Facilitating complex shape drawing in Williams syndrome and typical development

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Abstract

Individuals with Williams syndrome (WS) produce drawings that are disorganised, likely due to an inability to replicate numerous spatial relations between parts. This study attempted to circumvent these drawing deficits in WS when copying complex combinations of one, two and three shapes. Drawing decisions were reduced by introducing a number of facilitators, for example, by using distinct colours and including facilitatory cues on the response sheet. Overall, facilitation improved drawing in the WS group to a comparable level of accuracy as typically developing participants (matched for non-verbal ability). Drawing accuracy was greatest in both groups when planning demands (e.g. starting location, line lengths and changes in direction) were reduced by use of coloured figures and providing easily distinguished and clearly grouped facilitatory cues to form each shape. This study provides the first encouraging evidence to suggest that drawing of complex shapes in WS can be facilitated; individuals with WS might be receptive to remediation programmes for drawing and handwriting.

Keywords: Drawing; developmental disorders; Williams syndrome; typical development; perception; graphic planning; remediation.

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1. Introduction

The ability to produce a drawing is underpinned by a range of abilities, such as perception, spatial cognition and the execution of planned movements (Bonoti, Vlachos & Metallidou, 2005). As a result, drawing is a marker of both cognitive and neurobiological maturation. Williams syndrome (WS) has often been associated with poor drawing ability (e.g. Bertrand, Mervis & Eisenberg, 1997), although few studies have investigated this. WS is a rare genetic disorder that results from a hemizygous 1.6 Mb microdeletion of approximately 26 contiguous genes on chromosome 7q11.23 (Nickerson, Greenberg, Keating, McCaskill, & Shaffer,1995; Tassabehji, 2003) which affects one in 20,000 live births (Morris, Demsey, Leonad, Dilts, & Blackburn, 1988). Individuals with WS typically display mild to moderate learning difficulties (average IQ between 50 and 60) and an unusual cognitive profile comprising of relatively strong linguistic ability and poor visuo-spatial performance (Ewart et al., 1993; Ferrero et al., 2007; Mervis & John, 2008; Smoot, Zhang, Klaiman, Schultz, & Pober, 2005).

Mark-making ability is generally poor in WS; difficulties with handwriting are observed in 93% of individuals with WS (Semel & Rosner, 2003, p. 154). Throughout development, drawings made by individuals with WS are often seriously disorganised, lack detail and exhibit less mastery than typically developing (TD) individuals of the same mental (MA) or chronological (CA) age (Bertrand et al., 1997; Stiles, Capirci & Volterra, 2000; Wang & Bellugi, 1993). Until recently, this pattern of behaviour in WS had been explained by the local processing hypothesis which suggests that when copying an image, individuals with WS typically attempt to depict the details of the image but fail to replicate the overall spatial arrangement of these details (e.g. Bellugi, Sabo, & Vaid, 1988; Bellugi, Wang & Jernigan, 1994). Current understanding of visuo-spatial ability in WS accepts that a local-level bias does not characterise the visuo-spatial phenotype in WS as a whole (e.g. Farran et al., 2001; 2003, also see Deruelle, Rondan, Mancini, & Livet, 2006; Pani, Mervis, & Robinson, 1999).

Hudson and Farran (2011) refuted the local processing hypothesis in a drawing task and suggested that poor drawing performance in WS might be due to a reduced ability to understand the relations of parts and an increased sensitivity to the complexity of images, relative to TD controls. The net result of this in WS is a reduced ability to strategically replicate images, which is likely to also be affected by poor mental imagery (e.g. Farran et al., 2001). Despite clear graphomotor deficits there is a distinct lack of research to understand these difficulties in WS and the means to remediate problems. This study therefore focused on understanding how drawing can be facilitated by manipulating drawing demands and is the first of its type to focus exclusively on methods to facilitate drawing performance in WS and TD children.

The decisions that are made when attempting to accurately produce a drawing include kinematics such as force and pressure on a stylus, selecting starting and cessation points, depicting appropriate line lengths and directional changes (such as initial direction choice, turning points and the angle of directional change; Broderick & Laszlo, 1988). In the current study, we introduced facilitation methods designed to manipulate the graphomotor decisions that are made during drawing. These were: 1) a dot-joining measure (Guide dots); 2) edge markers for individual shapes; 3) half-completed shapes and 4) marks to indicate the typical starting location for each shape. The rationale for each of these conditions is described in turn below.

To successfully complete the current drawing task, participants must utilise perceptual grouping ability in order to visualise the elements as contiguous forms. Smith and Gilchrist (2005a) demonstrated a strong tendency of drawers to perceptually group edge markers of shapes (as in the Edge Marker condition used in the current experiment) by completion across the space between markers, even in instances when this was not requested. Dot-joining also requires perceptual grouping of elements and has been used to facilitate drawing of simple shapes in TD children (Broderick & Laszlo, 1988) and an individuals with WS (Stiles et al., 2000). These conditions encourage participants to group the given elements to create lines within the figure on the basis of perceptual grouping factors such as similarity, closure and proximity (Wertheimer, 1923). Edge markers and dot-joining marks also provide explicit guidance for starting and cessation points, directional changes and line lengths and so greatly reduce planning demands.

We know that the ability to perceptually group elements is present in WS (Farran, 2005; Grice et al., 2003; Wang, Doherty, Rourke & Bellugi, 1995), therefore providing guiding features such as edge markers should aid drawing in a WS group by reducing planning demands and encouraging grouping of the given features into shapes. However, for participants to benefit from this kind of facilitation, the global form of the model must be processed and related to the the guiding features provided by the response sheet. Should a local processing preference exist, participants with WS would have difficulty replicating figures using facilitation methods that rely on perceptual grouping, due to the need to appreciate the global features of the model and response sheet. Thus, this study also assessed the efficacy of the local processing bias in explaining drawing in WS.

Less emphasis on perceptual grouping ability was presented in a condition where participants were presented with a pre-drawn half of each shape. In this condition, participants were subject to reduced planning demands as starting and cessation points were provided and participants only has to determine a change in angle once. Provision of half a shape to guide drawing has previously been investigated in constructional apraxia (CAp; Smith & Gilchrist, 2005b), which is an acquired deficit in localising elements of visual space, and in TD children (Broderick & Laszlo, 1988). In both of these groups drawing of squares with and without a pre-drawn half of the square educed no significant differences in the angular deviation of drawn lines. Conversely, drawing diamonds using pre-drawn half-shapes led to greater angular deviation of drawings than when no facilitation was provided; this suggests a specific difficultly with replication of oblique lines even when graphic planning demands were reduced. This type of facilitation has not been investigated in WS; the current study aims to determine if individuals with WS benefit from being given half-drawn shapes to guide drawing, by recognising that production of a mirror image of the half-shape is required.

For each of the conditions discussed above, in addition to using standard black line drawings, colour was added as a further form of facilitation. We hypothesised that this would increase the distinction across the elements of the image and could be used as a platform for verbalisation strategies. Nakamura et al. (2001; 2002) demonstrated that in a small group of individuals with WS (although no control participants) the use of a coloured dot matrix (each dot was a different colour) in a dot-joining task compensated for poor spatial localisation ability relative to a single-coloured matrix.

Participants were able to draw figures on the coloured matrix that could not recognisably be drawn on a single-coloured matrix. However, using a similar task, Farran and Dodd (submitted) demonstrated that the facilitation effect of colour observed in a WS group, although present, was weaker than that observed in non-verbal ability matched TD children. Despite this, these studies suggest that colour can be used by individuals with WS as a means of increasing drawing accuracy. This might potentially be due to reduction of graphic planning demands and increased salience of individual elements. Additionally, the use of colour permits verbalisation of the elements of the matrix. This enables individuals to use language, a relative strength in WS (Jarrold, Baddeley & Hewes, 1998), to improve their drawing accuracy.

We present an exploratory analysis of the types of facilitation that might benefit drawing accuracy in WS and TD groups. Given the difficulty that participants with WS have with replicating multiple spatial relations (e.g. Hudson & Farran, 2011) in this study, we sought to determine whether this deficit could be remediated by facilitating drawing of one, two and three overlapping geometric shapes in which models and response sheets provided black or coloured facilitation elements. The WS group were predicted to show a greater benefit of coloured figures over balck figures, when compared to the TD group due the potential to scaffold drawing using verbalisation strategies. It was hypothesised that of all the facilitation types that were provided, greatest drawing accuracy would result from providing guide dots or edge markers. These conditions reduced participant planning demands by informing participants about the length of lines and points that a change in line direction should have occurred. Drawing accuracy was anticipated to be poorest when no facilitation was provided due to the need to self-generate all graphomotor decisions.

2. Method

2.1. Participants

Seventeen participants with WS were recruited through the Williams Syndrome Foundation UK (seven male, ten female; fourteen right-handed, three left-handed). All participants had previously been diagnosed with WS by a clinician and a positive Fluorescence In Situ Hybridisation (FISH) test to ensure deletion of the elastin gene, observed in 95% of individuals with WS (de Souza, Moretti-Ferrereira & Rugolo, 2007). Seventeen TD control participants were recruited through advertisements at the University of Reading (nine male, eight female; sixteen right-handed, one left-handed). Participants were individually matched on non-verbal ability using Raven's Coloured Progressive Matrices scores (RCPM; Raven, 1993). RCPM is a standardised measure and has previously been used successfully as a matching measure for visuo-spatial tasks in developmental disorder groups such as Autistic Spectrum Disorder (e.g. Davies, Bishop, Manstead & Tantum, 1994) and WS (e.g. Farran et al., 2003; Van Herwegen, Farran & Annaz, 2011). The two groups did not differ in RCPM scores, which indicates that matching was successful, $t(32) = .12$, $p = .91$.

Both groups also completed the British Picture Vocabulary Scale II (BPVS; Dunn, Dunn, Whetton & Burley, 1997) which assessed verbal ability (receptive vocabulary). The WS group's BPVS score was significantly higher than the TD group, $t(32) = 6.52$, $p < .001$, demonstrating a typical pattern of WS performance as verbal ability was relatively strong compared to non-verbal ability. Table 1 illustrates WS and TD participants' CA, BPVS and RCPM scores.

Table 1 about here

Table 1

WS and TD Participants' Chronological Age, BPVS and RCPM Scores.

2.2. Materials and Apparatus

2.2.1. One-shape figures. Participants' ability to use each type of facilitation was first assessed in single black-lined figures. Models comprised of a square, circle or diamond shape (each 250mm², .75 point line weighting); each model was presented separately, centrally on a portrait orientation A4 sheet of paper. The same model was used in each facilitation condition, whilst the response sheet changed across facilitation types (see Section 2.2.4). Colour was not used as a facilitation condition for one-shape figures as it provided no additional facilitation.

2.2.2. Two-shape figures. A circle and diamond (identical to those used in the one-shape condition, 250mm², .75pt line weighting) were overlapped in order to create black and coloured two-shape figures (see Section 2.2.4). In the black shape condition a circle was placed above a diamond that overlapped the circle on a vertical plane. Both the model and response sheet facilitation types were coloured black. In the coloured condition, figures consisted of a green circle and a yellow diamond; the circle was presented to the right of the diamond, both overlapped horizontally. The model and response sheet were both coloured, with the response sheet colours corresponding to the colours of the model (that was identical in all facilitation conditions).

2.2.3. Three-shape figures. A diamond, circle and square (identical to those used in the One-shape Condition, 250mm², .75pt line weighting) were overlapped to create black and coloured three shape figures (see Section 2.2.4). The spatial arrangement of shapes for the colour and black condition for each facilitation type can be seen in Figure 1. Coloured three shape figures comprised of a yellow circle, red square and blue diamond. Note that the colour associated with each shape was different to those in the two-shape figures. Colour was used to increase the salience of individual shapes and it was not intended that participants associated a particular colour with a specific shape. As in the two shape figures, the colour of the model corresponded to the colour of the response sheet facilitation for black and coloured figures.

***2.2.4.* Facilitation types.** Examples of each of the facilitation types can be seen in Figure 1. In the coloured condition the colouring of facilitation elements for each shape corresponded in spatial location and colour to the shape in the model.

2.2.4.1. No Facilitation. In this condition participants were given a blank piece of A4 paper presented in a portrait orientation; therefore participants had to self-generate all planning and drawing decisions as no facilitation was provided.

2.2.4.2. Half Shapes. In the Half Shapes condition participants were provided with half of each shape on the response sheet, therefore the shape was completed by producing the remaining half of each shape present in the model. Participants replicated the upper-most right angle of a square and the right-hand half of diamonds and circles.

2.2.4.3. Edge Markers. Edge markers were presented at the apices of each shape to encourage participants to perceptually group the markers to form each target shape by completion across the gap between markers. In diamonds and squares, markers were formed by two 5mm lines which formed a right angle junction to mark the form of the four apices of each shape. For circles, 5mm arcs marked the upper-, lower-, left- and right-most portions of the shape to encourage participants to group the arcs as a circle. This ensured that all shape-types were marked by four markers to indicate the form of the shape.

2.2.4.4. Guide Dots. Guide dots were provided so that participants could join the dots to complete each shape from the model. The forms of square, diamond and circle shapes were indicated by eight 5mm radius dots (coloured in a corresponding manner to the model). Dots were placed at the apices of the diamond and square and 25mm along each sideline at equidistant points. In circles the dots were placed equidistantly at 25mm points around the circumference of the circle.

2.2.4.5. Starting Point. In the Starting Point condition the location to commence drawing of each shape was indicated by a single 5mm radius dot (coloured corresponding to the model). For squares the starting point was at the top left of the shape, the uppermost point of a diamond and a circle. These locations were in line with previous literature that described the typical starting location for drawing of each shape (Braswell & Rosengren, 2000; Hayes, 1978; Van Sommers, 1989).

Figure 1 About Here

Figure 1. Facilitation provided to assist overlapping figure replication.

2.3. Procedure

Participants first completed the one-shape condition in order to assess competency of shape replication with each type of facilitation when shapes were in isolation. One-shape trials allowed participants to become familiar with the types of facilitation that would be used to draw more complex, multiple shape figures. Presentation of facilitation types and shapes were randomised for each participant. Presentation of two- and three-shape figures was counterbalanced between participants. Black and colour shape conditions were presented in blocks and were counterbalanced. Participants were shown a model and were given the corresponding response sheet, an HB pencil and an eraser to correct any errors. In the No Facilitation condition participants were shown the model and asked to copy it exactly on to a blank sheet of paper. For Half Shape figures, participants were told by the experimenter "I've already drawn half the shape(s) for you, can you draw the rest of the shape(s) to make it look like this/these one(s) (experimenter pointed to model)?". In the Edge Markers condition participants were told "Do you see these (experimenter pointed to edge markers) these show you the edge of the shape(s). Do you think that you can join these to make a shape/shapes like this (experimenter pointed to model)?". In the Guide Dots condition participants were instructed "Do you see these dots? You can join the dot(s) to make this shape /these shapes (experimenter pointed to model)". In the Starting Point condition participants were told "Do you see this dot/ these dots? This dot/these dots tell(s) you where to start drawing to copy this shape/ these shapes (experimenter pointed to the model)". Participants were permitted to correct any perceived errors but only final drawings that were offered were analysed. The angular deviation of drawn lines was measured for squares and diamonds. Eccentricity was measured for circles.

***2.3.1.* Coding drawings: Percentage correctness.** In order to make drawing performance comparable across each shape-type the angular deviation of diamonds and squares and the eccentricity of circles were converted to a 'percentage correctness' score (squares and diamonds: [absolute angular deviation of drawn line/ angle in model figure [e.g. 90° for a square or for diamonds 45° or 135°]]*100; Circles: [length of axis/ 5mm model line length]*100). This value provided a measure of how accurately participants drew each shape on a comparable scale, indicating the divergence of drawing from its exact form. A line in a diamond or square that was drawn with no angular deviation therefore achieved 100% drawing accuracy.

In order to ensure that measurements of the angular deviation of lines were reliable, a second coder measured angles from two randomly selected participants from each group (11.76% of drawings). The correlation between coders indicated high inter-rater agreement, r (N = 1040 angles) = .84, $p < .001$, therefore the experimenter's measurements were used for analysis.

3. Results

3.1. One-Shape Drawing Accuracy

A group (WS, TD) by shape (square, diamond, circle) by facilitation type (No Facilitation, Half Shapes, Edge Markers, Guide Dots, Starting Point) analysis of variance (ANOVA) was performed on the percentage correctness of drawn lines in each one-shape figure. There was no effect of group, $F(1, 32) = 2.68$, $p = .11$, $\eta_p^2 = .08$ (WS M = 85.02%, SE = 1.33%; TD M = 88.11%, SE = 1.33%) suggesting that drawing performance was comparable between WS and TD participants. All further interactions with the group variable were non-significant, $p > .05$. There was a significant effect of facilitation type, $F(4, 128) = 27.44$, $p < .001$, $\eta_p^2 = .46$, this can be seen in Figure 2 which illustrates each group's shape drawing accuracy with each facilitation type.

Figure 2 About Here

Figure 2. The effect of facilitation type for drawing accuracy of single (baseline) shapes by each group: (Mean: SE).

The percentage for each facilitation type was significantly different across all conditions, except for comparable drawing accuracy between the No Facilitation and Start-Point condition (p = .52) and the Edge Marker and Guide Dots condition (p = .13). Therefore, overall drawing accuracy was greatest in the Edge Marker and Guide Dots conditions and least accurate in the No Facilitation and Start-Point conditions. Half Shapes were an intermediary as performance was not significantly different from any condition, but was significantly greater than drawing in the No Facilitation condition.(p = .004).

There was a significant effect of shape ($F(2, 64) = 27.85$, $p < .001$, $\eta_p^2 = .47$) as squares (M = 93.97%, SE = 1.05%) were drawn significantly more accurately than diamonds (M = 85.01%, SE = 1.59%) and circles (M = 80.71%, SE = 1.53%), and diamonds were drawn significantly more accurately than circles. There was a significant interaction of facilitation type by shape, $F(8, 256) = 11.10$, $p < .001$, η_p^2 = .26. Squares and circles were drawn significantly more accurately than diamonds ($p < .001$ for all conditions) except in the Guide Dots condition where there were no significant differences between drawing accuracy of any of the shapes ($p > .05$).

3.2 Two-Shape Drawing Accuracy

A group (WS, TD) by shape (diamond, circle) by facilitation type (No Facilitation, Half Shapes, Edge Markers, Guide Dots, Starting Point) by colour (black, colour) ANOVA was performed on the percentage correct of drawn lines in each two-shape figure. There was a significant effect of group ($F(1,32) = 6.76$, $p = .01$, $\eta_p^2 = .17$) as drawing accuracy was significantly greater in the TD group relative to the WS group (WS $M = 73.15\%$, $SE = 3.02\%$; TD $M = 84.26\%$, $SE = 3.02\%$). There was a significant effect of facilitation ($F(4, 128) = 10.58$, $p < .001$, $\eta_p^2 = .25$), this can be seen in Figure 3 which depicts each group's drawing accuracy with each facilitation type.

Figure 3 About Here

Figure 3. The effect of facilitation type for drawing accuracy of two shapes by each group. (Mean: SE).

There were significant differences in drawing accuracy between all facilitation types ($p < .001$) except between the No Facilitation and Start-Point condition ($p = .39$) and between the Half Shapes condition and both Edge Markers ($p = .58$) and Guide Dots ($p = .52$) conditions. Similarly to single shape drawing the most accurate shapes were produced in the Edge Markers and Guide Dots conditions although the Half Shapes condition benefitted two shape drawing which was not seen for single shape drawing. Least accurate drawing was observed in the No Facilitation and Starting Point conditions, again this was also the case for single shape drawing. The effect of colour was not significant ($F(1, 32) = .56$, $p = .46$, $\eta_p^2 = .02$), all other main effects and interactions were non-significant, $p > .05$.

3.3 Three-Shape Drawing Accuracy

A group (WS, TD) by shape (square, diamond, circle) by facilitation type (No Facilitation, Half Shapes, Edge Markers, Guide Dots, Starting Point) by colour (black, colour) ANOVA was performed on the percentage correct of drawn lines in each three-shape figure. In contrast to two-shape drawing, but in line with one-shape drawing, there was no effect of group, $F(1, 32) = 3.52$, $p = .07$, $\eta_p^2 = .10$ (WS: M = 73.90%, SE = 3.11%; TD: M = 82.16%, SE = 3.11%). There was a significant effect of colour ($F(1, 32) = 7.34$, $p = .001$, $\eta_p^2 = .19$) as coloured figures (M = 80.38%, SE = 2.51%) led to significantly greater drawing accuracy than black figures (M = 76.68%, $S E$ = 2.21%). There was a significant effect of facilitation type ($F(4, 128) = 6.80$, $p < .001$, $\eta_p^2 = .18$) that can be seen in Figure 4 which illustrates both groups' drawing accuracy with each type of facilitation.

Figure 4 about here

Figure 4. The effect of facilitation type for drawing accuracy of three shapes by each group. (Mean: SE).

Figures drawn in the Edge Markers condition were significantly more accurate than figures drawn in the No Facilitation ($p = .04$), Guide Dots ($p < .001$) and Starting Point ($p < .001$) conditions. Figures drawn in the Half Shapes condition were significantly more accurate than figures drawn in the Guide Dots ($p = .01$) and Starting Point ($p = .003$) conditions. Shapes drawn in the Starting Point condition were significantly less accurate than in the No Facilitation condition ($p = .02$). The most accurate shapes were therefore drawn in the Half Shapes and Edge Marker (previously found in the single and two-shape figures) conditions, followed by the No

Facilitation condition, with the least accurate shapes drawn in the Guide Dots (which had previously led to the greatest drawing accuracy of one and two shapes) and Starting Point conditions.

A significant effect of shape, $F(2, 64) = 25.95$, $p < .001$, $\eta_p^2 = .45$ was similar to that observed for one-shape figures; it resulted from significantly more accurate drawing of squares (M =86.07%, SE =1.89%) than diamonds (M = 76.68%, SE = 2.41%; $p < .001$) and circles (M = 71.35%, SE = 3.08%; $p < .001$), and significantly more accurate diamonds than circles ($p = .03$). There was a significant interaction of colour by facilitation, $F(4, 128) = 9.41$, $p < .001$, $\eta_p^2 = .23$. This resulted from significantly less accurate drawing of black shapes in the Guide Dots condition compared to in the coloured condition, $t(33) = 5.03$, $p < .001$. In all other facilitation types, similar to two-shape drawings, there was no difference in drawing accuracy between coloured and black conditions, $p > .05$.

There was a significant interaction of colour by shape $F(2, 64) = 5.57$, $p = .001$, $\eta_p^2 = .15$. This resulted from significantly more accurate drawings of diamonds when figures were coloured compared to black, $t(33) = 5.21$, $p < .001$. Squares and circles were drawn with comparable accuracy between coloured and black figure conditions, $p > .10$. Therefore the main effect of colour was solely driven by more accurate drawing of diamonds when facilitation elements were coloured compared to black.

There was a significant interaction of facilitation type by shape $F(8,256) = 2.72$, $p = .001$, $\eta_p^2 = .08$. In the Half Shapes and Guide Dots conditions all shapes were drawn with comparable accuracy, $p > .05$. Squares were drawn significantly more accurately than circles in all conditions ($p < .001$), but there were no differences in drawing accuracy between diamonds and squares in all conditions ($p > .05$), except in the Starting Point condition where diamonds were more accurate than circles (p = .001). All other interactions were non-significant, $p > .05$.

4. Discussion

This is the first study to demonstrate that drawing deficits in WS are amenable to facilitation and can even be improved to the level of non-verbal ability matched TD participants; this is despite evidence of developmentally delayed and atypical drawing in WS when drawing complex figures (e.g. Bertrand et al., 1997; Hudson & Farran, 2011). The study also refutes a local processing preference in WS as few group differences emerged, even for the most complex figures. That is, global forms were well-depicted in the WS group. Use of the facilitation methods relied on the WS group perceiving and acting upon the global configuration of the elements provided for facilitation. Additionally participants had to perceptually group facilitation elements to exploit these cues when drawing. The facilitation that was used assisted participants in their understanding of the spatial relations between whole shapes and the component lines of shapes within the complex overlapping figures. Hudson and Farran (2011) demonstrated that when drawing complex figures containing many spatial relations, a WS group showed significantly poorer performance than a TD group. Here we demonstrated that the difficulty that individuals with WS experience with replicating multiple spatial relations is not impervious to remediation. Importantly, this finding can inform interventions for individuals with WS to improve drawing and potentially handwriting ability.

Facilitation methods improved drawing accuracy in both groups when copying single, two and three shapes. Therefore even at the most basic level (single shapes) drawing was amenable to facilitation in both groups. The efficacy of the facilitation methods relied on participants' ability to perceptually group facilitation elements using proximity, orientation and closure, to scaffold their drawing performance. Thus, both the WS and TD groups showed that perceptual grouping could be used to guide drawing. This study extends previous research (Farran, 2005; Grice et al., 2003; Wang et al., 1995) to show that perceptual grouping is evident in WS and can be acted upon in order to draw.

Both groups' ability to group elements led to improvement in drawing accuracy beyond self-generated accuracy of shape-drawing (No Facilitation condition). When drawing one and two shapes, drawing accuracy was lowest when no facilitation was provided or when a starting point was provided. These conditions afforded minimal facilitation as participants had to make numerous planning decisions, such as changes in direction and line lengths; this suggests that when planning decisions are high, drawing accuracy is low. Grouping by closure to complete across the gaps using Edge Markers was the most successful facilitation method; it was the only condition to benefit drawing of single, two and three shapes. This is likely because edge markers provided participants with information about the precise length and angle of lines that should be drawn. The participant therefore had to make very few graphic planning decisions, and drawing accuracy was resultantly high. Although Guide Dots provided similar assistance, the angle of the turning point of each apex had to be self-generated and the dots became confusable and led to inaccurate drawing of three shapes. Therefore explicit cueing for where lines should change direction (edge markers) are an important influencing factor for drawing accuracy.

Colouring of individual shapes only benefitted drawing of three shapes by making the component elements more distinguishable (particularly in the Guide Dots condition), and had no effect on drawing accuracy of one or two shapes. Colouring of elements may have allowed for verbalisation of facilitation parts as a strategy to aid drawing and compensated for poor spatial localisation ability when drawing diamonds. The benefit of facilitation using colour supports the work of Nakamura et al. (2001; 2002) who showed a similar effect in a WS group, but lacked a TD control group. The current study, in line with Farran and Dodd (submitted) suggests that the benefit of colour is not unique to WS as the TD group also showed a benefit when replicating coloured diamonds.

The particular benefit of colour on diamond drawing is interesting as unpublished work from our lab has suggested that both WS and TD groups struggle to draw diamonds; diamonds are one of the final shape-types that TD children master (at seven years old; Cox, [2005]) due to the complex component oblique lines. Overall, when drawing one and three shape figures participants drew squares more accurately than diamonds and diamonds more accurately than circles. Colouring of facilitation elements might have served to reduce perceptual errors in the location of oblique lines that form diamonds (Koehn, Roy & Barton, 2008). Therefore, in the current experiment, colouring of lines differentiated the facilitation elements that belonged to each component shape, leading to less uncertainty about the elements to join in order to draw oblique lines at the correct orientation.

The data suggest that in order for facilitation to be beneficial to drawing, the facilitation cues must be readily grouped and distinct; facilitation of drawing is a trade-off between reducing planning demands and providing easily distinguishable and perceptually grouped elements. This is evident when participants drew three shapes in the Guide Dots condition, where drawing accuracy was significantly greater in the coloured condition compared to the black condition. This is likely the result of a failure in the black dot condition to locate the correct dots to join when the dots were not easily distinguished in both groups. If one examines the schematic of this condition in Figure 1 it is apparent that precisely locating the correct dots to join is a complex task, made much less demanding by colouring of dots. Grouping of coloured dots likely facilitated participants' ability to localise and correctly join dots to form each shape. In the Half Shapes and Edge Markers conditions successful use of the facilitation cues relied on perceptually grouping the cues, which was not assisted by use of colour to indicate which facilitation elements each shape was comprised of. Although in the Edge Marker condition there were twelve elements on the response sheet, the clear grouping of facilitation elements for each shape meant that these elements were distinct and were less confusable than in the Guide Dots condition. This suggests that provision of many reductions in graphic planning demands does not facilitate drawing and instead reduced drawing accuracy. In order to facilitate drawing, elements must be easily distinguishable and readily perceptually grouped.

The results of this study have implications for educational remediation in both WS and TD children that are struggling with graphomotor performance. It is estimated that children engage in graphomotor tasks for 31-60% of their school day (McHale & Cermak, 1992) and there is a wide body of evidence to suggest that handwriting legibility is associated with academic achievement (e.g. Simner, 1996; see Feder & Majnemer, [2007] for review). Therefore children displaying poor graphomotor skills are likely to fall behind their peers as a result of the volume of writing required in a school day, which impacts upon academic achievement and also psychosocial development (such as self-esteem and poor attention; Feder & Majnemer, 2007; Sandler et al., 1996). Currently interventions typically involve enhancing fine motor skill (e.g. Case-Smith, 2002; Dibek 2012) although the results of the current study suggest that relatively simple interventions can improve graphomotor performance. The strategies could be implemented in children that already have graphomotor deficits or might be useful for training; for example in the current study individuals with WS with established graphomotor deficits as well as TD children showed a relative benefit of drawing accuracy using facilitation when compared to self-generated performance. Coloured guide dots could be used in young, pre-school children to foster good graphomotor performance when drawing shapes as a precursor for handwriting performance as there is a relationship between drawing and handwriting performance (e.g. Adi-Japha & Freeman, 2001). Handwriting performance in early school-age children could be facilitated by using coloured edge makers for individual letters that provide clear cues to line length and directions; edge markers led to the greatest accuracy in the current task when completing the most complex figures and so might be most useful for letter-formation training. This would familiarise children with configuration of letters, as children gain confidence with forming letters facilitation could be reduced (such as providing only starting points for letters) to encourage children to self-generate more graphomotor decisions.

These strategies would be inexpensive and simple to implement. The techniques are suitable for use in domestic settings without the need for specialist equipment. This is important as remediation of graphomotor deficits could potentially be of benefit to children's educational and psychosocial development. Further work is needed to ascertain the efficacy of these types of intervention although this study goes some way to suggest that simple interventions can improve graphomotor performance. This study has suggested that there is a trade-off between reducing planning demands and providing readily distinguishable and perceptually grouped elements; those wishing to devise graphomotor training techniques should make careful consideration of this when creating interventions.

In summary, the results of this study provide the first evidence to show that individuals with WS can be facilitated to draw complex figures to the same level as TD participants. These results suggest that although individuals with WS struggle to draw complex figures with multiple spatial relations (Hudson & Farran, 2011), they can be assisted in drawing complex shapes. These findings refute a local processing bias in WS as cohesive figures were drawn and suggest that a difficulty with drawing multiple spatial relations can be remediated. Drawing accuracy was greatest when participants were provided with half of shapes, edge markers and Guide Dots, with least drawing accuracy seen when no facilitation was provided or only a starting point was presented. In order to increase drawing accuracy, facilitation elements should reduce planning demands but should be easily distinguished and clearly grouped to form each component shape. This suggests that the graphomotor difficulties with depicting diamonds present in both groups can be attenuated by facilitation. Colouring of figures facilitated participants' ability to draw diamonds in three shape figures and also improved drawing accuracy overall in three shape figures (particularly in the Guide Dots condition). Colour served to increase the distinction between shapes and increased participants' ability to differentiate between facilitation elements on the response sheet. These findings can be applied to remediation strategies for drawing and handwriting deficits in children with WS and TD children struggling to acquire graphomotor skills.

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Figure Captions.

Figure 1. Facilitation provided to assist overlapping figure replication.

Figure 2. The effect of facilitation type for drawing accuracy of single (baseline) shapes by each group: (Mean: SE).

Figure 3. The effect of facilitation type for drawing accuracy of two shapes by each group. (Mean: SE).

Figure 4. The effect of facilitation type for drawing accuracy of three shapes by each group. (Mean: SE).