Abstract

Social relationships are particularly important during adolescence. In recent years, histological and MRI studies have shown that the brain is subject to considerable structural development during adolescence. Brain regions that are implicated in social cognition, including parts of prefrontal, parietal and superior temporal cortex, undergo the most pronounced and prolonged change. However, the development of social cognition during adolescence and its neural underpinnings remains poorly understood. Here, we begin by outlining how the brain changes between childhood and adulthood. We then describe findings that have emerged from behavioural and neuroimaging studies of the recognition of facial expression during adolescence. Finally, we present new data that demonstrate development of emotional perspective taking during adolescence. In this study, 112 participants, aged 8–36 years, performed a computerised task that involved taking an emotional perspective either from the participant's own point of view or from that of another person. The results showed that average difference in reaction time (RT) to answer questions in the first person perspective (1PP) and third person perspective (3PP) significantly decreased with age. The RT difference of adults tended to cluster close to the zero line (3PP = 1PP), while a greater proportion of pre-adolescents had higher difference values in both the positive (3PP > 1PP) and negative direction (1PP > 3PP) of the scale. The data suggest that the efficiency, and possibly strategy, of perspective taking develop in parallel with brain maturation and psychosocial development during adolescence.

Keywords: perspective taking, brain development, adolescence, social cognition, prefrontal cortex, parietal cortex

INTRODUCTION

Adolescence is the transitional period between late childhood and the beginning of adulthood, and marks the beginning of the reproductive lifespan in humans. Adolescence involves sexual maturity in terms of hormones and physical development of the body, and is also characterised by an increase in the complexity of group interactions and thus social behaviour (Lerner and Steinberg, 2004). Adolescence is a period of development and consolidation of the social self, of one's identity and understanding of the self in relation to the social world (Coleman and Hendry, 1990). Anecdotal evidence and self-report data suggest that children seem to become progressively self-conscious and concerned with other people's opinions as they go through puberty and the period of adolescence (Steinberg, 2005). The psychosocial context of adolescents is markedly different to that of children and
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adults. Relationships with peers, family and society go through distinct changes during this time. Adolescents begin to assert more autonomous control over their decisions, emotions and actions, and start to disengage from parental control. At the same time, the school context involves an intense socialisation process during which adolescents become increasingly aware of the perspectives of classmates, teachers and other societal influences (Berzonsky and Adams, 2003).

Recent evidence has shown that the brain goes through a remodelling process during adolescence. It is possible that neural plasticity facilitates the development of social cognitive skills required during the period of adolescence. In the following section, we describe evidence for neural development during adolescence.

Go to:

DEVELOPMENT OF THE ADOLESCENT BRAIN

Recent structural MRI studies have demonstrated that the brain undergoes considerable development during adolescence. Both cross-sectional and longitudinal data demonstrate that changes in the frontal and parietal regions are especially pronounced and prolonged (Giedd et al., 1999; Sowell et al., 2003; Gogtay et al., 2004; Toga et al., 2006). Grey matter (GM) development in these areas is non-linear, in contrast to its linear development in the occipital lobes. The volume of GM in the frontal lobes increases during childhood with a peak occurring at around 12 years for males and 11 years for females, roughly coinciding with the age of puberty onset. This is followed by a decline in GM volume during adolescence (Giedd et al., 1999; Sowell et al., 2003; Gogtay et al., 2004; Toga et al., 2006). Similarly, parietal lobe GM volume increases during the pre-adolescent stage to a peak at around 12 years for males and 10 years for females, and is followed by a decline during adolescence (Giedd et al., 1999; Gogtay et al., 2004). While frontal and parietal cortex development is relatively rapid during adolescence, GM in the superior temporal cortex, including superior temporal sulcus (STS), reaches a peak at around 16 years and then follows a steady decline, not reaching maturity until relatively late (Toga et al., 2006). At the same time, there is an increase in prefrontal cortex (PFC) and parietal cortex white matter (WM) density from puberty onset, throughout adolescence and into adulthood (Giedd et al., 1996; 1999; Reiss et al., 1996; Sowell et al., 2001; Barnea-Goraly et al., 2005; for more detailed reviews of structural development in the brain, see Paus, 2005; Blakemore and Choudhury, 2006; Toga et al., 2006).

Earlier post-mortem investigations of human brain development revealed that two main cellular processes occur in the frontal cortex during adolescence:
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Synaptogenesis followed by synaptic pruning (Huttenlocher, 1979; Huttenlocher et al., 1983); and axonal myelination (Yakovlev and Lecours, 1967). Myelinated axons appear white in MR images, whereas non-myelinated matter appears grey. Thus, the increase in WM seen in certain brain areas in MRI images during childhood and adolescence is thought to reflect the increase in myelination in those areas. The decrease in GM during adolescence might simply be a consequence of the increase in WM (since there is no increase in total brain volume). However, the non-linearity of GM development suggests it does not simply reflect the consequences of increased WM. Instead, it has been suggested that the pattern of GM development reflects, at least in part, the synaptic reorganisation that takes place during that period (Paus, 2005). The combined effect of these maturational processes might be to fine-tune neural circuitry in the PFC and other cortical regions, and thus increase efficiency of the cognitive systems they subserve (see Blakemore and Choudhury, 2006 for review).

**DEVELOPMENT OF SOCIAL COGNITION**

**Emotion processing in adolescence**

The Social Information Processing Network (SIPN) model (Nelson et al., 2005) posits that social information processing occurs by way of three interacting neural ‘nodes’, which afford the detection of social stimuli that are then integrated to a larger emotional and cognitive framework (Nelson et al., 2005). Nelson and colleagues propose that the ‘detection node’, comprising the intraparietal sulcus, STS, fusiform face area as well as temporal and occipital regions, deciphers social properties of the stimulus such as biological motion. The ‘affective node,’ including limbic areas of the brain including the amygdala, ventral striatum, hypothalamus and OFC, processes the emotional significance of the social stimulus. Finally, the ‘cognitive-regulatory node’, consisting of much of the PFC, is responsible for theory of mind, impulse inhibition and goal-directed behaviour. Development during adolescence of the nodes, the connections between them, the innervation by gonadal steroid receptors and the maturation of the neural substrates themselves, are proposed to explain development of social cognitive behaviours.

**The imaginary audience**

The emergence of the social self seems to be marked by a period of heightened self-consciousness, during which adolescents are thought to become increasingly preoccupied with other people’s concerns about their actions, thoughts and
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appearance. This development has been described in terms of phases of egocentrism during childhood and adolescence (Elkind, 1967) and is based on Piaget's stages of cognitive growth (Inhelder and Piaget, 1958). It is proposed that after children develop internal representations of objects and referential thinking during early childhood, they reach the stage of the ‘emergence of concrete operations’. Between the ages of 7 and 11 years, children's abilities to deal with classes and hierarchies are proposed to be restricted to concrete, physical entities and do not extend to abstract thought. Children of this age group therefore manifest an inability to distinguish between a mental construction and perceptual phenomena. By age 11, the emergence of ‘formal operational thought’ enables children to differentiate between the perception of an object and their own mental construction of it, allowing them to objectify their own thoughts and reason about them. Piaget proposed that this new form of thinking allows children at early adolescence to conceptualise other people's thoughts and take their perspectives (Inhelder and Piaget, 1958).

The development of adolescent egocentrism is therefore thought to be a dialectic process: it is the ability to represent other people's thoughts as distinct from their own and therefore decentre themselves that also drives the new form of egocentrism. In other words, as soon as they are able to understand that other people have distinct thoughts and perspectives, they become preoccupied with the notion that other people's thoughts are focused on their own behaviour or appearance (Elkind, 1967). Elkind's original theoretical model of adolescent egocentrism delineates two ideation patterns thought to arise as a consequence, and to characterise common adolescent social behaviours: the 'imaginary audience' and the 'personal fable'. The notion of the imaginary audience refers to adolescents' beliefs that they are the object of other people's scrutiny. According to Elkind's theory, this belief results in increased self-consciousness, a tendency to anticipate the reactions of other people in relation to the self, and a feeling of being the focus of attention, regardless of whether a real audience exists or not in the situation. The personal fable, a related construct, denotes adolescents' convictions of their own personal uniqueness, giving rise to the sense of being 'special' (Elkind, 1967).

Since this original account of adolescent egocentrism, social psychological studies have investigated the imaginary audience with questionnaires and qualitative approaches. The exact age, validity and explanation (e.g. Lapsely and Murphey, 1985; Frankenberger, 2000; Vartinian and Powlishta, 2001; Bell and Bromnick, 2003) of Elkind's account of adolescent egocentrism have been challenged, and the theory has since evolved.
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**Perspective taking**

The ability to take another's perspective is crucial for successful social communication. Reasoning about others, and understanding what they think, feel or believe, involves stepping into their 'mental shoes' and taking their perspective (Gallese and Goldman, 1998). The distinction between the phenomenal and representational levels of self-other relationships is worth noting. As detailed by Frith and de Vignemont (2005) and Vogeley and colleagues (2004), one can take different perspectives in terms of spatial representations, such that the locations of other entities in space are represented by the beholder in different reference frames. In an egocentric frame of reference, the location of an object is represented in relation to the subject, i.e. in relation to the personal agent (e.g. is the line on your right or left?), whereas in the allocentric frame of reference, the location of one object in relation to another object is represented by the agent (e.g. is the line on the right or left of the square?). Thus, while the egocentric perspective relates that which is seen to the agent who sees it, the allocentric perspective is independent of the agent's position. At the phenomenal level, however, the first-person perspective (1PP) (e.g. is the line on your right or left?) and the third-person perspective (3PP) (e.g. is the line on his right or left?) are both centred on an agent. Perspective taking at this phenomenal level requires ‘the translocation of the egocentric viewpoint’ from the 1PP to the 3PP (Vogeley and Fink, 2003).

Perspective taking includes awareness of one's own subjective space or mental states ('first-person perspective' or 1PP) and the ability to ascribe locations, mental states or emotions to another person ('third-person perspective' or 3PP). Perspective taking is related to first-order theory of mind in that it involves surmising what another person is thinking or feeling (Harris, 1989). It requires the ability to distinguish the self from someone else and appreciate another's intentions or beliefs. The ability to adopt another's viewpoint may underpin the ability to read other minds and understand another's feelings (Humphrey, 1976). Thus, emotional perspective taking, considering how ‘she’ would feel rather than how ‘I’ would feel necessitates a shift in the egocentric perspective, from one's own to another person’s egocentric perspective.

**Development of perspective taking during adolescence**

A large body of research has focussed on the development of theory of mind during childhood (e.g. Wimmer and Perner, 1983; Perner et al., 1987; Gopnik and Astington, 1988) and its impairment in autism (e.g. Baron-Cohen et al., 1985). Since Piaget's studies using the three mountain problem (Piaget and Inhelder,
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1948, 1956), only a handful of social psychology studies have investigated perspective taking in early to middle childhood (e.g. Bosacki and Astington, 1999) and, to our knowledge, none has considered its development during adolescence. Studies have shown that theory of mind develops in infancy by the age of 5 years (Barresi and Moore, 1996; Leslie, 1994). So, what are the cognitive consequences of the continued development of its underlying neural circuitry? Clearly, the development of associated abilities will be subtle. Given that the social environment dramatically changes during adolescence, and that the brain undergoes a restructuring process, it might be expected that social cognitive abilities such as perspective taking develop during adolescence. We therefore investigated development of perspective taking during adolescence.

Subjects

We recruited 107 right-handed participants, comprising 30 pre-adolescent children (12 males, mean age 8.6 years, s.d. = 0.46), 40 adolescents (19 males, mean age 12.8 years, s.d. = 1.20) and 37 adults (19 males, mean age 24.0 years, s.d. = 4.05) (Choudhury et al., 2005). The study was approved by the local ethics committee. Written consent was obtained from each participant, and from his or her parent or guardian for subjects under 16.

Perspective taking task

The task involved answering questions that required the participant to imagine either how s/he would feel (for 1PP scenarios), or how a protagonist (for 3PP scenarios) would feel in various scenarios (Figure 1). The participant was asked to choose as quickly as possible one of two emotional faces in answer to each question (from a total of five possible emotional faces). Each participant’s non-directional reaction time difference between 3PP and 1PP (ΔRT) was calculated and analysed using a one-way ANOVA to test the effects of age and gender on ΔRT.

Discussion

The synaptic reorganisation in the frontal and parietal cortices during adolescence is likely to have implications for social cognitive processes that depend on these brain regions, such as mentalising, perspective taking and related processes. This conjecture is supported by the findings from our perspective taking study. If we assume that, among the age groups tested, adults are most experienced in social interaction and have mature frontal and parietal neural circuitry, then a low difference in ΔRT (3PP = 1PP) is likely to indicate the highest proficiency in
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perspective taking. In contrast, the most pronounced difference in RT between 1PP and 3PP, seen in the pre-adolescent group, would therefore indicate relatively inefficient processing. It might be speculated therefore, that prior to adolescence, the unsystematic direction of ΔRT reflects an immature cognitive mechanism for perspective taking.

We have described how neuroimaging and behavioural data demonstrate that executive functions, recognition of facial emotions and emotional perspective taking develop during adolescence, in terms of cognitive and neural strategies. This may be interpreted in terms of the SIPN model (Nelson et al., 2005). Executive function abilities such as risk assessment, decision making and impulse inhibition, and social cognitive abilities such as facial emotion recognition and perspective taking, are associated with components of the three nodes of the SIPN, including PFC, amygdala and STS. These social cognitive processes show development, while the neural substrates themselves show plasticity in terms of actual structure or changes in activity with age in the social cognitive tasks we have reviewed.

However, the SIPN is perhaps also limiting as it neglects the role of the parietal cortex. Parietal cortex (particularly IPL) undergoes a developmental trajectory similar to that of PFC and is associated with processes related to social cognition, such as perspective taking in the motor, conceptual and emotional domains (Ruby and Decety, 2001, 2003, 2004) and imitation of other people's actions (Decety et al., 2002; Jackson et al., 2006). Parietal development has already been linked to the improvement in abstract reasoning skills during adolescence (Luna et al., 2004b; Qin et al., 2004). Further investigations are required to determine how parietal development influences social cognitive development, and which regions are particularly involved.

New studies might consider what mechanisms are directing social cognitive development. The SIPN proposes a ‘multi-step’ route, in which neurally based nodes process social stimuli in a sequential manner. Somewhere in this route, however, between detecting that a stimulus is animate and imbuing it with emotional significance, the brain must assign it to the correct agent. In other words, in the framework of the SIPN, an additional ‘agency node’ linked to IPL might be involved in distinguishing whether the action is related to the self or to another before the limbic node would process approach or avoidance decisions and before the cognitive-regulatory node would perform higher level social processing. Indeed, as mentioned above, IPL seems to be involved in distinguishing between self and other, in terms of imagining how someone would think or feel (Ruby and
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Decety, 2003, 2004), making an action (Farrer and Frith, 2002) or imagining making an action (Ruby and Decety, 2001).

CONCLUSION

Changes in social behaviour are driven by both social and biological factors.

Perspective taking is a cognitive mechanism that underlies everyday social interaction. The significant decrease in the difference between RTs for 1PP and 3PP during adolescence found in the current study may reflect cognitive and behavioural features both experimentally (Steinberg, 2005) and anecdotally associated with adolescent development (Time Magazine, 7 June 2004). Our data suggest that, prior to adolescence, children are less efficient and have a less systematic style of processing the emotional perspectives of other people. Future neuroimaging studies are necessary to test our prediction that this reflects a developmental shift in the neural strategy required for perspective taking.

To what extent the developing brain interacts with socio-cultural influences in the environment of adolescents is a question for future research. Further studies are also needed to investigate the interaction between sexual maturity and social cognition. It is unknown, for example, how sex hormones influence the organisation of the brain's connectivity, and how this interacts with social cognition. Finally, as the recent study on IQ and cortical thickness (Shaw et al., 2006) highlights, the role of individual differences in cognitive skills must be taken into account.
Preguntas del examen

a) Global reading
   1. Skim the Abstract write, in no more than three sentences, what the study is about.

b) Detailed reading
   2. What gap do the authors mention in relation to the topic of this study?
   3. What is the purpose of this study?
   4. How did the authors characterize adolescence?
   5. What brain regions influence, according to the authors, the social development of the adolescents?
   6. Explain in detail the method and the theories that the authors expose.
   7. What are the limitations of this study and suggestions for future research?