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Block Design performance in the Williams syndrome phenotype: A problem with mental
imagery?

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Abstract

Williams syndrome (WS) is a rare genetic disorder which, among other characteristics, has a distinctive cognitive profile. Non-verbal abilities are generally poor in relation to verbal abilities, but also show varying levels of ability in relation to each other. Performance on block construction tasks represents arguably the weakest non-verbal ability in WS. In this study we examined two requirements of block construction tasks in 21 individuals with WS and 21 typically developing (TD) control individuals. The Squares task, a novel two-dimensional block construction task, manipulated patterns by segmentation and perceptual cohesiveness to investigate the first factor, processing preference (local or global), and by obliqueness to examine the second factor, the ability to use mental imagery. These two factors were investigated directly by the Children's Embedded Figures Test (CEFT; Witkin, Oltman, Raskin & Karp, 1971) and a mental rotation task respectively. Results showed that individuals with WS did not differ from the TD group in their processing style. However, the ability to use mental imagery was significantly poorer in the WS group than the TD group. This suggests that weak performance on the block construction tasks in WS may relate to an inability to use mental imagery.

Block Design performance in the Williams syndrome phenotype: A problem with mental imagery?

Introduction

Williams syndrome (WS) is a genetic disorder which is associated with a unique collection of biological, behavioural and cognitive characteristics (see Mervis, 1999). The discrepancy between the verbal and non-verbal abilities of individuals with WS is well documented and is seen as a strong cognitive marker of the condition (Mervis, 1999; Howlin, Davies, & Udwin, 1998). Non-verbal abilities are generally weak, however variation in the level of ability achieved on different types of non-verbal tasks also occurs within this domain (Farran & Jarrold, 1999). A particularly weak ability is shown by performance on block construction tasks, such as the Block Design task of the Wechsler scales (WAIS, WISC: Wechsler, 1981; 1992) or the Pattern Construction task of the Differential Ability Scales (DAS; Elliot, 1991) (e.g. Arnold, Yule, & Martin, 1985; Bellugi, Sabo, & Vaid, 1988; Udwin, Yule, & Martin, 1987). In this task, the participant is given a set of blocks, and shown a 2 dimensional pattern. The individual is asked to put the blocks together so that the upper faces resemble the pattern. Performance is universally poor in WS, indeed Mervis (1999) suggests that a Pattern Construction score below the 20th percentile is a cognitive characteristic of WS.

Previous studies have suggested that the poor performance on block construction tasks in WS is related to individuals' processing preferences (e.g. Bellugi et al., 1988; Bellugi, Wang, & Jernigan, 1994; Mervis, Morris, Bertrand, & Robinson, 1999). There are two levels at which information can be processed. At the local level, the individual focuses on the individual elements in the visual array, whereas global processing involves attending to the whole pattern of elements in the array. In typical development, individuals are able to focus on both local and

global levels, but have a tendency to attend more to the global aspect of a display (Navon, 1977). Bellugi and colleagues (Bellugi et al., 1988; 1994) suggest that individuals with WS process information predominantly by attending to the parts of an image, and that this local processing bias can explain the poor ability demonstrated by individuals with WS on the Block Design task. This conclusion was reached through the observation that individuals with WS have problems maintaining the overall global configuration of the blocks, and has been offered as an explanation for weak performance on a number of tasks. Rossen, Klima, Bellugi, Bihrlle, and Jones (1996), for example, employed a drawing version of the Navon task (Navon, 1977) to examine processing preferences. Individuals with WS were asked to copy a figure presented as a number of small letters that formed another, larger letter e.g., a number of letter 'L's organised to form the shape of a letter 'D'. The group attended to the local level at the expense of the global level; the smaller letters were drawn correctly, but were not arranged correctly to resemble the larger letter. Bertrand, Mervis, and Eisenberg (1997) and Bellugi, Bihrlle, Neville, Doherty, and Jernigan (1992) studied the drawings of individuals with WS, again finding a lack of global awareness and attention to the details of the drawings. These examples, however, involve drawing, which appears to be generally delayed in WS (Bertrand & Mervis, 1996), rather than the manipulative and visuo-spatial constructional requirements of block construction tasks.

Contrary to the studies reviewed above, Mervis et al. (1999) and Pani, Mervis, and Robertson (1999) report evidence against a local processing preference of individuals with WS in a visual search task. Individuals with WS were affected by both local and global manipulations of the visual array. Mervis et al. (1999) also tested perceptual processing in WS using a block construction task, by segmenting the blocks of the image slightly. In typical development, segmentation reduces response time as it increases the salience of the local elements (Shah &

Frith, 1993). In contrast, individuals with autism, who are considered to have a local processing bias, already see the pattern as a collection of parts and so segmentation has less of a facilitatory effect in this group (Shah & Frith, 1993). Similarly, a local processing bias is an advantage on the Children's embedded figures test (CEFT; Witkin, Oltman, Raskin, & Karp, 1971). This task assesses a participant's ability to locate a local element (a triangle) that is embedded in a global image. (see Shah & Frith, 1983). Individuals have to inhibit their predominantly global method of processing in order to locate the triangle. Individuals with autism find this task relatively easy (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). If individuals with WS also have a local processing bias, this group should have less difficulty on the CEFT, and performance should be less affected by segmentation in segmented block construction tasks, than in typical development. Mervis et al. (1999) demonstrated that segmentation of the blocks did improve performance in WS, which implies that these individuals are not solely driven to process locally as has been suggested. However, Mervis et al. (1999) did not employ a control group, thus the relative influence of local and global processing in WS cannot be ascertained. The facilitation effect could be weaker than that found in typical development, which would indicate that local elements are more influential in perceptual processing in WS

The present study was designed to explore the causes of poor block construction in WS by manipulating the task requirements of standard block construction tasks. The magnitude of the difference in performance between segmented and nonsegmented conditions was examined by directly comparing the performance of individuals with WS to that of typically developing control individuals. A second factor was also investigated which relates to a difference in the task requirements between two block construction tasks: the Block Design task, which features in the Wechsler Intelligence Scale for Children (WISC) and the Wechsler Adult Intelligence Scale

(WAIS), and the Pattern Construction task, which is a subtest of the DAS. The WISC and WAIS blocks have faces of one complete colour, and faces where the two colours are divided obliquely by a diagonal line into two triangles. In addition to these face types, the DAS blocks also have faces where the two colours are divided into two rectangles by a perpendicular, non-oblique line through the centre of the square. In typical development, non-oblique lines are easier to discriminate among than oblique lines (Cecala & Garner, 1986), which could relate to the requirements of block construction tasks. In order to successfully construct the block patterns, each block face must be oriented correctly. This can be accomplished in two ways; by manipulating the blocks manually until the correct orientation is reached (manual manipulation); or by employing a dynamic form of mental imagery, which enables the individual to form a mental image of the block face which they can move into each possible orientation (mental manipulation). Constructing the block patterns by mental manipulation would intuitively be more time-efficient. However, manipulation of the blocks by mental imagery is also more difficult to employ than the more concrete, manual method of manipulation. It is possible that the higher discriminability of the nonoblique in comparison to the oblique faces in block construction tasks could affect how the patterns are constructed. It might be easier to form a mental image of the different orientations of the nonoblique faces, than the oblique faces. Difficulty in using mental imagery may lead the individual to rely on hand movements alone to reach the correct orientations of each block. Given these considerations, in this experiment, in addition to investigating the effect of segmentation of the block patterns, the effect of constructing patterns consisting of nonoblique or oblique lines was compared.

The present study employed three tasks: the Squares Task (a construction task adapted from the Block Design subtest of the WISC), the Children's Embedded Figures Test (CEFT), and a

rotation task. Two factors were assessed through the Squares task. First, the target patterns were constructed from squares with either oblique or nonoblique faces, in order to investigate whether differences in discriminability affected the ease at which stimuli could be manipulated mentally. Second, local-global processing style was assessed through the Squares Task in two ways; by the configuration of the individual squares, segmented or nonsegmented, and by the perceptual cohesiveness of the actual pattern that the squares made. The segmentation manipulation was similar to that of the segmented block construction tasks above (Shah & Frith, 1993; Mervis et al., 1999). Perceptual cohesiveness represents the extent to which the pattern resembled a whole image. These two manipulations of processing style thus addressed the local-global properties of both the image as a construction of four smaller elements and of the patterns themselves. The rotation task had two conditions: mental rotation and manual rotation. The mental rotation task assessed an individual's dynamic mental imagery abilities (i.e. whether they are able to create and also manipulate an image mentally) and the manual rotation task acted as a control condition to assess whether the task could be completed once the mental imagery component had been removed, i.e., whether the stimuli can be reoriented successfully by hand movements. As noted above, the CEFT measures the ability to disembed a local element from a global image (Shah & Frith, 1983; Happé, 1999). The rotation tasks and the CEFT were employed as specific measures of mental manipulation ability and local-global processing style, the two factors manipulated by the Squares task. These two tasks were included in order to provide potentially confirmatory evidence that the use of mental imagery and an individual's processing preference (local or global) are factors which effect performance on the Squares tasks, and thus also served as a verification of the validity of the Squares task.

The Ravens Coloured Progressive Matrices (RCPM; Raven , 1993) was chosen as a measure of non-verbal mental age (NVMA), to match the WS group to a typically developing (TD) control group. In this task, the individual is shown a pattern, or pattern sequence with a section missing. The participant is shown 6 pattern pieces and asked to indicate which of these alternatives would accurately complete the pattern or pattern sequence. Previously unpublished data showed that performance on the RCPM in WS is highly correlated with Block Design performance (Farran & Jarrold, 1999), which suggests that these tasks share some of the same cognitive demands. However, level of ability on the two tasks differs significantly in WS. Weak Block Design performance contrasts to relatively strong RCPM performance (Farran & Jarrold, 1999), thus the Block Design task must require additional cognitive skills, not required by the RCPM, which themselves weaken the level of ability achieved on this task by the WS population. This is consistent with previous studies, which have also found significantly poorer performance on the Block Design task than on the RCPM (e.g. Bellugi et al., 1988; 1994; Grant et al., 1997). Two such factors that the RCPM does not share with block construction tasks are the strong local-global component, and the rotational requirements being manipulated in the Squares task in this study. Through matching by the RCPM, one can be sure that the control group have the appropriate level of non-verbal ability, and that the danger of masking any interesting results due to similarities between the RCPM and the three experimental tasks is eliminated.

The requirements shared by the experimental tasks lead one to predict that performance of individuals with WS on the CEFT will relate to the effects of segmentation and perceptual cohesiveness on this group as measured by the Squares Task. High scores on the CEFT in comparison to controls, less facilitation by segmentation, and less effect of perceptual

cohesiveness would indicate a local processing bias in WS. Performance below the level of controls on the CEFT could indicate that individuals with WS have problems disengaging from the global configuration and should be linked to a larger effect of segmentation and perceptual cohesiveness than controls. If both groups have the same level of ability on the CEFT, then they should also be affected to the same extent by the local-global manipulations on the Squares Task; this would suggest that local-global perception is not deviant in WS.

Performance relating to the third variable manipulated in the Squares Task, obliqueness, should relate to mental rotation ability. The nonoblique squares should be easier to discriminate between, which would make them more imageable, thus manipulation by mental imagery would be the most effective way to complete the task in these conditions. Oblique orientations are harder to discriminate between, thus task completion in the oblique conditions may rely on manual object manipulation, a more concrete strategy. If individuals with WS have an ability to employ mental imagery as a means of manipulating images (as investigated by the mental rotation task), then this should have a positive effect on RT on nonoblique trials, but less so for oblique trials. If individuals cannot perform mental object manipulation, a concrete strategy will be used for both types of squares, and less difference in processing speed will be seen between them. In summary, the roles played by two factors in the block construction performance of individuals with WS are explored in this experiment; perceptual processing preference; and ability to manipulate images using mental imagery in both WS and typically developing groups.

Method

Participants

Two participant groups were assessed, 21 individuals with diagnosed WS and 21 typically developing children. The WS individuals were recruited from the records of the UK's Williams

Syndrome Foundation of individuals in the Bristol and Southampton areas and their surrounding counties by means of a letter to parents and guardians inviting them to take part in the study. Six of the participants had received a diagnostic “fluorescence in situ hybridisation” test (FISH) and a deletion of the elastin gene on chromosome 7 was confirmed in all six of these cases. This gene is deleted in approximately 95% of individuals with WS (Lenhoff, Wang, Greenberg, & Bellugi, 1997). None of the WS participants had received negative FISH results. The remaining 16 participants were diagnosed by medical practitioners before the FISH test was available as a diagnostic tool in WS. Their diagnosis was based on the distinctive medical, behavioural, cognitive and facial characteristics unique to WS. The experimenter considered all of these individuals to have the recognisable WS “elfin face”, many had heart problems and had experienced hypercalcaemia in infancy, which is common in WS. The characteristic social personality was present in all members of the group. Previously published data from 14 of the sample confirmed the cognitive phenotype of WS (Jarrold, Baddeley & Hewes, 1998) and the remaining seven participants also displayed a discrepancy between verbal ability (measured by the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Pintilie, 1982) and non-verbal ability (Measured by the RCPM). Thus, despite not having undergone a FISH test, medical opinion, the WSF, and the experimenter deemed that these individuals fitted the WS phenotype. The typically developing (TD) individuals were recruited from a local mainstream school. The groups were matched individually by score on the RCPM, the details of which can be seen in Table 1.

Table 1 about here

Procedure

CEFT. The standard CEFT (Witkin et al., 1971) is composed of two levels, in which a triangle/ tent (level 1) or a house (level 2) is embedded in a picture. For this Experiment, only level 1 was employed, which contains eleven trials. The standard training and testing procedure was followed. Testing began with item 1 for all individuals, and stopped upon completion of all of the tent trials. Identification time was recorded and a 30 second time limit was imposed, after which a score of 0 was given. Correctly completed trials received a score of 1.

The Squares Task. This is a novel task modelled on block construction tests. Participants were shown a stimulus pattern and were instructed to make the pattern themselves by placing squares on a board. The board was designed to force the participant to maintain the correct global, two by two formation. Patterns were composed of 4 squares. Figure 1 shows the complete set of designs in condition 1. These were 10 segmented trials, five of each employing obliquely or nonobliquely divided squares. Condition 2 employed segmented versions of the same patterns. The least and most perceptually cohesive patterns were where the pattern is made of four separate components (pattern a) or one whole component (patterns e) respectively. Trials between these extremes progressed systematically. Pattern c, was of two identical components, one on top of the other. Patterns b and d, represented a progression from no cohesiveness (pattern a), and part cohesive (pattern c), and between part cohesive and complete cohesiveness (pattern e) respectively. The perceptual cohesiveness created by the position of each of the squares in the oblique patterns was mirrored in the nonoblique patterns.

Figures 1 and 2 about here

The participant was given the appropriate set of 4 squares, as dictated by obliqueness (see figure 2), and one of two boards. The board used in the segmented condition was divided into 4 segments allowing the individual squares to be placed in the correct segmented format. In the

nonsegmented condition, the board served to frame the four squares as a complete pattern in which the squares were touching each other. Demonstration trials preceded each set of 5 trials and conditions 1 and 2 were counterbalanced. Oblique trials always preceded nonoblique trials and perceptual cohesiveness always followed the same pattern, in the order of trials a, e, b, d, c. The time taken to complete each trial was recorded. If the pattern was not completed in 60 seconds, the response was recorded as a fail.

Rotation tasks. A mental rotation task and a manual rotation task were employed. In both tasks, two templates were displayed depicting mirror-imaged stick figures, 'Sally' and 'Jane'. 'Sally' held a red square in the left hand and a blue circle in the right hand, whilst 'Jane' held the objects in the opposite hands. This difference was explained to the participants and practise trials were given by asking the individual to identify an upright figure as either 'Sally' or 'Jane'. Testing began when the participant had made three consecutive correct identifications. The mental rotation task used a stimulus booklet consisting of 36 images. The figures were displayed at one of 6 rotations about the central axis. These were: 0 degrees (upright), 60, 120, 180, 240 and 300 degrees. The 36 trials consisted of six of each of the rotated positions, three for each figure. Participants were asked to identify the presented figure as either 'Sally' or 'Jane'. In the manual condition, the composition of trials was the same. The stimulus booklet was substituted by two boards with a rotating disc attached to each. 'Jane' or 'Sally' was depicted on the disc, which was freely rotatable about the central axis. This enabled the individual to manually rotate the figure to the upright in order to make an identification. RT and correct responses were recorded. Participants were not given feedback for individual trials.

Results

Results were recorded by response time (RT) and by the number of correct responses. In all RT analyses, fails on the CEFT were scored as 30 seconds, and those on the Squares task as 60 seconds as these were the respective cut-off points at which a fail was awarded. This technique credits both groups, but particularly the group with the most fails, with a higher success rate than was actually achieved. Any significant group differences are therefore unlikely to result from this adjustment to the scores, as the adjustment would bring level of ability closer together.

Performance was analysed firstly within each task to assess the effect of each of the independent variables separately on each task. Where possible, measures of both RT and number of correct responses were investigated in order to provide a thorough analysis of performance. Both types of analyses are presented for the CEFT and the Squares task. However for the rotation tasks analysis of the correct responses only is presented. This is because in order to obtain a complete data set using RT, both pass and fail responses would have to be included. This introduces the problem of guess responses, where mental rotation was not attempted and thus the RT is not proportional to the degree to which the figure had been rotated. Including guess responses would reduce any effects of degrees of rotation in the analysis. Effect sizes, denoted by partial η^2 , are reported for all significant and key results. Effect size measures the percentage of variance in the dependent variable that is associated with the independent variable so that the strength of their association can be ascertained. Partial η^2 values range from 0 to 1, and a value that is closer to one indicates that the significance difference found has a strong association to the independent variable.

Within task analysesCEFT

Analysis of RT performance on the CEFT by independent samples t - test showed that there was no significant difference between the WS and TD groups, $t=-0.25$, $df=40$, $p=.80$ (partial $\eta^2=.002$). Similarly, analysis of the number of correct responses did not reveal a significant difference between the two groups, $t=-0.24$, $df=40$, $p=.81$ (partial $\eta^2=.001$). Means and standard deviations for both RT and the number of correct responses are shown below in Table 2.

Table 2 about here

Rotation tasks

ANOVA analysis of the number of correct responses had two within subject factors: degrees of rotation (6 levels: 0, 60, 120, 180, 240, 300 degrees), and type of rotation (2 levels: mental, manual) and one between subject factor of group (2 levels; WS, TD). Means and standard deviations for the number of correct responses by group in each condition, are shown in Table 3. There were significant main effects for all 3 factors. The main effect of group, $F(1,40)=15.92$, $p<.001$ (partial $\eta^2= .29$), was due to higher accuracy in the TD group than the WS group. The main effect of type of rotation, $F(1,40)=44.83$, $p<.001$ (partial $\eta^2= .53$), was due to there being significantly more correct responses on the manual rotation task than the mental rotation task. The significant main effect of degrees of rotation, $F(5,200)=35.76$, $p<.001$ (partial $\eta^2= .47$), was analysed further through post-hoc paired comparisons. Significantly more trials with 0, 60 and 300 degrees of rotation were completed than for 120, 180 and 240 degrees, $t \geq 5.51$, $df=41$,

$p < .001$ for all comparisons. 0 degree trials were also identified significantly more accurately than 300 and 60 degrees, $t \geq 2.75$, $df=41$, $p \leq .01$. Accuracy among 120, 180 or 240 degree trials did not differ significantly.

A significant interaction between type of rotation and group, $F(1,40)=13.67$, $p < .001$ (partial $\eta^2 = .26$), was due to a significant effect of group only at mental rotation, $F(1,40)=19.77$, $p < .001$, compared to manual rotation, $F(1,40)=1.34$, $p = .25$, with the WS group showing poorer performance on the mental in comparison to the manual rotation task, $F(1,20)=54.41$, $p < .001$, whereas the accuracy of the TD group differed less, although still significantly, between mental and manual rotation, due to reduced accuracy on the mental rotation condition, $F(1,20)=4.46$, $p = .05$. Similarly, effect sizes for rotation type were larger in the WS group (partial $\eta^2 = .73$) than the TD group (partial $\eta^2 = .18$). There was a significant interaction between degrees of rotation and group, $F(5,200)=6.80$, $p < .001$ (partial $\eta^2 = .14$). Post hoc analysis of simple effects showed that this was due to a larger effect of degrees of rotation on accuracy for the WS group, $F(5,100)=28.60$, $p < .001$, than the TD group, $F(5,100)=8.42$, $p < .001$. Again, this is echoed in the effect sizes (WS: partial $\eta^2 = .59$; TD: partial $\eta^2 = .30$). The effect of group at each level of degrees became increasingly significant as the degree of rotation moved further away from the upright, with the WS group becoming increasingly less accurate. A significant interaction between type of rotation and degrees of rotation, $F(5,200)=18.17$, $p < .001$ (partial $\eta^2 = .31$), was due to a larger effect of degrees of rotation in the mental rotation condition (accuracy decreased as the degree of rotation moved further away from the upright), $F(5,200)=31.55$, $p < .001$ ($\eta^2 = .44$), than in the manual rotation condition, $F(5,200)=5.80$, $p < .001$ ($\eta^2 = .13$).

There was a significant three way interaction across all factors; type of rotation by degrees of rotation by group, $F(5,200)=7.43$, $p < .001$ (partial $\eta^2 = .16$). This was due to the interaction

between group and type of rotation being significant only for 120 degrees: $F(1,40)=18.04$, $p<.001$, 180 degrees: $F(1,40)=9.96$, $p=.003$, and 240 degrees: $F(1,40)=8.97$, $p=.005$. In these cases, the WS group were less accurate than the TD group in mental, but not manual rotation ability. Nonsignificant interactions were evident at 0 degrees: $F(1,40)=0.29$, $p=.59$, 60 degrees: $F(1,40)=1.07$, $p=.31$, and 300 degrees: $F(1,40)=0.12$, $p=.73$. There was a nonsignificant group by degrees of rotation interaction in the manual rotation condition, $F(5,200)=1.12$, $p=.35$ (partial $\eta^2=.03$), compared to a significant group by degrees of rotation interaction for the mental rotation condition, $F(5,200)=8.19$, $p<.001$ (partial $\eta^2=.17$). This significant interaction is illustrated in figure 3 in which the percentage of correct responses made by each group in the mental rotation task is plotted at each point of rotation.

Table 3 about here

Figure 3 about here

The Squares Task

RT and correct response data were analysed by ANOVA with 3 within-subject factors; obliqueness (whether patterns contained oblique or nonoblique lines: 2 levels; oblique, nonoblique), segmentation (2 levels: segmented, nonsegmented), and perceptual cohesiveness (from none to complete across 5 levels); and one between-subject factor: group (2 levels: WS, TD). Means and standard deviations for measures of RT and correct responses for the Squares task are shown in Tables 4 and 5 below.

 Tables 4 & 5 about here

Analysis of RT data revealed significant main effects of each factor. The main effect of group, $F(1,40)=5.66$, $p=0.02$ (partial $\eta^2=.12$), reflected the fact that TD participants were faster than individuals with WS at completing the task. The main effect of segmentation, $F(1, 40) = 36.6$, $p < .001$ (partial $\eta^2=.48$), was due to a facilitation effect in the segmented condition. A significant main effect of obliqueness was a reflection of the fact that the RT for completing the nonoblique trials was shorter than that of the oblique trials, $F(1, 40)=61.05$, $p<.001$ (partial $\eta^2=.60$). There was also a significant main effect of perceptual cohesiveness, $F(4, 160)=5.29$, $p<.001$ (partial $\eta^2=.12$). Paired comparisons showed that this was due to a shorter RT on patterns a (no cohesiveness), c (part cohesive), and e (complete cohesiveness), than on patterns b and d (pattern a: $p=.02$, $p=.01$; pattern c: $p=.01$, $p<.001$; pattern e: $p<.001$, $p<.001$ for patterns b and d respectively). Note that the highest effect sizes were for the main effects of obliqueness and segmentation, which reflects a strong association between the variance in RT and these two independent variables.

There was a significant segmentation by obliqueness interaction, $F(1, 40)=12.89$, $p=.001$ (partial $\eta^2=.24$). Analysis of simple main effects revealed that this was due to a highly significant effect of segmentation on nonoblique trials, $F(1,40)=36.11$, $p<.001$ (partial $\eta^2=.47$), in comparison to a smaller, though still significant effect of segmentation on oblique trials, $F(1,40)=6.73$, $p=.01$ (partial $\eta^2=.14$). In addition, the effect of obliqueness on segmented trials was higher, $F(1,40)=58.03$, $p<.001$ (partial $\eta^2=.59$), than the effect of obliqueness on nonsegmented trials, $F(1,40)=14.60$, $p<.001$ (partial $\eta^2=.27$). The interaction between

segmentation and perceptual cohesiveness was also significant, $F(4, 160)=3.04$, $p=.02$, although the effect size was small (partial $\eta^2=.07$). The interaction was due to the fact that the effect of perceptual cohesiveness was significant for nonsegmented trials, $F(4,160)=7.22$, $p<.001$ (partial $\eta^2=.15$), but was not significant for segmented trials, $F(4,160)=1.10$, $p=.36$ (partial $\eta^2=.003$). This indicates that difficulty with the perceptual cohesiveness of some trials is eliminated by segmenting the individual squares. A significant interaction of obliqueness by perceptual cohesiveness, $F(4, 160)=4.02$, $p<.01$, occurred, although again with a small effect size (partial $\eta^2=.09$). Analysis of simple main effects revealed that there was a stronger effect of perceptual cohesiveness at nonoblique trials, $F(4,160)=8.55$, $p<.001$ (partial $\eta^2=.18$), than at oblique trials, $F(4,160)=2.93$, $p=.02$ (partial $\eta^2=.07$). There was a significant difference between processing oblique and nonoblique trials at each of the levels of perceptual cohesiveness with longer RT for oblique trials; pattern a: $F(1,40)=28.95$, $p<.001$; pattern b: $F(1,40)=11.87$, $p=.001$; pattern c: $F(1,40)=47.87$, $p<.001$; pattern d: $F(1,40)=29.65$, $p<.001$; pattern e: $F(1,40)=8.82$, $p=.005$.

A significant interaction occurred between obliqueness and group, $F(1, 40)=6.14$, $p=.02$ (partial $\eta^2=.13$). Analysis of simple main effects showed that this reflected the fact that there was a significant group effect for nonoblique trials, $F(1, 40)=9.78$, $p=.003$ (partial $\eta^2=.20$), but not for oblique trials, $F(1,40)=2.01$, $p=.164$ (partial $\eta^2=.05$). The TD controls showed a larger decrease in RT on nonoblique trials in comparison to oblique trials, $F(1,20)=46.02$, $p<.001$ (partial $\eta^2=.70$), than the decrease in RT between these two levels of obliqueness for the participants with WS, $F(1,20)=16.76$, $p<.001$ (partial $\eta^2=.46$). This interaction is clearly illustrated in figure 4. The steeper line in the TD group represents a stronger difference between nonoblique and oblique trials than represented by the less steep slope for the WS data. In comparison, the

interactions between group and segmentation and between group and perceptual cohesiveness were nonsignificant ($F < 1$).

Figure 4 about here

ANOVA analysis of the number of correct responses also revealed a significant main effect of each factor. The significant main effect of group was due to the TD group producing more correct responses than the WS group, $F(1,40)=6.84$, $p=.01$ (partial $\eta^2=.81$). The significant main effect of segmentation reflected the fact that there were more correct responses on segmented trials than on nonsegmented trials, $F(1,40)=22.08$, $p<.001$ (partial $\eta^2=.36$). The significant main effect of obliqueness, $F(1,40)=33.21$, $p<.001$ (partial $\eta^2=.45$), was due to participants producing more correct responses on the nonoblique trials than on the oblique trials. Paired comparisons were carried out to investigate the significant main effect of perceptual cohesiveness, $F(4,160)=5.00$, $p<.001$ (partial $\eta^2=.11$). This revealed that patterns, a (no cohesiveness), c (part cohesive), and e (complete cohesiveness) were completed more often than patterns b and d (pattern a: $p<.01$, $p<.01$; pattern c: $p=.02$, $p=.001$; pattern e: $p=.02$, $p<.01$, compared to patterns b and d respectively).

A significant interaction between segmentation and obliqueness, $F(1,40)=9.63$, $p=.004$ (partial $\eta^2=.19$), was due to a stronger effect of segmentation on nonoblique trials, $F(1,40)=24.27$, $p<.001$ (partial $\eta^2=.38$), in comparison to oblique trials, $F(1,40)=3.15$, $p=.083$ (partial $\eta^2=.07$). There was also a significant interaction, although with a small effect size, between obliqueness and perceptual cohesiveness, $F(4,160)=2.45$, $p=.05$ (partial $\eta^2=.06$). A further analysis of simple main effects revealed that this was due to a stronger effect of perceptual cohesiveness on nonoblique trials, $F(4,160)=6.25$, $p<.001$ (partial $\eta^2=.14$), than oblique trials, $F(4,160)=2.92$,

$p=.02$ (partial $\eta^2=.07$). The effect of obliqueness on perceptual cohesiveness was significant for all trials apart from pattern e (a completely cohesive pattern); pattern a: $F(1,40)=20.70$, $p<.001$; pattern b: $F(1,40)=6.08$, $p=.02$; pattern c: $F(1,40)=20.70$, $p<.001$; pattern d: $F(1,40)=15.63$, $p<.001$; pattern e: $F(1,40)=2.36$, $p=.13$. In this analysis, all 2-way group interactions were nonsignificant: group by segmentation: $F(1,40)=0.51$, $p=.48$; group by obliqueness: $F(1,40)=1.33$, $p=.26$; and group by perceptual cohesiveness: $F=0.33$, $p=.86$. Finally, none of the 3-way or 4-way interactions were significant ($F<1$ for all).

Comparison across tasks

A discriminant function analysis was carried out to determine if performance on the experimental tasks predicted group membership accurately. Eight variables were entered as possible predictors; average RT on the CEFT, score on the CEFT, mental rotation score, manual rotation score, average RT for segmentation, average score for segmentation (these two variables derived by subtracting nonsegmented from equivalent segmented trials and averaging across the 10 derived numbers), average RT for obliqueness, and average score for obliqueness (derived by subtracting oblique from equivalent nonoblique trials and averaging across the 10 derived numbers). A score for perceptual cohesiveness was not included in this analysis as, for this analysis, local-global processing style is represented adequately in the Squares task by the segmentation measures. As there were two groups, WS and TD, one discriminant function was derived, which thus accounted for 100% of between-group variability. Chi-squared analysis, which tests the reliability of the discriminant function, showed a strong association between groups and predictors, $\chi^2(8)=28.33$, $p<.001$ (Wilks' Lambda =.46). The loading matrix of correlations between predictors and the discriminant function suggests that the best predictors for distinguishing between the WS and TD groups are mental rotation score and obliqueness score

with loadings of .64, and -.41 respectively. This is in line with the significant group interactions with rotation type and the RT for obliqueness in the ANOVA analyses. The remaining six predictors did not load substantially on the function (loadings of $<.2$). These factors were those in which no interaction with participant group occurred, and so cannot be used to predict group membership. The classification results based on the discriminant function, correctly classified 90.5% of the participants (95.2% of WS individuals, and 85.7% of TD controls).

Discussion

The central aim of this study was to investigate factors that affect the performance of individuals with WS on a block construction task. Individuals with WS, matched to TD controls by level of ability on the RCPM, showed significantly poorer performance on a two-dimensional block construction task, the Squares task, relative to the control group. Significant group effects were seen in the analysis of RT and of the number of correct responses and a comparison of effect sizes revealed that the main effect of group was comparatively larger for the number of correct responses, relative to the effect size in the RT analysis. The results demonstrate that the individuals with WS were making many more errors than the TD controls, on the Squares task which is consistent with previous studies that have demonstrated that level of ability on the block construction tasks is significantly weaker than level of ability achieved on other non-verbal tasks (e.g. Arnold et al., 1985; Udwin et al., 1987; Mervis et al., 1999).

To further examine the weak block construction ability in WS, this study investigated two contributing factors to performance on the Block Design task. The first factor was employed to determine whether individuals with WS are influenced by local or global information in a manner that differs from that seen in typical development. The results from the CEFT

demonstrated that the performance of individuals with WS did not differ from that of TD controls. This was evident in the analyses of both RT and the number of correct responses, where similar, non-significant effect sizes were observed. As noted in the introduction, different studies provide apparent evidence to support opposing processing biases in the WS population. The CEFT provided a specific measure of these individuals' ability to locate a local element within a global image and clearly shows that, in perception, individuals with WS process information in a typical manner.

The second factor investigated in this experiment concerned the ability of individuals with WS to form and manipulate mental images of stimuli. To test this systematically, a mental rotation task was employed. Individuals with WS performed poorly on the mental rotation task in comparison to an equivalent manual rotation task. The TD controls showed significantly stronger mental rotation abilities than the WS group. This suggests that individuals with WS have difficulty manipulating stimuli using mental imagery.

On the basis of these results from the CEFT and mental rotation task, it would be expected that in a block construction task, individuals with WS should not show a particular preference for processing the local elements at the expense of the global pattern or neglect the local elements any more so than would the TD population. The results would also lead to the expectation that an individual with WS should not be able to take advantage of increased imageability in the same way as in typical development, as they are likely to struggle to manipulate these images mentally. Instead they may rely on a concrete, manual orientation technique, for completing block construction tasks. The above predictions are supported by the results of the performance of the WS group on the Squares Task. The effects of segmentation and perceptual cohesiveness were associated with perception at local and global levels, whereas the effect of obliqueness was

associated with the influence of oblique and nonoblique orientations on the manipulation of the Squares, mental or manual. The results showed that segmentation, and perceptual cohesiveness did not affect performance differentially between the WS and TD groups, as no significant group by segmentation or group by perceptual cohesiveness interactions were observed. This suggests that both groups were processing local and global information in the same way. Segmented trials were completed both faster, and more successfully than nonsegmented trials to the same extent in both groups. Thus, by making the local elements more salient, performance improves comparably in both groups. The effect of perceptual cohesiveness corresponded, on some pattern types, to the extent to which the pattern resembled a complete, global image; patterns a, c, and e were completed more accurately and with faster RTs than patterns b and d. Pattern e has one whole image component, which supports the hypothesis that higher perceptual cohesiveness, i.e., stronger global properties, makes a trial easier to complete. Individuals may have used a strategy based less on the specific orientation of each individual square, and more on global properties by following the form of the image as a whole. However, the same argument cannot be applied to explain the relative ease of processing trials employing patterns c and e which correspond to images composed of 2 and 4 components respectively (see figure 1). It appears that the relative ease of completing these trials corresponds to the regularity of the pattern. These patterns were more regular than patterns b and d (see figure 1). Each square of pattern a was in an identical orientation, thus the participant simply had to repeat the same process four times, one at each of the four locations. Similarly, the top two squares of pattern c were a repetition of the bottom two squares. This regularity might have simplified completion. In comparison, patterns b and d were not so regular and could not be completed in such a systematic way. This manipulation of perceptual cohesiveness, as well as the segmentation manipulation, were designed to detect any

differences in local or global processing preferences between the WS group and the control group. The results from the Squares task show that in both factors, segmentation and perceptual cohesiveness, individuals with WS were affected in the same way as TD individuals.

In contrast to the group similarities above, and as predicted by the mental rotation task, the effect of obliqueness differed between groups as shown by a significant interaction with the time taken to complete oblique and nonoblique trials in the Squares task. Individuals with WS were slower than the TD individuals in both oblique and nonoblique trials, but were less affected by differences in obliqueness than the TD controls. This might reflect a change in processing technique in the TD group that is not available to the WS group, i.e., a change from manual to mental manipulation of the squares. The TD group may have utilised a predominantly manual form of object manipulation for the oblique trials, and then switched to a predominantly mental object manipulation for the nonoblique trials. In contrast, the WS group may have relied on a technique that involved manual orientation of the squares throughout. The mental rotation task has demonstrated that they are unable to manipulate images mentally. A reliance on concrete hand movements to manipulate the squares can account for both their longer RT, and also for the smaller difference in RT between oblique and nonoblique trials in this group.

Each task's ability to predict group membership was assessed by discriminant function analysis. The discriminant function was able to assign a high proportion of participants (90.5%) to the correct groups. It accurately identified performance on the rotation tasks, and the ability to complete oblique versus nonoblique trials in the Squares task, as the factors with the most predictive value. This is in line with the significant group interactions observed in this study. However, although the differential effect of obliqueness seen between the groups in the present study can be convincingly explained by an inability to employ mental imagery in the WS group

only, one must consider why both mental rotation and obliqueness have relatively high predictive value for group membership. There might be other factors, which also impact on obliqueness scores that may affect the predictive value of this factor on group membership. The first such factor relates to the use of verbal labels. Oblique lines are harder to apply verbal labels to than nonoblique lines. The English language does not differentiate between the differing orientations of diagonals i.e. there are no words that distinguish a left-to-right diagonal from a right-to-left diagonal. This contrasts to the distinct verbal labels that can be used to represent nonoblique lines such as up, down and across. It is possible that in the Squares task, the TD group might have utilised verbal codes, and in principal the relatively strong verbal skills of the WS should also enable them to use verbal strategies to complete tasks. However, these verbal labels are spatial in nature and spatial language is known to be difficult to comprehend in WS (Phillips, Jarrold, Baddeley & Karmiloff-Smith, 2000). The verbal coding possibility could be investigated further by asking participants to carry out the task while engaging in articulatory suppression (Baddeley, Thompson & Buchanan, 1975), thus making it impossible to employ verbal coding.

The group differences in the effect of obliqueness seen in this experiment could also occur at an earlier stage of processing. It is possible that at the perceptual level, before mental or manual manipulation comes into play, individuals with WS find it harder to discriminate between the nonoblique lines than the TD group, creating less of a contrast between the perception of nonoblique and the perception of oblique lines. This possibility could be investigated by employing a task similar to the Squares task, but without the constructional element. Participants could be asked to discriminate among the four different orientations of the Square, oblique and nonoblique, in a perceptual matching type task, thus enabling the effect of obliqueness to be measured at a purely perceptual level.

Despite the possible factors outlined above, poor mental imagery ability offers a very plausible explanation for impaired performance of individuals with WS on block construction tasks. Poor mental imagery ability seems to affect response latencies, and so can explain why individuals with WS are slow at block construction tasks. Analysis of group accuracy, however, does not reveal the same group by obliqueness interaction, therefore the effect of obliqueness cannot necessarily account for the overall poor level of ability in block construction tasks. The low scores of individuals with WS achieved on block construction tasks may also relate to other factors that remain to be investigated. For example, it is possible that a processing bias might still exist, but at the level of construction, which is an ability that block construction tasks rely heavily on. Bellugi et al. (1988) observed that individuals with WS have problems maintaining the global configuration of the Block Design task. This was attributed to a perceptual problem, however it could equally be due to a local bias in construction (see Farran & Jarrold, submitted). Perceptual tasks that measure local and global processing abilities, require an individual to recognise the parts of the image and also to recognise the pattern or picture as a whole image, whereas in construction, there is an additional requirement to comprehend the spatial relationship between the parts. This 'configural' information is essential if reconstruction of the image is to be completed successfully. This difference between perception and construction can also explain why there appears to be a discrepant pattern of results reported in a number of previous studies. Evidence for a local processing bias from drawing studies (Bertrand et al. 1987) and copying versions of the Navon task (Rossen et al. 1996) is not based on analysis of perception, but refers to the end products of each of these tasks, i.e., the drawings produced. Authors infer from the local bias observed at this stage, that individuals with WS also perceive the image in a local manner. However, it is equally possible that their perception of the image, the 'input', is normal,

but that they are unable to reproduce the image, i.e., they have problems at the 'output' stage of the task. Pani et al. (1999) measured perception through visual search where results showed that both global and local manipulations affected individuals with WS. A direct comparison with TD adult controls revealed that individuals with WS had relative difficulty disengaging from the global configuration. Thus it appears that these results from visual search tasks support the present data in providing evidence against a local processing bias in perception in WS. We propose that the results seen in both the present study and in visual search, differ from the results of drawing studies, the Navon task and block construction tasks because different skills are being investigated; perception and production through drawing or construction respectively. The present experiment has demonstrated that when the perceptual input of block construction tasks is examined, processing preferences resemble those seen in typical development. Further investigation of the apparently contrasting results of previous studies could involve a direct investigation of the perceptual components of other constructional and drawing tasks.

Further investigation of mental imagery in WS would also be fruitful. Mental rotation is one form of mental imagery, but one cannot assume that poor mental rotation ability equates to poor mental imagery in general, particularly since mental rotation requires dynamic imagery, i.e. moving the created image. Generation and maintenance of static images could also be investigated. Additionally, different forms of transforming mental images such as mental subtraction and mental scanning would increase our understanding of the mental imagery abilities of individuals with WS.

In order to interpret the meaning of the level of ability on a task, one must establish how the individual is approaching the task. This study was prompted by the contrasting results across studies that have investigated block construction tasks using different methodologies. Systematic

investigation of two of the contributing factors of block construction have demonstrated first, that the weak performance in WS cannot be explained by an aberrant perceptual processing style in the form of a local processing bias, as suggested by many previous studies. At the perceptual level, local-global processing style does not differ from that of typical development. Second, investigation of the techniques used to manipulate the squares, suggests that individuals with WS have difficulty manipulating stimuli using mental imagery, and instead rely on manual strategies for completing tasks. This study has contributed to a clearer picture of how individuals with WS approach block construction tasks, and has implications for understanding how non-verbal tasks are approached in WS. Further investigation will make clearer what factors have positive and negative effects on visuo-spatial performance in WS. This information can then potentially be used to develop intervention techniques that are optimally tailored to developing the abilities of individuals with WS.

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Table 1: Participant details

	Williams syndrome (n=21)		Typically Developing (n=21)	
	Mean (SD)	Range	Mean(SD)	Range
CA(months)	239.90 (101.62)	114-461	79.05(7.26)	64-86
RCPM score	18.14 (5.20)	11-30	17.90(4.73)	8-28

Table 2: Reaction time and correct responses for the CEFT

	Mean (SD)	
	RT(secs.)	Correct responses (out of 11)
WS	12.36(4.53)	8.38(1.83)
TD	12.69(4.00)	8.52(1.99)

Table 3: Rotation tasks

Number of correct responses(out of 6): Mean(SD)												
Rotation type	mental						manual					
Degrees of rotation	0	60	120	180	240	300	0	60	120	180	240	300
WS	5.52	4.95	2.38	2.14	3.05	5.29	5.71	5.67	5.48	5.10	5.43	5.52
	(0.68)	(1.47)	(2.09)	(1.85)	(1.77)	(1.10)	(0.72)	(0.80)	(0.75)	(0.94)	(0.98)	(0.81)
TD	5.86	5.52	4.86	4.67	4.81	5.67	5.95	5.86	5.48	5.57	5.48	5.81
	(.36)	(1.21)	(1.31)	(1.98)	(1.63)	(0.80)	(0.22)	(0.48)	(0.75)	(0.87)	(0.87)	(0.40)

Table 4: RT for the Squares task

		RT(secs.): Mean (SD)	
		Oblique	Nonoblique
WS	Segmented	43.21(20.58)	31.49(20.49)
	Nonsegmented	47.08(18.67)	43.93(20.28)
TD	Segmented	36.85(20.43)	17.99(13.36)
	Nonsegmented	40.89(20.20)	31.09(19.84)

Table 5: Correct responses for the Squares task

Correct responses (out of 5): Mean (SD)			
		Oblique	Nonoblique
WS	Segmented	2.14(1.98)	3.24(1.99)
	Nonsegmented	1.76(1.87)	2.00(1.87)
TD	Segmented	3.10(1.64)	4.62(0.86)
	Nonsegmented	2.81(1.60)	3.57(1.72)

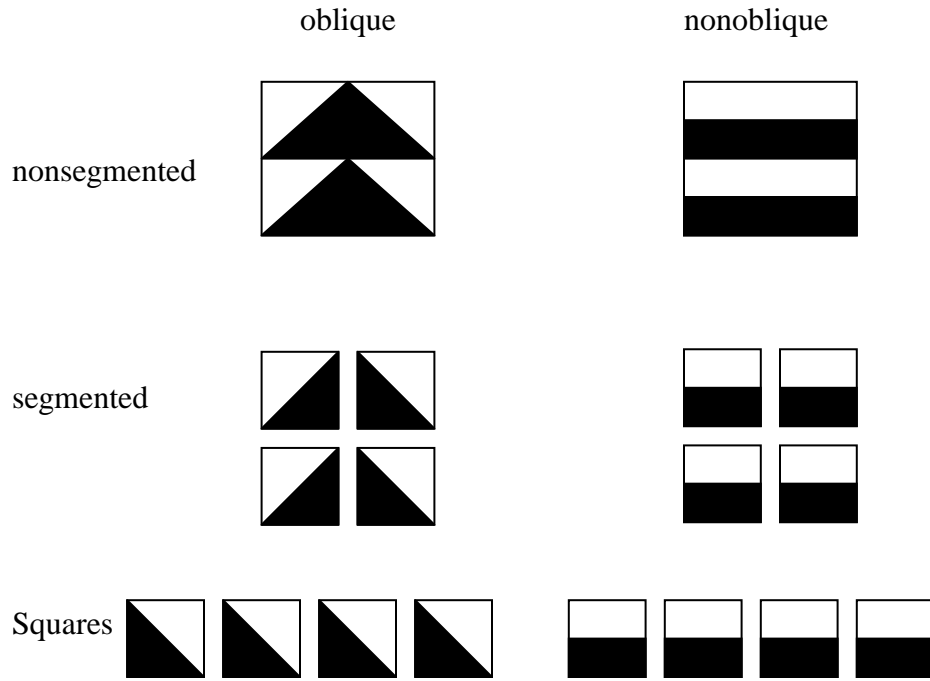
Figure Captions

Figure 1: The Squares task: Complete Set of Designs (Nonsegmented Versions) from 4 to 1 Components

Figure 2. Examples of the Squares Task: Nonsegmented and Segmented Versions of Oblique and Nonoblique Patterns. The Design is to be Constructed from Four Identical Squares; Oblique or Nonoblique.

Figure 3: Mean Percentage of Correct Responses on the Mental Rotation Task

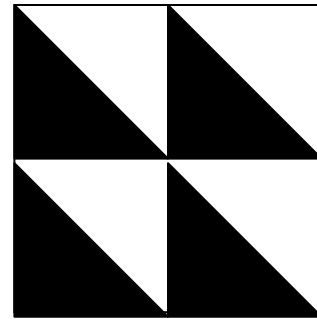
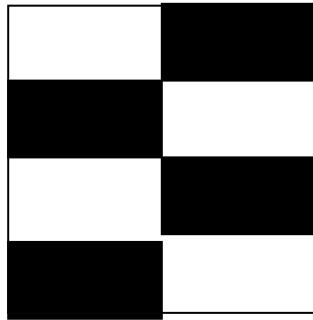
Figure 4: Group by Obliqueness Interaction on the Squares Task



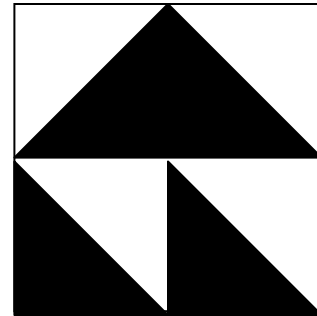
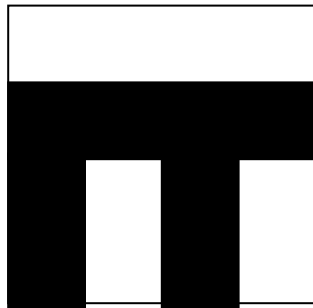
Nonoblique

Oblique

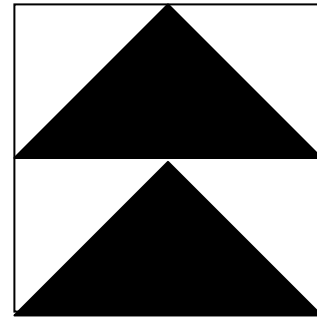
a.



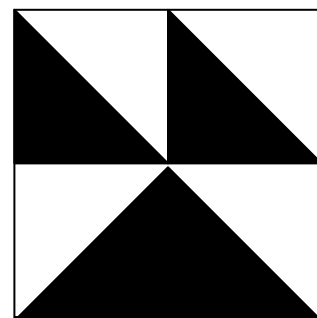
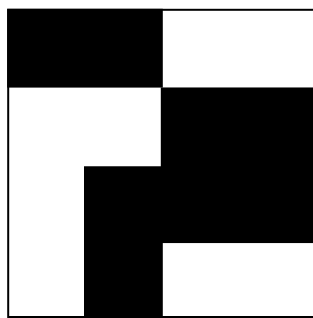
b.



c.



d.



e.

