al. (2005) have shown that the capacity to perceive causality and the ability to infer causality depend respectively on the right and on the left brain hemispheres. Perceptual causality is intended as the direct perception of causal structure from object interaction and differs from the inference of causal structure from observation and real-world knowledge. In this frame, simple two-dimensional displays evoke an illusion of causality (Michotte 1946 / 1963), this illusion is constructed by the visual system in a manner similar to the construction of high-level percepts such as three dimensional object structure from motion (Scholl and Tremoulet, 2000). Empirical evidence supports this interpretation. From a study with two split brain patients emerges that the perception of causality from dynamic events is the result of right hemisphere processing.

Evidence for causal perception is usually complicated by the methods used to assess the perceptual experience. Adult observers are typically asked to report verbally or through an explicit rating, whether they perceived that the motion of an object caused the motion of another. These self reports are obviously open to the influence of post-perceptual interpretation and may reflect the outcome of inferential processes. Therefore the evidence for causal perception from observer reports can be confounded with causal inference. This is evident also from the fact that not all observers report perceptual causality when they first see the launching stimulus (White 1988), reports of perceptual causality are moreover subject to contextual effects and sensitivity to causal structure undergoes changes during infancy (Cohen et al 1998).

Developing reasoning abilities contribute also to reports (Schlottmann, 1999; Schlottmann et al 2002). One of the problems is that the variance in the reports of the observers is potentially due to response bias effects and not to changes in the percept. These age and experience related changes highlight the difficulty in associating the concept of modularity to the perception of causality (Schlottmann 2000).

Schlottmann and Shanks 1992 made the most successful attempt to separate causal perception from causal inference in a psychological study. They assessed whether a learnt association between a predictive event (a colour change) and the movement of an object, affected the perception of causality in launching events. In this experiment, the collision
between two objects did not predict reliably the movement of the second, while the colour change of the second object did so. However, participant’s ratings of the degree of perceived causality were not affected by the colour change, suggesting that they were not based on the predictive contingency but rather on the temporal properties of the collision. In a second task the participants were asked to judge (infer) the necessity of collisions for movement in a set of events. These judgements were sensitive to the contingency between the colour change and the movement, but ratings of perceived causality were not. The perceptual ratings of the subjects showed a contiguity effect, while judgements about the necessity of the collisions for movement was subject to a contingency and a lower contiguity effect. This suggested that these two aspects of causality understanding involve different processes, in sum there seems to be a strong difference between judged and perceived causality. While perceptual causality means a supposed perceptual process that originated the verbal reports of the observers, the process of inferential causality describes the application of logical rules and conceptual knowledge to the interpretation of events.

Through the testing of split-brain patients it has been shown that the right hemisphere possess an advantage for tasks that require visuo-spatial integration or discrimination, such as mental rotation. Conversely the left hemisphere has greater capacities in terms of interpretation of complex stimuli and actions, including those of the right hemisphere. The left hemisphere often creates complex interpretations for events in spite of the fact that this can interfere with tasks that would be more easily accomplished without such elaboration (Gazzaniga 2000).

The double dissociation between perception and inference of causality in split-brain patients implies that the ability to draw inferences is not sufficient to determine the causal structure of dynamic events. It seems that the right hemisphere can extract the causal structure from dynamic events, but cannot draw simple causal inferences, while the left hemisphere infers causality from patterns of covariation between events but is not able to perceive causality in collision events (Roser et al 2005).

These findings were later confirmed in a functional magnetic resonance (fMRI) study in which 16 right-handed adult participants were imaged while viewing launching events or non-causal equivalents in which a spatial or a temporal gap preceded the movement of the second shape (Fugelsang et al. 2005). The results showed that spatial and temporal cues to causality recruited a network of frontal/parietal and frontal/temporal regions localized within the right hemisphere, this suggests that the extraction of causal structure from dynamic visual displays depends on the right hemisphere not only in split brain patients but also in the normal brain.
Moreover the activation of the right pre-frontal cortex suggests that such stimuli require additional executive attentional resources beyond those afforded by the visual system. Also Fugelsang et al. (2005) proposed that the prefrontal activation could represent the selective allocation of attentional resources to causal stimuli. Understanding of causality is likely to be a complex process in which perception and inference may operate independently and rely on different brain networks (Fugelsang et al 2005).

2.5 The perception of intentionality

Animacy, Social-Psychological Causality and Agency

The perception of animacy, of causality and the attribution of agency and intentionality are extremely interwoven in adult observers, either because the environmental stimuli are often a complex of these different components and because perceptual abilities are necessarily integrated with knowledge.

One main question in developmental psychology concerns the developmental course of infants’ ability to distinguish animate and non animate entities, hence causality, animacy and agency are central concepts in this debate. In order to achieve this result experimental designs try to disentangle the different features characterising objects, agents and interactions.

Earlier studies about the animate/non animate distinction focussed on the knowledge underlying it. For instance Gelman and Spelke (1981), in one of the first attempts to define the difference between animates and non animates describe a wide generic series of different characteristics. First of all, they claimed that animates are agents, therefore they can initiate the action in a causal event while non animates can only be acted on, moreover animate objects grow and reproduce, can have mental states such as knowing, perceiving and emotions, they have parts (like limbs) that are linked to a biological function, and finally they are capable of communication and reciprocity (Rakison and Poulin Dubois 2001).

On one hand most of these characteristics reflect adult’s and older children’s knowledge of the world and can hardly describe how infants or young children come to distinguish animate beings from non animate objects. On the other hand although their theory didn’t provide an adequate developmental account, Gelman and Spelke individuated some directly visible characteristics of animate entities, such as their capacity to initiate an action, their aspect, and their ability to communicate and act contingently.
More recent studies focus on infants’ perceptual capacities in order to investigate the developmental origins of the ability to distinguish animate beings from non-animate objects.

Two main developmental hypotheses about infant’s recognition of intentional agents have been formulated. On one hand there are those scholars who think that infants can identify agents because they are characterised by a set of specific features (faces, eyes, biological motion etc.) proper of animate agents. Children would come to reason about the behaviour of persons, using different principles, only later (i.e. “people act because they have goals”), on the other hand there are those who believe that the reasoning principles come first and lead the infant to the identification of intentional agents (in this sense, the identification of the goal-directedness of an action or the capacity to react at a distance would be fundamental for the identification of an agent).

The first is considered a more traditional account (Meltzoff 1995; Legerstee et al. 2000), linked to infant’s well-known preference for social stimuli like faces, voices, human movement and from the early or innate abilities of motor mimicry and contingent social interaction displayed by the infants (Meltzoff and Moore 1977). Furthermore such an account assumes that only animate agents can be perceived as intentional.

The second is more innovative (Carey and Spelke 1994; Gergely et al. 1999; Leslie 1995), the hypothesis that “domain-specific reasoning principles” help the identification of intentional agents implies for example that if the observed behaviour can be described as goal-directed, the entities involved will appear intentional even in the absence of other evident biological “agency” cues. This type of conception derives from the well known early perceptual abilities of infants relative to features in the behaviour of animate and inanimate objects in the world, such as causal agency, contingency, goal directedness of actions.

It is likely that these two mechanisms operate jointly in development and help infants in their early individuation and understanding of agents.

**Biological agents**

Naturalistic stimuli displaying living animate agents reflect everyday life experiences of adults as well as those of infants. Usually the animate agents present in the world correspond to living biological organisms characterised both by biological features of appearance and movement, and by the contingency and intentionality of their actions.

As already underlined, social stimuli and particularly people’s actions have a crucial role among infant’s first experiences of the world. The developing mind has definitely some innate tendency towards stimuli that are necessary for the development of social cognition.
Everyday experience and experimental evidence show that infants are particularly attracted by animate agents since the first moments of life. Biological features of the other agents have a great appeal for children since birth and this preference is adaptive: infants’ preference for people (face, voice, contingent interaction and motion) is really important for their survival in the first moments of life when they have to communicate their needs to the caretaker and to establish a relationship of reciprocal attachment (Harlow 1958; Bowlby1969).

Since birth infants show an innate preference for stimuli topographically arranged as human faces (Morton and Johnson 1991), moreover very young infants between birth and three months of age are able to recognise their mother’s voice and face (Mehler et al 1978; Barrera and Maurer 1981).

Infants are naturally endowed with the ability to interact contingently with their caretaker and even to reproduce the adult’s facial expressions, moreover infants are subject to the emotional contagion, this means that they usually assume the emotional attitude of the person they are interacting with (Hatfield 1994; Meltzoff and Moore 1977, 1997).

The early motor mimesis is supposed to be at the basis of infant’s perception of other people’s actions and behaviour and to the successive ability to understand and imitate the goals of their actions. The early imitative capacity is particularly surprising as infants are able to reproduce with their own face something that they can only see, in fact they can see the other’s faces but can’t see their own, at the same time infants can’t feel the other’s face but can feel their own, the question is how they can match what they see with what they do.

Current interpretations of these data converge on the hypothesis of a common coding between perceived and generated actions, in this view the mirror neurons system is what allows such mechanisms of imitation (Gallese et al. 1996, Rizzolatti et al 2001).

Mirror neurons are a particular population of neurons of the pre-motor cortex, that is activated either when a person makes an action or when the person perceives this same action, therefore our cognitive system has a direct way to feel other people’s actions as if we were performing them, action observation involves neural regions similar to those directly involved in action production. Although very promising the mirror neurons hypothesis still lacks direct empirical evidence at the developmental level, in fact nothing is known about the maturation of this neural system.

An important developmental datum that indirectly supports the mirror neuron’s hypothesis comes from young children imitative capacities: 18 months old children are likely to imitate the goal of an action performed by a person but they don’t imitate an action when it is performed by a mechanical device (Meltzoff 1995).
The lack of imitation of an action performed by a mechanical device could also depend on the fact that imitation is usually inserted in a social situation, therefore they don’t find natural to imitate an inexpressive and non interacting mechanical device. Infants as young as 6 months fail to attribute goals to an action performed by a rod instead of an arm, while they attribute the goal-directedness to an action when it is performed by an arm and an hand (Woodward 1998). Similarly, mirror neurons don’t activate when the action is performed by non-biological devices.

A very interesting replication of Woodward’s findings comes from a recent study by Schlottmann et al. (2006a). In this study the procedure ideated by Woodward was implemented in a graphic animation in which the agent was either a rigid square or a non-rigidly moving “caterpillar like” shape reaching for a stationary coloured ball. The study replicated Woodward’s results as six months infants dishabituated more to the change in goal than to the change in direction and attributed goal directedness to the geometrical shape only if it displayed animacy features.

Therefore, it seems likely that the features associated to the motion pattern of an agent are very salient during infancy, they allow the identification of an animate agent from the characteristics of its motion and the successive attribution of intentionality, and encoding of the goal of its actions.

Experimental evidence shows that Infants interact differently with animate and non animate objects. For instance Legerstee (1994) compared the reaction of 4 months old to events in which a person or an inanimate object disappeared behind an occluder, she found that the infants behaved differently according to what was the object hidden behind the occluder: in the case of the object, infants touched the door, while if it was a person they vocalized.

**Perceptual animacy**

Perceptual animacy concerns the direct perception of the “animateness” features of an object, like for example from its aspect or from its motion. Animacy is a visible enduring property of an object, linked essentially to biological motion features (Berthenthal 1987; 1993; 1994), to features that generally characterise living organisms, or goal directed behaviour, even if not to self-motion in itself (Opfer 2002; Schlottmann and Ray 2004).

It is likely that the sensitivity to the perception of animacy is innate and hardwired in the human brain, in fact infants’ early sensitivity for social stimuli is in place since the first moments of life, they are naturally attracted by face expressions, eye gaze, human voice,
human motion and have an innate capacity to respond contingently to social stimuli (Meltzoff and Moore 1977; Johnson and Morton 1991; Berthental 1987).

Originally one of the distinctive features of animate agents was supposed to be the fact that they can move autonomously, while objects need the action of an external mechanical force to start moving. Based on this evidence Premack (1990) proposed a nativist account of the animate-non animate distinction based on self-propelled motion. According to him an object beginning to move by itself represented the prototypical example of animate agent, moreover such an object was expected to engage in goal-directed action which is perceived as intentional. Premack’s theory was based on the observation of the movement of the objects in the world, he also proposed that at an higher level the distinction between animate and non-animate objects was based on the perception of psychological causality, or better from the perception of intentionality. He hypothesised the existence of an innate system apt to perceive self-propelled motion and interpret it as intentional independently from the appearance of the object involved.

It is now widely recognised that self-motion in itself is nor necessary neither sufficient to trigger the interpretation of an object as animate or intentional.

**Biological motion and features**

It is possible to identify moving organisms purely from motion information as it has been demonstrated by Johansson (1973;1975). This Swedish psychologist ideated an experiment in which a human body was represented only by means of light points corresponding to the joints: when the actor was sitting, the adult subjects tested couldn’t perceive anything more than a set of meaningless lights, while, as soon as the body started moving, they could immediately recognise a human body from the motion of the joints, and even discriminate the kind of activities performed by the person displayed. Moreover successive work has demonstrated that people can even perceive subtle differences in human gate.

Similar experiments were replicated with infants, showing that 3-5 month-old infants are able to distinguish the canonical biological movement of a person from a similar but perturbed patterning, (Bertenthal et al. 1987). It’s interesting to notice that the same findings were not replicated when the point light displayed a spider instead than a person (Bertenthal and Pinto 1994), as if 5 months old were already in possess of a representation of human form and its movement but not of other forms, this is again coherent with the mirror neurons hypothesis.
Baron Cohen (1995) suggested that the perception of biological patterns of motion, characteristic of animals and people, in infants produces directly the identification of agents with goals and desires. However, it is not clear how the infants should come to perceive the mental states of an agent only on the basis of a biological pattern of movement, without previous knowledge about biological agents or without a visible goal. This would imply that infants can attribute goals and intentions because they know from experience that biological organisms can have goals, desires and mental states. Furthermore, an animate agent can also move in a non-goal-directed fashion, therefore in order to attribute goals and intentions to it the infant should make an inference based on previous knowledge of biological agents. However, it is likely that biological features of appearance and motion attract infants’ attention and are fundamental in orienting their experience of agents.

At the age of five months infants can distinguish between purposeful and non-purposeful behaviours: while they recognise a hand grasping an object as a goal-directed action, a non-purposeful analogue behaviour such as the back of a hand touching the same object is not perceived as goal-directed (Woodward 1999). Therefore, it is difficult to claim that infants interpret any example of animate motion as intentional, moreover if mirror neurons are responsible for the recognition and interpretation of goal-directed actions these two types of action (intentional – unintentional) could be coded completely differently at the neural level.

Motion patterns, causality, and biological features are directly available to perception and can be used by infants in order to distinguish animates from non-animates, it is commonly assumed among developmental psychologists, that infant’s interest for faces, eyes and people drives their attention towards developmentally relevant stimuli.

Though, in naturalistic situations animate beings are complex entities in which all these (and many more) characteristics are present at the same time. The isolation of some of these factors in experimental designs allows to establish which of them are at the basis of infants’ ability to differentiate animate beings from objects.

Some of the studies about the origin of the animate-inanimate distinction have tried to assess infants’ sensitivity to certain characteristics such as the human face, the human gate, the properties of solid objects and self-motion (among the others: Morton 1991; Berthental et al 1987; Spelke et al. 1995; Booth et al 2002; Premack 1990). However, the property of animacy can be perceived also in simple displays. Michotte himself suggested that simple motion cues provide the foundation for social perception, he claimed that: “in ordinary life the specifying factors like gestures, facial expressions and speech are innumerable and can be
differentiated by an infinity of nuances. But they are all additional refinements compared with the key factors, which are the simple kinetic structures”.

Animacy is associated to the concept of life, the perception of animacy can concern an object in itself and not necessarily the object in relation to something else, animacy is principally a feature of the motion of an object or of its appearance. The motion of living organisms can be described as non-rigid, characterised by irregularities in trajectory and speed, many different parameters can be varied in the motion of an object in order to define what exactly makes biological motion so different from any other motion.

Animacy and intentionality can be dissociated, in fact a creature characterised by biological movement can seem animate and at the same time non goal-directed, it can simply look alive because of its movement. If a visible goal is present, the behaviour of the agent will be directly perceived as goal-directed. An example of this can be found in Blythe et al’s experiment (1999) in which the subjects were shown two animated computer characters simulating the interactive behaviour of two bugs that moved contingently in various ways (i.e. fighting, chasing and escaping) in an empty rectangular environment. These authors found that the adult subject tested could correctly individuate the intentional movement displayed in a 50% of the cases, however they reported that in a second study, when only one bug instead of two was shown, the accuracy in the individuation of the intentional movement decreased dramatically. This demonstrates that the motion of one shape alone in an empty environment can provide insufficient information for an attribution of intentions. The converse is also true, in fact a non-biological rigid movement can be perceived as goal-directed when there is a visible goal, for instance this can happen in the perceptual causality animations.

Therefore even if the property of intentionality can be inferred by the biological movement of an object, animacy doesn’t necessarily imply intentionality at the perceptual level, and intentionality is not necessarily linked to animacy features.

The studies about perceptual animacy involve at least the perception of a simple shape alive-like although many of them go further and employ displays that give rise to the attribution of goals and even of mental states.

In Heider and Simmel’s seminal experiment in which three geometric figures moved around a rectangle, interacting in various ways, observers reports were consistent in attributing personality traits and emotions to the shapes. Heider and Simmel explained these findings by asserting that the features of temporal contiguity and spatial proximity produced phenomenal relationships among the figures.
A large number of studies have assessed the generality and robustness of such phenomena. Early work suggesting that the perception of animacy is context sensitive used to prime the subjects with emotional information or giving the shapes iconic facial expressions. However experimental works of this kind can be inconclusive as they don’t allow to isolate motion features from the biological hints associated to the object.

Others have demonstrated that the specific animated descriptions elicited by such displays are consistent across a wide range of cultures (Barrett et al. 2005), and developmental research has shown that also 3-4 years old children can attribute desires, emotions and personalities to the geometric shapes involved in Heider and Simmel’s animations.

Anyway, other developmental work has revealed that children interpret simple geometrical shapes as intentional agents just on the basis of their motion patterns. Gergely and colleagues have shown that motion displays can produce an impression of goal-driven behaviour in nine months old infants.

Recent research with adults supports the hypothesis that exactly the motion kinematics and not the featural properties of the objects are responsible for perceptual animacy. For instance, animacy is perceived even when the simple actors in an animation sequence are groups of items rather than unified shapes (Bloom, Veres 1999).

Moreover, Berry et al. (1992, 1993) suggested that adult’s and infant’s proneness to describe the animations in anthropomorphic terms is based upon the properties of the movement that characterise the animation and not on the characteristics of the objects displayed.

In their study a version of the stimulus which selectively eliminated features properties did not affect observer’s descriptions, whereas the elimination of motion information reduced perceptual animacy.

**Animate motion cues in complex displays**

One of the outstanding questions about perceptual animacy is the identification of the specific motion cues that produce its perception.

Among the first experimental works about the perception of social interactions in adult subjects is that of Bassilli (1976, reported in Rochat et al 2004) who found that a temporal contingency between the changes in direction of two circles produced the percept of an interaction between the figures, and that spatial contingencies influenced the perception of intentionality.
Later research has also explored the relationship between the perception of interaction, intention and animacy. Dittrich and Lea (1994) presented adult subjects with displays containing randomly moving letters (distracters) and a target letter whose movement was designed to simulate biologically meaningful intentional motion. The conclusion reached on the basis of the answers of the observers was that the perception of animate motion depends on the degree of interaction between the target and its goal, (for instance a direct trajectory towards the goal is usually considered more intentional), and on the impression of intentionality produced by the movement since the recognition of intentionality wasn’t impaired even when the goal was not visible. Their data indicated also that the perception of interaction depends upon the relationship between the trajectories of the distracters, and that the perception of intentionality depends on the trajectory of the target. Moreover their observers were better at detecting the target object when it moved faster than the distracters. These authors came to the conclusion that the perception of intentionality is the result of a process of interaction between visual features and knowledge.

Other authors like the often cited Stewart (unpublished work reported for example in Tremoulet and Feldman 2000, p. 943) hypothesised that the observers should perceive animacy whenever the motion of the object violates Newtonian laws, in the sense that a motion that would require hidden energy sources like smooth accelerations or sudden stops would be perceive as animate. She tested this idea by showing the subjects several displays. However the data obtained were ambiguous and only three types of motion among those shown generated consistently animate percepts: starts from rest, changes in direction to avoid collision, direct movements towards a goal.

Besides that, such effects are clearly mediated by other contextual factors, otherwise observers should report that the first items in most launching displays look animate, and this doesn’t happen.

Gelman and colleagues (1995) replicated Stewart’s findings in a series of follow-up experiments. Their experiments consisted in several animated computer displays showing one or two small balls moving in environments of static lines and geometric shapes. The displays varied in terms of the shape of the trajectories, the presence or absence of a second ball and the type of environment depicted.

The observers reported more animacy in environments in which the movements of the balls were consistent with some aspect of the environment representing either an obstacle or a goal. By contrast observers favoured inanimate interpretations when the balls moved in “odd” environments or when no environmental information was given. Gelman and colleagues
suggested therefore that the ability to classify objects into animates and non animates is not based only on perceptual information but also upon innate or early-developing knowledge of causal principles. According to their view the categorisation of an object as animate or inanimate depends upon an inference about the causes of its motion, in example if a motion appears to be self generated as caused by an internal rather than by an external energy source, then it should produce an impression of animacy.

This conclusion was already in Premack (1990) and contrasts obviously with the fact that for example self moving toys don’t look animate, and that self motion by itself is not sufficient to convey animacy in simple animated displays, like in the chasing event (figure 6). In fact also when no information about the onset of motion of object A is given, observers usually don’t make any assumption about its animateness only on the basis of self initiated motion. In causal percepts even when no hint about the starting point of A is provided its behaviour is still perceived as goal-directed. Finally empirical data show that an agent can be perceived as animate if its motion has features of biological motion even in an empty environment or with a visible goal, this is the case of expanding and contracting caterpillar stimuli (i.e. Michotte 1946, Schlottmann and Surian 1999).

On the other hand self motion is fundamental in reaction events in which the motion at a distance of object B is perceived as caused by object A, and B is considered an animate rather than a non animate agent. Thus self motion produces an attribution of animateness/intentionality when the movement of an object B is the effect of a visible cause at a distance, that is the movement of object A.

The characteristics of the environment are more likely to influence the perception of rigid movement, in conclusion a geometrical shape moving in a non-animate way looks ambiguous, it provides insufficient information for the observer to make any assumption about its intentionality. On the contrary it is true that if the shape reacts to something in the environment, that is, it engages in a goal-directed behaviour, it will be perceived as animate.

Therefore while animacy pertains to the object in itself intentionality is a relational concept that links the object to a goal.

**Animacy in simple displays**

The displays used to investigate the perception of animacy and intentionality have usually been more complex (in terms of trajectories or in terms of the environments) than those used to investigate the perception of physical causality, this kind of stimuli have...
generally tried to reproduce features of real organisms and environments. This has made it difficult to conduct a rigorous analysis of the mediating factors of perceptual animacy.

However, some authors like Tremoulet and Feldman (2000) have made some progress in this direction, creating very simple displays in which one single object moved across a uniform background.

Their experiments demonstrated that even the pattern of movement of a single object on a uniform field can convey the impression of animacy. The trajectory and speed of the displayed object changed simultaneously, and the judgments of the observers were influenced by four parameters: the extent of the speed change, in fact a greater increase produced more judgments of animacy, the change in direction, an elongated shape of the object, and the fact that the principal axis of the object and its direction of motion were aligned. According to Tremoulet and Feldman such a pattern of motion was interpreted as controlled by the will of the object.

Moreover they report that such a motion pattern suggested that the object was interacting with an unseen target conveying therefore a direct bottom-up impression of intentionality “and hence of animacy”.

Acceleration produced greater impression of animacy than deceleration, therefore the general hypothesis that animacy can be conveyed only by failure in energy conservation (Stewart 1982) is not confirmed. Moreover the mis-alignment of the shape axe with its direction produced the smallest attribution of animacy even if the energy pattern of motion shown was the same. Nevertheless adult observers have shown to be sensitive to violations of energy conservation, and this element influences the perception of animacy, therefore it remains true that several factors influence the extraction of animacy features from motion.

Tremoulet and Feldman’s study demonstrated that the combination of two types of features of motion, namely a change in direction and change in speed, can produce an impression of animacy, even on a featureless background. Follow-up experiments confirm that the motion of one object on a simple path might convey intentionality despite the absence of a goal or of a context. Moreover, if another object is added to the display, the strength of the animacy perception depends upon the position of this second dot, this replicates Gelman’s et al finding that the presence of an environment can influence the perception of animacy.

Furthermore, the result that simple features like a simultaneous change in speed and direction, in absence of any other visible features that might explain the velocity change, can convey an impression of animacy, are consistent with those of Dittrich and Lea (1994), who
suggested that the perception of animacy is under the control of two factors: an impression of intentionality, and an interaction between a target and its (possibly invisible) goal.

Animacy interpretation is defined by Tremoulet and Feldman (2000) as an “unconscious inference to the best explanation”: they suggest that it is inferred when the event can’t be interpreted as ordinary inanimate motion. Simultaneous speed, together with direction changes, not due to contact with any other entity or environmental features, are examples of such cues. They suggest that the perception of intentionality and animacy can be relatively immediate and bottom-up and report that the strongest impression of animacy occurred on trials in which the object accelerated, that is, where observable motion energy was clearly not conserved. The authors argue that in this account the default presumption of inanimacy is thought to be necessary in order to explain why animacy is not perceived everywhere in everyday scenes. There is an interaction between the two factors, low-level aspects of a target’s motion path can suggest the relation with an unseen second entity, this gives an impression of intentionality and thus of animacy.Animate cues might include any behaviour that suggests the presence of intentions, goals, perceptual competence or any other capacity that is exclusive to animals. Therefore, simultaneous speed and direction changes, not explained by contact, are particularly salient cues.

2.6 Perceptual causality and Social attribution

The debate about the perception of social causality begins with Michotte’s objections about the perceptual nature of social causality in reaction events. He considered social attribution not as the result of perception but as the result of interpretation, in fact he refused to consider psychological causality at the same level of physical perceptual causality of the launching event. One of the objections commonly used against the perceptual nature of social causality is that (in adult subjects) it is reported less frequently than physical causality, therefore it has been hypothesised that its perception could depend uniquely on the hints to consider the objects as animate agents. In his experiments Michotte found that adult subjects were more likely to perceive causality when they were given some hint about the animateness of the interacting objects.

Action-reaction sequences representing animate agents are generally more complex than mechanical sequences, for instance Heider and Simmel’s original animations contained multiple changes in trajectories and their movement had expressive features. However, a simple display similar to that commonly used for the launching event (Michotte 1946-1963) can represent a good example of social perceptual causality, moreover the chasing event used
by Kanizsa and Vicario (1968), elicits attributions of animateness to the object that is being chased even in total absence of biological animacy features.

Brief, schematic simple events such as those used by Michotte or Kanizsa and Vicario are characterised by minimal features, therefore, they are not apt to represent more complex interaction, to elicit the production of complex plots and attribution of mental states. The perception of social-psychological causality in such displays concerns the relationship between two entities, that is abstracted by the characteristics of how the motor behaviour of the one affects the motion of the other. It represents an interaction in which an object (A) affects the motion of another object (B) at a distance.

The type of causal interaction displayed can indicate the animateness or inanimateness of object B that undergoes causality. While the launching event produces the impression that object B is inanimate as it undergoes mechanical causality, the chasing event produces in the observer the impression that B is animate as it reacts at a distance. The attribution of animacy therefore can be bottom up, as it can emerge directly from the perception of motion features, or top down, as it can be inferred from causality.

Agency like causality is a relational percept, it is attributed to an entity that acts in a goal-directed way. It is also a property that can be inferred either by animacy (an animate agent can act in a goal directed way) or by causal percepts (an entity affects the motion of another entity). Agency concerns the capacity to act in some way, an agent can be either animate (that is alive, biological like), or non animate (i.e. a geometrical shape). Agency is attributed by adults even to non-biological agents when they are involved in interactions characterised by features, like an interactive behaviour, goal directedness, causality. The kind of interaction displayed, brings the observer to make certain attributions about the nature of the agents involved.

People tend to attribute agency to an object that has features of animacy because its motion has biological characteristics, or because it acts in a goal directed way, and to an object that acts or reacts in a causal interaction. As it emerges from experimental research with physical causality, agency is not necessarily attributed only to animate agents, but rather to entities that affect others behaviour either through a physical or a psychological interaction. In causal events, the reaction (either active or passive) of B determines the fact that A is perceived as an agent even if its nature remains not specified, B is recognised as agent only if it reacts at a distance, otherwise if it undergoes physical causality it is perceived as if it was an object.
Rochat and colleagues (2004) report that 3 months old infants already prefer to look at displays where two discs engage in a systematic social interaction rather than at displays showing the discs moving independently one of the other, this demonstrates that young infants can distinguish at some level the movements that specify social causality (for adult observers) from those that don’t.

In the events representing interactions at a distance, animacy and agency are inferred from the perception of the causal interaction between the two objects, which happens at a distance.

**Social causality and animacy in animated displays**

The peculiarity of perceptual causality and animacy is their character of visual percepts although they involve what are traditionally thought to be higher level concepts.

The perceptual nature is precisely what makes these phenomena interesting, in fact it is commonly accepted that people can conceive some visual object as causing some changing or as animate, the fact that such phenomena instead reflect perceptual processing is more interesting: this evidence suggests that perceptual processes have more to do with domains that were previously considered purely cognitive. Another important discovery that makes these percepts even more interesting is the early age at which infants are able to perceive and discriminate them. Also in developmental studies the perception of causality and animacy must be distinguished from the inference of causality and animacy. Faces, hands, the biological motion of point light displays are specific stimuli used in studies about causality and animacy, but they have to be treated separately from the studies that used the animations of simple 2D geometrical shapes.

While the studies with complex naturalistic stimuli are interesting because they allow to show infants’ reaction to real animate agents, simple animated displays are interesting in that they represent only the essential features that characterise causality and animacy.

Animated displays generate those that Michotte called functional relations referring to the perception of various properties in simple displays that are not in the events neither in their retinal projections. Simple displays can give rise to high-level percepts.

Perceptual systems can produce high-level impressions for instance in the perceptual recovery of other properties such as 3D structure. While basic visual features (like local orientation) can be directly recovered, others, like depth, cannot be unambiguously extracted from retinal projections without other assumptions, like for instance the heuristic assumption of rigid objects that the visual system makes in order to extract structure from motion. Such
assumptions appear to be hard-wired in the visual system, and are thus implicit, not accessible by consciousness and distinct from higher –level cognitive interpretations. The assumptions made by the visual system can be discovered with the methods of psychophysics by means of simple displays that satisfy the assumptions in the more minimal way possible (Scholl and Tremoulet 2000).

Like in the “kinetic depth effect” that allows the visual system to compute 3D structure from motion information, in fact such displays depth is conveyed solely by the variation in velocity and direction of each dot, and the impression disappears as soon as the motion stops), (Palmer 1999; Wallach and O’Connel 1953), causal displays as those used by Michotte, Heider and Simmel, or Kanizsa and Vicario have the characteristics to allow the visual system to compute not only causality but also features that were thought to be related only to the biological domain, like animacy, simply from the motion of schematic 2D representations.

Other researchers have further extended Michotte’s studies by continuing the exploration of the spatiotemporal variables and widening the number of functional relations to other phenomena.

For example White and Milne (1997) created displays that elicit the impression of one object pulling another, similar to Michotte experiments about traction.

Finally developmental studies have tried to determine at what age infants perceive causality in animated displays (among others, A. Leslie, L.B. Cohen, A. Schlottmann).

Experimental studies about social causality are in line with the studies about the perception of physical causality.

The substantial difference between physical and social causality (as we intend it here) consists in the fact that while the first is supposed to represent a transmission of force or energy from the causal to the effect system, the second is supposed to represent a reaction at a distance between two animate agents.

While in the launch the motion of the second object is perturbed by a physical force, in the chase the origin of the motion of the second object is a goal-directed reaction to the motion of the first that can be perceived as guided by psychological laws internal to the object.

Habituation with simple schematic animated displays offers a powerful research paradigm because it allows to test causal perception in infants, and to test developmental hypothesis about causal thinking.
In fact, the traditional research about the development of causal thinking has used methods that required the children to answer questions or verbal requests. It is evident that such method leaves unexplored causal perception and thinking in children under 2-3 years of age because of the still immature development of language.

According to the hypothesis formulated by Michotte the perception of causality in animated events like the launching was to consider as the foundation of our notion of cause. The question of the early ability to perceive causality either in the physical and in the social domain is considered important from the point of view of development as the precocious ability to perceive causal interactions could be at the origin of infants’ ability to distinguish agents from physical bodies, and social interactions from simple physical interactions. Perception of causation at a distance could allow early understanding of psychological causality and this could support the development of social cognition.

Social exchanges are evidently different from interactions in the object world because they can happen at a distance, without physical contact between the entities involved (excluding remote controls etc.).

For example a predator affects it’s prey’s behaviour at a distance without touching it, and people don’t usually interact by hitting each other in order to move in a certain direction.

Infant’s studies have shown how physical causality in animated moving displays is perceived already early in life, by the age of 6 to 10 months (Leslie, 1984; Leslie and Keeble, 1987; Oakes and Cohen 1994)

Studies about the perception of social causality are aimed to understand if and when, during development, infants come to perceive a causal link in the behaviour of two moving entities (like for instance two geometrical shapes) that interact at a distance.

Schlottmann and Surian (1999) found that 9 months old infants demonstrate a sensitivity to causation at a distance in a computer-animated display. Following Michotte, they used a perceptual hint to animacy as in their displays the shapes moved in a non rigid “caterpillar like” way. Infants were habituated to a chase event (causal), in which the second square started moving while the first one was still approaching, and to an analogue event in which there was a pause between the movement of the first and that of the second square (non causal). In the test trials using the research paradigm ideated by Leslie (1982) the infants were shown the same events but played on reverse. This corresponded to a role reversal in the causal events, but there wasn’t any reversal of the roles in the case of the non causal event. The assumption was that if the babies perceived the causality in this event they should regain attention for the event played in reverse showing a switch in causal roles.
In agreement with this prediction, the babies dishabituated to the reverse of the chase event but not to the reverse of the pause one, demonstrating to be sensitive to causation at a distance that is typical of social exchanges, and precisely to be sensitive to the causal roles played by the shapes involved.

These descriptions are coherent with the overall social achievements of infants around the age of 9 months. This phenomenon has also been named “the 9 months miracle” in social cognitive development (Tomasello). Around this age infants make important progresses in their social life, they start in fact engaging in joint attention episodes, manifest the first understanding of gestural communication such as pointing and gaze following (Bates et al. 1979; Carpenter et al. 1998), and begin to demonstrate social referencing that is different from the mere emotional contagion (Rochat et al. 2004). In other words around this age infants clearly begin to treat other people as intentional agents.

More recently Rochat et al. (2004) habituated 3 to 10 months old infants to a complex abstract animation in which two discs moved one chasing the other, (i.e., the red chasing the blue) than, they showed another sequence (test) in which the chaser was now being chased. The animations shown by Rochat and colleagues were expressive: each of the two discs was associated to a particular behaviour or “vitality. Only infants of 8 to 10 months of age dishabituated to the reversed pattern and the authors concluded that the dishabituation to the role reversal was a sign of their sensitivity to relational rather than discrete perceptual information.

In another study (Schlottmann et al. under revision) through a series of habituation tests demonstrated that 8-10 month old infants’ perception of social causality doesn’t depend on motion onset or on motion patterns that are typical of animate motion, but only on the configuration of the events shown. In fact infants in the study detected a causal structure in reaction events also when the agents moved rigidly or with a non-rigid motion considered less animate, moreover, they detected a causal structure even without self-initiated motion.

As claimed by Michotte, adult’s judgments strongly depend on their knowledge about the agents, and non-rigid agent motion strongly enhances adults’ impression (Schlottmann et al. 2006b), but it is very interesting that children are less affected by it: eight months old infants in Schlottmann et al study detected causality with rigid and non-rigid agent motion alike (Schlottmann et al., under revision). Even if we can’t tell if infants perceive non-rigid motion as animate (although if it results certainly more salient than rigid motion), the fact that they perceive causation at a distance shows that this ability doesn’t depend on the characteristics of the agent’s motion.
It remains to understand if infants have an *unspecific impression* of causality as “A does something to B”, and this impression becomes later linked to the physical and psychological domain, or if they distinguish contact-mechanical causality from non-contact psychological causality.

The fact that infants can distinguish the launching and chasing event and perceive causality in both of them seems to support the second hypothesis.

If so, the possession of two distinct percepts for animate and non-animate motion could help the child to distinguish the physical and the social domain.

**Perceptual causality in events displaying real objects and people**

Experiments displaying real people and objects can’t be totally assimilated to those displaying geometrical shapes for at least two reasons.

First of all people and objects can be identified by the infant on the basis of knowledge, therefore the configuration of the event doesn’t offer information about the nature of the entities involved in the event as such information is already in the agents involved. Moreover especially with very young infants it can be that the appearance of the objects shown is too appealing for the child who concentrates on the objects instead than on the causal structure of the events displayed.

It is evident that the displays showing real objects are not neutral as the geometrical shapes can be, in fact toys and real people can already be categorised as animate or non-animate in the infant’s mind, and this is particularly true when the infants tested are older than 10 months.

These kind of studies on perceptual causality using real objects and people don’t test perceptual causality but rather infant’s knowledge and expectations about the behaviour of animate and inanimate objects.

While perceptual causality is a bottom up process, the interpretive process tested by experiments with real objects is supposedly top down, with knowledge guiding perception in situations that present the child with conflicting or otherwise coherent information.

Experimental tasks involving real objects and people can be useful to test infants’ knowledge through the violation of expectation. They can be useful to tell us something about what infants know about agents rather than about what they perceive.

We must underline that experiments displaying real objects have produced different results in terms of age and of the ability to perceive causality respect to the data obtained with schematic animations.
Real objects can be too complex to process for younger infants. In one study, Lucksinger, et al. (1992), using an occluded object task with drawings of a toy car and of a toy truck, found that 6 months old did not respond in terms of causality, while 10 months old did.

Oakes and Cohen (1994) examined 6 and 10 months old infants, with realistic toy vehicles. Infants were habituated to a direct launching, a delayed launching, or a no collision event, and were then tested on all three types of events (it is the same design later used by Cohen and Amsel 1998). Clear evidence of causal perception was found at 10 but not at 6 months of age.

Thus the kind of objects involved in the interaction make a difference in the reaction of the infants. An unfamiliar real object like a toy car for instance is presumably more difficult to process and to distinguish from another similar object, it could be difficult for the infant to categorise it. With simple blocks or geometrical shapes that differ only in the colour, it should be easier for the infant to conceive the objects as separated and different.

Other research data confirm that older infants and toddlers have some knowledge and expectations about the different motor behaviour of real world animates and non animates: Redwood and Cohen (1996) found that 10 but not 14 months old infants perceived causality at a distance in events involving real inanimate objects, this result could be taken as the demonstration that only older infants know that inanimate objects don’t usually interact without contact and have expectations about their behaviour (Redwood and Cohen 1996).

Spelke et al (1995) report that 7 months old infants differentiate how people and inanimate objects should interact, since in their experiment infants dishabituated when an inanimate object was set in motion without contact (unexpected event), but not when a person was set in motion without contact (expected event). These data seem to support the view that agency and causality are linked from early on in the infant mind, as young infants have already some knowledge about how real-world agents behave.

Legerstee et al. (2000) have investigated whether infants expect people to interact differently with social and non social entities. Legerstee and colleagues adopt the piagetian view that the sense of causality has its basis in the understanding of the causal power of the self. According to this theory, in order for infants to be able to understand that others are animate agents they must first understand that they themselves are animate agents that make things happen. Moreover this research was driven by the hypothesis that before infants can understand that other persons are intentional beings, with goals that can be achieved with
different means, they must understand that people are animate beings, that not only move by themselves but also behave in certain ways.

According to Legerstee infants identify with other humans since birth, (see among others Trevarthen, 1979), and this allows their understanding that people can be acted on from a distance, but that inanimate objects need contact. In fact, the results of the experiment showed that by 4 months, infants vocalise towards hidden people but reach for the occluder behind which objects have disappeared (Legerstee, 1994). This suggests that infants understand that people can be acted on from a distance, but that inanimate objects need contact.

In a successive study the same author investigated whether 5- to 6-month-old infants expect other people to behave in ways they do. Infants were habituated to a person who either talked to, or reached for something hidden behind an occluder. During the test trials the occluder was removed and either a person or an object appeared. Infants that had been habituated to an actor talking, looked longer at an inanimate object than at a person during the test events. Infants that had been habituated to an actor reaching, looked longer at a person than at an inanimate object during the test events. In conclusion infants are surprised when they see people performing actions in which they would not usually engage. These findings suggest that 5- to 6-month-old infants understand that other people communicate with social objects but act on inanimate objects.

Another study by Molina et al. (2004) concerned the animate-inanimate distinction in displays showing human actors. Infants of 4 to 6 months were shown some scenes in which a person, by means of physical contact, caused the motion, of another person (unnatural) or of an object (natural). In the other condition the person spoke to the person (natural) or to the inanimate object (unnatural). If the interactions shown violated their expectations, 6 months infants were expected to look longer at the unnatural conditions, but the results show that infants looked longer at the appropriate conditions. This result can be interpreted as the natural orienting of the child towards an appropriate behaviour, moreover such a preference is common when the task or the stimuli are too complex or the infants has not been able to encode the information available in the stimuli.

**Attribution of agency**

Leslie’s experiments about the perception of causality through the reversal playing technique demonstrate that the infants perceive a role reversal even in physical causality
events, at 6 months they show to be sensitive to the agency component of the event. Causality is therefore linked to the concept of one thing doing something to another thing.

The role reversal is possible only when there is a relationship (causal) between the two objects, the roles of agent and patient depend on this relation. Agency can be conveyed by a causal interaction, even if the object involved doesn’t have animacy features, one of the things that make it possible is that causality implies the goal directedness of a behaviour.

Moreover these data are in line with Gergely et al.’s experiments, as for infants the domain of agency is not restricted to particular object kinds but is over-extended. Normally the proper domain of naive psychological reasoning are human action and human mental states, although such reasoning is frequently applied to non-human phenomena, such as natural forces or behaviour of computers as well. The usual explanation for such a tendency is that it reflects an overextension of an interpretational strategy, which has originally developed in order to interpret human intentional actions. However, several studies have demonstrated that infants are willing to attribute intentionality to non-human objects as well. Therefore, several authors have proposed that the initial domain of the application of psychological principles is not confined to human beings but corresponds instead to the wider ontological category of animates or agents where the category membership is defined by the object’s ability to initiate movement by itself.

Between 9 and 12 months of age infants discriminate between a more or less rational movement of some objects involved in a computer animated situation (Csibra et al. 1999; Gergely et al.1995). The infants were habituated to a display of a ball jumping over an obstacle and reaching another ball. In the test trials after the habituation the obstacle disappeared and the first ball either went straight toward the second or continued following the same trajectory as if the obstacle was still there. The fact that by the age of 9 months the infants dishabituated to the event in which the ball followed the same trajectory even if the obstacle wasn’t there anymore, but didn’t dishabituate to the analogue event in which the ball went straight to the other ball, is interpreted as the evidence that they were surprised by the fact that the ball jumped (irrationally) over the obstacle even if there wasn’t any obstacle. Therefore, the hypothesis is that the infants were already interpreting the movement of the ball as goal-directed and not in terms of its spatial and temporal features.

In a subsequent analogue study (Csibra et al. 1999) the infants observed a computer-animated figure approaching another one by flying over an obstacle. In this case however the object came into the scene already in movement giving no hint about the source of its movement, moreover there were no other expressive features in the movement of the objects.
The results replicated the pattern of findings reported in Gergely et al. (1995), these studies thus indicate that 9- and 12-month-old infants can interpret the behaviour of a computer-animated abstract figure as a case of rational goal-directed action. In the second study the goal-approaching object exhibited no movement cues of agency such as self-propulsion, irregular path of movement, or non-rigid transformation of surface, but the results demonstrate that 9- and 12-month-old infants do not require perceptual evidence of self-initiated movement in order to interpret the behaviour of an object as goal-directed and rational. Thus, agency cues such as self-propulsion are neither sufficient nor necessary for the teleological interpretation of behaviour.

These findings demonstrate that the infants in the experimental condition could recognise the rationality of the object’s goal-approaching behaviour in the absence of evidence of self-initiated movement and could predict its future action accordingly.

According to Csibra et al. (1999) this pattern of results suggests that the domain of naive psychology is initially defined only by the applicability of its core principles and its ontology is not restricted to object kinds characterised by specific features such as persons, animates, or agents.

So far we have seen that an agent can have an animate or an inanimate identity, this means that it can have biological – animacy features or otherwise it can have an inanimate appearance. Anyway, the fundamental thing is that these characteristics are dissociable: a biological or biologically-looking entity can be static or it can move not performing any action, while a non biological and not biologically-looking one can perform goal directed actions.

In the cases in which the two characteristics come together, (biological movement or appearance + goal-directed actions) for adults the impression of intentional agency is even stronger, while animacy features in displays of physical or psychological causality affect infants’ performance at a smaller extent (Schlottmann et al under revision). What seems really important for infants is only the goal directed nature of the action.

The fact that animacy features don’t enhance infants’ performance in habituation experiments concerning physical causality and goal directed behaviour is controversial especially as adults performance is facilitated by these cues. It could signal that adult perceptual processes are strictly interwoven with inferences and knowledge about the agents, while infants processes are principally based on perception. While adults apply a top down reasoning where their knowledge about the nature of the agents generates expectations about
the object’s behaviour, infants apply a bottom up principle that allows them to infer the nature of the objects involved on the basis of the interaction displayed.

However, it could be that the animacy introduced in the studies is not perceived as such by infants, in the end it could also be that the biological features presented in the animation are a representation that doesn’t have much in common with what infants perceive as animate, and that it is perceived as animate by older children and adults only thanks to an interpretive process. However, this last point doesn’t seem very likely as very young children of three years of age associate the caterpillar movement with biological motion.

Yet, these data could simply confirm that the essence of an agent is in its actions, the agent is what it does, or what is perceived as its goal. For instance in causal interactions physical causality describes an inanimate agent, while causation at a distance is compatible with an animate agent.

Finally Schloßmann et al.’s (2006a) study about 6 months old infants’ ability to attribute goals to simple geometrical shapes engaging in a goal-directed behaviour (reaching a coloured circular shape) is coherent with the current literature on this topic, moreover the infants attributed goal-directedness only to those object moving in an animate way (caterpillars).

Several conclusions can be drawn by this result, first of all it rules out the hypothesis of the importance of the motion onset of an object as a rigid self moving shape didn’t elicit goal-attribution, secondly it shows that caterpillar like stimuli elicit an impression of animateness even in young infants, thirdly while causal interactions in causal displays are the most salient feature and the appearance of the agents is not important (at least for infants), in a display in which the action consists in reaching for an inanimate static object the information given is not enough for the infant to attribute intentionality to a rigidly moving shape. This demonstrates that goal-directed, intentional action can be attributed on the basis of motion features characterising the motion of the object and its causal interaction with other objects present in the environment.

**Perceptual causality in children**

The ability to perceive causality is available early in development when the child has still limited experience of the world, therefore it could support development. The evidence about infant’s early sensitivity to causality already at 6 months of age is coherent with this view (Leslie and Keeble 1987; Oakes and Cohen 1994; Cohen and Amsel 1998).
It has been suggested that perceptual causality abilities depend on the activity of an innate module dedicated to the individuation of agency (Leslie 1988, 1994, 1995; Scholl and Tremoulet 2000) though, this account goes beyond the available data. In fact, infant’s sensitivity to the causal structure in launch events does not imply that they can categorise it as mechanical causality. It is possible that they initially perceive some differences between the events, and these differences will acquire a new meaning only later as innate perceptual abilities will be integrated with the knowledge of experience.

The developmental study of perceptual causality could be useful in order to solve the nativist question, in fact if causal perception is independent from experience children should be able to identify launch events from early on and this ability shouldn’t be subject to a process of maturation, while if perceptual causality is based on acquired knowledge there should be age differences. Developmental studies have found differences in verbal reports of launch events (i.e. Thommen, et al. 1998), however these could reflect differences in language development instead than perceptual abilities.

Thommen et al. (1998) reported that 10 and 12 years old, like adults, differentiated between physical and social-psychological causality in their verbal reports. 7 and 8 year-olds noted the presence or absence of contact, while 5 and 6 year-olds attributed intentionality to both events.

Since intentional action usually implies animate agents, it can be thought that what allows the child to distinguish the type of causality of an event is the nature of the agents involved. However, animate agents, as well as material bodies can engage in both physical and intentional action, moreover, people attribute social causality features even to inanimate geometrical shapes (Heider & Simmel 1944; Csibra et al 1999). Therefore, since social interaction is attributed to inanimate objects, some hints about the mode of causation must be independent of the agents while being linked to the interaction itself.

Recently a study (Schlottmann et al 2002) investigated children’s perception of physical and psychological causality in launch and reaction events in order to understand if children were able to make ontological distinctions on the basis of essential perceptual information.

In order to reduce the effect of verbal abilities in the task the research used a non verbal response method based on the choice between pictures that were designed to represent mechanical causality, psychological causality and the non causal event.

The logic was that of a categorisation approach in which attention to causality is demonstrated if the children group events into causal and non-causal categories, but ignore
differences in lower order features. If the children attend only to the spatiotemporal structure, they may discriminate the different events but not categorise them consistently. Eight distinctive animated events were presented, in order to understand if the children would group them into three categories of physically causal, psychologically causal, or non-causal motion.

The eight events shown included launch events, reaction events and the corresponding delayed control events with and without contact. Also the nature of the agents involved was of two kinds, the non animate rigid squares or non rigid expanding and contracting caterpillar-like squares, which allowed to test how agent features such as animacy affect perceptual causality.

Animacy cues affect perceptual causality in adults but not in infants, therefore it is interesting to trace a developmental course of the effect of animacy on the perception of causality.

The first part of the experiment involved 3 to 9 years old children, and the data showed that older children’s causal choices were similar to those of adult subjects, this in contrast with previous findings (Thommen et al 1998). Probably the better performance was due to the lower verbal demands, to the structured answer method and the use of appropriate non causal control events.

The distinction between physical and social events was made by means of the spatial contact, but animacy cues were ignored at all ages.

Age differences emerged in the use of temporal information to distinguish causal from non causal events. Many preschoolers ignored the pause choosing the collision event in case of contact and the chasing in case of non contact.

Due to possible ambiguities in the design of the experiment that could have brought young children to an alternative strategy based on simple contact matching strategy, there was a second experiment with 3 to 5 years old children in which the pictures and the procedure were modified.

The results of this second part of the experiment confirm that preschoolers are able to associate the animations to the event schemas for collisions and chases.

At age 4 children were sensitive to causality signalled by temporal continuity, and were also sensitive to the domain distinction signalled by the presence or absence of contact between the two agents. The almost perfect identification of causal events was contrasted with the improving performance in the identification of non causal ones for a reason which is not totally clear.
The experiments demonstrated that even preschool children are able to perceive causality in schematic motion patterns and distinguish them from non-causal sequences based on an analysis of interaction features, but this ability is independent of the nature of the agents.

The function of perceptual causality during development should be that to help children to learn about the surrounding environmental entities.

It is likely that children’s difficulties in giving accounts of perceptual causality previously reported (Thommen et al. 1998), could depend on the level of language and on the free verbal report method rather than on perceptual abilities.

### 2.7 Brain mechanisms of physical and intentional perceptual causality in adults

In different studies with the functional magnetic resonance imaging (fMRI), adult subjects were exposed to causal events and to their non-causal equivalents in which a ball collided with another ball (Fugelsang et al. 2005; Blakemore et al. 2001). The results of these investigations show that the visual system is predisposed to extract the causal structure of visual events and that it is relatively independent from top-down knowledge.

Fugelsang and colleagues (2005) found significant higher levels of relative activation in the right middle frontal gyrus and the right inferior parietal lobule for causal relative to non-causal events. Moreover, from the subtraction of the differential effects of spatial and temporal incontiguities, derived both common (right prefrontal) and unique (right parietal and right temporal) regions of activation as a function of spatial and temporal processing of contiguity, respectively. These data taken together provide a means to help determinate how the visual system extracts causality from dynamic visual information in the environment using spatial and temporal cues. The data led to conclude that specific brain networks are involved in the extraction of the causal structure from the world. The processing of the spatial and temporal cues produces a frontal-parietal and a frontal-temporal activation of the brain areas involved in visual perception and in the executive processing.

The extraction of the causal structure seems to be a property of the visual system. Similar to visual grouping and illusory contours completion.

The network of areas involved in the perception of causality seems to be in the right hemisphere, and this is coherent with the fact that these areas are those dedicated to visual
attention and the perception of causal events could require the allocation of more attentional resources.

Blakemore et al. found a significantly higher level of activation of V5/MT/MST complex bilaterally (temporal regions activated by processing of visual motion), the superior temporal sulcus bilaterally (involved in processing of goal-directed action) and the left intraparietal sulcus to causal relative to non-causal events. These results support Michotte’s hypothesis that causality is directly processed by the visual system as the attention to mechanical causality has no influence on how the brain processes causal stimuli.

Brain imaging studies validate the hypothesis that perceptual causality is a low level mechanism not influenced by top-down processes (Schlottmann and Shanks 1992).

In a successive study Blakemore and colleagues (2003) used non-linear launch and reaction stimuli in an fMRI study, the animations depicted two irregular shapes moving either in an a rigid or in an animate way. However, in the animate condition the type of motion wasn’t similar to biological motion, as the shape moved simply rotating in a self-propelled fashion. The results show an activation of the middle temporal gyrus and of the intraparietal sulcus during perception of mechanical contingencies and an activation of superior parietal areas during the detection of animate contingencies at a distance.

Moreover, the right middle frontal gyrus and left superior temporal sulcus, became activated when subjects specifically attended to the contingent nature of the animate–chasing stimuli.

These results suggest that low-level perception of agency in terms of objects reacting to other objects at a distance is processed by parietal networks. In contrast, the activation of brain regions traditionally associated with theory of mind tasks appears to require attention to be directed towards agency and contingency.

The perception of mechanical causality seems to be automatic and unaffected by top down processes like attention and expectations. Also the perception of causation at a distance is based on automatic bottom-up processes unaffected by attention, this is evident in the activation of the parietal neural networks dedicated to complex visuo-spatial detection. However contingency and animacy are two cues to agency, and the explicit detection of these two factors could be at the basis of activations in the right middle frontal gyrus and the left Superior Temporal Sulcus that could be caused by the attention to possible agents in animate-contingent displays, and not their detection on the basis of visual cues. When subjects were required to focus their attention on the contingent relationships between the objects rather than to their physical aspect or their movement, an activation of the right middle frontal...
cortex and left STS was recorded. These regions are also implied in theory of mind tasks such as inferences about mental states. These results are also consistent with those of Castelli and colleagues in which the “Heider and Simmel” animations triggered mental-state attributions and the subsequent activation of the STS and medial prefrontal cortex (Castelli et al 2002).

Perceptual and inferential processes of causality seem to be dissociable in the brain, or to depend on the activity of different areas. Gazzaniga (2000) has argued for a “left hemisphere interpreter” that should have the function to interpret and generate hypothesis about complex stimuli and actions. A primary role of this “left hemisphere interpreter” could be in causal inference.
3 The perception of schematic animated events in autism: verbal accounts and brain imaging studies

A few studies investigated how adults and children with autism interpret stimuli similar to those used by Heider and Simmel (1944). This kind of stimuli elicit descriptions in terms of intentions and mental states in typically developing children and adults, therefore since it is widely recognised that autism is characterised by great difficulties in the process of attribution of thoughts and feelings to other people it has been investigated how they deal with schematic animations in which geometrical shapes interact conveying an impression of intentionality.

3.1 Social attribution ability and false belief test

The ability to attribute mental states to other people has been called Theory of Mind or Mentalising, and it represents an aspect of social intelligence. For a long time the ToM abilities were tested with the so-called false-belief test, in which the child has to recognise the character’s mistaken mental state in order to predict a behaviour that is based on that false belief. Typically developing children are able to pass this kind of test between the age of 3 and 4 years while children with autism show a constant difficulty with such tests and this fact was initially taken as a proof of a lack of theory of mind (ToM) in autism (Wimmer and Perner 1983; Baron Cohen et al. 1985).

After Baron Cohen et al.’s pioneering paper the research about ToM abilities has been very intense and it has been shown that false-belief tasks have many limitations.

One of the main critics against the validity of false belief tests as a measure of theory of mind claims that mental state reasoning is not the only ability needed to solved false belief tasks, in fact typically developing children fail to pass them because of an inability to inhibit responses based on reality (Leslie & Thaiss 1992). Moreover when the false belief test is modified in several ways, addressing simplified questions, and providing memory aids, also younger children can pass it. This means that passing the false belief test requires more sophisticate processing abilities (German and Leslie 2000; Bloom and German 2000). Also linguistic abilities have a role in false belief tasks, and it has been found that children with
specific language impairment (SLI) have difficulties when the task has an high linguistic complexity, in other words the linguistic demands of false belief tasks affect the performance of the child. A question with an embedded complement structure, and a mental state verb “Where does Sally think the marble is?” is too much demanding for children with SLI (Miller 2001). Moreover despite the initial finding of a ToM deficit generalised to the overall population it has been found that some high functioning individuals with autism and Asperger syndrome are able to pass these experimental tests although they show a severe social deficit in everyday life (Frith et al. 1994). In addition it has been found that performance of children with autism in standard tests of theory of mind is strongly related to their overall verbal language level (Eisenmajer and Prior 1991; Frith and Happé 1994; Happé 1995). Children with autism in fact require higher verbal abilities in order to pass false belief tests respect to normal and mentally handicapped control children, and this result suggests that children with autism can solve theory of mind tests in a verbally mediated fashion. Finally, theory of mind tasks present the problem giving verbal instructions, therefore the overall level of language is linked to the child’s ability to pass the test. In false-belief tests the information is provided in an explicit way. Theory of mind tasks address explicit questions, therefore the child is invited to use his or her knowledge of mental states in order to employ a problem-solving strategy. Real life social situations are not characterised by such an explicit format, therefore the same people with autism who have severely impaired social behaviours and understanding of other people can be able to pass explicit theory of mind tasks). The overall cognitive and verbal level strongly influences the ability to pass the test. In conclusion theory of mind tests don’t seem to be adequate predictors of real life social functioning, and having theory of mind skills doesn’t coincide with equivalent social adaptation skills in real life situations. Moreover learning theory of mind skills doesn’t imply any improvement neither in social nor in communicative skills (Klin 2000).

The social attribution task

On the basis of this evidence Klin (2000) proposed an alternative task based on Heider and Simmel’s (1944) animation displaying two triangles, a circle and an enclosure, with the idea that such a task could be more similar to an on-line elaboration of a real social situation and offer less elements believed to facilitate ToM tasks performance. In this classical animation the shapes interact either through contact or at a distance.

The social attribution task (SAT) consists in the attribution of social meaning to ambiguous visual stimuli. Such a task was studied to reduce verbal instructions and explicit
definitions of the problem in order to analyse the spontaneous interpretation and saliency of the social elements. As we have already pointed out Heider and Simmel’s stimuli are one of the best examples of how simple schematic moving shapes can trigger social attributions in absence of any sound or of any anthropomorphic or animacy cues.

The stimuli shown in the SAT can be analysed at different levels going from simple description of the movement to attribution of mental states. Contrary to classical theory of mind tests such a procedure allows to measure the ability to attribute social meaning to ambiguous stimuli in a dimensional way.

The answers provided by the subjects (Klin 2000) were judged according to several indices (pertinence, salience, theory of mind, animation, person, problem solving), the results show that in the clinical population about one third of the answers were irrelevant or non-pertinent. Only one fourth of the social elements were individuated, there was a reduced number of mentalistic attributions, the understanding of the animation was characterised by a low level of social sophistication, there was a reduced capacity to attribute personality features to the shapes and finally the results show that individuals with autism have a consistent disability in making social attributions to ambiguous visual stimuli even when the test was presented in a more explicit way. The impairment was independent from the age or the IQ level. Adolescents with autism produced geometrical, mechanical descriptions of the stimuli while typically developing peers spontaneously searched for, and described the social elements present in the situations.

Another study concerning the attribution of mental states to geometrical shapes is that of Abell and colleagues (2000), in this case the movies displayed two triangles and an enclosure, the triangles moved around the screen in three different conditions studied in order to elicit attribution of actions, of interactions and of mental states. The descriptions were rated according to accuracy and type of description. The results show that adults used action descriptions to describe random animations (like bouncing), interaction descriptions for goal-directed sequences (like fighting), and mentalising descriptions for theory of mind sequences (like tricking). High functioning children with autism used mentalising descriptions less often than normally developing 8 year old kids, and even the children who were able to pass standard false belief tasks showed inappropriate descriptions of ToM animations confirming an impairment in on-line mentalising processes. Children with autism often referred to inappropriate mental states, overall the data confirmed that the capacity to pass false belief tests is not linked to the ability to interpret other’s mental states in every-day social situations. The absence of any explicit verbal information in the movies may have caused the infant’s
poor performance, in fact verbal information could help children with autism in their interpretation of the animations.

Castelli et al (2002) have shown the same type of animations used by Abell et al. (2000) (random, goal directed and theory of mind) to 10 adult individuals with autism and control peers during a PET scan study, and they also recorded the subject’s verbal answers. The answers were recorded after each scan and were than coded according to three parameters, *intentionality, appropriateness* and *length*.

The results show that the answers of the two groups of subjects didn’t differ significantly when they observed the random and goal-directed condition, while for ToM animations the group of individuals with autism used fewer and inappropriate mental state descriptions than did the controls.

The comparison of the neuroimaging data of typical individuals show that several brain regions activated during the ToM animations but didn’t activate during random animations: basal temporal area, superior temporal sulcus at the temporo-parietal junction, extrastriate cortex (inferior occipital gyrus), and medial prefrontal cortex.

The comparison between the two groups of subjects shows a significant reduced activity in the brain of the clinical population in these areas: basal temporal areas, superior temporal sulcus, and medial prefrontal cortex. On the contrary the extrastriate regions were activated to the same extent in both groups.

An analysis of the connectivity showed that in the brain of individuals with autism the extrastriate region of the occipital cortex, that was identified as area V3 in the visual cortex (responsive to form and motion) and lateral occipital complex (involved in early stages of object recognition) was significantly less connected with the superior temporal sulcus (STS).

The greater activation of these extrastriate regions both in subjects with autism and in normal controls could indicate that the ToM stimuli were more complex respect to the other stimuli shown. However, in the autism group the detection of complex visual information didn’t reach the network of brain regions typically associated with mentalizing.

The STS may be linked to the processing of agents’ motion, and its activation has been reported in other studies in which the subjects had to process biological motion Grezes et al (2001). The weak connectivity between V3 and STS in autism may reflect a lack of top-down modulation from more anterior regions such as the amygdala and surrounding temporal pole and medial prefrontal cortex which would normally enhance attention to the incoming visual stimuli transmitted from V3.
Socially relevant stimuli are perceived by cortical regions in the temporal lobe, the superior temporal sulcus (perception of biological motion, mouth and eye gaze, visual motion of animated shapes), the superior parietal lobule and motor cortex (perception of other’s actions), whereas the amygdala, the right somatosensory, orbitofrontal and cingulate cortices participate together in linking perception of such stimuli to motivation, emotion, and cognition.

Some limbic structures are believed to be fundamental for social cognition, among them the amygdala and the orbito-frontal cortices: focal lesions to these structures comport an impairment in linking visual percepts to the social and emotional information that characterise them. A dysfunction affecting the amygdala might contribute to an impairment in linking the perception of socially relevant stimuli to social knowledge, moreover the perception of social stimuli wouldn’t elicit appropriate social behaviour (Adolphs 2001; Adolphs et al 2001).

The top-down modulation doesn’t seem to occur in autism, and as a consequence the social meaning of movements seems more difficult to perceive.

In a previous PET scan study (Castelli et al 2000) six adult subjects were scanned while watching the same silent computer animations of moving geometrical shapes used by Abell et al. 2000. The process of mental state attribution produced increased activation in four main regions: medial prefrontal cortex, temporoparietal junction (superior temporal sulcus), basal temporal regions (fusiform gyrus and temporal poles adjacent to the amygdala), and extrastriate cortex (occipital gyrus). Activation of these areas has been reported during tasks requiring self-monitoring, the perception of biological motion, and the attribution of mental states using verbal stimuli or visual depictions of the human form. These regions form a network for processing information about intentions.

On the basis of this evidence Castelli and colleagues (2000) suggested that the ability to make inferences about other people’s mental states evolved from the ability to make inferences about other creatures’ actions and movements. This fits with the observation that we can commonly infer intentions on the basis of observed action outcomes. Finally the activity of the prefrontal cortex and temporo-parietal junction in the present study was combined with activity in a ventral visual pathway, from the extrastriate cortex to the inferior and middle temporal gyri. Thus the regions activated by viewing goal-directed animated triangles appear to reveal a network for processing visual-kinetic information about intention in action.

In a recent study Schultz et al (2004) modelled a chase scenario between two computer animated shapes. In such animations the chasing object used different strategies to reach the
target object: the chaser either followed the target’s path or appeared to predict its end position.

The results show that when the chaser seemed to infer the goals of its target and anticipated its movement there was a greater activation in the superior temporal gyrus. Attending to the chaser’s strategy induced slightly greater activation in the left superior temporal gyrus than attending to the outcome of the chase.

The identification of complex goal-directed motion causes the activation of the superior temporal sulcus. This datum is coherent with previous works reporting the activation of STS during tasks of identification of biological movement or agents acting in a goal-directed way (Castelli et al. 2000; Blakemore et al. 2000; Blakemore et al 2003), the greater activation of these areas when the chasing object predicts the movement of its target suggest an implication of this region in the identification of intentional agents.

No activation of the medial prefrontal cortex was recorded in this study, the activation of this area has been reported in studies with complex animations (Castelli et al 2000) but not in studies with simple animations (Blakemore et al. 2003; Blakemore et al. 2001), this seems to suggest that no mentalizing processes were triggered by these animations. Therefore coherently with the proposal of Blakemore and colleagues Schultz and colleagues suggest that Superior Temporal Sulcus activation (which is present either with simple and complex animations) is not due to ToM processes but rather to the identification of intentional agents (2003).

Simple perceptual causality animations like reaction events represent goal-directed actions and interactions, therefore they can be conceived and described in goal directed rather than mentalistic terms, this would justify a good perception of reaction events in autism with an identification of intentional agents in absence of mental state attribution.

3.2 Perceptual causality in autism

Perceptual causality stimuli are simple representations of events in which how an action of object A causes a reaction of object B: A causes the movement of B by means of physical contact or at a distance. They differ from stimuli used in social attribution tasks in terms of lower duration and complexity, this because they usually involve the representation of an action-reaction at a time, with straight trajectories and very strict spatio-temporal parameters.

Heider and Simmel’s (1944) or similar stimuli are more complex as they represent narrative plots composed by many action-reaction sequences involving two or more shapes
and as we have already outlined they elicit complex social attributions. Perceptual causality stimuli represent parts of the longer interactions represented in Heider and Simmel’s stimuli.

Since perceptual causality is in place very early in typical development, it is supposed to allow the infants to learn about the causal structure of the world without the need for previous knowledge or experience. It has been suggested that the perception of contact causality can promote learning about mechanical interactions of material bodies (Leslie 1988; Schlottmann 1999) and that analogously the perception of non-contact causality could promote learning about the social interactions of intentional agents. In this sense, it would be a precursor to theory of mind abilities (Schlottmann and Surian 1999; Baron Cohen 1991).

Infants as young as six months are sensitive to the causal rather than to the spatial and temporal features of launch events (Leslie and Keeble 1987) and from at least 3 years of age they can link launching to mechanical causality (Schlottmann et al. 2002). The perceptual basis of the concept of cause could help to explain how children acquire a knowledge of the physical world so fast as they do, a fact that is difficult to explain on the basis of the traditional Piagetian (1974) framework (Schlottmann et al. 2006).

Infants as well as adults with autism have a poor attention for social stimuli, the process is twofold, on one hand social stimuli seem to be less salient for people with autism, and on the other hand the lack of social stimulation hampers the development of social knowledge and expertise. Schematic animations representing social interactions as well as causal interactions at a distance could be assimilated to naturalistic social stimuli. Hence children with autism could manifest an impaired perception of such stimuli.

In typical development perceptual causality abilities emerge from at least 6 months of age, before those behaviours that are supposed to be precursors of theory of mind, like joint attention or proto-declarative pointing.

Children with autism could be impaired in their perceptual causality abilities. A tendency to process visual information at the local rather than global level, is very common among individuals with autism, this local bias might operate at the perceptual level, and it could affect the ability to perceive causal Gestalts in general. A problem with the perception of mechanical causality in launch events could be linked to basic perceptual and attentional processes, while a problem with the perception of social causality depicted in reaction events could be linked to general problems in the perception of social interactions and stimuli and it might be expected to produce problems in the understanding of the behaviour of intentional agents. However either launch and reaction perception could be intact in autism.
The idea that perception of contingent interactions at a distance could be a precursor to theory of mind abilities was explicitly suggested by Rochat et al. (1997) who found that three months old infants are able to discriminate between patterns of movements of two disks moving contingently like in a chase interaction or moving randomly, independently one of the other. Since the sensitivity to goal-directed behaviour, and to interactions at a distance between two animated shapes emerges before other important social behaviours like the capacity to follow another person’s gaze, to engage in joint attention and to point to orient other’s attention, it was suggested that it could be a prerequisite for the development of such abilities.

Schlottmann and Surian (1999) went further hypothesising that perceptual causality abilities could be a precursor to theory of mind. The ability to perceive causality at a distance in reaction events emerges also very early at least at the age of 6 months (Schlottmann, Ray and Surian 2002). It is not clear if the infants can distinguish between causality in two different domains but from the age of three years onward they reliably associate reaction events to social causality. This perceptual capacity thus could be linked to infant’s knowledge of agents and the social world. Perceptual causality of both launching and reaction stimuli is present in young infants since the age of six months, therefore early sensitivity to perceptual causality could represent the precursor of an early capacity to discriminate between the domain of inanimate objects and that of animate agents.

Children with autism don’t show problems with the perception of mechanical interactions, thus the question about perceptual causality abilities in children with autism originates from the abnormalities in social development typical of the syndrome.

Individuals with autism don’t seem to reach an expertise for the processing of social stimuli, and seem to treat social and non-social stimuli in an analogue way. It has been shown that children and adults with autism focus their visual attention on non-social rather than on socially relevant elements (Klin et. Al 2002; 2005). Moreover either children and adults with autism have important problems in engaging in social interactions with other people, therefore they are likely to miss socially relevant information and will have a limited direct experience of social interactions. In sum they will never reach a sufficient expertise on social stimuli and interactions. If these characteristics could be associated to a selective problem with the perception of social causality represented in interactions at a distance, it could be the sign of an early disruption that concurred to cause an abnormal developmental course and an impaired understanding of the social domain.
The development of social cognition could already be disrupted at its early perceptual level when the absence of specific mechanisms and abilities could cause an impoverished experience or perhaps an anomalous neural specialization of some brain areas.

In general an early disruption of perceptual causality could mean the inability to perceive events as a coherent flow of causes and effects, it could mean a fragmented experience of the events of the world and above all the impossibility to understand the behaviour of agents. A fragmented experience of the world has been described also in self reports made by high functioning individuals with autism and Asperger syndrome (Grandin 1996; Gerland 1997), and it is supposed to characterise individuals with autism in their perceptual peculiarities with parts of objects, and in local processing as manifested in their superior abilities in tasks requiring to isolate parts of a global configuration (Shah and Frith1993; Happé 1999).

The incapacity to perceive social causality and the general inattention for social stimuli typical of autism from infancy to adulthood is likely to produce a fragmented experience. The incapacity to perceive interactions at a distance hinders the understanding of social interactions. The constant focus on non-relevant aspects of social scenes brings to a poor understanding of other people’s behaviour.

The ability to perceive causality in launching and reaction events has been investigated by Bowler and Thommen (2000). On the basis of the deficit in joint attention and in the use of communicative gestures in people with autism they predicted an impairment in the capacity to distinguish physical and social causality. In the first part of their study they asked children with autism (VMA range about 5 to 11 years, CA about 7 to 15 years) to provide verbal accounts of launch and reaction events, while in the second part other children (VMA range 5-11, CA 7-15) were asked to describe a schematic animation involving three geometrical shapes. The results showed no significant difference between children with autism and matched controls in the discrimination of launch and reaction events, but in the second part of the study with longer and complex stimuli, similar to those used by Heider and Simmel (1944), emerged that the children with autism made fewer descriptions of interactions at a distance between the shapes, while no difficulty was shown in the description of contact interactions. Therefore the authors concluded that children with autism had a difficulty in the description of coordinate actions of two animate agents when their interaction didn’t involve contact.

However the results of the first part of the study can be questioned because of two main methodological problems. The children were shown 4 launching and 4 reaction events in
a random sequence, their answers were considered appropriate if they consistently distinguished between launch and reaction by mentioning the contact between the two shapes for the launch or a chase for the reaction. This criterion doesn’t allow to understand if the children really individuated and distinguished between two types of causality. Moreover non-causal stimuli were not shown to the children, therefore it is not clear whether they really perceived causality or used a simple contact non-contact matching strategy in order to describe the events.

The result of the second experiment, shows a difficulty in the description of coordinate interactions at a distance is coherent with that of Klin (2000): he asked adult individuals with HF autism and Asperger syndrome to produce narrative descriptions of an Heider and Simmel animation, and found that the subjects with autism individuated only a quarter of the pertinent social elements present in the scene with a use of ToM terms very scarce independently of their verbal IQ level.

A potential problem is also represented by the answer procedure used in these two studies. The narrative competence of children with autism is usually related to the cognitive level of the child and to his verbal abilities, moreover children with autism tend to give minimal answers instead of complex accounts.

The verbal answer method may not be the optimal procedure neither to assess perceptual causality in children with autism, nor to reveal potential problems with perceptual causality, in fact it has been reported that also typically developing children (5 to 12 years old) mainly describe launch and reaction events in terms of their spatial and temporal features and not in terms of causal features (Thommen et al 1998). While on the other hand as we have already pointed out, experimental evidence shows that typically developing preschoolers are able to differentiate these events according to causality when a non-verbal answer procedure is used (Schlottmann et al. 2002).

In a recent study Ray and Schlottmann (2007) further investigated perceptual causality in children with autism (CA=8.4, VMA= 5.1) and mental age matched children with learning difficulties and typical development.

In order to reduce the demands of the test and provide a more sensitive test of disruption in perceptual causality a non-verbal answer procedure was used. The task required the children to watch each of the stimuli and then choose between three images displaying mechanical causality (Postman Pat having just kicked a ball), social causality (Postman Pat chasing for another character) or a non-causal interaction (Postman Pat standing still while another character was going away). All the pictures involved two entities and in none of the
picture was depicted a contact between the two in order to avoid to elicit the use of a simple contact matching strategy instead of the individuation of contact causality.

The children were shown 8 stimuli: the launch and reaction stimuli as well as their corresponding non-causal controls were presented in two agent conditions, with rigidly moving or non-rigidly moving animate agents.

The results show that children with autism were impaired in their recognition of launching events, while their performance was similar to that of the controls in the responses to reaction stimuli that were correctly associated to the social-causality image.

On the basis of the literature on perceptual abilities and the enhanced local processing and local bias in children with autism Ray and Schlottmann hypothesised that event duration might be the crucial difference between launch and reaction stimuli, and that the impaired performance in the perception of launching events could depend on such a duration factor. In fact, although the launch and the reaction stimuli had the same duration, the information critical for the identification of a reaction lasts longer than that for the identification of launching. A longer interaction might allow children with autism to process the stimulus globally and to perceive causality or to shift attention from the first shape to the second in order to perceive the causal interaction.

Both local and global processing have been found in autism, meaning that there is not a deficit in global processing but rather an enhanced local processing and intact global processing abilities (Plaisted 2001; Mottron and Burack 2001; Mottron et al., 2006).

For instance, some studies with Navon tasks have suggested that stimulus duration is an important factor for global processing in autism with local precedence for short stimuli of about 10-25ms. (Mottron and Belville 1993), but global precedence with long stimuli, 1000 ms in a selective attention task (Ozonoff et al. 1994).

Furthermore attentional processing problems have been reported in autism and these could be linked to deficits in social interaction (Allen and Courchesne 2001). Problems in orienting and slower shifting of the attentional focus could influence the ability to perceive launch and reaction events so to perceive one shape as the cause of the movement of the second shape. Therefore the interaction between the two shapes could be easily missed especially in launch events that require a faster shift in focus from the first shape to the interaction between the two shapes.

An intact reaction perception on the other hand is not surprising as mental state reasoning is not necessary for the perception of social causality, in fact this event can be
perceived and described in terms of goal-directed behaviour and children with autism are able to perceive goal-directedness.

Children with autism are as accurate as typically developing peers in the description of more complex animations designed to represent goal-directed interactions (Abell et al 2000), however they are less accurate in the description of sequences involving mental state understanding.

Thus even if a problem in reaction perception could be correlated to later difficulties with mentalising abilities, reaction perception per se doesn’t require mental state reasoning, therefore there can be an intact ability to perceive reaction events in spite of a problem in mental state attribution.
4 The present study

The present study investigates perceptual causality perception of social and mechanical causality in children with autism and verbal mental age matched controls with typical development.

This is of interest because at the perceptual level children with autism are often characterised by a bias that facilitates first of all the perception of local details. Global processing is supposed to be slower than local one, this could mean a problem in the processing of fast/short stimuli (Plaisted et al 1999, Mottron and Belville 1993, Ozonoff et al. 1994), therefore children with autism could show specific difficulties in the perception of causal Gestalts and this could have several developmental implications. Moreover, a specific problem in the perception of reaction events as that found by Bowler and Thommen (2000) could be related to difficulties with theory of mind (Baron Cohen et al.1985) or social attribution (Klin 2000), while problems only in the perception of launch events could be due to the different duration of the causal interaction depicted in such events (Ray and Schlottmann 2007). Finally it is also possible that children with autism are not impaired in perceptual causality.

Previous studies about perceptual causality in autism have used different methodologies and have come to different conclusions. While some have found no impairment in the distinction of launching and reaction events (Bowler and Thommen 2000), others report deficits only in the individuation of the social elements of actions and interactions at a distance (Bowler and Thommen 2000; Klin 2000), or in launch perception (Ray and Schlottmann 2007). Several differences among these studies could account for the different results.

The present study further analysed the issue using a nonverbal answer procedure, like in Schlottmann et al’s (2002) and Ray and Schlottmann’s (2007) study, the children had to look at animated stimuli and answer by choosing among three pictures. This approach would seem more sensitive, in particular for use with a special population, than methods with heavy verbal demands.

The early perception of causality, as well as the early distinction of causal domain could be fundamental for the maturation of a conceptual understanding of objects behaviour on one hand, and of animate agents on the other hand. In children with autism such a
maturation could be disrupted already at the basic perceptual level because of the perceptual peculiarities characterising this population.

The study was expressly designed to investigate causal perception in children with autism in order to understand more about their ability to perceive causality as well as that to discriminate between causal domains.

4.1 Picture matching response

As already pointed out, the testing procedure used was first ideated to study perceptual causality abilities in young children and it is particularly helpful because of the verbal language difficulties that often characterise children with autism and could limit their performance. In its first application the procedure was successfully used in order to reduce verbal and memory demands in children as young as 3 years (Schlottmann et al. 2002), it was then used with children with autism (Ray and Schlottmann 2007). The non-verbal answer procedure requires the child to choose the appropriate image instead of providing a verbal answer to the experimenter. Although the test still includes verbal instructions and questions, the images help the children in answering. The images are in front of the child who can look at them at any time and have therefore a reminder of the corresponding concept, moreover the images are a powerful mean of communication and organization of though for many children with autism given their good visual abilities. Iconic systems can be in fact used with non verbal children with autism in order to teach them functional communication and facilitate the acquisition of verbal language (i.e. The Picture Exchange Communication system – Bondy, Frost 2001).

Respect to free verbal answer procedures the choice of the image allows to test if the children can categorise the stimuli appropriately according to a causal criterion, in fact either children with autism and typical development in their free verbal reports often don’t mention causality. The choice of the image instead induces the child to take into account the causal element and answer according to it.

All the pictures involved two agents (figure 9), and as in Schlottmann et al (2002) and Ray and Schlottmann (2007) none of the test pictures involved contact between the two agents in order to avoid a simple contact matching strategy in which contact could mean physical causality while distance could be associated to psychological causality. Moreover the physical causality picture represents a movement more similar to that displayed in the launching animation, a boy pushing a cart, instead of kicking a ball.
4.2 The present stimulus events

In the present study the stimuli shown to the children included launch and reaction events (figure 1) and the corresponding delayed control events with and without contact (figure 6-7). The presence of the temporal pause (temporal discontinuity) in the control stimuli was meant to suggest non-causality, while the presence or absence of contact (spatial discontinuity) jointly with contiguous (not overlapping) opposed to simultaneous (overlapping) motion is at the basis of the causal domain difference between launching and chasing events.
The nature of the agents was also varied as the animations involved either rigid or non-rigid expanding and contracting squares. The latter, already identified by Michotte as caterpillar stimuli (Michotte 1946/1963), give an impression of self-produced animal motion to adults, and therefore it can be said that such stimuli contain a cue to animacy (figure 12). Although typically developing children and infants seem less influenced by the aspect of the agent (Schlottmann et al 2002), the caterpillar condition allows to observe whether features associated to the agent can eventually affect the perception of causality. In particular the question is whether the animacy cue could boost the psychological interpretation of the stimulus.

**Figure 12 – A schema of the cycle of expansion and contraction in the motion of the non-rigid caterpillar stimulus.** First with the left edge stationary the square expands until it becomes a rectangle larger than two times its original size. At this point with the right edge stationary, it contracts until the original square shape is recovered. The cycle repeated 3 times for each agent in each event.

In addition to these stimuli as used by Ray and Schlottmann, further stimuli were included in the design to help elucidate the nature of children’s difficulty in perceptual causality. To examine if the supposed difficulty of children with autism in the identification of physical causality stimuli could be due to the fact that the critical information that allows the perception of causality is displayed in just one frame, while the critical information in reaction events lasts much longer (Ray and Schlottmann 2007), it was introduced a stimulus in which the physical causality interaction had a longer duration, (and particularly the same duration of the simultaneous movement in the reaction event). Such a stimulus is called entraining (figure 13) and it was already described by Michotte (1946 / 1963). An equivalent event was realised also in the non-rigid agent condition.

**Figure 13 Entraining**
In order to understand if children with autism differed from typically developing controls in their judgments of perceptual causality another stimulus was created. It consisted in an ambiguous stimulus in which the two shapes engaged first in a chase interaction, then as A moved faster than B it reached it. A stopped upon contact with B, while at the same time B started moving (figure 14). The data about children with typical development, at 3, 5 and 7 years of age suggest that this stimulus is generally perceived as an example of physical causality (Watts, Schlottmann and Ray 2007) and this means that the contact feature is very important for typical kids and dominates over the feature of motion at a distance. A different pattern of answers can be predicted if children with autism had a specific difficulty in the perception of the physical causality represented in launch events, in this case they would be expected to choose psychological causality demonstrating a dominance of motion at a distance in their judgments. The same event was presented also in the non-rigid agent condition.

**Figure 14 – ambiguous event**

Finally, two more stimuli were realised in which the crucial moments of the launch and of the chase events were signalled by means of an attentional cue (figure 11 and 12). As previously discussed, individuals with autism generally show an abnormal and inconsistent pattern of static attention. It can be either over focussed (on particulars) or under-selective (they can be more distractible). Still, one of the diagnostic criteria of autism concerns the “restricted, repetitive and stereotyped patterns of behaviours, interests and activities” (DSM IV). This implies that individuals with autism are generally able to sustain attention at least in certain contexts and this seems to be strongly related with motivation and sensorial peculiarities. Additionally, the shifting of attentional focus is often problematic for children with autism (Ozonoff et al. 2005). The idea of the introduction of an implicit attentional cue as control, had the purpose to test whether children with autism didn’t perceive causality simply because they didn’t pay attention to the right point of the interaction at the right moment, either because of a lack of motivation or because of a problem with fast focus shifting. The cue was
a flash which had the function to bring the child’s attention to the causal interaction right before it took place. This stimulus was presented only in the rigid agent condition either because the test could be long for children with autism and because the attentional cue lost his efficacy in non-rigid agent stimuli.

Finally the length of the cue (about 415 ms) and of the interval with the target was chosen according to the literature. An optimal cue-to-target delay for individuals with autism should be between 100 and 800 ms (Wainwright et al 1993; Wainwright and Bryson 1996) as they seem to have a slower disengage/move component of attention.

Summarising, the present study addresses the issue of perceptual causality abilities in children with autism and verbal mental age matched controls with typical development. Children with autism could present problems in the perception of causal Gestalts in general because of the local bias that is typical in this population. Problems with the perception of causality in interaction at a distance could be related to difficulties with theory of mind, and finally problems only in the perception of physical causality could be due to peculiarities characterising attentional and perceptual processes of individuals with autism. On one hand the difficulty in attention shifting could hinder the perception of the contiguous movement in launch events, on the other hand the local bias in processing could cause problems for the perception of physical causality in launch events because the short lasting crucial information characterising the stimulus could be processed only at the local rather than at the global level, while the perception of reaction events would be unaffected as it depicts a longer causal interaction. The issue is not clear since previous studies have come to different conclusions.
The present study addresses the question by showing the children 14 different animations that have to be associated to three different pictures depicting physical causality, social causality and non-causal independent movement.

### 4.3 Method

#### Participants

42 children participated in the study, 20 children with autism were tested during their periodical control at the Child Neuropsychiatry Unit of the Hospital in Siena, and in L’Aquila, while 22 children with typical development attended a primary school in Quartu S.E. (CA).

In the perceptual causality test 19 of the 20 subjects with autism provided judgments for all the stimuli, 1 of them completed only the first part of the test (the rigid agent condition).

6 more children (4 boys and 2 girls) were excluded from the study, 3 of them although potentially able to provide answers refused to complete the test and the cognitive evaluations, 1 didn’t show to be able to understand the instructions neither to provide any answer probably because problems in language understanding, and finally the remaining two young girls were not able to provide any answer and refused to stay still and attend to the stimuli, probably because severe problems in hyperactivity, cognitive delay and their young age (6 years and 5 months and 8 years).

Psychometrics and ADOS assessments for children with autism were made in two separate sessions by the psychologists and doctors of the hospital.

<table>
<thead>
<tr>
<th>group</th>
<th>Chronological Age</th>
<th>Verbal Mental Age</th>
<th>Verbal IQ</th>
<th>Performance IQ</th>
<th>Full Scale IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yrs. Mths</td>
<td>Yrs. Mths</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autism (n=20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>13.0</td>
<td>9.7</td>
<td>73.8</td>
<td>79.05</td>
<td>74.65</td>
</tr>
<tr>
<td>Range</td>
<td>8.1-18.4</td>
<td>5.0-15.6</td>
<td>45-111</td>
<td>45-120</td>
<td>40-110</td>
</tr>
<tr>
<td>SD</td>
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<td></td>
<td>21,319</td>
<td>23,476</td>
<td>22,933</td>
</tr>
<tr>
<td>Typical Dev.(n=22)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>9.5</td>
<td>-</td>
<td>124,77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Range</td>
<td>8.10- 9.10</td>
<td></td>
<td>97-143</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td>12,474</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Participants’ characteristics
Chronological ages and psychometric data are presented in table 1., the IQ was assessed with the WISC-R (Wechsler Intelligence Scale for Children – Revised), Italian version (Translated by Rubini and Padovani - Organizzazioni Speciali, Firenze 1986), age 6 to 16,11 years.3

Verbal age matching between the groups was chosen as the test on perceptual causality comprehends a part of verbal instructions, and the full scale IQ is not a reliable measure of the cognitive abilities of children with autism given their usually unbalanced cognitive profile (Burack et al 2002). The Full cognitive profile was assessed for children with autism.

The IQ levels were either already present in the clinical records of the children or they were assessed in another session by the psychologist of the hospital (11 in Siena and 2 in L’Aquila).

The IQ levels present in the records of 7 of the children in the sample were previously assessed by experienced professionals. They were considered valid since generally IQ scores in the autism population are considered to maintain stable from childhood to adulthood unless the individual makes dramatic gains or experiences considerable losses in cognitive skills (Shea and Mesibov 2005). According to the doctors an the psychologist of the hospital in Siena none of the children tested had made such cognitive improvements to justify a new cognitive assessment.

Children with autism received also a certified diagnosis with the ADOS, Autism Diagnostic Observation Schedule, a standardized protocol for the observation of social and communicative behaviour. Module 3 for children with fluent verbal language (C. Lord, M. Rutter, P.C. DiLavore e S. Risi 1999), all the ADOS were administered by the clinical psychologist working at the Child Neuropsychiatry Unit in Siena.

Children with typical development were administered only the verbal part of the WISC-R, for them the test on perceptual causality and the cognitive evaluation were made at school in a unique session of about 60 min. for each child.

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3 The new version (WISC –III) of the scale has just been published in 2006 and therefore it is still not in use. The most commonly used version is the 1986 one.
Design

Each child completed the perceptual causality (PC) task. Testing on PC took place in a 20 to 30 minutes individual session, and it was run in a quiet room.

In the PC task, children saw 14 animated events, all differing in their spatio-temporal configuration and presented in two sets of 8 and 6 each, separated by a brief pause. The stimuli in the first set involved rigidly moving shapes, while stimuli in the second set involved non-rigid motion. For each event, children chose which of 3 pictures corresponded best to each movie.

Summarising a total of 14 stimuli was shown to the children:

<table>
<thead>
<tr>
<th>Rigid agent condition</th>
<th>Non-Rigid agent condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Launch</td>
<td>1. Launch</td>
</tr>
<tr>
<td>2. Launch delay</td>
<td>2. Launch delay</td>
</tr>
<tr>
<td>3. Reaction</td>
<td>3. Reaction</td>
</tr>
<tr>
<td>4. Reaction delay</td>
<td>4. Reaction delay</td>
</tr>
<tr>
<td>5. Entraining</td>
<td>5. Entraining</td>
</tr>
<tr>
<td>6. ambiguous reaction + launch</td>
<td>6. ambiguous reaction + launch</td>
</tr>
<tr>
<td>7. Launch + attentional cue</td>
<td></td>
</tr>
<tr>
<td>8. Reaction + attentional cue</td>
<td></td>
</tr>
</tbody>
</table>

Experimental task

Materials

Movies

The stimuli were 2D animations realised with Macromedia Director Software (Macromedia Inc, S. Francisco California), and were integrated in a graphic interface (figure 13). They were shown on a portable PC (Toshiba Satellite M-30 853) on a TFT 15 inches (20x35 cm) screen with a resolution of 1280 x 800 pixels.
The interface involved a numbered button corresponding to each of the stimuli, and a “white screen” where the stimulus was displayed (see Figure 13), therefore the children were advised to look at the white part of the screen to see the shapes moving. Some of the children enjoyed to activated the buttons themselves following the random order provided by the experimenter. Each stimulus repeated continuously until it was stopped by the E. after the child provided an answer.

![The interface](image)

**Figure 17 – The interface**

In the present study each movie lasted 480 frames, (about 8 seconds) and repeated continuously for the duration of a trial with a pause (60 frames - about 1 second) during which the screen turned from white to gray at the end of each repetition.

The stimuli lasted almost a double time 480 frames (2 pixel/frame at 60 f/s) respect to those of the study of Ray and Schlottmann (2007), in which each stimulus lasted 240 frames (4 pixel/frame at 60 f/s) and repeated continuously for the duration of a trial with 30 frames of black separating cycles. In the present study the overall speed of the animation was reduced because the movement of the stimuli at the original rate was not fluid on the computer used for the test, therefore the shape advanced of only two pixels for each frame in order to make the movement look more fluid.

Each of the 14 movies involved 2 squares, one blue (A) on the left and one red (B) in the middle of the screen, initially stationary, each square was 60 x 60 pixels (1.5x1.5 cm). The movement proceeded always from left to right and square A moved always before square B, the trajectory of either A and B lasted always 120 frames (240 pixels, corresponding to about 6 cm on the screen).
In the eight movies of the first set the squares moved rigidly at a constant speed of 2 pixels/frame (about 3 cm/s). In contrast, in the six movies of the second set the shapes moved non-rigidly by expanding and contracting with the same average translation speed. With the left edge stationary, the non-rigid shape expanded horizontally for 20 frames at a rate of 4 pixels/frame (about 6 cm/s), until the original square shape was transformed in a rectangle of 60 x 140 pixels (1,5 x 3,5 cm). Then it contracted with the right edge stationary until the original square shape was recovered. These steps repeated three times in each movie cycle. To equate cycle length between movies with and without delay and those involving rigid and non-rigid motion, the stationary periods at the beginning and end of each cycle were adjusted. The spatial and temporal configuration of the path followed by the non rigid-agents was identical to that of their relative rigid stimuli.

Contact movies

In the Launch event, and the launch event with attentional cue, A moved first, it stopped on contact with B, than B moved almost instantaneously (1 frame) after contact and after a while it stopped. In the non-causal delayed control movie B moved 120 frames after contact (about 2 s. of delay).

In the last contact movie, the entraining, A didn’t stop upon contact with B but instead continued moving as pushing B for 40 frames. The entraining event starts with A stationary (140 frames) on the left and B stationary in the middle of the screen. A moves first and continuously for 120 frames, it moves by itself for 80 frames and on contact with B for 40 frames at a speed of 3 cm/s. When A stops B continues moving by itself at the same speed for 80 frames before stopping.

Non-Contact movies

In the reaction event, and the reaction event with the attentional cue, B started moving 40 frames (about 666ms) before A stopped, therefore A and B’s motion temporally overlapped for 40 frames. In the non-causal control events A stopped 20 pixels (0,5 cm) short of B and B moved 120 frames (about 2 s) after A stopped. The reaction and the entraining stimulus have the same amount of overlapping motion between the two shapes.
**Ambiguous event: Motion at a distance + Contact movie (reaction+launch)**

Finally there was an ambiguous event in which both mechanical and social causality was displayed. In this event the agent A chases after B, but as it moves faster, it reaches it and pushes it stopping upon contact.

The event begins with A and B stationary (for 140 frames) in their usual positions. A starts moving and moves for 120 frames at a speed of 3 cm/s. The motion of A and B overlap for 40 frames, but B moves at a speed of 1.5 cm/s. As B starts moving when A is at a distance of 40 pixels (20 frames at 2p/f) from B and A has a double speed respect to B, the two shapes make contact at the end of the overlapping motion. At this point A stops and B continues moving but at a speed of 3 cm/s for 80 more frames.

**The Attentional cue (flash)**

In attentional cue stimuli a small flash appears on square B anticipating the movement of B in the launch (exactly at mid-point in the sequence that is frame 240), and the clue moment of the *chase* interaction between A and B, that is when B starts moving (at frame 220). The structure of the flash was 10 frames flash (166 ms) + 5 frames normal (80 ms) + 10 frames flash. The flash was obtained with a colour fade of shape B (giving the impression of a double blink) – (see figure 15-16).

Because the launch and reaction events have a different spatial and temporal configuration, in the launch event the flash could interfere with the perception of causality, therefore the attentional cue was situated before the impact, while in the reaction as the temporal overlap of the movement of A and B lasts 40 frames the attention was driven to B when it started moving. In conclusion the cue lasted 25 frames (415 ms), but in the launch the cue disappeared 11 frames (about 182ms) before the impact, while in the chase it disappeared 15 frames (249 ms) before A stopped moving.

The six events in the in the non-rigid motion set were identical to the eight in the rigid motion, but the attentional cue stimuli were eliminated.

Two additional animations were only used in the training phase. In the first stimulus square A climbed over the square B. In the second the two squares initially one beside the other at the centre of the screen started moving apart towards two opposite directions (see figure 18 and 19).
During the experimental phase children responded by choosing among three drawings (sized 14x21 cm), illustrating the target concepts (see figure 5). In the psychological causality picture a boy chased a girl, in the physical causality picture the boy is shown right after he has pushed a cart, and in the non causal picture the boy is depicted standing still by himself while the girl is walking away.

The additional events used during the practice only (figure14-15) corresponded to two pictures (sized 14x21 cm) that were used only for the training phase. The first picture depicted a boy climbing over a fence, and the second depicted a boy and a girl walking toward opposite directions (see Figure 20).
**Procedure**

The procedure used was generally similar to that used by Ray and Schlottmann (2007) with two main differences: in the present study more verbal instructions were provided to the children as the verbal level of the group was higher, and the children were prompted about animacy.

The experiment had two phases. In the training phase, children were familiarized with the pictures and the picture matching approach. The test phase was divided in two separate sessions, the first for the rigidly moving agents and the second for the non-rigidly moving condition, the two sessions were separated by a brief pause in order to give a 2 to 5 minutes break to the child. During the pause the child was allowed to stand up or just relax.

In the test phase children saw the experimental stimuli in each set, and for each chose the picture that corresponded best to it.

**Training phase**

Children were initially asked to describe the five pictures presented in a random order. The experimenter listened to the description made by the child, giving promptings and explanations when needed and verbally reinforcing the correct answers.

When the description was partial or mentioned only the agents and not the causal interaction, the children were explicitly asked to tell what the agents in the pictures were doing and what it was happening. If necessary, when the children gave a partial description or when they were not able to provide a description, they were explicitly told what was in the pictures in order to avoid misinterpretations. For the practice images the experimenter told that “the boy is climbing over, he goes up and then down”\(^4\), “The children are walking in two opposite directions one is going this way and the other is going that way”\(^5\) – tracing the directions of the movement pointing with the finger. For the experimental images the experimenter said “The boy is pushing the cart” Il bambino spinge il carretto, “the boy is standing while the girl is walking away” un bambino è fermo, la bambina va via, “the boy is chasing after the girl, she escapes” il bambino rincorre la bambina, la bambina scappa.

\(^4\) il bambino scavalca, va su e poi giù
\(^5\) I bambini vanno da due parti diverse, uno di qua e uno di là.
The procedure of familiarisation with the pictures was usually rehearsed twice, the experimenter asked the child to describe each picture, provided the correct interpretation when needed and asked again in order to check that the child understood and recalled the description.

The correct understanding of the pictures was always verified showing the five images a second time one by one and asking the child to utter at least the main concept like for instance: “spinge” – *pushes*, “rincorre, scappa” - *chases after, escapes*, “uno sta fermo, l’altro va via” – *he is standing, the other is going away*. In the end all the children demonstrated to understand the main concept illustrated in the picture.

The computer was opened, the interface was already on the screen (figure 17), for children with autism only the two training pictures were on the table to simplify the task, while for children with typical development all the five pictures were left on the table. The children where asked to concentrate on the white part of the screen, and they were told to watch carefully at what was going to happen. After a few repetitions of the climbing movie the experimenter asked the child: *did you see the two squares moving? Does it look like one of these pictures? Which one?*

In Ray and Schlottmann’s study also the children with autism were showed all the 5 pictures during the training phase.

The training stopped when the child appropriately matched the picture with the corresponding movie. After the training phase both the example drawings and the corresponding stimuli were removed and the experiment was started.

**Test phase**

The stimuli were shown in a random order different for each subject. However in the rigid-agent condition the attentional cue stimuli were always last (launch, reaction), and in the non-rigid agent condition the ambiguous and entraining stimuli were shown last (reaction+launch, entraining).

At the beginning of the testing session the experimenter told each child that he would see the shapes moving and that he/she should choose an image for each movie just like in the previous phase. The experimenter also said to look at the computer as long as needed.

After the child saw the animation, the Experimenter (E.) asked two general questions - “what happens in the movie?” *che succede?*, -“what do the squares do?” *cosa fanno i...* 

---

6 To avoid the unnecessary exclusion of children the experimenter usually tried to test even those children who demonstrated difficulties already in the training phase, but the test was soon interrupted if they were not able to provide any answer or if they showed signs of impatience.
and the child was asked to choose a picture. Than the experimenter waited for the child to provide an answer, if the child hesitated than the E. invited him to look at the pictures also pointing alternatively to each of them. Than the E. invited the child to choose one asking if the movie seen was similar to one of the pictures.

General questions like “what's happening in the movie?” and the verbal invitation to look at the pictures were the default procedure. Obviously the interaction had to be adapted to each particular child. The more cognitively able children didn’t need any other questioning a-part from the initial instruction. While some of the children, especially the more distractible ones needed more interaction to concentrate on the task, therefore they were repetitively invited to look at the displayed animation and to look and choose a picture.

The second session presented to the children the movies with animate agents. The E. showed the first stimulus (in a random sequence) to the child, and stressing the difference with the verbal prompt “it is different from the one you have seen before” asked him or her, “what do the red and the blue look like?” “what could they be?”.

Than if the child gave an answer, and where the child identified by himself the “animacy” feature saying either “caterpillars”, “worms” , “snakes”, “slugs” the E. said “good, it is true, you are right”, otherwise if the child didn’t answer or answered “rectangles” the E. said “yes, but they could also seem worms, or snakes, don’t you think?”.

Therefore every child was prompted to see animacy in the “non rigid” stimuli before answering the questions about causality. Each stimulus was shown only once but repeated N times for as long as it took the child to give an answer.

Answers were recorded by S.C and, for all but 4 children, by a second observer blind to the specific stimulus shown. Both observers agreed in 99% of the cases. In cases of disagreement, the second observer’s response was taken for the analysis.

For the statistical analysis the answers were coded (physical= 1, Non Causal= 0, Psychological= -1) like in Schlottmann et al (2002) and in Ray and Schlottmann (2007).

In 4 instances involving 3 different children, children spontaneously picked 2 pictures, both answers were recorded, and for the statistical analysis, the average of their responses was used (for numerical coding, see result section below).
4.4 Results

Introduction of the pictures

When the children with autism were asked to describe the images two things occurred, on one hand there were 14 children who described the image without problems, on the other hand there were 6 children that needed more direct questioning, like “what’s the boy doing?” *cosa fa il bambino?* or “what do the kids do?” *cosa fanno i bambini?*. This appears linked to the verbal abilities of the children as the mean VIQ level of the first group, 83.07 (SD 18.32, min. 58, max. 111) was sensibly higher than that of the second 52.16 (SD 7.19, min. 45, max. 60).

As expected in the clinical population, when asked to describe the pictures many of the children gave initially only minimal accounts often describing only one character in the picture: the boy is standing, *il bambino è fermo*, or for instance not mentioning the causality in the chasing picture that could be described just as a simple action: he runs – *corre*, they run, *corrono*.

However, in the end, at the rehearsal all the 20 children with autism correctly identified the causal pictures and gave a non causal account of the non causal picture uttering at least the essential target description of the images: pushes- *spinge*, standing and walking- *sta fermo*, *cammina*, chases after- *rincorre*.

The same procedure was used with typical children, no problem was found and all of the 22 children were able to provide a good description of the interactions depicted in the images without any specific questioning. In the end all the children correctly identified and discriminated among the pictures and recognised the causal relations depicted.
Children’s understanding of the movies

*Autism group:*

**Figure 21-** Picture choice frequencies. Rigid agent (top) Non rigid agent (bottom)
Typical development group:

![Graph showing individual answers (22 subjs) - rigid agent stimuli](image1)

![Graph showing individual answers - (22 subjs) non rigid agent stimuli](image2)

*Figure 22 - Picture choice frequencies. Rigid agent (top) Non rigid agent (bottom)*
The group data in the *rigid agent* condition, presented in Figure 21 (top panel) show that overall the children with autism and the controls identified appropriately the various events, choosing the collision picture for the launch event as well as for the entraining and the launch+flash. They mostly chose the chasing picture for the non contact event without pause (reaction) and for its flash equivalent. The events with delays were mostly associated to the non causal picture (*walking on his own*). However especially in the contact+delay condition a few children chose the physical causality picture. Finally the ambiguous event received overall more physical than psychological attributions in the autism but not in the control group where more children chose the social causality picture (figure 22 top).

In the *non rigid agent* condition (Figure 21, bottom panel), the data pattern is largely similar. The answers reflect still a main tendency to attribute physical causality to the launch, social causality to the reaction stimuli and to associate the non causal picture to both the delay conditions. However in this case in the autism group the entraining and the reaction+launch event receive more social than physical attributions, in the control group (figure 22 bottom) the entraining is still considered as an example of physical causality, but the attributions of social causality increase and the reaction+launch stimulus is ambiguous between physical and social causality.

Noticeably more social attributions appear throughout for all events (red bars), as an effect of the non-rigid agent.

This could be justified by the fact that all the children were explicitly prompted to see animacy in the non rigid agents before starting the second half of the test. In the autism group animacy was individuated spontaneously by 37% of the children who described the non-rigid agents as “snakes, worms” and so on, while the 42% of them spontaneously described red and blue as “rectangles”. After prompting or after they were told explicitly 11% didn’t answer, 68% of the children agreed on the animacy while the 21% insisted in the description of the agents as rectangles. In the control group the majority of the children individuated animacy spontaneously and all of them agreed on animacy in the end (see table 2).

<table>
<thead>
<tr>
<th></th>
<th>Spontaneous account</th>
<th>Final account</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>autism</td>
<td>typ.dev.</td>
</tr>
<tr>
<td>Doesn’t answer</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Animacy</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>Non animate</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

*Table 2 – individuation of animacy in the non-rigid agent*
The Chi–square analysis shows that in general the kids were not guessing, in the autism group (table 3-4) the answers for all but the launch delay in the non-rigid movement condition are above chance level.

Table 3
Autism group Chi-square rigid agent set

<table>
<thead>
<tr>
<th></th>
<th>s-launch</th>
<th>s-launch-[d]</th>
<th>s-reaction</th>
<th>s-reaction-[d]</th>
<th>s-reaction+launch</th>
<th>s-entraining</th>
<th>s-la+flash</th>
<th>s-re+flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-Square(a,b)</td>
<td>24,100</td>
<td>7,600</td>
<td>6,400</td>
<td>12,100</td>
<td>9,100</td>
<td>19,600</td>
<td>5,000</td>
<td>16,300</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>,000</td>
<td>,022</td>
<td>,041</td>
<td>,002</td>
<td>,011</td>
<td>,000</td>
<td>,025</td>
<td>,000</td>
</tr>
</tbody>
</table>

a 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.7.
b 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 10.0.

c 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.7.

Table 4
Autism group Chi-square non-rigid agent set

<table>
<thead>
<tr>
<th></th>
<th>c-launch</th>
<th>c-launch-[d]</th>
<th>c-reaction</th>
<th>c-reaction-[d]</th>
<th>c-reaction+launch</th>
<th>c-entraining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-Square(a,b,c)</td>
<td>10,526</td>
<td>,737</td>
<td>15,211</td>
<td>10,842</td>
<td>7,737</td>
<td>12,789</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>,005</td>
<td>,692</td>
<td>,000</td>
<td>,004</td>
<td>,052</td>
<td>,005</td>
</tr>
</tbody>
</table>

a 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.3.
b 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.5.
c 4 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 4.8.

In the control group (table 5-6) the only events that receive attributions at chance level, are the ambiguous reaction+launch stimulus in both rigid and non-rigid agent conditions, and the entraining in the non rigid condition.
### Table 5
**Control group Chi-square rigid agent set**

<table>
<thead>
<tr>
<th></th>
<th>s-launch</th>
<th>s-launch d</th>
<th>s-reaction</th>
<th>s-reaction-d</th>
<th>s-reaction+ launch</th>
<th>s-entraining</th>
<th>s-la+flash</th>
<th>s-re+flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-Square(a)</td>
<td>19,182</td>
<td>5,818</td>
<td>19,182</td>
<td>12,091</td>
<td>3,364</td>
<td>19,182</td>
<td>19,727</td>
<td>23,273</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.000</td>
<td>.055</td>
<td>.000</td>
<td>.002</td>
<td><strong>186</strong></td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
</tbody>
</table>

*a 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.3.*

### Table 6
**Control group Chi-square non-rigid agent set**

<table>
<thead>
<tr>
<th></th>
<th>c-launch</th>
<th>c-launch d</th>
<th>c-reaction</th>
<th>c-reaction d</th>
<th>c-reaction+ launch</th>
<th>c-entraining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-Square(a,b)</td>
<td>15,636</td>
<td>12,091</td>
<td>11,636</td>
<td>12,091</td>
<td>1,182</td>
<td>1,727</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.000</td>
<td>.002</td>
<td>.001</td>
<td>.002</td>
<td><strong>.670</strong></td>
<td><strong>.422</strong></td>
</tr>
</tbody>
</table>

*a 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.3.*

*b 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 11.0.*
Table 7
Proportion of children's picture choices (%) in response to each of the eight movies previously used by Ray and Schlottmann (2007). Phy = physical causality picture, ψ = social-psychological causality picture, NC= non-causal picture, (appropriate choices in bold).

The charts show that overall the children with autism appear to display intact perception of causality. In contrast to Ray and Schlottmann (2007), these data show that children with ASD had no particular difficulty with launch events, or the perception of physical causality in
general. In contrast to Klin (2000) the children with autism seemed to have no difficulties in individuating the social elements present in the animations, reliably associating the non-contact interaction events to the image representing social causality and differentiating them from contact and non-causal ones.

Ray and Schlottmann (2007) observed that the performance of the children in their study was lower than in previous work (Schlottmann et al. 2002), and hypothesised that this could depend on the less elaborate instructions used. Coherently with this view the performance of the children in the present study was generally superior (table 7) and this could have occurred because of the higher verbal level of the children and of their older age that allowed to use the procedure that Schlottmann et al. 2002 used with typical developing young children.
Group analysis

For the main statistical analysis, children’s choices of the physical causality picture were assigned a score of 1, a score of -1 was assigned to choices of psychological causality and a score of 0 to the non causal choices. As the occasional choice of two pictures was averaged (for instance the choice of the images of psychological -1 and physical causality +1, is averaged to 0), the null score can also count as the average between the two causal choices, however this happened only twice with the reaction+launch stimulus in the autism group.

<table>
<thead>
<tr>
<th></th>
<th>Autism</th>
<th>Typ. Dev. Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>s-launch</td>
<td>N 20, Mean .80, Std. Dev. .523</td>
<td>N 22, Mean .68, Std. Dev. .646</td>
</tr>
<tr>
<td>s-entraining</td>
<td>N 20, Mean .70, Std. Dev. .657</td>
<td>N 22, Mean .68, Std. Dev. .646</td>
</tr>
<tr>
<td>s-launch+flash</td>
<td>N 20, Mean .75, Std. Dev. .444</td>
<td>N 22, Mean .73, Std. Dev. .550</td>
</tr>
<tr>
<td>s-reaction-launch</td>
<td>N 20, Mean .45, Std. Dev. .826</td>
<td>N 22, Mean -.18, Std. Dev. .907</td>
</tr>
<tr>
<td>s-reaction</td>
<td>N 20, Mean -.40, Std. Dev. .821</td>
<td>N 22, Mean -.68, Std. Dev. .646</td>
</tr>
<tr>
<td>s-react+flash</td>
<td>N 20, Mean -.70, Std. Dev. .571</td>
<td>N 22, Mean -.73, Std. Dev. .631</td>
</tr>
<tr>
<td>s-launch-d</td>
<td>N 20, Mean .20, Std. Dev. .616</td>
<td>N 22, Mean .36, Std. Dev. .658</td>
</tr>
<tr>
<td>s-reaction-d</td>
<td>N 20, Mean -.00, Std. Dev. .562</td>
<td>N 22, Mean .05, Std. Dev. .575</td>
</tr>
<tr>
<td>c-launch</td>
<td>N 19, Mean .53, Std. Dev. .772</td>
<td>N 22, Mean .55, Std. Dev. .800</td>
</tr>
<tr>
<td>c-entraining</td>
<td>N 19, Mean -.132, Std. Dev. .9696</td>
<td>N 22, Mean .14, Std. Dev. .889</td>
</tr>
<tr>
<td>c-reaction+launch</td>
<td>N 19, Mean -.184, Std. Dev. .9008</td>
<td>N 22, Mean -.09, Std. Dev. 1.019</td>
</tr>
<tr>
<td>c-reaction</td>
<td>N 19, Mean -.95, Std. Dev. .229</td>
<td>N 22, Mean -.86, Std. Dev. .351</td>
</tr>
<tr>
<td>c-launch d</td>
<td>N 19, Mean -.05, Std. Dev. .780</td>
<td>N 22, Mean .05, Std. Dev. .575</td>
</tr>
<tr>
<td>c-reaction d</td>
<td>N 19, Mean -.105, Std. Dev. .5671</td>
<td>N 22, Mean .05, Std. Dev. .575</td>
</tr>
</tbody>
</table>

Table 8 - mean causal scores - mean of the choices of the two groups: a score close to 1 indicates prevalence of physical causality choices, a score close to 0 indicates prevalence of Non causal choices, a negative score indicates prevalence of psychological causality choices.

The mean causal scores show the same picture as the data in figure 21-22.

s- squares
c-caterpillars

Table 8 above clearly shows that the delayed events receive non-causal attributions, and their value is close to 0, a positive score still signals the prevalence of physical attributions, while a negative one reflects the prevalence of negative attributions.

The first analysis, a 2group x 2 spatial configuration (contact, no-contact) x 2 temporal configuration (delay, no delay) x 2 type of agent motion (rigid, non-rigid) factorial ANOVA, considered the 8 stimuli previously used by Ray & Schlottmann (2007). This led to significant
effects for the spatial configuration, $F(1,39) = 95.899$, $MSe = 0.0493$, $p<0.001$, an agent effect $F(1,39) = 7.047$, $MSe = 0.0484$, $p=0.011$, and a spatial x temporal configuration interaction effect $F(1,39) = 69.881$, $MSe = 0.443$, $p<0.001$.

There was also a trend for the temporal configuration $F(1,39) = 3.759$, $MSe = 0.257$, $p=0.060$, and for the temp x group interaction $F(1,39) = 2.905$, $MSe = 0.257$, $p = 0.096$, but all other effects were non-significant: agent x group $F(1,39) = 0.348$, space x group $F(1,39) = 0.21$, agent x space $F(1,39) = 0.176$, agent x space x group $F(1,39) = 0.385$, agent x temp $F(1,39) = 0.682$, agent x temp x group $F(1,39) = 0.682$, space x temp x group $F(1,39) = 0.001$, agent x space x temp $F(1,39) = 2.279$, $MSe = 0.300$, $p = 0.139$, agent x space x temp x group $F(1,39) < 0.001$.

Figure 23 Overall analysis: group x agent x spatial configuration x temporal configuration

Figure 23 shows a clear domain distinction for launch and reaction events: the launch event receives more physical causality attributions while the reaction event receives more social causality attributions. The chart shows also that the delayed events were associated mostly to the non causal picture, therefore their score is close to zero (even if the launch-delay event receives slightly more attributions of physical causality). Finally it is evident that the type of agent influences the judgments of the children, the non rigid-agent produces an increase in the number of attributions of social causality, therefore the scores for launch and
reaction events in the non-rigid agent condition are lower than those in the rigid agent condition.

Figure 24  autism group: Agent x spatial configuration x temporal configuration

Figure 25  control group: Agent x spatial configuration x temporal configuration
The main effect for the spatial configuration reflects the domain distinction, with positive scores and physical attributions to contact events, but negative scores and social attributions to non-contact events. Observing the charts (figure 23-24-25) it emerges that the effect of the spatial configuration is not present in both temporal conditions, in fact, as reflected in the spatial x temporal interaction, the contact and non-contact conditions don’t differ significantly when there is the temporal delay, with scores close to 0 that don’t differ much across stimuli. This means that the children treated the causal conditions differently from the non-causal ones, in fact they considered the spatial configuration for the domain distinction, while no domain distinction was made when the events were not causal.

A main effect of the temporal configuration (delay / no-delay), was not expected because positive and negative scores for events without delay should average to 0 and thus lead to the same mean score as for delayed events. However there was a trend for the temporal configuration and for the temporal configuration x group interaction, probably due to the fact that the launch delay event is considered equally physical and non causal by the kids in the control group, as it is confirmed by the separate analysis of the two groups showing that the temporal configuration produces a significant effect for the children with typical development but not for the children with autism.

The agent x spatial configuration x temporal configuration ANOVA in the autism group shows a significant effect for the spatial configuration F(1,18) = 64.125, MSe = 0.333, p < 0.001, as well as for the spatial x temporal configuration interaction, F (1,18) = 14.533, MSe = 0.491, p < 0.00, and finally it shows a trend for the agent F(1,19) = 3.717, MSe = 0.639, p = 0.070. All other effects were not significant.

The agent x spatial configuration x temporal configuration ANOVA in the group of children with typical development shows the same pattern of results previously seen in the autism group: a significant effect for the spatial configuration, F (1,21) = 41.711, MSe = 0.630, p < 0.001, a significant effect for the spatial x temporal configuration F (1,21) = 41.264, MSe = 0.333, p < 0.001, and a weak trend for the agent F (1,21) = 3.166, MSe = 0.352, p = 0.090.

The only difference is that the temporal effect was significant for the control group F(1,21) = 9.295, MSe = 0.198, p= 0.006, but not for the autism group F(1,18) = 0.020, while all other effects didn’t reach significance.

Follow up analysis were conducted for events with and without delay, respectively. In the first, there were no significant effects, type of agent F (1,39)= 1.855, MSe= 0.464, p= 0.181,
agent x group interaction $F(1,39)= 0.017$, spatial configuration $F(1,39)= 2.085$, $MSe= 0.413$, $p= 0.157$, space x group interaction $F(1,39)= 0.019$, agent x space interaction $F(1,39)= 2.706$, $MSe= 0.213$, $p= 0.108$, agent x space x group $F(1,39)= 0.307$. In contrast, scores for events without delay were affected not only by whether there was contact between the agents $F(1,39)= 148.006$, $MSe= 0.523$, $p<0.001$, but also by the type of agents involved in the interaction $F(1,39)= 6.465$, $MSe= 0.439$, $p=0.015$. All other effects were not significant, the agent x group interaction $F(1,39)= 1.018$, $MSe= 0.439$, $p= 0.319$, the agent x space interaction $F(1,39)= 0.383$, the agent x space x group interaction $F(1,39) = 0.159$.

Overall, these results demonstrate intact perception of causality in children with autism, with a pattern of answers similar to that of typical developing controls matched for verbal mental age. This in contrast to Ray and Schlottmann results, but similar to the data for normal young children (i.e. Schlottmann et al 2002). We now turn to the analysis of the six additional stimuli in this study.

The attentional cue (flash) stimuli

Firstly, we presented two stimuli in which the moment of impact in the launch or the onset of the chase in the reaction were cued by a brief flash (figure 15-16). The attentional cue was used to test if increased attention to the launch would improve subjects’ performance on launch events, that had been impaired in Ray and Schlottmann’s study, with the reaction-flash stimulus as a control to make sure that the flash would not interfere with the task. From the previous results it is already clear, however, that the flash cannot improve performance on launching, because it was not impaired in this sample in the first place.

Figure 26-27 show similar high positive (physical) scores for launching with and without flash, and similar negative (psych) scores for reaction with and without flash, there is a clear domain distinction between launch and reaction events.
Figure 26 - autism group: comparison of launch and reaction with the corresponding attentional cue stimuli

Figure 27 - control group: comparison of launch and reaction with the corresponding attentional cue stimuli
In line with this visual impression, the 2 group x 2 contact (yes/no) x 2 flash (no / yes) within subjects ANOVA, shows a main effect of the space factor $F(1,40) = 123.056, MSe = 0.636, p < 0.001$. On the contrary all other effects are not significant: the effect of the attentional cue, $F(1,40) = 1.103, MSe = 0.291, p = 0.300$, of the attentional cue x group interaction $F(1,40) = 1.103, MSe = 0.291, p = 0.300$, the space x group interaction $F(1,40) = 0.116$, the attentional cue x space interaction, $F(1,40) = 0.944$, the attentional cue x space x group interaction, $F(1,40) = 0.206$.

In both groups, the effect of the spatial configuration confirms the clear domain distinction given by the spatial configuration of the launch and reaction stimuli, but the lack of effect for the presence of the flash shows that the flash neither improves nor interferes with perceptual causality.

**Launch and entraining**

The entraining stimulus (see figure 13) was introduced in the experimental design in case the children with autism manifested any difficulty with the standard launching probably due to the short duration of the contact between A and B. The entraining stimulus differs from the launch only in the fact that A doesn’t stop right upon contact with B but later, therefore the two shapes move along for a while. The two events represent cases of physical causality.

It is evident in figure 28 and 29 that in the rigid agent condition there is not a salient difference between launch and entraining events that are mostly judged as examples of physical causality. On the other hand, the non rigid agent condition, determines a general increase in the attribution of psychological causality. Especially the entraining event is mostly judged as psychological by children with autism and more psychological but still mostly physical by the control group.

The 2 groups x 2 agent (rigid / non-rigid) x 2 duration (short / long) ANOVA was performed to compare the standard launch to the entraining in order to see if the length of the interaction influenced the perception of physical causality. From the analysis it emerges an effect of the duration $F(1,39) = 7.976, MSe = 0.439, p= 0.007$, and of the agent $F(1,39) = 12.464, MSe = 0.634, p= 0.001$, and also a trend for the agent x duration interaction $F(1,39) = 3.164, MSe = 0.652, p= 0.065$. All other effects were not significant, the agent x group interaction $F(1,39) = 0.634$, the duration x group interaction $F(1,39) = 0.728$, the agent x duration x group interaction $F(1,39) = 0.081$. 
The trend for the agent x duration interaction is in line with Figure 21 that shows an interaction between the duration and the type of agent motion particularly in the autism group: there is not much difference between launch and entraining events, but there is a difference in the non-rigid agent condition with positive scores for the launch and more negative scores for the entraining.

Follow-up analysis of the separate non-rigid and rigid conditions show a duration effect for the first $t(36) = 2.313, p = 0.27$, but not for the second type of events $t(38) = 0.533, p = 0.597$, only in the autism group. There are no significant effects in the answers of the control group: rigid agent $t(42) = 0, p = 1$, non-rigid agent, $t(42) = 1.604, p = 0.116$.

![Figure 28 – autism group agent x duration of contact](image)

Figure 28 – autism group agent x duration of contact
Reaction and entraining

It is also useful to compare entraining to reaction events because launch and reaction differ in both temporal and spatial configurations, therefore the domain distinction between the two could reflect spatial or temporal factors or both.

Since the entraining and reaction stimuli differ in their spatial configuration, but have an equivalent temporal configuration (as the time of the contact between A and B in the entraining corresponds to the length of the overlapping motion of A and B in the reaction), the comparison between entraining and reaction allows to test whether the domain distinction can be based only on the spatial configuration.

Figure 30 and 31 show that the reaction and entraining are associated respectively to the social and to the physical causal domains, though, overall the attributions of social causality increase in the non rigid agent condition and also the entraining stimulus becomes more social to the eyes of the kids.

The 2 group x 2 agent (rigid / non rigid)x 2 space (contact / non contact) ANOVA confirms the visual impression with a main effect of the spatial configuration F(1,39) = 19.021, MSe = 0.545, p <0.001, and of the type of agent F(1,39) = 99.299, MSe = 0.483, p <0.001. All other effects were not significant, agent x group interaction F(1,39) = 1.478, MSe = 0.545, p = 0.231, the space x group interaction F(1,39) = 0.803, the agent x space
interaction $F(1,39) = 2.383$, $MSe = 0.533$, $p = 0.131$, the agent x space x group interaction $F(1,39) = 0.002$. This reflects the pattern of results of the two groups of children separately and suggest that in this case the causal domain distinction can be based on spatial configuration alone.

**Figure 30** – autism group: agent x spatial configuration

**Figure 31** – control group: agent x spatial configuration
Comparison of the reaction+launch (ambiguous) stimuli with the launch condition (physical causality) and with the reaction condition (physical-psychological causality)

Figure 32 autism group: ambiguous stimuli comparison with launch stimuli

Figure 33 control group: ambiguous stimuli comparison with launch stimuli
The intentionally ambiguous stimulus in which the interaction starts with a reaction but ends with a launch was introduced in order to test if children with autism provided a preferential interpretation of the causal domain eventually due to their particular visual processing capacities. Normal young kids at 3, 5 and 7 years of age associate such event to the physical causality image (Watts et al. 2007), but the typically developing kids in our control group who were 9.5 years old provided more social than physical attributions.

Figure 32 and 33 show that while launch events in either groups and in either agent conditions received more physical causality attributions, the reaction+launch stimuli were considered ambiguous and have scores close to zero, but not in the case of the reaction+launch rigid agent that was considered physical by the children in the autism group.

The figures show also that the non-rigid agent condition influenced the answers of the children in both event-type conditions as there is an increase in the attribution of psychological causality either to the launch and to the reaction+launch in both groups.

From the 2 group x 2 agent (rigid / non rigid) x2 type (launch / reaction+launch) ANOVA emerges a main effect of the type of event F(1,39)= 22.292, MSe= 0.760, p< 0.001, and a trend for the agent F(1,39)= 2.968, MSe= 0.717, p=0.93. All other effects were not significant, the agent x group interaction F(1,39)= 2.407, MSe= 0.717, p= 0.129, the type of event x group interaction F(1,39)= 0.594, the agent x type of event interaction F(1,39)= 0.058, and the agent x type of event x group interaction F(1,39)= 1.418, MSe= 0.583, p= 0.826.

When the two groups are considered separately, the trend for the agent effect emerges in the results of the autism group in which there is a main effect of the agent F(1,18) = 8.918, MSe = 0.402, p = 0.008, while for the control group the agent effect is limited to a trend F(1,21) = 0.12.
Comparison of the reaction+launch (ambiguous) stimuli with the reaction condition (physical-psychological causality)

Figure 34 autism group: ambiguous stimuli comparison with reaction stimuli

Figure 35 control group: ambiguous stimuli comparison with reaction stimuli
It was also performed a comparison of the reaction+launch stimulus with the reaction one, figure 34 and 35 show that in either agent conditions the reaction event is associated to the social causality image, while as already pointed out the reaction + launch stimuli receive overall scores close to zero but not in the rigid agent condition which is considered physical by children with autism.

The type of agent has an effect either on the reaction and on the ambiguous stimulus that receive more social attributions in the non-rigid movement condition.

From the analysis 2 group x 2agent x 2type ANOVA it emerges an effect of the type of event F(1,39)= 40.951, MSe= 0.535, p<0.001, an effect of the agent F(1,39)= 6.406, MSe= 0.545, p= 0.016, and an effect of the agent x group interaction F(1,39)= 4.569, MSe= 0.545, p= 0.039. The other effects were not significant, the type of event x group interaction F(1,39)= 0.707, the agent x type of event interaction F(1,39)= 0.093, and the agent x type of ev. x group interaction F(1,39)= 0.762.

The agent x group effect signals that the two groups responded differently to the agent type. The agent effect was significant for the autism group F(1,18) =13.667, MSe = 0.405 p=0,002, but not for the controls F(1,21)= 0.068, while the type of event (reaction or reaction+launch) was significant either for the autism group F(1,18) = 18,422, MSe=0.709, p<0,001 and for the controls F(1,21)= 23.124, MSe= 0.385, p<0.001.

The children in the autism group gave ambiguous answers when asked to categorise the ambiguous stimuli, not revealing a preferential interpretation of the ambiguous condition, even if their judgments are influenced by the animacy features of the agents involved in the interactions. On the other hand typical developing controls considered the reaction + launch as an ambiguous event but contrary to what was expected they provided more social than physical attributions.

In conclusion, both the standard launch and reaction are distinct from the ambiguous event in terms of causal domain. The agent involved modifies the perception of all of the three stimuli, but particularly for children with autism the ambiguous event results more physical in the rigid-agent condition and more psychological in the non-rigid agent condition. The general ambiguity of attributions to the reaction+launch stimulus shows that the children didn’t provide a preferential interpretation for this stimulus.
**Individual response pattern**

**Rigid agent set**

Individual response patterns mirror the group results and confirm that most of the children categorised the events appropriately.

If the correct pattern is intended as that in which the launch, the entraining, the launch + attentional cue correspond to the pushing picture, the reaction+launch can be associated either to the pushing or to the reaction picture, the reaction and reaction + attentional cue correspond to the reaction event and the delayed events correspond to the walking picture, we have that the majority of children, 13 on 20 children in the autism group and 16 on 22 in the control group give 6 or more (75% or more) correct answers.

In the autism group the wrong associations (see table 9-10) regarded mostly the delayed events that were associated to causality of the corresponding domain. For the launch-delay event 7 children chose the corresponding causal picture instead of the non-causal one and 2 children chose the reaction image for the reaction-delay event. In the control group 10 children associated the physical causality image to the launch-delay, while 3 chose the reaction picture for the reaction-delay event. Other patterns of answers like calling a contact event psychological and vice-versa were very rare in both groups.

Only 3 children in the autism group and 2 in the control group chose the pushing picture for all the contact events (launch, entraining, launch-delay, reaction+launch and launch+flash), while none of the children in the autism group and only one in the control group associated the chasing picture to all the non-contact stimuli (reaction, reaction+flash, reaction-delay), this suggests that in general most of the children were not using a simple contact non-contact criterion to discriminate the causal domains.

Instead the most recurrent pattern of answers provided by the children was that associating the physical image to the launch, to the entraining and to the launch+ attentional cue and the psychological image to the reaction and the reaction+ attentional cue, 8 of the children with autism and 9 of the controls presented this overall pattern.

**Non-rigid agent set**

Considering a pattern of correct answers in which the launch and the entraining, correspond to the pushing picture, the reaction+launch can be associated either to the pushing
or to the reaction picture, the reaction corresponds to the chasing picture and the delayed events correspond to the walking picture, the individual response pattern for the non-rigid events shows that 11 on 19 children with autism and 19 on 22 in the control group give 4 or more correct answers that means they are right in at least 66.6 % of cases. (Among these, 9 children in the autism group and 10 in the control group provided 83.3% of correct answers).

It is significant that with non rigid agents the most diffused pattern of mistakes consists in the attribution of social causality either to both delayed and to all the contact events, 11 children with autism made at least one wrong attribution of social causality, but 6 of them made more than one. In the control group 14 children made at least 1 wrong attribution of social causality and, 3 made more than 1.

Besides that, none of the children in the autism nor in the control group made the converse mistake of attributing physical causality to the reaction event, and only 2 children in the autism group and 4 in the control group attributed physical causality to the reaction-delay event. In the autism group also the ambiguous event receives more social than physical causality attributions (contrary to the attributions in the rigid-agent condition).

In the non rigid agent condition the overall correct pattern associating the launch event to physical causality, the reaction event to social causality and both the delayed movies to the non causal image was shown by 8 children of the control group, while the pattern of answers of the children in the autism group presents generally more wrong attributions of social causality.

Overall the individual response pattern in both sets of stimuli reflects the group results.

<table>
<thead>
<tr>
<th>Subjects showing the pattern of answer</th>
<th>Autism</th>
<th>Typ. Dev. control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rigid</td>
<td>Non-rigid</td>
</tr>
<tr>
<td></td>
<td>20 N</td>
<td>19 N</td>
</tr>
<tr>
<td>All correct</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Causal attributions to delayed events</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Other patterns</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 9
Number of children with different response patterns.

-All correct answers as it is explained in the text. Total of causal attributions to non causal events: either launching to non-causal launching or reaction, or reaction to either non-causal launching or reaction.
<table>
<thead>
<tr>
<th>Pattern of incorrect answers</th>
<th>Autism</th>
<th>Typ. Dev. control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rigid N 20</td>
<td>Non-rigid N 19</td>
</tr>
<tr>
<td>Total number of Causal attributions to delayed events, of which:</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Phy. to react-delay</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Social to react-delay</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Phy. to launch-del</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Social to launch-del</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Phy. to reaction</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Social to launch</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 10

Total number of wrong attributions to different events

Total number of Causal attributions to delayed events: either social or physical causality to non-causal launching or reaction events.

The specific type of attribution is specified in the 4 rows below:

- Physical causality attributions to non causal (delayed) reaction.
- Social causality attributions to non causal (delayed) reaction.
- Physical causality attributions to non causal (delayed) launching.
- Social causality attributions to non causal (delayed) launching.

Total Number of physical attributions to the reaction event
Total Number of Social attributions to the launching event
4.5 Discussion

Our experiment investigated perceptual causality in children with autism and verbal mental age matched typically developing controls. The data suggest that children with Asperger Syndrome and high functioning autism (mean VMA 9.7 years) perceive physical and social causal Gestalts to the same extent as matched children with typical development.

In the present study the children in the clinical population showed an appropriate causal differentiation, matching the contact causal events (launching, entraining, launch+flash) with the picture representing physical causation, the delayed events with the picture depicting the non causal interaction, and the non contact causal events (reaction and reaction+flash) with the picture representing social causality. The ambiguous reaction+launch stimulus received either physical and social attributions: for children with autism more physical than social attributions in the rigid-agent conditions and more social causality than physical causality attributions in the non rigid agent condition, in the control group it received more social than physical attributions in both agent conditions.

The overall good performance of the children indicates also that they didn’t have problems with the test itself, confirming that their understanding of the pictures, of the movies and of the procedure was adequate.

The children with ASD in our sample demonstrated to answer in a mature fashion, being able to use principally the temporal information to distinguish causal from non-causal events and the spatial configuration to differentiate physical from social causality.

Finally, the results show that the animacy cue characterising the non-rigid caterpillar agent influenced strongly the answers of the children with ASD and to a smaller extent those of typically developing children.

The main finding of unimpaired perception of launch events is in contrast with Ray and Schlottmann’s (2007) finding of children with autism answering at chance level for launch events, and not differentiating them from delayed control events (Ray and Schlottmann 2007).

The children in the present study had a good performance not only with launching events but with all the stimuli representing physical causality, differences in age and verbal level could account for the diversity in results as the children in our group had an higher chronological age as well as an higher verbal mental age respect to the children in Ray and Schlottmann study.
On the other hand the unimpaired perception of reaction events is in agreement with Ray and Schlottmann (2007), and with Bowler and Thommen’s (2000) finding of a good differentiation between launching and reaction events in their sample of children with autism, however it is in contrast with their interpretation of a specific problem in the description of non-contact interactions in more complex (Heider and Simmel) animations. Moreover also Klin (2000) found that children with autism were less able in the individuation of the social elements present in Heider and Simmel’s animations and in the attribution of social features to the shapes depicted in the animations. Differences in answer procedure and in the stimuli shown to the children in the different studies could account for this apparent contradiction in results.

The last dissimilarity concerns the influence of the animacy feature on the performance of children with autism and to a smaller extent on the performance of typically developing children in the present study but not in Ray and Schlottmann (2007), differences in the procedure and between the characteristics of the groups of children participating in the two studies, like chronological age and verbal level, could account for this result.

Reaction perception, theory of mind and understanding of intentions

Reaction perception in our sample of children with autism was unimpaired, as already pointed out this result is coherent with that of Ray and Schlottmann (2007) and with the results of the perceptual causality study in Bowler and Thommen (2000) but in contrast with Bowler and Thommen claim of a specific problem in the description of interactions that didn’t involve contact between the shapes.

The main difference between the present study and Bowler and Thommen’s one is in the experimental design, in the stimuli and in the answer procedure used: in the first part of their study Bowler and Thommen (2000) showed 10 children (mean VMA 7.6) a series of launch and reaction events and asked them to provide a verbal description of these events. Since children were able to distinguish launching from reaction events the authors concluded that children with autism were as able as typically developing matched children to distinguish self propelled (intentional) from not self propelled (mechanical) motion. However the fact that non-causal control events were not included in the experimental design represents a main methodological problem because reaction and launching events present a different spatial configuration and can be distinguished simply according to the presence or absence of contact between the shapes, therefore it is not clear if the children in Bowler and Thommen experiment were distinguishing the events according to causality, while it seems clear that
children in the present study were able to distinguish causal from non-causal events and between social and physical causality.

In the second part of Bowler and Thommen’s study 11 children (mean VMA 7.10) were shown an Heider and Simmel (1944) animation, and the results suggested that the children with autism had a particular difficulty in the description of interactions at a distance. The authors report that in this case the children with autism produced fewer spontaneous verbal descriptions of the interactions between the shapes and particularly of the interactions not involving contact. This last finding is also coherent with Klin’s (2000) results that reveal a reduced capacity to individuate the social elements in complex schematic animations and to make social attributions concerning the geometrical shapes involved in such complex interactions in a group of adolescents and young adults with autism and Asperger Syndrome with high verbal level.

These findings together suggest that the perception of social causality in reaction events is not impaired in children with autism or Asperger syndrome and this fact seems to be independent of age and verbal level. On the other hand when action and reaction sequences are embedded in more complex animations similar to those ideated by Heider and Simmel (1944), children as well as adolescents and adults with autism and Asperger syndrome and high cognitive and verbal functioning show a specific difficulty in making social attributions. Thus there is a crucial difference between these two kind of stimuli in terms of complexity of the situation depicted. Complex schematic animations require a fast on-line processing of a series of actions and of the consequent reactions and require an integration of the different elements into a coherent whole. While this process seems easy and spontaneous for typical individuals who solve the task by means of mental state reasoning, it is difficult for people with autism and this difference seems to mirror the specific difficulty of people with autism in the on-line processing of real life social scenes. It has been suggested that simple animations representing goal-directed interactions don’t trigger mental state attribution (Blakemore et al. 2003), while complex attributions with expressive movements and multi-episode interactions would automatically elicit mentalizing processes (Castelli et al. 2001).

A second difference concerns the answer procedure, in fact verbal accounts could be not adequate to test the child’s perceptual abilities because also typically developing children (5 to 12 years old) mainly describe launch and reaction events in terms of their spatial and temporal features and not in terms of causal features (Thommen et al 1998). However this could depend on the fact that verbal accounts can be more demanding than the non verbal answer procedure: as we have already pointed out, experimental evidence shows that also
typically developing preschoolers are able to differentiate these events according to causality when a non-verbal answer procedure is used (Schlottmann et al. 2002).

Rochat (1997) argued that since in typical development the sensitivity towards interactions at a distance appears even before other early social behaviours, like joint attention and communicative gestures, it could be a precursor for the emergence of such abilities. Schlottmann and Surian (1999) suggested that the perception of causality in reaction events could be at the basis of the understanding of mental states in typical development. As we have already pointed out, the sensitivity to interactions at a distance emerges before the nine months of age and it could allow the child to isolate events that can be later analysed in psychological terms. Perceptual causality of reaction events could be therefore abnormal in children with autism given their difficulties in tasks and situations requiring mentalising. In accord with this view, a disruption in perceptual causality abilities should correspond to problems in understanding other minds, that are typical of autism.

Ray and Schlottmann (2007) included a classical false belief task in their study in order to assess theory of mind abilities in their sample of children with autism, this because a problem with reaction perception could be related to problems in theory of mind. However the results show that the percentage of children with autism passing the false belief task was comparable to that of typical children. This is compatible with previous findings about false belief tests in children with autism and is likely to reflect limits of false belief tests more than theory of mind abilities (see for instance Happé 1995).

Thus in Ray and Schlottmann’s study either “theory of mind abilities” measured with the false belief task and the perception of reaction events were in the norm, but still the children had severe problems in on-line everyday social interaction. The false belief task wasn’t included in the present study, but we can claim that in spite of the children’s severe problems in social development and everyday social interactions the perception of reaction events resulted in the norm also in our study.

Ray and Schlottmann proposed two interesting and equally plausible interpretations for this result. On one hand they claimed that the typical pattern of answers present in older children doesn’t rule out the hypothesis that reaction perception might still be necessary at an early age, perhaps in infancy, on the other hand they argue that the link between the perception of social causality in reaction events and theory mind abilities could be not straightforward.

The first point argues that even if older children with autism respond in a typical manner to reaction events, their social behaviour is impaired and this could depend also on an
early impairment in perceptual causality perhaps already in infancy. Therefore (although the
difficulties that it might cause) a group of younger children with autism would be a more
appropriate control group for future investigations, as younger children could still show
anomalies in perceptual causality that can be overcome with age. It would be also useful to
investigate perceptual causality with eye tracking in order to see eventual differences in
attentional processes.

The second point is more problematic as it proposes that reaction perception is not
directly related to theory of mind difficulties. As discussed earlier, reaction perception doesn’t
necessary require mentalising and also normal adults and children often describe reaction
events with goal-directed language and not with mental state terms (Schlottmann et al. 2006).

It has also been reported that children and adults with autism are able to use goal-
directed language to describe more complex schematic animations despite their impairment in
mental states attribution (Abell et al 2000; Castelli et al. 2002), therefore it could be that they
perceive reaction events just in goal-directed terms but these animations don’t trigger any
process of attribution of mental states to the shapes involved. Indeed, the reaction event can
be defined as the representation of goal-directed motion intended as an autonomous
movement in which the agent contingently directs its movement toward or away from another
object (Csibra 2003). Therefore the present causal perception test composed by simple stimuli
would provide a measure of the ability to perceive goal-direction in causal interactions,
without any direct implication for the development of mental state reasoning.

In most of cases reaction and launch events as those displayed in the present study are
too short and simple to elicit complex descriptions even by typical children and adults. These
short interactions can represent single parts that are usually included in more complex
animations like those ideated by Heider and Simmel (1944). Even though the present study
with the picture choice system constrained children’s answers and could probably elicit
further interpretations of the animations and social attributions to the shapes we don’t have a
clear measure of this interpretive process.

The present results seem to show that older and high functioning children with ASD
don’t have any problem in the perception of causal events and in the discrimination of causal
from not causal events when a non verbal answer method is provided. This means that
potential attentional and perceptual peculiarities (like a the enhanced perception at the local
level), didn’t interfere with the perception of such events nor in the process of discrimination
of the causal domain.
On the basis of the temporal and spatial information the children distinguished actions directed on objects, and the consequent behaviour of objects, from interactions between animate agents, and the reactions of animate agents, then they associated the animations to the corresponding images representing intentional, goal-directed actions and interactions.

Such an intact perceptual ability, not accompanied by the insight about the non-visible reasons underlying animate agents’ actions, could be the sign of an immature understanding possibly due to the early insensitivity towards social interactions and perceptual causality at an early age.

The sensitivity to goal-directed actions appears very early during development and is supposed to have a main role in orienting the infant in his successive understanding of other people, however, this has not be confirmed in recent studies about the understanding of intentions in young children with autism. In fact these children seem to be sensitive to the goal directedness of other people’s actions even if they have problems in understanding the mental reasons that drive them (Carpenter et al 2001).

In this case our findings would confirm an intact perception and understanding of goal directed actions not accompanied by social attribution, and in spite of severe social deficits.

**Launch events, perceptual bias and attentional processes**

Our results show that the children with autism attributed physical causality to launch events. This finding is opposite to that of Ray and Schlottmann (2007), in fact in their study the children had an impaired performance only in the attribution of causality to the launch event.

This difficulty was interpreted as the effect of the short duration of the critical information defining the launch event: namely the duration of the contact between the two shapes that they report as lasting roughly 21ms. It has been suggested that such a short duration didn’t allow the children to process the launching stimuli at the global level in order to perceive causality. On the contrary the length of the motion overlap between the two shapes in reaction events was believed to be sufficient as children demonstrated to perceive causality in such events. Ulterior evidence supported the hypothesis of the enhanced local processing, in fact the low performance in perceptual causality in the launch event was also negatively correlated with an high performance in the Pattern Construction, a test that requires good local processing, contrary to the launch gestalt that requires more holistic processing.

This explanation implies that rather than a domain-specific deficit in the perception of mechanical causality, children with autism could have problems in the perception of very
brief interactions because of the perceptual local bias that can emerge in the processing of short lasting visual information (Mottron and Belleville 1993). However in the present study the children were able to associate physical causality to launching events even if the contact between the two shapes had a short duration of less than 21ms, similar to that in Ray and Schlottmann (2007) study.

In the present study unimpaired perception of physical causality in general is also evident in the good performance of children with autism with the other stimuli like the entraining and the launch + attentional cue.

Several stimuli were included in the design in order to further investigate the supposed difficulty of children with autism in the perception of physical causality. It is clear (figure 21) that the entraining event in the rigid-agent condition was considered equivalent to the launching event, and this demonstrates that the children had a good conceptual understanding of the image depicting physical causality, and associated it either to a short or a longer action of pushing. Besides that, also the reaction-launch stimulus in the rigid-agent condition receives mostly physical attributions by children with autism.

Two main differences could account for the different result of the present study respect to Ray and Schlottmann’s one, namely the higher chronological age (respectively 13 and 8.4) as well as the higher verbal mental age (respectively 9.7 and 5.1) of children with autism in the present study. Especially the higher verbal level allowed to use more rich verbal instructions that could support a good performance.

The group of children with autism in the present study had an higher verbal age and none of the children manifested problems in understanding the verbal instructions provided. More articulated verbal instructions about the procedure of the test facilitated the children’s understanding of what they were required to do, that is, watch the animation on the screen and choose the corresponding image. Moreover the children were required to provide a verbal description of each of the images and they were provided the correct description when not able to individuate it by themselves. This helped to avoid possible misunderstandings about what the images represented and made more likely that the child correctly understood what he or she was required to do and associated the animation with the corresponding concept represented in the image. Happé (1995) has found a correlation between higher verbal level and the capacity to pass false belief tests and she suggested that children with autism might solve theory of mind tests in a verbally mediated fashion. In a similar way the high verbal level might help children with autism to solve the perceptual causality task with the help of language, and this could be linked also to the verbal instructions provided to the child.
The higher chronological age could help as well because this perceptual causality test was highly demanding in terms of attention and concentration for 20-30 minutes. Such an amount of time can be long especially for younger and low functioning children also because the test is not very interesting for the child. Thus older children can be more able to cope with the experimental situation itself and have a better performance.

Moreover it could be that while perceptual causality is impaired during infancy and early childhood, it simply develops later and this would explain the good performance of older children.

In conclusion, chronological age as well as verbal mental age can allow the child to overcome the launch perception impairment.

The influence of animacy and incorrect answers

The data show that in the non-rigid agent condition the causal domain distinction was still appropriate but the attributions of psychological causality increase overall. The influence of the animacy cue, together with the simultaneous movement of the two shapes brings the children to make more social attributions, the entraining receives more attributions of psychological causality, and the same thing happens to the reaction+launch stimulus.

It has been previously reported that the animacy cues have less influence on the causal attributions of typically developing children (Schlottmann et al. 2002), however they affect somewhat the performance of infants who seem to attribute goals preferentially to animate-like agents (Schlottmann and Surian 1999; Schlottmann et al. 2006).

In the present study the non-rigid caterpillar motion is linked to weaker impressions of physical causality for launch and entraining events and to stronger impressions of social causality for gap and reaction events coherently with recent adult data (Schlottmann et al. 2006). In this sense children with autism respond to the non-rigid motion slightly differently from matched children, and more similarly to adult subjects. This result agrees with the idea that non-rigid motion can have perceptual as well as cognitive effects (Michotte 1946/63). However, contrary to Michotte’s thought the data confirm also that the perception of social causality doesn’t depend exclusively on animate-like motion or on other expressive hints, and also rigid square shapes receive attributions of social causality, in agreement with Kanizsa and Vicario (1968).

The influence of animate agents on the answers of the autism group suggests that the type of motion displayed is recognised as a naturalistic feature of animacy that can have a strong impact on the child’s attribution of causality. This is important because it is the sign of
a top down influence of knowledge on perception. In this case the child’s knowledge about animate entities and goal-directed behaviour seems to orient his attribution of causality. Such an influence didn’t appear in Ray and Schlottmann’s study (2007) in which the children were not prompted about animacy.

Even if the animate-like agent effect could be a direct consequence of the prompting, on the other hand it is also true that some of the children with autism and the majority of children in the control group spontaneously identified the animacy feature in the non-rigid agents when prompted about the difference between square and caterpillar shapes. Still the influence of animacy on the judgements of children with typical development was weaker and this could imply that their answers were less dependent on the motion features of the agents involved. On the other hand it could suggest that children with autism were more influenced by the animacy features, and this could mean that they their answers were based on their knowledge about the behaviour of animate agents.

The most common pattern of mistakes consisted in the attribution of causality to the non-causal event of the same domain (physical causality to contact events and social causality to non-contact event), while the attribution of physical causality to non-contact events and vice versa the attribution of social causality to contact events was very rare. This shows that the distinction between the physical and the social domain depends clearly on the spatial configuration, contact interactions are associated to physical causality, while interactions at a distance are associated to social causality even when the stimuli have the same temporal configuration like in the case of entraining and reaction events. This would suggest that the presence or absence of contact in the interaction is the fundamental element that allows the distinction between an animate agent and an inanimate object: if A causes the motion of B at a distance B is perceived as animate, while if A causes the motion of B by means of contact B is perceived as non-animate.

Conclusions

The ability to perceive and categorise causal events could be a developmental precursor of social knowledge and of social attributions, which are generally impaired in the population of individuals with ASD. Some researchers argue that perceptual causality could help infants to learn about the causal structures of the world in absence of previous causal knowledge. Thus perceptual causality can allow the process of learning about causal interactions and the behaviour of objects and people (Baron Cohen 1994; Leslie 1988;
Mandler 1992). Michotte himself (1946/1963) claimed that perceptual causality provides a unique foundation for the notion of cause.

Physical and social perceptual causality could be impaired in autism, however in the present study children with high functioning autism and Asperger syndrome with a mental age between 5 and 10 years showed perceptual causality abilities in the norm, in spite of the severe social disability of these children in daily social interactions and independently of their cognitive level.

In comparison with Ray and Schlottmann’s (2007) finding of an impaired perception of physical causality in launching events our data show that such an impairment can be overcome with age and a good verbal level that allow to cope with the experimental situation itself and to understand more articulated verbal instructions, moreover children with autism with better verbal functioning might solve the perceptual causality task in a verbally mediated fashion like already hypothesised by Happé (1995) for the role of verbal language abilities in solving theory of mind tasks.

For future research it will be important to investigate the possibility of difficulties with perceptual causality in younger children. It will be important to understand if the difficulty in the perception of physical causality is related only to launching events or if it concerns physical causality in general, as well as further evaluate the possible correlation of these difficulties with more general perceptual and attentional processes. However, the hypothesis that children with autism could have a deficit in the perception of physical causality in general would be unexpected as children with autism don’t show impairments in reasoning about mechanical interactions, thus younger children with autism could have an impairment in the perception of very brief but not of longer interactions.

Our results show the presence of mature causal perception abilities and impaired social development. This can have implications for the role of perceptual causality in social development: even if perceptual causality abilities point towards important social information, a good perception of causal events is evidently not sufficient to reach a good social knowledge and to develop an adequate behaviour in the interaction with other people, nor to improve the ability to infer the non visible causes of other people’s actions.

Klin (2000) has shown that high-functioning individuals with autism have difficulties in the individuation of social elements in expressive and complex schematic animations like those ideated by Heider and Simmel (1944). On the light of the present study this is not likely to depend on the basic perception of the single social and mechanical causal interactions depicted in the animations, instead it could depend on the fact that simple causal stimuli can
be described in goal-directed rather than mentalistic terms while Heider and Simmel stimuli usually trigger complex mental state narratives that seem unattainable by people with autism.

Through the eye tracking technique it has been shown that children and adults with autism are likely to miss important social elements when they watch everyday social situations (Klin et al. 2002; 2005) and probably also when they watch schematic animated events. The task in the present study was different as the animations were quite short and elemental, the children had a clear instruction and the answer method was structured. Thus our result show that children with high functioning autism can have a good performance in simple perceptual causality tasks but perceptual causality abilities don’t seem a good predictor of the spontaneous ability of mentalising, neither of real-life social perception and skills. Similarly there’s a discrepancy between the performance in traditional explicit theory of mind tests and the everyday social behaviour (Klin 2000).

In typical development the infants’ attention is naturally attracted towards causal events, and there is good evidence that infants are sensitive to the causal structure of launch and reaction events, although it is unclear whether infants are able to distinguish the two types of causality that characterise these events (Leslie and Keeble 1987; Schlottmann, Ray and Surian 2002; Schlottmann and Surian 1999). Nevertheless, at three years of age typically developing children show to be able to distinguish social from physical causality (Schlottmann et al 2002).

Perceptual causality could be impaired in early phases of development of children with autism, and this would have several implications for their subsequent development. A disruption of this ability during early infancy would hinder the perception of causal interactions. We can’t exclude the eventuality of an incapacity to perceive causal events very early in development, at the moment in which this ability could be useful to support the early phases of social development orienting the child’s attention towards socially relevant information.

A possible consequence of such an early disorder in perceptual mechanisms would be the lack of perceptual experience of causal events, and a poor differentiation between the behaviour of objects and that of intentional agents, together with the incapacity to infer the nature of the agent on the basis of its movements. Children with autism never achieve an optimal level of performance in on-line naturalistic tasks of social attribution, and this difficulty could have its basis on the early perceptual disability in the perception of contingent and causal interactions in spite of the maturation of the perceptual mechanism later on in development.
As far as now we still don’t know when this ability begins to be operative during the development of children with autism, we just know that perceptual causality is in place in older children, but it could still be absent during infancy when it could be fundamental for successive social development.

As already suggested (Ray and Schlottmann 2007) the good performance in perceptual causality, and especially with reaction events that are supposed to be relevant for the social domain could have implications for early intervention. If perception of social causality in reaction events does not require mentalising, anyway it points towards socially relevant information and could provide access to it, therefore simple schematic goal-directed animations could be useful learning devices as they allow to show reciprocal social interactions.
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