ELSEVIER

Cognition 76 (2000) 59–89

COGNITION

www.elsevier.com/locate/cognit

A componential view of theory of mind: evidence from Williams syndrome

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Received 4 January 1999; received in revised form 17 November 1999; accepted 15 February 2000

Abstract

In this paper we argue that there are two distinct components of a theory of mind: a social-cognitive and a social-perceptual component. Evidence for this proposal is presented from various sources, including studies of children with Williams syndrome, a rare genetic neuro-developmental disorder. Earlier work has demonstrated that people with Williams syndrome appear to be spared in the social-perceptual component of a theory of mind. In this paper we present evidence that they are not spared in the social-cognitive component of theory of mind. Three experiments with young children with Williams syndrome were conducted. In each experiment the children with Williams syndrome were compared to age-, IQ-, and language-matched children with Prader–Willi syndrome, and children with non-specific mental retardation. The experiments used different measures of theory of mind ability, including false belief (Experiment 1), explanation of action (Experiment 2), and recognition of emotional expressions (Experiment 3). In none of these experiments did the children with Williams syndrome evidence superior performance compared to the control groups. The results from this and other studies on Williams syndrome support the view that the social-cognitive and social-perceptual components of a theory of mind are dissociable. In Williams syndrome only the latter components, which are linked to distinct neurobiological substrates, are spared.

Keywords: Componential view; Theory of mind; Williams syndrome

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0010-0277/00/$ - see front matter
PII: S0010-0277(00)00069-X

1. Introduction

What are the cognitive mechanisms that underlie the capacity to understand and reason about other people? Interest in the development of the ability to interpret the behavior of others within a mentalistic explanatory framework – or theory of mind – has become a central and compelling question for cognitive scientists in recent years. Since Premack and Woodruff (1978) first stimulated the interest of cognitive scientists in theory of mind, a wide assortment of tasks, methods, and theories has accumulated in the literature on this topic. Prototypical mental states used to interpret behavior are desires and beliefs, but a good case has been made to include a range of additional cognitive and emotion states within the framework of theory of mind (e.g. Wellman, 1990). Philosophers have pointed out that stringent evidence for a genuine representational understanding of mind involves the capacity to attribute false belief (cf. Bennett, 1978; Dennett, 1978). Indeed, much of the early work in this area focused on the development of false belief understanding in normal children (Wimmer & Perner, 1983), and its selective impairment in autism (Baron-Cohen, Leslie & Frith, 1985).

Over the past decade, the construct of theory of mind has broadened to include other mental states and tasks that do not strictly test for a *representational* concept of mind. For example, research on infants and toddlers has included tasks that assess the distinction between human and physical motion, the attribution of intentionality to human action, and talk about mental states (e.g. Bartsch & Wellman, 1995; Meltzoff, 1995; Woodward, 1998). Paralleling these changes, the term theory of mind is now sometimes used interchangeably with other related terms such as *social intelligence* or *mentalizing capacity* (Frith, Morton & Leslie, 1991). At the same time, despite a healthy interest in developing alternative theories of theory of mind (e.g. Carruthers & Smith, 1996), there has been little work in formulating a model of theory of mind or, more broadly, social knowledge. What are its basic concepts, rules and representations (in a way analogous to what we have in the domain of language)? The absence of such a model has led to the broadening of the concept of theory of mind, with little regard to potentially important theoretical distinctions that have implications for underlying mechanisms within this broad domain.

In this paper we propose a first step toward developing a componential model of theory of mind, and then provide evidence for this model based on studies of children with Williams syndrome. Our main hypothesis is that there is an important distinction between *perceptual* and *cognitive* components of social knowledge or intelligence. In using these terms we draw attention to a distinction between the on-line immediate judgement of mental state, from the capacity to make more complex cognitive inferences about the content of mental states. Although we use these terms, we do not wish to imply that the perceptual component does not itself entail cognition processing, which is clearly not the case in this domain. Our evidence for this division into perceptual and cognitive components rests on differences in (1) how tasks tapping each component are related to other cognitive abilities including language, (2) developmental timing, (3) the neurobiological substrate for each component, and (4) selective sparing or impairment found in different populations, particularly autism spectrum disorders. We begin by outlining these two components of a theory of mind and briefly review the evidence that supports this hypothesis. We then present a series of experiments on young children with Williams syndrome which provides additional evidence that these components may be dissociated from one another. We acknowledge at the outset that the evidence we discuss is quite preliminary. Nevertheless, our primary goal in this paper is to present the model in order to stimulate further research and discussion on a componential analysis of theory of mind.

2. Two components of theory of mind

The *social-cognitive component* of social intelligence incorporates what has traditionally been referred to as theory of mind, referring back to the important philosophical distinctions defined by Dennett (1978) and others. This component entails the conceptual understanding of the mind as a *representational* system. False belief tasks are the prototypical measure of the social-cognitive aspect of theory of mind. These tasks appear to be closely linked to other cognitive capacities, for example, theory-building (e.g. Gopnik & Wellman, 1992). Furthermore, the development of a representational understanding of mind is closely related to the acquisition of both general and specific aspects of language, in particular, sentential complements (de Villiers, 2000). Thus, the cognitive component of theory of mind interacts closely with other domains, especially language, and tasks tapping this component often have additional information processing demands (e.g. Carlson, Moses & Hix, 1998; Hughes, 1998; Roth & Leslie, 1998). This component of social knowledge begins to emerge at around the age of 3 years, when children begin to talk and reason about epistemic states, and is firmly in place by 4 years, when they are able to pass false belief and other representational theory of mind tasks. More advanced social-cognitive knowledge continues to develop during middle childhood (e.g. understanding the role of intentionality in interpreting certain non-literal utterances, or for moral attributions), building on the basic social-cognitive constructs of belief and intention that are in place by the age of 4 years (see for example, Bennett, 1993).

The primary brain areas that appear to be involved in these aspects of social-cognition that entail reasoning about the content of other minds include regions in the *prefrontal cortex*. These include the orbito-frontal cortex (Baron-Cohen & Ring, 1994), which is involved in making judgements of social appropriateness of action (cf. Eslinger & Damasio, 1985). Preliminary research has also found that this region is uniquely activated in functional neuroimaging studies when subjects are asked to judge lexical terms for *cognitive* mental states, such as *think*, *want*, *doubt* or *imagination* (Baron-Cohen, Ring, Moriarty, Schmitz, Costa & Ell, 1994). Regions in the medial frontal cortex (Fletcher et al., 1995; Goel, Grafman, Sadato & Hallett, 1995) are activated in other theory of mind tasks, especially tasks tapping more advanced abilities. For example Fletcher et al. (1995) tested story comprehension and contrasted the brain activation patterns to stories that required mental state attributions to those that entailed physical causation. They found that the mental state (theory of mind) stories uniquely activated the left medial temporal gyrus (Brodmann's area 8). Goel et al. (1995) explored brain activation during a task that asked subjects to reason what another person might infer about the function of an unfamiliar object. They too found left medial frontal activation (Brodmann's area 9) that was unique to the theory of mind condition, however, their task also activated regions in the left temporal lobe.

Evidence from autism suggests that this neurodevelopmental disorder involves selective impairments in social-cognitive aspects of theory of mind. Most studies find that subjects with autism perform significantly worse than matched controls on a wide range of these kinds of theory of mind tasks (Baron-Cohen, 2000a,b; Baron-Cohen, Tager-Flusberg & Cohen, 1993). At the same time, it is interesting to note that some individuals with autism (including those diagnosed with Asperger syndrome, generally considered to be a milder form of autism) do pass these tasks. Furthermore, language, specifically syntactic ability, appears to be the best predictor of autistic subjects' performance on tasks tapping a representational understanding of mind (Tager-Flusberg, 1997, 2000; Tager-Flusberg & Sullivan, 1994). Adults with Asperger syndrome who perform well on a range of basic and higher-order theory of mind tasks, however, do not activate the same regions of the medial frontal cortex when they are engaged in theory of mind tasks as do normal adults. This suggests that they may be relying on different, non-social cognitive and linguistic mechanisms to process social-cognitive information (Happé et al., 1996).

The second component of a theory of mind we term the *social-perceptual component*. Unlike social-cognition, the capacities that are encompassed within this component are less related to other cognitive abilities or language, though they may be more closely connected to the affective system. They are generally considered under the rubric of person perception and knowledge, and include the capacity to distinguish between people and objects, and to make on-line rapid judgements about people's mental state from their facial and body expressions. One could argue that strictly speaking this kind of perceptually based judgement does not constitute a *theory* in that it does not involve reasoning about behavior. Nevertheless, these social-perceptual capacities are involved in making mental and evaluative judgements about people and their actions, and are what may be implicitly referred to under the rubric of mentalizing abilities (Baron-Cohen, 2000a; Frith et al., 1991).

There have been fewer studies that have included tasks that tap social-perceptual understanding, but in general such tasks involve the on-line attribution of intentional, emotional or other person-related knowledge (such as personality traits) primarily on the basis of immediately available perceptual information. Such information might include facial or vocal expression, motion or actions. We should note, however, that most experimental tasks that might be considered measures of the social-perceptual component of theory of mind also involve some additional linguistic and cognitive (e.g. working memory or attentional) ingredients, and probably overlap with social-cognitive capacities. Thus, tasks generally measure both components of social knowledge, reflecting our real-life social reasoning, which involves an integration of perceptual and cognitive information processing in this domain.

Developmentally, this component is evident earlier than social-cognitive aspects of a theory of mind. Even newborns orient differently toward social stimuli, especially human faces and voices (for a review see Mehler & Dupoux, 1994). By the end of the first year, infants respond differently to facial expressions of emotion in others, and can use eye gaze to make inferences about what another person is attending to (Baron-Cohen, 1994). Several theorists, coming from different perspectives, have argued that the social-cognitive component of theory of mind builds on social-perceptual knowledge (e.g. Baron-Cohen, 1994; Hobson, 1993; Wellman, 1990), although there have been no direct empirical tests of this hypothesis. At the same time, although the onset of the social-perceptual component is earlier than the social-cognitive, development of this component probably continues throughout childhood.

The neurobiological substrate for this component of social knowledge primarily involves the *amygdala* and associated regions of medial temporal cortex, including the superior temporal gyrus. The amygdala is known to be involved in processing emotions, especially fear (e.g. Adolphs, Tranel, Damasio & Damasio, 1994), and other complex social stimuli (Brothers, Ring & Kling, 1990; Perrett et al., 1990). It is uniquely activated in functional brain imaging studies using tasks that tap the recognition of facial expressions of emotion and other mental states (Baron-Cohen et al., 1999; Breiter et al., 1996) and the perception of biological or intentional motion (Bonda, Petrides, Ostry & Evans, 1996). Associated areas of the medial temporal cortex are also important in the perception and recognition of faces (e.g. Perrett et al., 1990).

The social-perceptual component of social knowledge is selectively impaired not only in autism but also in high-functioning people with autism or Asperger syndrome (Baron-Cohen, Joliffe, Mortimore & Robertson, 1997). These deficits are exemplified by their poor performance on tasks that entail attributing intentional and social significance to ambiguous visual stimuli (Klin, Schultz & Cohen, 2000) or interpreting the mental state expressed in eyes (Baron-Cohen et al., 1997). Thus, while autism may involve impairments to all components of social knowledge, both cognitive and perceptual, Asperger syndrome may selectively involve deficits on tasks that primarily tap the perceptual component.[1]

To summarize, we argue that there are two distinct components to a theory of mind that depend on distinct underlying neuro-cognitive mechanisms, and have a different developmental time course. Together, social-cognitive and social-perceptual capacities constitute what people refer to as social knowledge or theory of mind. The brain systems that underlie both these components make up what Brothers (1990) refers to as the 'social brain'. The *amygdala–medial temporal cortex–prefrontal cortex* forms a unified complex neural system to mediate the processing of a range of social information from recognizing faces, emotions, and intentional motion to inferring the contents of another person's mind. In everyday life both components function in a complex interconnection fashion such that our social

[1] Earlier we noted, however, that even though people with Asperger syndrome typically pass tasks that tap into the cognitive component of theory of mind, they may do so by by-passing the social-cognitive mechanisms that are used by non-autistic people.

judgements, inferences and reasoning entail perceptual and cognitive systems that are based in the integrated neural system that Brothers (1990) first described. At the same time, we argue that these components are potentially dissociable, and in this paper we present evidence for this on the basis of studies of people with Williams syndrome.

3. Williams syndrome

Williams syndrome (WMS) is a rare genetically-based neurodevelopmental disorder that, in recent years, has captured the interest and imagination of cognitive scientists, neuroscientists, and developmental psychologists (Bellugi, Bihrle, Neville & Doherty, 1992; Mervis & Bertrand, 1997; Udwin & Yule, 1991). It is caused by a hemizygous microdeletion on the long arm of chromosome 7 (7q11.32), which includes somewhere between 16 and 25 genes (Bellugi, Lichtenberger, Mills, Galaburda & Korenberg, 1999a). The syndrome is characterized by a unique phenotype that typically includes physiological abnormalities of the heart and other organs, a variety of connective or soft tissue disorders, cranio-facial dysmorphology (referred to as *elfin facies*), and an unusual combination of cognitive and behavioral features (Morris & Mervis, 1999). The cognitive and behavioral profile of WMS is striking because of its marked peaks and valleys, which are typical in both children and adults with this disorder.

The majority of individuals with WMS are mentally retarded; their IQ levels are usually in the mild to moderate range (Mervis, Morris, Bertrand & Robinson, 1999). Nevertheless, some aspects of their cognitive functioning appear relatively spared, including vocabulary knowledge (Bellugi et al., 1992; Mervis et al., 1999; Rossen, Klima, Bellugi, Bihrle & Jones, 1996; Volterra, Capirci, Pezzini, Sabbadini & Vicari, 1996), face processing (Bellugi, Marks, Bihrle & Sabo, 1988; Bellugi, Wang & Jernigan, 1994; Pezzini, Vicari, Volterra, Milani & Ossella, 1999), and auditory rote memory (Mervis et al., 1999; Morris & Mervis, 1999; Udwin & Yule, 1991). Studies report that subjects with WMS score significantly higher on tasks tapping these cognitive abilities than either mental age-matched comparison groups, such as Down syndrome or non-specific mental retardation, or relative to norms on standardized tests. At the same time, other cognitive domains are extremely impaired in WMS, especially visual-spatial construction, as measured, for example, on block design or drawing tasks. On visual-spatial tasks, individuals with WMS score significantly below mental age-matched controls (Bellugi et al., 1988, 1992, 1994; Bertrand, Mervis & Eisenberg, 1997; Mervis et al., 1999; Morris & Mervis, 1999), or significantly below norms, given their overall mental age. Thus, the unevenness of the WMS cognitive profile is striking especially in comparison to other groups of individuals who function at similar levels of mental retardation.

The behavior and personality of people with WMS also suggest some unique characteristics. The most remarkable feature of both children and adults with WMS is their extreme interest in people. They have a warm, outgoing, cheerful and friendly personality style (Udwin & Yule, 1991; Udwin, Yule & Martin, 1987).

They are described as being empathic towards other people (Gosch & Pankau, 1997), and compared to other retarded groups, children with WMS are less reserved toward strangers, more approaching, curious and extroverted, and overly affectionate and friendly (Gosch & Pankau, 1997; Sarimski, 1997; Tomc, Williamson & Pauli, 1990; Van Lieshout, De Meyer, Curfs & Fryns, 1998).

The cognitive and personality profile associated with WMS has led several researchers to propose that WMS may be characterized by sparing in the domain of theory of mind (Karmiloff-Smith, Klima, Bellugi, Grant & Baron-Cohen, 1995; Tager-Flusberg & Sullivan, 1996; Tager-Flusberg, Boshart & Baron-Cohen, 1998). The combination of relatively good language skills, excellent face processing abilities, a strong social interest, and attention to faces and people (Mervis & Bertrand, 1997) have helped to foster the hypothesis that theory of mind might be spared in this population.

In considering this issue of spared and impaired cognitive abilities in atypical populations, it is clear that researchers may use different definitions of sparing (or impairment), depending on the goals of their work. Sparing of cognitive function can be defined in either absolute or relative terms. In the absolute sense, sparing denotes abilities that are commensurate with chronological age-matched individuals in the normal population. Thus, according to this definition one might predict that people with WMS would perform on theory of mind tasks within the normative range, or on the same developmental timetable as normally developing children. Rarely do individuals with neurodevelopmental disorders who are mentally retarded (as are the majority of individuals with WMS) show absolutely spared cognitive capacities. More generally, sparing is defined in relative terms. There are, however, several different definitions of relative sparing. Relative sparing may be defined in comparison to other cognitive abilities within the same population (e.g. in WMS face processing is relatively better than visual-spatial ability), in comparison to overall mental age level (e.g. in WMS vocabulary knowledge is higher than overall mental age), or in comparison to another population, at the same general cognitive or IQ level (e.g. in WMS language is relatively spared compared to Down syndrome). In a parallel way, one can define impairment as the inverse of sparing. Impairment may be absolute when a particular cognitive ability is never acquired, or relative compared to other matched populations, or to other abilities or norms. It is these patterns of cognitive functioning, defined in terms of relative or absolute sparing (or impairment), that may be used to provide interesting and novel clues to the organization and architecture of human cognition.

Only a few studies have been conducted on theory of mind in WMS. Tager-Flusberg et al. (1998) compared adults with WMS to a well-matched group of adults with another rare genetic syndrome, Prader–Willi syndrome (PWS), on a task tapping the social-perceptual aspect of theory of mind. PWS is caused by the hemizygous loss of paternally donated genes on chromosome 15 in the q11–13 region (Butler, 1990, 1994). The IQ distribution among individuals with PWS is very similar to WMS (mild to moderate retardation). However, the typical cognitive profile in PWS is not characterized by the contrasting strengths or weaknesses in verbal and visual-spatial abilities that is seen in WMS (Dykens, 1999). This study used the Eyes task, introduced by Baron-Cohen et al. (1997), in which a subject is asked to select which of two terms best describes the mental state expressed in a photograph of the eye region of a face. Tager-Flusberg et al. (1998) found that the adults with WMS performed significantly better on this task than the adults with PWS. Furthermore, half the WMS group performed at the same level as normal age-matched adults. These findings were taken as evidence that WMS involves sparing in theory of mind; some people with WMS may be spared in the absolute sense (i.e. those performing within the limits of the normal population) while others may be spared in the relative sense (compared to matched adults with PWS). In another study, Sullivan and Tager-Flusberg (1998) and Tager-Flusberg and Sullivan (1999) found that young children with WMS showed significantly greater empathy than a matched group of children with PWS. Their task involved comparing the verbal and non-verbal responses of the subjects to the distress exhibited by an experimenter when she feigned hurting her knee. The children with WMS showed greater concern, more appropriate affect, and made more relevant verbal empathic comments than the comparison group. Both of these studies involved measures of the social-perceptual component of theory of mind in that they tap the ability to read facial expressions of mental states rather than the ability to make inferences about the contents of another person's mind. Taken together, they provide evidence for at least relative sparing in this 'mentalizing' component of theory of mind.

There have been two reported studies on the social-cognitive aspect of theory of mind in WMS. Karmiloff-Smith et al. (1995) used a set of standard theory of mind tests taken from the developmental literature in this area. These included both first- and second-order false belief tasks as well as a higher-order task that involved attributing intentions to linguistic utterances. Karmiloff-Smith et al. (1995) found that the majority of the subjects with WMS passed the first-order tasks, and some even passed the second- and higher-order tasks. They concluded from their findings that WMS involves an "islet of relatively preserved ability" (Karmiloff-Smith et al., 1995, p. 202) in theory of mind.

There are, however, methodological limitations in the study published by Karmiloff-Smith et al. (1995) which need to be considered before concluding that their findings offer clear evidence for the sparing of theory of mind in WMS, even for relative sparing. First, the participants in their experiments were between 9 and 23 years old, which is significantly older than the age at which normally developing children pass the tasks that they used. Second, no matched control group was included; instead Karmiloff-Smith et al. (1995) compared the performance of their subjects with WMS to data that had been collected in other studies from autistic or normally developing children. The absence of an appropriate control group is a serious concern because their subjects with WMS were mentally retarded. While the majority of people with autism are also retarded, a comparison to this population, which is known to involve specific and unique deficits in theory of mind (e.g. Baron-Cohen, 1995; Baron-Cohen et al., 1993), could not be particularly revealing about whether WMS might involve domain-specific sparing. Third, the number of subjects with WMS who participated in their experiments was fairly small (ranging from 11 to 16), especially given the wide range of ages in the sample. Finally, most of the tasks used by Karmiloff-Smith et al. (1995) were language-based measures of theory of mind. The subjects had to follow detailed narratives, and the test questions were grammatically complex. Because people with WMS have good language skills, at least commensurate with their mental age (Gosch, Stading & Pankau, 1994; Mervis et al., 1999; Udwin & Yule, 1990; Volterra et al., 1996), their performance on the theory of mind tasks might be attributable to language ability rather than to theory of mind. In order to seriously investigate whether WMS involves even relative sparing in theory of mind it would be important to include appropriate comparison groups well-matched on age, language, and IQ.

There has been only one study of theory of mind ability in younger children with WMS in which a standard location-change false belief task was used. Tager-Flusberg, Sullivan and Boshart (1997) compared 14 children with WMS, aged between 5 and 9 years, to a group of 10 children with PWS who were matched on chronological age and the Peabody Picture Vocabulary Test, a measure of receptive vocabulary. There were no significant differences between the two groups of children in their performance on the false belief task, although the percentage of children with WMS who passed the task (43%) was clearly not at ceiling, and was somewhat lower than what was found for the PWS group (60%). The findings from this study suggest that young children with WMS may not be any better than another group of retarded children on social-cognitive aspects of theory of mind ability. Thus, this study does not provide evidence for sparing, relative to a comparison group. However, we should note that the sample size in this study was also not large, and only a single theory of mind measure was included. Thus far, then, the evidence on false belief understanding in WMS is equivocal. The two studies reported in the literature suggest somewhat contradictory findings, yet both have methodological limitations.

The goal of the study reported here was to investigate further the social-cognitive aspects of theory of mind in children with WMS. We were especially interested in whether performance on social-cognitive tasks would parallel the sparing found in studies of the social-perceptual component of theory of mind, or whether, in contrast, this component would not reflect any spared cognitive ability. In order to counter the criticisms of the earlier studies, we focused exclusively on young children who are developmentally more appropriate for studying changes that occur at around the age of 4 years in normal children. We compared the children with WMS to two comparison groups: a group of children with PWS, and a group of children with mental retardation without specific etiology. The groups were matched on age, IQ, and language ability as measured by both a receptive vocabulary test (the PPVT-R) and a standardized test of sentence comprehension. This latter measure was included because theory of mind tasks often include complex language in both the narratives and test questions, and matching groups on this kind of measure has become an important issue in the literature on theory of mind ability (Astington & Jenkins, 1995, 1999; de Villiers, 2000; Tager-Flusberg, 1997, 2000; Tager-Flusberg & Sullivan, 1994). We compared our groups on three different theory of mind tasks, which are reported in the experiments below.

4. Experiment 1: false belief

The ability to predict another's behavior based on false belief has become the hallmark test of a representational theory of mind (Wellman, 1988). Although there is some controversy over exactly when normal children pass false belief tasks (Hala & Carpendale, 1997), it is generally agreed that children demonstrate a representational understanding of beliefs by the age of 4 or 5 years (Gopnik, 1993; Gopnik & Astington, 1988; Perner, 1991). In the location change task, first introduced by Wimmer and Perner (1983), a child is presented with a story in which a boy places an object in a particular location and then leaves the room. In his absence, the object is moved to a new location. The child is then asked to predict where the boy will look for the object upon his return. This task requires the child to impute to another person a false belief (or representation) about the location of the object that differs from both reality and what the child knows to be true. In the unexpected contents task, developed by Hogrefe, Wimmer and Perner (1986), the child is initially shown a familiar container, which when opened reveals unexpected contents. The child is then asked to predict what a naive person will think is in the box. Thus, again, this task requires the child to impute to another person a false belief about the contents of a box that differs from both reality and what the child knows to be true.

4.1. Method

4.1.1. Participants

Three populations participated in this experiment: children with WMS, PWS, and non-specific mental retardation (MRU). Table 1 presents the characteristics of these groups. The first group included 21 children (16 girls and five boys) with WMS. Referrals from the New England Williams Syndrome Association and the National Williams Syndrome Association were used to identify and contact local families. Nine children with WMS who attended the 1996 National Williams Syndrome Association Family Conference also participated in this study. The second group included 15 children (seven girls and eight boys) with PWS. Referrals from the Prader–Willi Association of New England were used to recruit and contact local families. Four children with PWS who attended the Prader–Willi Syndrome National Conference in 1997 also participated in this study.[2] The third group included 15 children (nine girls and six boys) with MRU. These children were drawn from special education classes in local public schools. Their mental retardation was linked to a variety of etiologies, which in most cases was unknown.

All the children were administered Form M of the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981), a receptive one-word vocabulary test, and the sentence structure subtest of the Clinical Evaluation of Language Fundamentals-Revised (CELF-R; Semel, Wiig & Secord, 1995), a standardized measure of sentence comprehension. We also administered either the Differential Abilities

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[2] Note that the groups with WMS and PWS in this experiment overlapped with the samples reported in Tager-Flusberg et al. (1997). In this experiment more children in each group were included, and the sample was extended downward in age to include some 4-year-olds.

Table 1
Participant characteristics for Experiment 1

	Williams syndrome ($N = 21$)	Prader–Willi syndrome ($N = 15$)	Non-specific mental retardation ($N = 15$)
Chronological age (years;months)			
Mean (SD)	7;2 (1;4)	6;11 (1;7)	7;7 (1;11)
Range	4;6–8;7	4;5–9;1	4;1–10;0
PPVT-R mental age (years;months)			
Mean (SD)	4;11 (1;4)	4;8 (1;10)	5;0 (1;8)
Range	3;1–8;2	2;2–9;5	2;5–8;10
PPVT-R standard score			
Mean (SD)	70 (12)	66 (21)	67 (21)
Range	48–94	40–103	34–98
CELF sentence structure (raw score)			
Mean (SD)	11.0 (4.1)	8.9 (3.7)	9.8 (3.8)
Range	3–17	5–16	3–17
Full-scale IQ score			
Mean (SD)	68 (12)	63 (17)	75 (18)
Range	43–93	25–95	42–106

Scales (DAS) (Elliott, 1990) or the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990) as a general measure of cognitive level. The DAS yields verbal and non-verbal domain scores, as well as an overall composite score, or GCA (General Conceptual Ability), which is equivalent to a full-scale IQ score. The K-BIT yields verbal and non-verbal domain scores, and an overall IQ score. Analyses of variance confirmed that the groups were well-matched on chronological age, PPVT-R mental age and standard score, CELF sentence structure raw score, and full-scale IQ.

4.1.2. Procedures

Two different false belief tasks were used in this study: a standard location change, and an unexpected contents (or 'Smarties') task. Some children received both these tasks, but only the data from one task for each child, representing that child's highest (best) performance, were used in the analyses.

4.1.2.1. Location change task Two stories were presented in counterbalanced order to assess children's understanding of first-order ignorance and false belief. The stories were acted out with props and dolls. For example, in one story, before going out to play a boy and his mother place the boy's cup in the dishwasher. In the boy's absence, the mother moves the cup from the dishwasher to the cupboard.

At the end of each story children were asked memory (*Where did Daniel and Mom put the cup before Daniel went out to play?*) and reality (*Where is the cup now?*) control questions to ensure they recalled the relevant story events. Children were then asked a test ignorance question (*Does Daniel know where the Superman cup is?*) and a test false belief question (*Where will Daniel look* ***first*** *for the cup?*). We chose to add the word 'first' to the false belief question because Siegel and Beattie (1991) found that 3-year-olds often respond correctly when asked to predict the *initial* behavior of the story character.

4.1.2.2. Unexpected contents task Two trials of an unexpected contents task were presented in counterbalanced order across subjects. Children were asked to predict the contents of a familiar container (e.g. small milk carton). After giving the expected answer (all participants did so) the child was then shown that the box contained something different (e.g. pennies). The container was then closed and the child was asked a reality control question (*Now, what's really in this box?*), followed by a test ignorance question (*When* (*friend or sibling's name*) *sees this box all closed up tight, will he/she know what's inside?*) and a test false belief question (*What will* ___ *think is inside?*).

Children were tested individually by two experimenters. Responses were audio-taped and later transcribed and checked by a second coder. The percentage agreement between the two coders calculated on a subset of responses (30%) was 100%. The local children were tested first; we then supplemented the groups with children from the national conferences. The local children with WMS or PWS received two trials of the location change task. Although performance differences between the location change and unexpected contents tasks have not been reported for normally developing children (e.g. Hughes, 1998), in our experience there is a small number of children with developmental disorders who perform better on the latter, perhaps because it does not involve a complex narrative. We therefore gave the unexpected contents task to all children who did not pass both trials of the location change task. Seven WMS and five PWS children received both tasks. Two WMS children and one PWS child who failed the location change task passed the unexpected contents task. For these three children only, the data from the unexpected contents task were used in the following analyses. The rest of the participants (drawn from national conferences or tested in schools) were given only the unexpected contents task.

4.2. Results

Children who failed more than one of the control questions were eliminated from later analyses of the data. Using this criterion, three (20%) of the MRU children, three (20%) of the PWS children and four (15%) of the WMS participants were removed from the analysis. The number of children across all groups failing the control questions was somewhat higher than is typically found for normal children.

Table 2 shows the means (and standard deviations) for each group (excluding the children who failed the control questions) on the ignorance and false belief questions. Overall, none of the groups performed extremely well. A 3×2 mixed design

Table 2
Experiment 1: mean scores (and standard deviations) by group and question type

	Question type[a]	
	Ignorance	False belief
Williams syndrome ($N = 17$)	0.76 (0.98)	0.58 (0.87)
Prader–Willi syndrome ($N = 12$)	1.00 (1.04)	1.00 (0.95)
Non-specific mental retardation ($N = 12$)	1.25 (0.96)	1.33 (0.88)

[a] Maximum score, 2.

ANOVA with group as the between subjects factor and question type (ignorance, false belief) as the within subjects factor was conducted. This analysis revealed no significant main effects or interactions.

We then looked at the number of children passing the ignorance and false belief questions, where passing equaled scoring correctly on both trials of the test questions. Table 3 shows the number and percentage of children scoring 0, 1, or 2 correct on each test question. Chi square analyses revealed that for the ignorance question, significantly more of the MRU children passed than did the WMS children ($\chi^2(1) = 4.31, P < 0.03$). Children in both the MRU and PWS groups scored significantly above chance on this question (binomial test, $P < 0.02$ and $P < 0.05$, respectively). On the false belief question, significantly more of the MRU and PWS children passed than did the WMS children ($\chi^2(1) = 5.30$, $P < 0.02$; $\chi^2(1) = 3.46$, $P < 0.06$, respectively). However, only the children in the MRU group scored significantly above chance (binomial test, $P < 0.02$).

Correlations were computed for each group between performance on the false belief task (summing correct responses to both the ignorance and false belief test questions) and chronological age, full scale IQ, PPVT age equivalent, PPVT standard score and sentence structure subtest. For both the WMS and MRU groups, none of these correlations was significant. For the PWS group, performance on the false

Table 3
Experiment 1: number (and percent) of children scoring 0, 1, or 2 correct by group and question type

	Question type					
	Ignorance			False belief		
	0	1	2	0	1	2
Williams syndrome ($N = 17$)	11 (65)	1 (6)	5 (29)	11 (65)	2 (12)	4 (24)
Prader–Willi syndrome ($N = 12$)	6 (50)	0	6 (50)	5 (42)	2 (17)	5 (42)
Non-specific mental retardation ($N = 12$)	4 (33)	1 (8)	7 (58)	3 (25)	2 (17)	7 (58)

belief task was significantly correlated with age ($r(12) = 0.63$, $P < 0.002$) and PPVT age equivalent ($r(12) = 0.49$, $P < 0.03$).

4.3. Brief discussion

These results show that young children with WMS were no better than two comparison groups in false belief understanding. In fact, when the number of children passing the task was analyzed non-parametrically, the children with WMS were significantly worse than the control children. These findings show that on a critical measure of a representational theory of mind, children with WMS are not spared relative to other groups of retarded children.

These findings extend those of Tager-Flusberg et al. (1997) who found that the children with PWS performed somewhat better than the children with WMS. The significant group differences found in the present study may have been due to the inclusion of a larger sample as well as extended group matching not only on receptive vocabulary (cf. Tager-Flusberg et al., 1997) but also on sentence comprehension and IQ.

In contrast to the findings of Karmiloff-Smith et al. (1995), who found that 94% of their subjects with WMS passed the false belief task, only about 25% of the WMS children in the present study passed. One possible explanation for this difference is that the WMS subjects in the Karmiloff-Smith et al. (1995) study were significantly older than the age at which normally developing children pass these types of tasks. The children included in our experiment were in a more appropriate mental-age range (3–8 years) for the developmental level of a false belief task. Including children in this younger age range allows for a clearer test of whether the cognitive component of theory of mind is indeed spared in this population. Another possible explanation for the discrepancy in our findings is that Karmiloff-Smith et al. (1995) used a non-standard location change task in which experimenters themselves acted out the story, rather than using dolls. Thus, differences in the way the false belief tasks were presented may account for the differences in the performance of the subjects with WMS. We return to this issue in the general discussion of this paper.

It was somewhat surprising and contrary to our predictions to find that the WMS group performed worse than the comparison groups. Interestingly, unlike other studies with both normal and autistic children (Astington & Jenkins, 1995, 1999; Happé, 1995; Tager-Flusberg & Sullivan, 1994) we did not find that our standardized language measures correlated with performance on the false belief tasks. One possibility is that we did not include the right measure of language. Recent studies by de Villiers (2000) and Tager-Flusberg (2000) suggest that it is specific knowledge of sentential complements (e.g. *John said that Mary went shopping*; *Fred thought that Mary was sleeping*) that is closely connected to the development of a representational understanding of mind. Perhaps our language measures did not capture the children's knowledge of sentential complements. Alternatively, it could be that the attentional demands of the task (i.e. having to keep track of and integrate a complex narrative sequence of events) were especially problematic for the WMS children given their documented difficulties in attention, concentration, and distractibility (Dilts, Morris & Leonard, 1990; Greer, Brown, Pai, Choudry & Klein, 1997; Morris & Mervis, 1999; Pagon, LaVeck, Stewart & Johnson, 1987; Sarimski, 1997). In Experiment 2 we used a less structured task to explore children's understanding of the relation between mental states and behavior.

5. Experiment 2: explanation of action

In Experiment 1, we assessed children's ability to predict behavior based on false belief – the classic measure of a representational theory of mind. However, we know from the developmental literature that young normal children are able to explain behavior in psychological terms before they are able to predict another's behavior, both in spontaneous speech samples (e.g. Bartsch & Wellman, 1995) and in experimental settings. For example, Bartsch and Wellman (1989) asked preschoolers to explain why characters performed various actions (such as looking for a kitten under a piano, when it was hiding under a chair). They found that children as young as 3 years old provided many desire explanations, although the older children were better at providing belief explanations (see also Lillard & Flavell, 1990). In this experiment, we used a task developed by Tager-Flusberg and Sullivan (1994) to explore children's ability to use mental states to explain the causes of human action. This task expanded the range of mental state explanations included by Bartsch and Wellman (1989) to include desire, simple and complex emotions and a range of cognitive mental states. Data from preschoolers confirm that this theory of mind measure correlates highly with performance on false belief tasks in preschoolers (Tager-Flusberg & Sullivan, 1994), though children are able to provide mentalistic explanations before they pass false belief tasks. Thus, this experiment employed a task that is developmentally simpler than the false belief measures of Experiment 1, a task that taps the emergence of social-cognitive knowledge, but is not a strict measure of a representational understanding of mind.

5.1. Methods

5.1.1. Participants

The children who participated in this experiment were largely the same as for Experiment 1, however, five of the children did not complete this experiment (one WMS, three PWS, and three MRU), resulting in the following group totals: 20 WMS, 12 PWS and 12 MRU children. There were no significant changes in any of the standardized measures presented in Table 1. The three groups remained well-matched on chronological age, PPVT-R mental age and standard score, CELF sentence structure raw score, and full-scale IQ.

5.1.2. Procedure

Children were tested individually on the Explanation of Action task developed by Tager-Flusberg and Sullivan (1994). The stimuli consisted of nine stories designed to elicit children's explanations of a person's actions using desire, emotion and cognition terms, with three items for each category of mental state. Three additional stories were included as controls and were designed to elicit non-psychological causal explanations. The stories were presented in random order, each accompanied by two photographs depicting the main characters and events. At the conclusion of each story, children were asked to explain the action of the main character. For example, in one of the emotion stories, children were told a story about Sally who sees a dog sitting in the grass while she is walking in the park. When the dog gets up and barks, Sally starts to run. Children were asked, '*Why does Sally run when the dog gets up and barks*?' On the mental state stories, if the child failed to produce a mental state term in their explanation, the following probe question was asked, 'What's going on in _____'s head when she/he ______?' Children's responses were audio-taped and later transcribed and checked by a second rater. Percent agreement, calculated on a subset (30%) of responses, was 100%. Responses were coded into two categories. (A) *Appropriate*: logical and appropriate responses to the target story. For the mental state stories appropriate responses had to include a mental state term; any mental state term was counted as long as it fit with the story context. For the control stories, any logical causal explanation was scored as appropriate, including both mental state or physical explanations. (B) *Inappropriate*: a response that was not logical or appropriate to the target story; these included non-psychological explanations to the mental state stories. Appendix A includes the complete set of stories for this task and examples of appropriate and inappropriate responses for each story.

5.2. Results

Preliminary analyses revealed no differences in the number or type of mental state responses provided before and after the probe. Thus, for the following analyses, responses to the initial and probe questions were combined.

Table 4 shows the mean scores for appropriate responses to the cognition, emotion, desire and control stories. A 3 × 4 mixed design ANOVA was conducted with group as the between subjects factor and story type (emotion, desire, cognition, control) as the within subjects factor. This analysis revealed a significant main effect

Table 4
Experiment 2: mean scores (and standard deviations) for appropriate responses by group and story type

Story type[a]	Williams syndrome ($N = 20$)	Prader–Willi syndrome ($N = 12$)	Non-specific mental retardation ($N = 12$)
Control*	1.55 (1.15)	1.67 (1.15)	2.08 (0.90)
Desire*	2.25 (1.02)	2.33 (1.07)	2.25 (1.14)
Emotion*	2.20 (1.01)	1.58 (1.08)	2.58 (0.67)
Cognition*	1.95 (1.05)	1.42 (1.24)	1.67 (1.15)
Total**	6.40 (2.66)	5.50 (2.87)	6.50 (2.50)

[a] Maximum score: *3, **12.

of story type ($F(3, 123) = 5.35$, $P < 0.001$). Post-hoc paired samples *t*-tests revealed that children produced significantly more appropriate responses for the desire stories than cognition ($t(43) = 3.54$, $P < 0.001$) and control stories ($t(43) = 2.99$, $P < 0.005$), and significantly more appropriate responses for the emotion stories than cognition ($t(43) = 2.55$, $P < 0.01$) and control stories ($t(43) = 1.74$, $P < 0.08$). There were no significant differences between the desire and emotion stories, or between the cognition and control stories. Thus, for all three groups the desire and emotion stories were more likely to elicit mental state explanations than the cognition stories.

The interaction between group and story type approached significance ($F(6, 123) = 1.78$, $P < 0.10$). One-way ANOVAs were conducted on each story category. These analyses revealed a significant effect of group for the emotion stories only ($F(2, 43) = 3.40$, $P < 0.04$). Post-hoc Tukey tests revealed that the MRU group gave significantly more appropriate responses than the PWS group. There were no other significant group differences.

Finally, we classified the mental state words that were used by the children across all the stories. Words were coded as emotion (e.g. *sad*, *angry*), desire (e.g. *want*) or cognition (e.g. *know*, *forgot*) terms. For each story, the first mental state word used was counted, and the analysis was conducted independent of the story category. A 3×3 mixed design ANOVA with group as the between subjects factor and mental state word (emotion, desire, cognition) as the within subjects factor was conducted. This analysis revealed a significant main effect of mental state word ($F(2, 82) = 17.71$, $P < 0.001$), but there were no significant differences between the groups. Overall, children provided an average of 3.41 desire terms, 1.47 emotion terms and 0.88 cognition terms. Post-hoc paired samples *t*-tests revealed that children produced significantly more desire terms than emotion ($t(43) = 3.39$, $P < 0.002$), or cognition terms ($t(43) = 5.52$, $P < 0.001$), and more emotion than cognition terms ($t(43) = 1.69$, $P < 0.09$). Thus, children produced more desire and emotion terms than cognition terms.

5.3. Brief discussion

The results from this experiment show that on a less structured task children with WMS performed at the same level but no better than comparison groups when asked to provide mental explanations for a person's behavior, suggesting that they are neither spared nor impaired on this measure of social-cognitive knowledge. Overall, the children in all three groups provided more emotion and desire terms than cognition terms in their explanations of behavior, a finding that is consistent with the results of others using similar procedures with normal preschoolers (Bartsch & Wellman, 1989; Tager-Flusberg & Sullivan, 1994). Furthermore, the children in all three groups in this study performed at a level comparable to normal 3- and 4-year-olds, but not as well as 7–10-year-olds, who were all given the same task in the Tager-Flusberg and Sullivan (1994) study. Given that the WMS children in this study performed at a level close to their mental or linguistic age, rather than their chronological age, we take this as evidence that they are not spared in either the absolute or relative sense on this task.

It is interesting to note, however, that the children with WMS were the only ones to perform worse on the control (non-mentalistic) than cognition stories, which were the most difficult ones for the other two groups (see Table 4). Although this finding did not reach statistical significance, possibly because of the wide variance in the scores from all three groups, it suggests that the WMS children might be better at providing psychological explanations for behavior and may have relatively more difficulty understanding the physical or non-psychological causes of action. This potential difference between psychological and physical reasoning in WMS deserves further investigation.[3]

6. Experiment 3: emotion matching

Another important aspect of a mentalistic understanding of other people is the ability to discriminate and label facial expression of emotions. This ability lays the foundation for a more complex understanding of emotions and for the ability to respond empathetically to others (Feshbach, 1982). Emotions are also closely linked to beliefs and desires (Astington, 1993; Wellman, 1990). For example, facial expressions often reveal information about whether a person's desire has been fulfilled (happy expression) or unfilled (sad expressions), or whether a person held a false belief (surprised expression). We also know that autistic people show specific deficits in discriminating facial expressions of emotions and other mental states, which have been related to their deficits in other aspects of theory of mind (Baron-Cohen et al., 1997; Hobson, 1993). In this experiment, we adapted a task used by Hobson, Ouston and Lee (1988) that was designed to tap younger children's ability to discriminate and match facial expressions of basic emotions. Based on our model of the two components of theory of mind, this kind of task would a priori be considered to be a social-perceptual task, rather than a cognitive task. Thus, we would predict that the children with WMS should perform better than the controls, supporting the view that they are relatively spared in this component. At the same time, however, studies show that using the kinds of methods employed in this task, normally developing children only perform above chance levels at about the age of 3 years (Gross & Ballif, 1991), and that in autism performance is closely linked to linguistic level (Hobson et al., 1988). Thus, it is not clear whether this experiment is exclusively tapping the perceptual component of social knowledge.

6.1. Methods

6.1.1. Participants

The children who participated in this experiment were, again, largely the same as those who were in Experiment 1. There was one additional child in the WMS group,

[3] It is interesting to note that Baron-Cohen (2000b) argues that autism involves intact 'folk physics' in contrast to impaired 'folk psychology' – the opposite pattern to what might be found in WMS.

and four fewer children in the MRU group, resulting in the following group totals: 22 WMS, 15 PWS and 11 MRU children. Again, there were no significant changes in any of the standardized measures, as presented in Table 1. The three groups remained well-matched on age and the standardized measures.

6.1.2. Procedures

Children were tested individually on a task developed by Hobson et al. (1988) to explore the ability to match expressions of emotions across different individuals. The test stimuli consisted of 16 full-face 3×5 inch black and white photographs that depicted two men and two women, each with four emotional expressions (happy, sad, angry, scared), that were modeled after Ekman and Friesen (1975) faces of emotional expressions. Children were initially shown four photographs of a target person (different from the test people) depicting a happy, sad, angry and scared facial expression. The experimenter labeled each of the four emotions depicted in the target photographs, and then asked the child to label each of the photographs. All children did so correctly. Children were then told that they would be given photographs of new people to match to the targets. The experimenter then randomly selected the first set of photographs of a test person to be sorted, placing them randomly in a 2×2 matrix in front of the child. Children were told to put the photographs of the new faces under the targets that they matched. That is, the happy face should be placed under the happy target and so forth. In the remaining trials, three sets of four faces were randomly presented each depicting a new individual with the same four emotional expressions.

6.2. Results

Children received one point for each correctly matched photograph, for a total possible score of 4 for each of the four emotions. Table 5 presents the mean scores (and standard deviations). A 3×4 mixed design ANOVA was conducted with group as the between subjects factor and emotion type (happy, sad, angry, scared) as the within subjects variable. This analysis revealed a significant main effect of emotion type ($F(3, 135) = 40.32$, $P < 0.001$). Overall, children correctly matched an average of 3.60 of the scared items, 3.38 of the happy items, 2.38 of the angry items and 2.33 of the sad items. Post-hoc paired samples t-tests revealed that children correctly matched significantly more of the scared items than happy ($t(48) = 2.29$, $P < 0.02$),

Table 5
Experiment 3: mean (and standard deviation) number of correct responses by group and emotion type[a]

Emotion type	Williams syndrome ($N = 22$)	Prader–Willi syndrome ($N = 15$)	Non-specific mental retardation ($N = 11$)
Scared	3.55 (1.01)	3.53 (1.06)	3.82 (0.40)
Happy	3.36 (1.22)	2.93 (1.39)	4.00 (0.00)
Angry	2.55 (1.41)	2.20 (1.01)	2.27 (1.01)
Sad	2.55 (1.41)	2.07 (1.16)	2.27 (1.10)

[a] Maximum score, 4.

sad ($t(48) = 7.35$, $P < 0.001$), or angry items ($t(48) = 7.27$, $P < 0.001$). Children also correctly matched significantly more of the happy items than angry ($t(48) = 5.25$, $P < 0.001$), or sad items ($t(48) = 5.54$, $P < 0.001$). There were no differences between the number of correctly matched angry and sad items.

The interaction of group and emotion type approached significance ($F(6, 135) = 1.81$, $P < 0.10$). One-way ANOVAs were conducted on each emotion category. These analyses revealed a significant effect of group only on the happy items ($F(2, 47) = 2.8$, $P < 0.07$). Post-hoc Tukey tests revealed that the MRU group correctly matched significantly more of the happy faces than the PWS group, which may be due to the ceiling performance by the MRU group on these items. There were no other significant group differences.

6.3. Brief discussion

The results from this experiment indicate that children with WMS are as proficient but no better than the control subjects in discriminating and matching facial expressions of emotion. Similar patterns of performance across the different emotion states were also found across all the groups in this experiment. Overall, the scared and happy expressions were the easiest for everyone to match, which is consistent with the findings of Hobson et al. (1988) with autistic populations, as well as research on normally developing children (Gross & Ballif, 1991).

The findings from this experiment contrast with those reported by Tager-Flusberg et al. (1998) who found that adults with WMS were significantly better than PWS controls in reading mental state expressions from the eye region of the face. Indeed, in Section 1, we took these findings from the Eyes task as evidence that WMS involves sparing in social-perceptual knowledge. On the face of it, the emotion matching task is also a measure of social-perceptual knowledge, so the absence of superior performance by the WMS children in Experiment 3 should be troubling, raising doubts about spared social-perceptual abilities. What might explain these contradictions?

One possibility is that the Eyes task is a more sensitive measure of the social-perceptual component of theory of mind related abilities. This task includes items for a range of emotional, cognitive, and desire mental states (Baron-Cohen et al., 1997), so it is likely to be a measure of both the social-perceptual and social-cognitive components. In support of this idea, the task has been found to activate both amygdala and prefrontal cortical brain regions (Baron-Cohen et al., 1999) in normal adults. At the same time, the visual stimuli used in the Eyes task are more ambiguous than those used in the emotion-matching task, because only the eyes (and not additional facial features) are available from which to draw mental inferences. This kind of ambiguity makes the task more of a perceptual challenge and therefore more dependent on the social-perceptual system. This would explain why people with Asperger syndrome, who do not activate the amygdala at all on this task, perform significantly worse than controls (Baron-Cohen et al., 1999). It would also explain the relative sparing found in WMS adults (Tager-Flusberg et al., 1998), who may have relied on their intact amygdala and associated temporal regions (cf. Bellugi, Mills, Jernigan, Hickok & Galaburda, 1999b) in processing the visual stimuli on the eyes task. There have been no comparable functional brain imaging studies using the stimuli and task paradigm from Experiment 3 so it is possible that this emotion-matching task, unlike the Eyes task, does not selectively activate the amygdala and superior temporal gyrus, perhaps because there are alternative, cognitive-linguistic means for interpreting the less ambiguous facial stimuli.

It is interesting to note that while the Eyes task discriminates between even high-functioning adults with autism or Asperger syndrome and controls, research on emotion-matching and understanding has not always found differences between children with autism and matched controls (Baron-Cohen, 1991; Braverman, Fein, Lucci & Waterhouse, 1989; Hertzig, Snow & Sherman, 1990; Ozonoff, Pennington & Rogers, 1990; Prior, Dahlstrom & Squires, 1990). It has been suggested that performance on emotion tasks in young children is primarily mediated by language, rather than non-linguistic or social-perceptual capacities. Thus, when children are closely matched on language, often no group differences are found between autistic and control subjects (Hobson, 1991). This may be especially confounded in our experiment because the training and the test instructions to the children for the emotion matching tasks emphasize the verbal labeling of the emotional expressions. Since we matched our WMS children to both the PWS and MRU controls on IQ and two language measures, it is perhaps not surprising that they did not perform better than the controls on this task, supporting the view that this is a more linguistically-based task. Thus, the Eyes task, developed for adults, may be more sensitive to non-linguistic mental state abilities, i.e. social-perceptual components of theory of mind, than the kind of tasks that have been used to tap emotion knowledge in young children. We acknowledge the speculative, post-hoc nature of this discussion, in which we try to reconcile why the children with WMS were no better than controls on a task that would seem to tap social-perceptual knowledge. Clearly, more research needs to be done in the development and evaluation of a range of tasks that measure the ability of children and adults to interpret mental states from facial expressions.

7. General discussion

We began this paper with a proposal for a new model of theory of mind, in which perceptual and cognitive components were distinguished on the basis of developmental and neurobiological evidence, as well as their potential differential impairment in atypical populations. Evidence for selective sparing in the perceptual component of social knowledge in WMS was presented, based on two studies with adults and children with this unusual neurodevelopmental disorder (Sullivan & Tager-Flusberg, 1998; Tager-Flusberg et al., 1998). In those studies, the subjects with WMS performed significantly better on the social-perceptual measures than a group of matched comparison subjects with a different neurodevelopmental disorder, namely PWS. In this paper we have presented evidence from three new experiments showing that, in contrast, children with WMS are no better than matched comparison groups of PWS and MRU on tasks that tap the social-cognitive component of theory of mind. Taken together, the evidence from WMS provides preliminary support for the view that these components of social knowledge are dissociable in that one (social-perception) appears to be relatively spared in comparison to other neurodevelopmental disorders, while the other (social-cognition) is not.

This difference in performance on perceptual and cognitive measures of theory of mind may help to explain the paradox of WMS: despite their strong interest in people, superficial social skills, and empathic qualities, clinical reports indicate that older children and adults with WMS have difficulty sustaining friendships and make poor social judgements. We suggest that their social responsiveness to others reflects social-perceptual sparing, whereas their poor social judgements and difficulty forming sustained friendships are part of their broader lack of sparing in cognitive aspects of theory of mind, especially higher-order theory of mind, making them more like other retarded populations who also have problems with peer relationships.

Although we have presented our componential model in the context of our studies on WMS, we do acknowledge that the evidence from this population is quite preliminary, especially for sparing in the social-perception component. The main study on which this is based was conducted with adults (Tager-Flusberg et al., 1998) and the findings from that study, showing that the subjects with WMS were significantly better than a matched comparison group, contrast with the findings in Experiment 3. One possibility is that in WMS there is a protracted period of development of the social-perception component of theory of mind such that sparing in this domain only emerges later, in adolescence or adulthood. Clearly more research on WMS is needed before drawing firm conclusions regarding the putative sparing of social-perception at different developmental stages.

Our central claim that there is a potential dissociation between the social-perception and social-cognitive components of theory of mind is based not only on the studies of WMS, but also from a number of other sources. Thus, our model is based on *converging evidence* from differences in the developmental timing of these components, and especially the provocative findings of differences in underlying neural systems that are activated for tasks that demand more on-line perceptual (amygdala, medial temporal lobe structures) or more cognitive inferencing (prefrontal cortical areas) in theory of mind related tasks. We have not, however, provided clear evidence for a double dissociation between these two components, either comparing the WMS subjects to our other groups, or even to autism. First, it is not clear that one can demonstrate a double dissociation for cognitive components with protracted developmental trajectories between groups of individuals with neurodevelopmental disorders using the current methodology (for a discussion see Bates & Appelbaum, 1994). Second, we do not yet have clear evidence from either the developmental or the cognitive science literature on how these components might be interrelated. Is the acquisition of the social-cognitive component dependent to some extent on at least some minimal level of social-perception, as may be inferred from the developmental literature? Alternatively, it may be that some individuals may acquire the capacity to solve social-cognitive tasks (e.g. false belief) via alternative neurocognitive pathways (e.g. language), as has been suggested for people with autism (e.g. Tager-Flusberg, 2000). It remains to be seen whether, for example, one might demonstrate a double-dissociation between autism and WMS in social-perception and some other cognitive domain, though even then there are likely to be problems in interpretation.

This study included a number of different theory of mind related measures. Experiment 1 involved a classic measure of a representational theory of mind (false belief), Experiment 2 used a less structured measure of the ability to use mental states to explain human behavior, and Experiment 3 used an emotion-matching task. The findings across these experiments varied: there were no significant differences between the three subject groups in Experiments 2 and 3, whereas in Experiment 1 we found that fewer children with WMS were able to pass the theory of mind test questions.

One question that needs to be considered is why our children with WMS were worse than controls with either PWS or MRU on the false belief task, especially since they performed at comparable levels to the controls on our other measures of theory of mind, and Karmiloff-Smith et al. (1995) found no such deficit. One explanation, offered earlier, was that children with WMS have significant attention problems (Dilts et al., 1990; Greer et al., 1997; Morris & Mervis, 1999; Pagon et al., 1987; Sarimski, 1997), which may have affected their ability to integrate the task information and formulate an inference about the contents of the false beliefs in others. The tasks used in our other experiments, including the social-cognitive explanation of action task used in Experiment 2, did not require this kind of complex information integration and inferencing.

A second possibility is that our subjects performed worse than those in the Karmiloff-Smith et al. (1995) study on false belief because we used dolls (location change task) or hypothetical people (unexpected contents task) whereas Karmiloff-Smith et al. (1995) used real people to enact location change stories. By using real people, Karmiloff-Smith et al. (1995) tapped into the spared social-perceptual domain in their WMS subjects. In contrast, in our false belief tasks we eliminated all those personal-affective or perceptual components from our tasks, and reduced them to logical-linguistic measures of a representational understanding of mind.[4] This possibility suggests that studies of theory of mind in WMS need to include tasks that will draw on the perceptual-affective strengths associated with this syndrome. It also suggests that in everyday life, in interactions with others, people with WMS may evidence more theory of mind abilities than they demonstrate on experimental tasks.[5]

One final possibility is that WMS may involve deficits in conceptual or theory

[4] Note that in both Experiments 2 and 3 our visual stimuli included photographs of real people, rather than just line drawings, although as noted earlier, we may have biased the children toward treating the emotion-matching task as a linguistic task.

[5] Interestingly, the opposite appears to be the case in autism: often those autistic individuals who pass theory of mind tasks still show very poor social reasoning in everyday life (Frith, Happé & Siddons, 1994; Klin et al., 2000).

change mechanisms (Johnson & Carey, 1998). While false belief tasks tap genuine changes to a representational understanding of mind, the explanation of action and emotion-matching tasks may simply measure the emergence (but not complete development) of a theoretical concept of mind. In the domain of folk biology, Johnson and Carey (1998) found significant impairments in adults with WMS on tasks that tapped conceptual change. Some have argued that developments in a theory of mind (particularly a representational understanding of mind) involve theory change (e.g. Gopnik & Wellman, 1992). If there is a general cognitive mechanism that underlies theory change across domains of knowledge, and this is selectively impaired in WMS, then this might explain why our children with WMS were worse on the task that tapped a representational understanding of mind. We consider this the least likely explanation for our findings for the following reasons. Johnson and Carey (1998) did not include a control group of other retarded people, who are also likely to have difficulty with tasks that tap conceptual change in biology. More importantly, evidence from both normal children and children with neurodevelopmental disorders argues strongly for domain-specific conceptual change, thus casting doubt on the existence of a general cognitive mechanism that underlies conceptual change (see Baron-Cohen, 2000b; Hirschfeld & Gelman, 1994).

Although we have argued here that the evidence from WMS suggests that the perceptual and cognitive components of theory of mind may be dissociated, as we have already pointed out this work is still quite preliminary. One concern is that we do not have tasks that unambiguously distinguish between these components of a theory of mind. Thus, it is not clear to what extent, for example, the emotion matching task used in Experiment 3 should be viewed as a measure of the perceptual or cognitive component. We argued that the procedures we employed encouraged the children to treat the task as more linguistic, thus biasing them toward tapping cognitive components of a theory of mind. In comparison to the perceptual component, the social-cognitive component of theory of mind does seem to be more closely connected to language and other aspects of cognition (e.g. de Villiers, 2000; Perner & Lang, 2000; Tager-Flusberg, 2000). Future work on this componential model of theory of mind will require the development of more clearly defined and differentiated tasks.

We might also question the nature of the perceptual component of theory of mind. Is this aspect of social knowledge based exclusively on perception, or does it always entail an affective component? The role of the amygdala in the processing of tasks that tap social-perception (cf. Baron-Cohen et al., 1999) suggests that affect is integral to this component, and this might explain its relative sparing in WMS. Future research should be directed toward further dissecting the perceptual and emotional components of social processing.

Although we have argued that perceptual and cognitive aspects of theory of mind are dissociable, dependent on different neural substrates, in everyday life, our capacity to make inferences about other people almost always involves both components and it is their integration with one another, as well as with other cognitive, affective, and linguistic capacities, that provides the hallmark of sophisticated social reasoning in humans. Considerable empirical work remains to be done to further this theoretical distinction between social-perceptual and social-cognitive components of theory of mind. It is also likely that other componential distinctions need to be considered in a more complete model of theory of mind, dissecting additional underlying mechanisms and brain regions that serve the domain of social cognition. Nevertheless, we believe the model we have proposed here advances current perspectives on the neurocognitive architecture of theory of mind. Research is needed to rigorously test the developmental and neurobiological predictions that emerge from this model, and to provide refinements and extensions to the proposals we have offered, and we suggest that the study of neurodevelopmental disorders, including Williams syndrome and autism, are likely to make important and unique contributions to theoretical and empirical work in this newly emerging field of social cognitive neuroscience.

Acknowledgements

This research was supported by a grant from the National Institute of Child Health and Human Development (RO1 HD 33470). We express our sincere thanks to the New England Chapters of the Williams Syndrome and Prader–Willi Syndrome Associations, to the National Associations for their help in recruiting children, and to all the families who participated. We also gratefully acknowledge the comments from the reviewers of an earlier version of this paper, which helped to sharpen the focus of our arguments.

Appendix A. Explanation of action task

A.1. Desire stories

1. This is Mike. He is walking through the library. He sees a new Waldo book on the shelf. Mike walks over to the bookshelf. He reaches for the Waldo book. *Why does Mike reach for the Waldo book on the bookshelf?*
   Appropriate Response: 'Because he *wants* to read it.'
   Inappropriate Response: 'Mike is in the library.'
2. This is Christine. She is shopping with her mother. Christine sees a whole shelf of cookies. Christine calls to her mother. Christine points to the cookies. *Why does Christine point to the cookies?*
   Appropriate Response: 'She *wants* the cookies.'
   Inappropriate Response: 'She likes milk.'
3. This is Bill. He sees a really neat toy in the store. Bill goes home to write a letter. Bill is sitting at his desk. He is writing the letter to Santa Claus about the toy he saw. *Why is Bill writing a letter to Santa Claus about the toy he saw?*
   Appropriate Response: 'Because he *wants* the skates.'
   Inappropriate Response: 'Santa has a big sleigh.'

A.2. Emotion stories

1. This is Frank. He just got home from school. He sees a shoebox in the middle of the living room floor. Frank opens up the shoebox and sees a mouse. He jumps up in the air. *Why does Frank jump up in the air when he sees the mouse?*
   Appropriate Response: 'Because he's *afraid* of the mouse.'
   Inappropriate Response: 'Frank just got home from school.'
2. This is Sally. She is taking a walk in the park. She sees a dog sitting in the grass. The dog gets up and barks. Sally begins to run. *Why does Sally run when the dog gets up and barks?*
   Appropriate Response: 'Because she's scared of the dog.'
   Inappropriate Response: 'That's a big dog.'
3. This is George. He just got a new ball. He is playing with it outside. Some big kids come and take George's ball. George throws a rock at them. *Why does George throw a rock at the big kids when they take his ball?*
   Appropriate Response: 'Because he's *mad*.'
   Inappropriate Response: 'They took the ball.'

A.3. Cognition stories

1. This is Rachel. (Point.) Yesterday the class went to the zoo. Today the teacher is asking questions about the trip. The teacher asks, 'Which animal did we see first?' Rachel raises her hand to answer. *Why does Rachel raise her hand to answer?*
   Appropriate Response: 'Because she knows the answer.'
   Inappropriate Response: 'Because she saw the lion.'
2. This is Bobby. Bobby is in the backyard. Bobby is playing. Bobby is dressed up like a leopard. He is growling and crawling around. *Why is Bobby growling and crawling around?*
   Appropriate Response: 'He's pretending to be a cat.'
   Inappropriate Response: 'He has a hat on his head.'
3. This is Harry. Harry is going to school. He takes his lunch with him to school everyday. This morning Harry's mom made him a good lunch. But Harry went to school without it. *Why did Harry go to school without his lunch?*
   Appropriate Response: 'He didn't remember it.'
   Inappropriate Response: 'His backpack is yellow.'

A.4. Control stories

1. This is Louise. She is outside drawing a picture. She leaves the picture outside. Then it rains on her picture. Louise is inside drawing the same picture. *Why is Louise drawing the same picture after it rained on her old picture?*
   Appropriate Response: 'Because the picture got all wet.'
   Inappropriate Response: 'Because she's likes blue.'

2. This is Mr. Clark. He is in his car. He is driving home. A few minutes later, the car begins to smoke. Mr. Clark walks home the rest of the way. *Why does Mr. Clark walk home after the car begins to smoke?*
   Appropriate Response: 'Because the car is broken.'
   Inappropriate Response: 'Because the tires are black.'
3. This is Sam. He is making breakfast. He is pouring milk in his bowl of cereal. Suddenly, someone bumps Sam's arm. He has to pour the milk again. *Why does Sam have to pour the milk again after someone bumps his arm?*
   Appropriate Response: 'Because it spilled all over the table.'
   Inappropriate Response: 'Because he's going to school.'

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