Big heads, small details and autism

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A B S T R A C T
Autism is thought to be associated with a bias towards detail-focussed processing. While the cognitive basis remains controversial, one strong hypothesis is that there are high processing costs associated with changing from local into global processing. A possible neural mechanism underlying this processing style is abnormal neural connectivity; specifically reduced structural or functional connectivity between brain regions might lead to good exemplar-based processing but poor generalisation. Abnormal neural connectivity has also been suggested to account for the increased incidence of macrocephaly in autism (increased head/brain size). The present study therefore investigated the effect of head size on the ability to switch between local and global processing in autism. 49 high-functioning 7–12 year olds with autism (12 with macrocephaly) were compared to 25 normally developing children in their performance on a Local-Global Switching task. Those children with autism who also had macrocephaly showed a greater processing cost when switching into global processing, or ‘zooming out’, than both the remaining children with autism and the control children. A second experiment revealed that macrocephaly in the context of normal development is not associated with difficulty switching into global processing but rather occurs in children who are physically large. Macrocephaly in the context of autism may therefore be a biological marker of abnormal neural connectivity, and of a local processing bias.

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1. Introduction

Individuals with autism are thought to be good at processing ‘local’ details of information rather than applying the context and extracting the ‘global’ meaning, an idea that has been strongly endorsed by the autism community (e.g. Gerland, 1997). This ability to perceive the elements rather than the whole was first attributed to a lack of drive for meaning, termed ‘weak central coherence’ (Frith, 1989) and more recently described as a local bias (Happé, 1999; Happé & Frith, 2006). There has, however, been little agreement on the mechanism that might support this processing style.

1.1. What is the cognitive mechanism behind a local bias?

When reviewing the evidence to date, the majority of studies employ designs in which both local and global processing are possible simultaneously and are in direct competition with each other. To pick a few notable examples, the Embedded Figures Task (first used in autism research by Shah & Frith, 1983) requires the participant to both ignore and inhibit Gestalt principles when viewing a picture that is designed to elicit global processing, and process the local elements instead. This is also the case in traditional Block Design tasks (first used in autism research by Shah & Frith, 1993), where the global Gestalt image must be rejected in order to segment the design into component elements. Hierarchical figure tasks performed under divided attention (first used in autism research by Mottron, Belleville, & Menard, 1999) similarly require participants to attend to both local and global aspects of the stimuli. A few studies of the local processing bias in autism have attempted to separate the local and global constraints of tasks. For example, the segmented version of the Block Design task (Shah & Frith, 1993) removes the global image and therefore requires the participant to simply match the local elements, and hierarchical figures performed under selective attention (first used in autism research by Ozonoff, Strayer, McMahon, & Filloux, 1994) direct a participant’s attention towards either local or global aspects of the stimuli. Interestingly, although local and global task components can be isolated, it seems that these paradigms are unable to capture the essence of a local processing bias; they indicate that global processing is intact rather than deficient and local processing is normal rather than enhanced in autism.

Instead, those tasks that appear to be most sensitive in detecting a local bias therefore either pit global and local processing against each other or require fast online responses that are capable of picking up this bias (see Happé & Frith, 2006 for a review of many recent studies). This body of research has led researchers with quite different theoretical ideas to agree that, when both local and global processing are simultaneously possible, local processing often takes precedence over global processing, resulting in a bias away from global and towards local stimuli (Happé & Frith,
than controls to correctly identify a global stimulus following a report of the second stimulus (Ward, 1982). This paradigm has been used to identify a local bias towards an alternative processing style in autism, the presence of both local and global stimuli simultaneously does not allow for an analysis of how this processing style arises and what the mechanism behind it might be. Furthermore, in addition to assessing processing capacity, the majority of tasks do not require fast online responses, allowing higher-order strategy use to also play a role in task performance; this confounds results and makes it extremely hard to interpret which factors contribute to both positive and negative findings. It is therefore still unknown how a bias away from global and towards local processing comes about, given that both global and local processing appear to be normal in autism when processing in only one of these domains is required.

More recently, a handful of studies have together begun to suggest a mechanism for this bias, in terms of difficulties broadening, but not narrowing, the spread of attention or an inability to shift out of local processing and into global processing (Mann & Walker, 2003; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001). Once individuals with autism are processing a small stimulus or element, they are slower and have more difficulty in zooming out and processing a large stimulus or element presented subsequently, but not vice versa. The suggestion being made is therefore that both local and global processing can be performed normally; however, a deficit in global processing may be seen when such processing is required immediately after local processing, thus requiring a fast switch from local to global. This deficit may also be present when a task involving local-global competition is open-ended, such as the Embedded Figures Task, as an individual with a local bias may remain stuck in local processing once they have shifted into this processing mode; the cost of switching into global processing will be high, making it easy to ignore global stimuli and possibly resulting in an enhancement in local processing ability relative to controls. While this shifting or switching deficit may at first be reminiscent of the executive function deficits commonly attributed to this disorder (see Hill, 2004 for a review), the crucial difference here is that the shifting deficit is proposed to be unidirectional: from local to global but not vice versa.

A particularly elegant novel paradigm, known as rapid serial object transformation (RSOT), has recently been introduced into the autism literature (López, Torres, & Valdés-Sosa, 2002; Valdés-Sosa, Torres, Iglesias, & López, submitted for publication). This task avoids some of the caveats of more traditional tasks: higher-order strategy use plays little role as fast online processing is necessary; and local and global processing are temporally separated which allows for a detailed analysis of the information the participant is processing and therefore a clearer interpretation of the results. The task uses hierarchical figures in a novel way so that they can be transformed to uncover either global or local meaningful components, rather than both simultaneously, presented as consecutive pairs of stimuli in an attentional blink paradigm. Stimuli can be presented under conditions that do not require attentional switching (e.g. a global stimulus followed by a global stimulus) or those that do (e.g. a local stimulus followed by a global stimulus). Participants often have trouble reporting a second stimulus that appears in quick succession (300–400 ms) after a first, as few attentional resources remain available to direct towards it, hence the attentional blink (Raymond, Shapiro, & Arnell, 1992). Moreover, if the participant is required to switch between two different modes of processing for the two stimuli, an additional attentional cost is required, lengthening the attentional blink and further reducing the probability of correctly reporting the second stimulus (Ward, 1982). This paradigm has been used to show that individuals with autism are less likely than controls to correctly identify a global stimulus following a local stimulus but not vice versa (López, Torres, & Valdés-Sosa, 2002; Valdés-Sosa et al., submitted for publication), indicating that switching from local into global processing has a higher processing cost for individuals with autism than typical observers.

1.2. Heterogeneity in the local bias

The literature regarding a local bias in autism is by no means unanimous in its support; however, negative findings have been reported alongside the positive ones (e.g. Brian & Bryson, 1996; Edgin & Pennington, 2005; Hoy, Hatton, & Hare, 2004; Kaland, Mortensen, & Smith, 2007; Ropar & Mitchell, 1999; Schlooz et al., 2006). Furthermore, one study found impaired rather than the expected enhanced performance on three visuospatial tasks (Burnette et al., 2005). While some of these findings appear to result from methodological issues, such as group matching, task design and instructions, one explanation for such mixed results is the idea of heterogeneity of this processing bias in the autistic population; perhaps one subset of individuals with autism may exhibit a local bias more than other subsets and the proportion of these individuals may vary in different studies. It is also possible that a local bias may not be a single construct but have a number of different processes contributing to it (e.g. a global deficit independent of a local enhancement), and that only subsets of individuals with autism display an abnormality in any one aspect of it (Booth, Charlton, Hughes, & Happe, 2003; López, Leekam, & Arts, 2008). While heterogeneity has rarely been studied, two recent experiments have reported the presence of an abnormally local bias in almost all children with autism tested (Jarrold, Gilchrist, & Bender, 2005; Pellicano, Maybery, Durkin, & Maley, 2006), while others have found only a small proportion of individuals with autism to show this processing style (Edgin & Pennington, 2005; Jarrold & Russell, 1997; van Lang, Bouma, Sytema, Kraijer, & Minderaa, 2006). From these latter studies, the studies which fail to find group differences and many other studies finding group differences, it is possible to infer from the group means and standard deviations that the range of performances seen in autism and control groups tend to overlap greatly, indicating that heterogeneity in local/global processing may well occur in autism.

1.3. What is the neural mechanism behind a local bias?

How is the subgroup of individuals with autism to be identified that may be particularly liable to show a local processing bias? At the biological level, it has been suggested that a local bias may result from abnormal neuronal connectivity, due to either structural or functional differences. These might involve a lack of synchronisation in activation between relevant brain areas (Brock, Brown, Boucher and Rippon, 2002) or reduced long-range and increased short-range physical connectivity (Just, Cherkassky, Keller and Minshew, 2004), both resulting in a lack of binding of parts into wholes; or numerous and inefficient feedback connections resulting in a lack of top-down modulation of early sensory processing and a lack of integration of sensory processing with cognitive monitoring (Frith, 2003). These ideas are supported by a growing number of functional imaging studies showing reduced connectivity and a lack of top-down modulation particularly between frontal cortex and other brain regions (e.g. Bird, Catmur, Silani, Frith and Frith, 2006; Horwitz, Rumsey, Grady and Rapoport, 1988; Just, Cherkassky, Keller, Kana and Minshew, 2007; Koshino et al., 2008). All of these ideas predict that the abnormal connectivity would give rise to a preserved or enhanced ability for exemplar-based information processing, in addition to a reduced ability to generalise across examples or processing information in context, reminiscent of a locally biased style of processing. While these accounts were intended to explain autism as a whole, it is possible that, like a local bias, there is heterogeneity in connectivity and that this may relate to
differences in the degree of local bias shown by different individuals with autism.

One of the more consistent neurobiological findings in autism, which was also noticed by Kanner (1943), is of increased head and brain size. This is seen to different degrees in different individuals and the distribution of head size in the autism population appears to be normal but broader than in the typically developing population, with a higher mean (Lainhart et al., 2006). Approximately 20% of the autistic population are thought to have macrocephaly, when defined as having a head circumference greater than the 97th percentile of the normal population (Bailey et al., 1993; Fombonne, Roge, Claverie, Court, & Fremolle, 1999; Lainhart, 2003; Stevenson, Schroer, Skinner, Fender and Simensen, 1997) and two postmortem studies of increased brain weight have supported this finding (Bailey et al., 1993; Bauman & Kemper, 1985). This enlargement appears to be general across the whole of the cerebral cortex (Hazlett et al., 2005) and be heritable, being present in the parents and siblings of individuals with autism (Lainhart et al., 2006; Miles, Hadden, Takahashi, & Hillman, 2000). Very recently, a possible genetic mutation in the PTEN gene has been suggested as the cause in some cases of macrocephaly in autism (Butler et al., 2005; Buxbaum et al., 2007).

However, macrocephaly cannot normally be detected until approximately 2 years of age (Courchesne et al., 2001; Lainhart et al., 1997; Stevenson, Schroer, Skinner, Fender & Simensen, 1997) although brain imaging studies indicate that the increased rate of head growth starts around 12 months of age (Courchesne, Carper, & Akshoomoff, 2003; Hazlett et al., 2005). There is evidence that feed forward connections are established very early in normal development whereas feedback connections are continually refined through neuronal elimination processes of pruning and apoptosis (Price et al., 2006), in order to eliminate faulty feedback connections and optimise co-ordinated neural functioning. It is plausible that there may be a decrease in these elimination processes in autism, leading to an excess number of synapses and coinciding with the increased rate of head growth from about 12 months of age (Frith, 2003). This suggestion is therefore consistent with the abnormal neuronal connectivity hypotheses mentioned above and therefore also with a local processing bias; this connection between abnormal connectivity and macrocephaly is however speculative. In support of this hypothesis, a computational model of autism has been constructed in which a lack of generalisation results from an increase in units (Cohen, 1994; Gustafsson, 1997).

Macrocephaly in autism has been linked to a number of behavioural features with mixed results, including increased social impairment and language delay (Lainhart et al., 2006) but also to reduced social impairment and improved adaptive functioning (Dementieva et al., 2005; Lainhart et al., 1997). At present, only one study has attempted to relate brain size with cognitive function however; Deutsch and Joseph (2003) examined the IQ profiles of individuals with autism and found that relatively high performance IQ compared to verbal IQ was associated with larger head sizes.

1.4. Relating cognition and neural mechanisms

It is possible therefore that increased head size is related to the local bias seen in autism. Given that macrocephaly is not universal in autism, some individuals may display more of a local bias than others, which might help to account for the variable results seen in the literature on cognitive style in autism. As macrocephaly is so clear an index by which to identify individual cases, one approach is to focus entirely on such individuals and establish whether there is any possible connection with a difficulty broadening attention or ‘zooming out’. To this end, the effect of head size on the ability to shift from local into global processing was examined.

2. Experiment 1

2.1. Method

Ethical approval for the study was received from the UCL Research Ethics Committee and consent was obtained from the parents of all participants prior to inclusion in the study. 49 children with autism spectrum disorder (ASD) and 25 normally developing children took part in the study, aged 7–12 years (see Table 1). The children with ASD had all received independent diagnoses from a qualified clinician and met criteria for an ASD on the Developmental, Dimensional and Diagnostic Interview (3Di:Skuse et al., 2004) at the time of this study, while none of the control children did ($F(2,68)>45.17$, $p<.001$). The 3Di measure is similar to the Autism Diagnostic Interview (ADI-R; Lord, Rutter, & Le Couteur, 1994) with which it correlates highly ($r$ for each area of the triad ranges from .53 to .64; Skuse et al., 2004). The majority of children with ASD also attended mainstream schools and had IQs within the normal range so can be considered high-functioning. This age and ability group was chosen in order to maximise the likelihood of detecting macrocephaly and of the child being able to complete the task. Each child’s head circumference was measured with a flexible tape measure and converted into z-scores adjusted for age and
The previously mentioned task, designed by Valdés-Sosa et al. (submitted for publication) and referred to here as the Local-Global (LG) Switching task, was employed to assess local processing bias. The experiment was run on a laptop computer using E-prime software (Psychology Software Tools, Inc.) and the child sat approximately 40 cm from the screen. The stimuli were five letters (E, H, P, S, U) presented either as a single large ‘global’ letter or many small ‘local’ letters. Each global stimulus was composed of many meaningless small elements (a rectangle divided in two by a horizontal line) arranged in a 3 × 5 grid (approximately 20° × 3° visual angle), for example five rows of small meaningless elements (a 3 × 5 grid) presented before, between and after the letters (see Fig. 1; a short animation of a trial can also be found at http://www.icn.ucl.ac.uk/dev/group/LGSwitch.htm). Global stimuli had a shorter duration (50 ms) than local stimuli (200 ms) in order to produce similar levels of accuracy (80%) across these two stimulus types (data from control adults; Valdés-Sosa et al., submitted for publication). The interstimulus interval, during which a blank was presented, therefore also varied for the different stimulus types (350 ms after global and 200 ms after local) in order to keep the stimulus onset asynchrony consistent (400 ms). The blanks presented at the beginning and end of each trial were displayed for 300 ms each.

The children were first introduced to the global and local stimuli that they would see during the task and then completed four blocked conditions in the following order; global-global (GG), local-local (LL), global-local (GL) then local-global (LG). Each block consisted of 5 slow practice trials followed by 25 randomly ordered test trials with corrective feedback after each; these 25 trials presented each possible combination of the 5 letters once each. The child was asked to identify both letters in each trial and select the first letters than the controls, group differences were not significant after accounting for the effects of age and IQ (F(2,67) = 1.32; p < .001).

All three groups were matched for age (F(2,71) = .92), height (F(2,45) = 2.09) and verbal IQ (WISC-III: Wechsler, 1992; F(2,71) = 2.19). However, there was a trend for both ASD groups to have slightly lower verbal IQs and the groups were not matched for performance IQ (F(2,73) = 3.94, p = .024), again with both ASD groups scoring lower. The ASD groups were well matched to each other for IQ though (vIQ t(47) = .42; pIQ t(47) = .58), enabling valid comparisons between these groups; as the control group was not so closely matched and there was a wide range of ages and IQs within the groups, both age and IQ were entered into all analyses as covariates. The critical comparison however was between the two well-matched ASD groups; the control group was interesting in as much as performance by these children was similar to those in the ASD group without macrocephaly. As an attentional blink could only be assumed to have taken place on those trials in which a child responded correctly to the first letter, only these trials were suitable for analysis; different numbers of trials were therefore entered into the analysis for different children. To ensure that any further analyses involved the same mean number of trials in each group, the number of correct responses to the first letter were therefore also analysed. While there was a slight trend for the children with ASD to respond correctly to fewer first letters than the controls, group differences were not significant after accounting for the effects of age and IQ (F(2,67) = 1.32; see Table 2).
No significant differences were found between the groups on any of the four main conditions for the proportion of correct responses to the second letter (GG, LL, GL or LG; \(F(2,68) < 1.7\); see Table 2). In order to calculate each individual’s ability to switch into a level of processing (local or global), the difference between the relevant non-switching and switching condition was calculated; for switching into global, each participant’s score was calculated as GG-LG, while for switching into local, LL-GL was used. This gave a measure for each child of the cost of switching into a level in comparison to that child’s own ability of processing within that same level, providing a baseline to control for individual variation in performance.

A 2 × 3 repeated measures ANCOVA comparing all three groups revealed no main effect of either condition (\(F(1,68) = 1.06\)) or group (\(F(2,68) = 1.48\)) but a significant interaction between the two (\(F(2,68) = 3.05, p = .027\); one-tailed test was used given the direction of this interaction was predicted). Post hoc tests indicated that this interaction was present between the two ASD groups (\(F(1,44) = 5.19, p = .014\); one tailed), and the same pattern was also seen between the macrocephalic ASD group and the control group (\(F(1,32) = 3.05, p = .045\); one tailed). Conversely, no sign of an interaction was present between the control group and the ASD children without macrocephaly (\(F(1,57) = .13\)). For the two ASD groups, this interaction arose from a difference between the groups in the cost of switching into global processing (\(F(1,44) = 8.93, p = .003\); one tailed), with the macrocephalic group having a greater switching cost. For the controls & macrocephalic ASD children, none of the post hoc tests within or between groups were significant due to a complete crossover. This pattern of results is shown in Fig. 2.1

Additionally, within the ASD group only, head size was correlated to the cost of switching into global processing (\(r = .36, p = .007\); one tailed); children with larger heads had a greater cost of switching into global processing than children with smaller heads. However, head size was unrelated to the cost of switching into global processing in the control group (\(r = -.22\)). Furthermore, it was unrelated to the cost of switching into local processing in either group (ASD \(r = .02\); control \(r = -.06\).2

2.3. Discussion

The relationship between head size and local bias in autism was investigated in a selected subgroup of individuals with ASD: those with macrocephaly. As predicted, the results from the interaction between head size and the LG Switching task confirm the hypothesis that a bias towards local processing may be characteristic of individuals with ASD and atypically large heads. The correlation between head circumference and the cost of switching into global processing also supports the idea that the same process may underlie these two measures and be present to different extents in different individuals. This raises the possibility that the increased head size, and therefore presumably brain size, seen in a proportion of individuals with ASD is a biological marker for a locally oriented processing style. This was predicted from the idea that macrocephaly may result from abnormal neuronal connectivity early in development and lead to good exemplar-based processing but poor generalisation and integration of information (Brock et al., 2002; Frith, 2003; Just et al., 2004).

The different conditions in the LG Switching task allow us to examine where the difference in this processing style may lie. Individuals with macrocephaly appear to have difficulties switching into a global level of processing or zooming out; they show a greater cost and presumably have to use greater resources to overcome this attentional barrier. There was no evidence however that individuals with macrocephaly had an enhanced ability to process local stimuli or had difficulty processing global stimuli per se; this is consistent with findings of normal global and local processing in autism under selective attention conditions (Plaisted, Swettenham, & Rees, 1999). Rather they had difficulty when having to switch out of local processing and into global processing, a finding which supports previous studies (Mann & Walker, 2003; Rinehart et al., 2001; Valdés-Sosa et al., submitted for publication). Indeed, in all three of these studies the group differences arise from a difficulty switching into global processing or zooming out, but not from an enhanced ability to switch into local processing or zooming in, supporting the original conceptualisation of the local processing bias as

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Table 2
Means (and standard deviations) for LG Switching task, experiment 1. Values given are raw data, not accounting for age and IQ.

<table>
<thead>
<tr>
<th></th>
<th>Control group (25)</th>
<th>ASD without macrocephaly group (37)</th>
<th>Macrocephalic ASD group (12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of correct responses to first letter (25 max)</td>
<td>GG 16 (5)</td>
<td>13 (5)</td>
<td>11 (4)</td>
</tr>
<tr>
<td></td>
<td>LL 20 (5)</td>
<td>18 (7)</td>
<td>16 (5)</td>
</tr>
<tr>
<td></td>
<td>GL 16 (5)</td>
<td>14 (6)</td>
<td>12 (5)</td>
</tr>
<tr>
<td></td>
<td>LG 18 (6)</td>
<td>17 (6)</td>
<td>15 (5)</td>
</tr>
<tr>
<td>Proportion of correct responses to second letter (given first letter was correct)</td>
<td>GG .64 (.29)</td>
<td>.70 (.23)</td>
<td>.64 (.17)</td>
</tr>
<tr>
<td></td>
<td>LL .79 (.24)</td>
<td>.83 (.18)</td>
<td>.70 (.25)</td>
</tr>
<tr>
<td></td>
<td>GL .55 (.24)</td>
<td>.52 (.17)</td>
<td>.52 (.19)</td>
</tr>
<tr>
<td></td>
<td>LG .56 (.28)</td>
<td>.55 (.30)</td>
<td>.39 (.19)</td>
</tr>
</tbody>
</table>

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1 This analysis was repeated with a reduced sample of the non-macrocephalic ASD group (n = 22) with head circumference z-scores of one or less; the interaction between the three groups was still significant (\(F(2,53) = 2.98, p = .030\); one tailed). This excludes any individuals who may have been on the borderline of macrocephaly.

2 This task was part of a larger battery of tasks including tests of executive function and theory of mind ability. While no specific predictions were made regarding a relationship between these tests and macrocephaly, group differences and correlations were analysed. Head circumference was found to be unrelated to either of these two cognitive domains.

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Fig. 2. Interaction between the cost of switching into global versus local processing in the macrocephalic ASD group versus the ASD group without macrocephaly and the controls. Error bars represent standard error of the mean. Cost of switching in the global condition is calculated as the difference between staying in global and switching into global processing mode (GG-LG) and the cost of switching in the local condition is calculated in a similar manner. Low scores therefore indicate efficient switching.
originating from some form of global deficit (weak central coherence; Frith, 1989). This could still result in a preference for local over global processing and therefore in a local enhancement in behaviour, through an inability to zoom out or switch into global processing, thus remaining in local processing. Furthermore, this would also be compatible with the idea of impaired top-down modulation of incoming information in autism (e.g. Bird et al., 2006; Horwitz et al., 1988; Just et al., 2007; Koshino et al., 2008), with top-down modulation being possible but costly and therefore not the default. The important difference to theories of local bias being suggested here, however, is that this processing style may be particularly characteristic of those individuals with ASD who also show macrocephaly. Just as there is heterogeneity in macrocephaly, there appears to also be related heterogeneity in the local bias seen in ASD.

These results also have implications for the executive function theory of autism (see Hill, 2004 for a recent review). This theory would have predicted impaired performance across both switching conditions, but the present results find little support for this idea. Those individuals with macrocephaly had difficulties specifically with switching in a particular direction, from local into global processing, but not vice versa. Furthermore, those individuals with ASD but normal head size were performing similarly to controls across all conditions, if anything performing slightly more efficiently on the switching conditions (see Fig. 2). This would indicate that any problems seen in the ASD population with switching set (e.g. Ozonoff et al., 2004) are likely to occur at a more conscious, strategic level, while the present task was assessing an individual’s intrinsic, automatic capacity to switch quickly between levels of processing. It is possible that the impairments seen on executive tasks may be more to do with prompting oneself to switch levels or choosing when to do so, while possessing an intact ability to perform the switch when prompted externally as in the current task.

One question that remains is whether a local bias is a feature of macrocephaly rather than autism and is therefore found in all individuals with macrocephaly regardless of whether they also have an autism diagnosis or not. Obviously, as the rate of macrocephaly is increased in ASD, this would still lead to higher rates of a locally biased processing style in ASD. In order to investigate this possibility, experiment 1 was repeated but this time in two groups of normally developing children: those with and without macrocephaly.

### 3. Experiment 2

#### 3.1. Method

In order to locate a group of normally developing children with macrocephaly, approximately 300 children aged 7–11 years were recruited through local primary schools. The parents of 12 children with macrocephaly agreed for them to take part and 13 further children without macrocephaly were also selected to be matched on age. The parents of 12 children were recruited through local primary schools. The parents of 12 children with macrocephaly were also selected to be matched on age, while possessing an intact ability to perform the LG Switching task and had their height measured.

#### 3.2. Results

A 2 × 2 repeated measures ANOVA revealed a main effect of condition in the LG Switching task (F(1,23) = 5.97, p = .023), with the global condition requiring a lower switching cost. A trend towards a main effect of group was also found (F(1,23) = 3.57, p = .072), with the children with macrocephaly performing slightly better across both conditions than the children without macrocephaly, although this effect was not significant for either condition individually (t(23) = .19 and .94). Importantly, no interaction between the two was revealed (F(1,23) = .26). Group means were also noted to be similar to both the typically developing group and the ASD group without macrocephaly in the first experiment. However, a difference was found between the two groups in height, with the children with macrocephaly being taller than the children without macrocephaly (t(23) = 2.17, p = .041; see Table 3).

#### 3.3. Discussion

Macrocephaly appears to arise for different reasons in autism and in normal development. The results in this second experiment indicate that in normal development, macrocephaly does not result in a locally oriented information processing style, as a relative advantage in the local or disadvantage in the global switching condition was not observed. Furthermore, the difference in height between the groups indicates that macrocephaly may occur as part of normal development in children who are physically bigger in overall size. This cannot be said to be the case in autism however; the children with ASD and macrocephaly in the first experiment were matched to the other two groups on the basis of height. Macrocephaly in the presence of ASD therefore appears to be a sign of abnormal neurodevelopment, resulting in a local bias. It would be of interest for future studies to address this relationship in other clinical populations.

### 4. General conclusion

In a population of high-functioning children with ASD, a subgroup with macrocephaly was selected and used to test the hypothesis that large heads are associated with a local bias, possibly due to abnormal neural connectivity. This was confirmed through the use of the LG Switching task. Those children with ASD and macrocephaly showed a bias towards local processing on the LG Switching task, portrayed as a greater processing cost when switching from local into global processing. Furthermore, this finding was restricted to ASD; macrocephaly in normal development, where abnormal neural connectivity is ruled out, did not result in a local bias. If these results prove to be robust and replicable with more direct measures of brain size, this would imply that a local bias is restricted to a subgroup of individuals with ASD and should not be considered universal to ASD. The tentative hypothesis can therefore be proposed that head size may be a biological marker of abnormal neural connectivity, resulting in a locally oriented processing style, and may provide a useful endophenotype for investigating the genetic basis of a subgroup of individuals with ASD.
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