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Research Report

Defining the cognitive phenotype of autism

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ABSTRACT

Although much progress has been made in determining the cognitive profile of strengths and weaknesses that characterise individuals with autism spectrum disorders (ASDs), there remain a number of outstanding questions. These include how universal strengths and deficits are; whether cognitive subgroups exist; and how cognition is associated with core autistic behaviours, as well as associated psychopathology. Several methodological factors have contributed to these limitations in our knowledge, including: small sample sizes, a focus on single domains of cognition, and an absence of comprehensive behavioural phenotypic information. To attempt to overcome some of these limitations, we assessed a wide range of cognitive domains in a large sample ($N=100$) of 14- to 16-year-old adolescents with ASDs who had been rigorously behaviourally characterised. In this review, we will use examples of some initial findings in the domains of perceptual processing, emotion processing and memory, both to outline different approaches we have taken to data analysis and to highlight the considerable challenges to better defining the cognitive phenotype(s) of ASDs. Enhanced knowledge of the cognitive phenotype may contribute to our understanding of the complex links between genes, brain and behaviour, as well as inform approaches to remediation.

Autism spectrum disorders (ASDs) are more common than was previously recognised, affecting approximately 1 in 100 children and adolescents (Baird et al., 2006; CDC, 2009). It is well established that ASDs are highly heritable. However, the genetic mechanisms are complex and include rare chromosomal anomalies, several individual genes of major effect, and numerous common variants of small effect (Abrahams and Geschwind, 2010). The term ASDs is now commonly used to describe a range of neurodevelopmental conditions that demonstrate considerable phenotypic heterogeneity, both in terms of presentation at any one age and across development ('the autisms'; Geschwind and Levitt, 2007), and which are likely to differ in underlying aetiology. However, they all share a primary impairment in social relatedness and reciprocity, alongside impairments in the use of language for communication and an 'insistence on sameness,' which is in keeping with Kanner's (1943) description of classically 'autistic' children. The presence of social and communication

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abnormalities, in combination with limited imagination and generativity, was characterised as the 'triad of impairments' by Wing and Gould (1979). The current classification systems include three domains of difficulties: reciprocal social interaction, abnormalities in communication, and patterns of non-functional restricted, repetitive and stereotyped behaviours (DSM-IV-TR; APA, 2000; ICD-10; WHO, 1993). However, the proposed revision for DSM-5 combines the social and communication impairments into one domain, with the restricted, repetitive patterns of behaviour, interests, and activities forming the second domain (http://www.dsm5.org). These difficulties were once considered a particular characteristic of rare individuals but are now more understood as a broad dimension of individual difference that is widely distributed in the general population (Constantino and Todd, 2003).

In addition to recognition of the heterogeneous aetiology and behavioural phenotype in ASDs, another challenge to perceiving autism as a unitary disorder has come from 'fractionation' of the autistic 'triad' of symptom domains, namely social impairments, communication impairments and rigid and repetitive behaviours (Happé et al., 2006). Ronald and colleagues' work on a large UK general population twin sample found that correlations between continuous measures of social, communication and repetitive behaviour were lower than expected. Further, whilst each aspect of the triad was highly heritable, the genetic influences on each of these domains of behaviour were largely non-overlapping (Ronald et al., 2005, 2006a,b). Happé and Ronald (2008) went on to review the evidence for 'fractionation' at the behavioural and cognitive level in diagnosed cases and found broadly supportive evidence.

1. Positioning the cognitive phenotype amongst genes, brains and behaviour

There is increasing evidence that multiple aetiologies may converge to disrupt the development and function of several brain systems that are implicated in the social and non-social behaviours that define ASDs (Happé and Ronald, 2008; Schroeder et al., 2010), including the frontal and temporal neocortex, the caudate, and the cerebellum (Abrahams and Geschwind, 2010). In addition, there is converging evidence from genetic studies and from brain imaging studies that decreases in functional connectivity between the frontal lobes and other brain systems may be characteristic of ASDs, leading to the suggestion that ASDs are 'developmental disconnection syndromes' (Frith., 2004; Geschwind and Levitt, 2007; Minshew and Williams, 2007). There is also intriguing evidence that there might be an abnormal brain growth trajectory in the first year of life in individuals with ASDs, which might account for the abnormal connectivity seen later (Carper and Courchesne, 2005). These perturbations precede the behavioural regression or setback that is seen in between one quarter and one third of cases. However, the processes underlying regression are unknown and no association has been found between head circumference trajectory and a history of regression (Webb et al., 2007).

Understanding the cognitive phenotype of ASDs may play a critical role in establishing the links between genes, brain development and behaviour, which will have far-reaching implications for science and practice. Increasing amounts are known from clinical and non-clinical populations about the brain systems that subserve particular cognitive functions. This means that when a cognitive profile is identified — with some cognitive abilities being impaired, others being spared/intact and still others being enhanced — this can act as a signpost pointing 'back' to the structure and function of the particular brain systems and circuits that are involved in these processes, and back further still to the genetic and epigenetic influences on these neural systems. In a different way the cognitive phenotype signposts 'forward' to behaviour on the assumption that cognition is one of the 'drivers' of behaviour. Sometimes cognition might be characterised not merely by intact/impaired/enhanced processing but by the recruitment of alternative or compensatory mechanisms to solve problems, which will become more pronounced as development proceeds.

Investigating the cognitive phenotype of ASDs may also provide insights into the 'autistic experience.' There has been a growing interest amongst cognitive psychologists in directly investigating how people with autism process (and therefore experience) the world around them. This interest has been enhanced by new technologies, such as eye tracking, which gave an insight in the 'world view' of individuals with autism outside of a set task or experiment (see the Yale 'Virginia Woolf Study' for one of the first, and perhaps most striking, examples; Klin et al., 2002). Another influence has been the experiential accounts of higher functioning individuals with ASDs, who have described their own unusual (and often aversive) sensory experiences and their self-developed strategies to minimise or manage these (Grandin, 2009; Williams, 1992). These experiences have not been easily accounted for by the dominant cognitive models that emerged in the 1980s. Put crudely, the 'theory of mind account' (Baron-Cohen et al., 1985) of ASDs was primarily motivated by consideration of which cognitive difficulties could explain social communication impairments, and the 'executive dysfunction account' (Ozonoff et al., 1991) was primarily motivated to explain lack of generativity, and repetitive and stereotyped behaviours. Partly in response to such personal accounts, and with the growing realisation that neither theory of mind nor executive dysfunction would provide a 'unitary account' of the autism behavioural phenotype, alternative cognitive theories emerged. These included Frith and Happé's weak central coherence account (Frith, 1989; Happé and Frith, 2006), Mottron's 'enhanced perceptual functioning' account (Mottron et al., 2006), Plaisted's (2001) theory of reduced generalisation and enhanced discrimination ability, and Baron-Cohen's notion of 'hyper-systemising' (Baron-Cohen et al., 2005). The weak central coherence account has specifically limited its explanatory scope to non-social assets and deficits seen in ASDs (Happé and Frith, 2006). Mottron's and Plaisted's accounts have been less clear in stating their explanatory scope, and the in/dependence of systemizing and empathizing is still somewhat uncertain (see Happé and Ronald, 2008), but in keeping with growing awareness of the heterogeneity of ASD, the zeitgeist has moved on from unitary accounts that attempt to account for all of the behavioural phenotype of ASDs to focus on explaining particular behavioural phenomena.