Thinking inside the box: Spatial frames of reference for drawing in Williams syndrome and typical development.

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Highlights

1. TD and WS groups have difficulty disengaging from orientation cues when drawing.
2. When drawing shapes inside a frame, TD children exhibit a scaling bias.
3. Individuals with WS show a global, not local processing style when drawing.
4. Individuals with WS draw diamonds, but not squares, less accurately than non-verbal matched TD children.

Abstract

Background: Successfully completing a drawing relies on the ability to accurately impose and manipulate spatial frames of reference for the object that is being drawn and for the drawing space. Typically developing (TD) children use cues such as the page boundary as a frame of reference to guide the orientation of drawn lines. Individuals with Williams syndrome (WS) typically produce incohesive drawings; this is proposed to reflect a local processing bias. **Aims:** Across two studies, we provide the first investigation of the effect of using a frame of reference when drawing simple lines and shapes in WS and TD groups (matched for non-verbal ability). **Methods and Procedures**: Individuals with WS (N=17 Experiment 1; N=18 Experiment 2) and TD children matched by non-verbal ability drew single lines (Experiment One) and whole shapes (Experiment Two) within a neutral, incongruent or congruent frame. The angular deviation of the drawn line/ shape, relative to the model line / shape, was measured. **Outcomes and Results:** Both groups were sensitive to spatial frames of reference when drawing single lines and whole shapes, imposed by a frame around the drawing space. **Conclusions and Implications:** A local processing bias in WS cannot explain poor drawing performance in WS.

What this paper adds

This is the first study to assess whether individuals with WS can effectively use spatial frames of reference when drawing, and in doing so acts as a direct test of the assertion that visuo-spatial cognition in WS is characterised by a local processing bias (Bellugi, Sabo & Vaid, 1988). This study also investigated the influence of a frame of reference in TD children to a more fine-grained level than previous studies. Results suggest that the WS group, like the TD participants, were influenced by the surrounding orientation cues provided by the frame, and thus refutes the local processing bias hypothesis. The Drawing Orientation

Task (DOT) and the whole-shape drawing task are suitable for use with clinical groups such as individuals with constructional apraxia or autism to investigate use of spatial frames of reference when drawing.

Keywords: Drawing, Williams syndrome, Development, Spatial, Orientation, Processing Style, Frames of Reference, Oblique lines.

1. Introduction

In order to understand the relationship between elements within a visual scene it is necessary to impose systems for describing the relative positions and orientations of those elements or parts. Gestalt theories of visual perception described this as ‘spatial frames of reference’ which Rock (1992, pg. 404) defined as “a unit or organization of units that collectively serve to define a coordinate system with respect to which certain properties of objects […] are gauged”. Based on this definition, the object or parts within a visual scene can be used as a frame of reference for locating other objects or parts within the scene. Equally, a frame that surrounds an image can provide a useful frame of reference for locating the relative positions of the elements within the image.

The ability to use a spatial frame of reference is necessary for producing accurate copies when drawing; that is, drawing requires the individual to determine a coordinate system by which to encode the relations of parts of a visual scene and to use this to replicate elements of a model and their relative positions. The drawer must be able to transfer the spatial frame of reference from the model to the drawing space to guide copying. During the course of drawing, the spatial frame of reference for the copy must also be updated to reflect the elements that have been completed and those that are yet to be drawn.

In a drawing task, Naeli and Harris (1976) provided evidence to suggest that typically developing (TD) four and five year-olds can recognise the congruence of orientation of a model and a surrounding border (a frame of reference) to increase “goodness of copy” (defined as the presence of three lines in the correct orientation in a four line figure). Similarly, drawing squares on A4 paper facilitates drawing accuracy by reference to the page boundary as a frame of reference to guide line orientation (Broderick & Laszlo, 1987; 1988). It is hypothesised that the presence of a border or page edge might reduce planning demands by allowing participants to integrate the boundaries provided by the border into their spatial frame of reference. This frame of reference provides additional reference points to guide orientation, distance and changes in the direction of drawn lines. Across two studies, we investigate the effect of using a frame as a reference when drawing simple lines and shapes in both TD children and in individuals with Williams syndrome (WS), for whom drawing is a specific weakness (Bertrand, Mervis & Eisenberg, 1997). To-date no studies have assessed whether individuals with WS can effectively use spatial frames of reference when drawing.

WS results from a deletion of approximately 28 contiguous genes on chromosome 7q11.23 (Nickerson et al., 1995; Osbourne, 2012; Tassabehji, 2003) with a prevalence of approximately one in 7500 to one in 20,000 live births (Morris et al., 1988; Strømme, Bjømstad & Ramstad, 2002). WS is typified by mild to moderate learning difficulties, and a disparity between relatively strong verbal ability and poor visuospatial skills (Ewart et al., 1993; Farran & Karmiloff-Smith, 2012; Ferrero et al., 2007; Mervis & John, 2008; Smoot, Zhang, Klaiman, Schultz & Pober, 2005).

Errors in drawings made by individuals with WS resemble those made in early typical development; that is, drawings typically lack cohesion (Bellugi, Lichtenberger, Jones, Lai & St. George, 2000; Bertrand et al., 1997; Georgopoulos, Georgopoulos, Kuz & Landau, 2004). The incohesive drawings seen in WS have been used to support the hypothesis that visuo-spatial cognition in WS is characterised by a local processing bias (Bellugi, Sabo & Vaid, 1988) in which details of a visual scene are preferentially produced without integration of those parts into the correct global configuration. However, detailed analysis of drawing strategies in WS suggest that the drawings of individuals with WS become increasingly diverged from those of TD children, as the complexity of the to-be-drawn image increases (Hudson & Farran, 2011). Evidence suggests that a local processing bias is too simplistic an account to explain the characteristic drawing observed in WS. For example, replication of a model line drawing of a house is not biased towards replicating the local elements over the more global elements in WS, relative to TD controls (Hudson & Farran, 2013a).

Poor drawing in WS relates to reduced attention to the model image (Hudson & Farran, 2013a) and, for relatively complex images, a difficulty in reproducing the spatial relations between the parts of an image, coupled with atypical replication strategies (Farran & Dodd, 2015; Hudson & Farran, 2011; 2013b). Thus, although a difficulty in reproducing the spatial relations between the parts of an image nods towards the local processing bias hypothesis, this is intertwined with a number of other atypical characteristics in WS, and does not necessarily support the local processing bias hypothesis (e.g. impaired spatial relationship production could relate to impaired spatial category understanding; Farran & Jarrold, 2005; Laundau & Hoffman, 2005; Farran, Atkinson & Broadbent, 2016). Here, by presenting a frame as a spatial frame of reference in drawing tasks, we will directly determine whether this influences participants' drawing accuracy. If individual with WS have a local processing bias, they should not be influenced by the frame.

Beyond the literature on drawing ability in WS, a deficit in the use of spatial frames of reference has been documented on spatial tasks from early in development in WS. Brown et al. (2003) demonstrated that infants with WS (mean age 29 months) were unable to use their body as a frame of reference when performing simple eye movements, which is an ability that emerges at three months in TD infants. In addition, individuals with WS have poor understanding of the configuration of objects in both a small-scale array (Nardini, Atkinson, Braddick & Burgess, 2008) and a large-scale environment (Farran et al., 2015). This is also suggestive of an impaired ability to use or construct a spatial frame of reference in WS. In light of the evidence above which suggests a deficit in using of spatial frames of reference in WS, the current study assessed the spatial frames of reference provided by a frame. The frames can be used as a reference to provide cues to orientation when drawing single lines (Experiment One) and whole shapes (Experiment Two). These experiments investigated whether deficits in the use of spatial frames of reference are present in the drawing domain in WS and whether use of the orientation cues provided by these frames differs from a non-verbal matched TD control group.

2. Experiment One: The Drawing Orientation Task (DOT)

2.1. Introduction

The Drawing Orientation Task (DOT) is a novel drawing task inspired by the perceptual Rod and Frame Test (Witkin & Asch, 1948). In the original Rod and Frame Test participants are seated in a darkened room and attempt to vertically orientate a rod within a tilted frame. Participants typically place the rod at the same angle as the frame and so are unable to overcome the cues provided by the surrounding frame of reference (Daini, Wenderoth, & Smith, 2003; Li & Martin, 2005; Rock, 1992). This might represent a bias towards the nearest gravitational axis (vertical, horizontal or diagonal; Beh, Wenderoth & Purcell, 1971). Participants with a global processing style (which is similar to field-dependence) have difficulty disengaging from the orientation referents provided by the frame, biasing alignment of the rod towards the frame. Conversely, participants with a local processing style (which is similar to field-independence) place the rod in isolation of the frame, at the true vertical, by disengaging from the spatial frame of reference that the frame provides (Milne & Szczerbinski, 2009).

The DOT was used to determine whether WS and TD groups were sensitive to orientation cues provided by a square frame in the drawing space when copying a single line (vertical, horizontal or oblique). If individuals with WS have a local processing bias then drawing accuracy should be unaffected by the orientation of the frame; drawing should occur in isolation of the frame's orientation influence. Nardini et al. (2008) suggested that individuals with WS have a difficulty with using array-based reference frames that rely on selection of a stable landmark as a referent for action, thus drawing in the current task might occur in isolation of the frame. However in the TD group participants might use the axes provided by the frame (e.g. Beh et al., 1971). In this case participants should show biased placement of the line towards the nearest axis of the frame which affects accuracy of the drawn line (see Figure 1). Therefore drawing will be accurate when the line and frame are congruently orientated (e.g. a vertical line in a square frame orientated at 90° from the horizontal) and less accurate when the line and frame are incongruent (e.g. a vertical line in 35° frame). If the WS group do not show a local bias, performance will resemble that of the TD group.

Figure 1

2.2. Method

2.2.1. Participants

Seventeen participants with WS were recruited through the Williams Syndrome Foundation UK (seven male, ten female; fourteen right-handed, three left-handed). Diagnosis of WS in all participants had previously been confirmed by a clinician and a positive Fluorescence In Situ Hybridisation (FISH) (de Souza, Moretti-Ferrereira & Rugolo, 2007). The control group consisted of seventeen TD participants (individually matched to the WS group for non-verbal ability) that were recruited through advertisements at the University of Reading (nine male, eight female; sixteen right-handed, one left-handed). Because the experimental tasks are visuospatial in nature, we chose a matching measure that was within the same (visuospatial) domain as the experimental task, but not so close in the abilities that were tapped into that we risked matching away any group differences (for a discussion of matching, see Jarrold & Brock, 2004). That is, participants were matched by performance on the Raven's Coloured Progressive Matrices scores (RCPM; Raven, 1993). RCPM is a standardised measure of non-verbal / visuospatial reasoning that has previously been used successfully as a matching measure for visuospatial tasks in developmental disorder groups (Davies, Bishop, Manstead & Tantum, 1994; Facon & Nuchadee, 2010). Furthermore, item and error analysis of RCPM performance has demonstrated that performance on the RCPM is supported by typical mechanisms in WS (Van Herwegen, Farran & Annaz, 2011). This verifies that the RCPM is a suitable tool for matching participants on visuospatial ability. The WS and TD groups did not differ in RCPM scores, suggesting that matching was effective, $t(32)=.12$, $p=.91$. Table 1 illustrates WS and TD participants' chronological age and RCPM scores. There were no between group difference in sex or handedness, $p > .05$.

Table 1

2.2.2. Materials and Apparatus

Participants replicated a 30mm long horizontal, vertical or oblique (45°) line inside a frame, using an HB pencil. Frames consisted of a 250mm² square presented at 0°, 5°, 15°, 25°, 35°, 45°, 55°, 65°, 75° and 85° of orientation from the vertical, printed on A4 paper. A black cardboard circular (5184mm²) aperture was placed over the page for each trial, which was secured with a clipboard; this was in order to minimise spurious orientation cues from the edge of the paper within the drawing space. In the baseline condition the line was drawn without the use of a square frame to assess drawing accuracy without the influence of a frame. There were 11 trials (one for each orientation and baseline condition) in each of the three model line-type conditions (vertical, horizontal, oblique).

In the practice condition participants copied model lines (vertical, horizontal, oblique) by joining two dots (30mm apart) to replicate each line-type (three trials per line-type) inside frames at 0° (square), 45° (diamond) and 75° frame. For both experimental and practice trials the model line (30mm in a horizontal, vertical or oblique orientation) was presented on A4 paper in a portrait orientation. The lines used and examples of frames can be seen in Figure 2.

Figure 2

2.2.3. Procedure

Block presentation of line-types (vertical, horizontal, oblique) was used in order to reduce potential difficulties with switching between line-orientations which could have led to maintenance of previous orientations; all trials were randomised within each block for each participant. Participants completed the practice trials first. Participants were shown the model and were given the printed frame of reference beneath the circular aperture cardboard overlay; it was explained that participants could copy the model line by joining the dots and that these trials were a practice for the following trials in which the lines were to be drawn without the dots. Once the three practice trials were completed and it was clear that participants understood the task, the experimental trials commenced. Participants were shown the same model lines as the previous practice trials and were instructed to replicate the line exactly within the frame. For the experimental trials, however, there were no dots to be joined and drawing was self-guided. In the baseline condition participants were instructed to copy the model line and no frame was provided (just the circular aperture). Errors were permitted to be corrected and only final replications were analysed. The angular deviation of each line with respect to the model was recorded.

2.3. Results

Absolute angular deviation of drawn lines from the model line (model lines: 0°, 45°, 90°) was calculated (see Figure 3). To determine reliability of measurement, a second coder measured the angular deviation of all drawn lines for two participants that were randomly selected from each group (11.76% of each group). Consistency between the angles measured by the experimenter and second coder was good $r(N = 120) = .98$, $p < .001$, therefore the angular deviations recorded by the experimenter were used in analyses.

ANOVA was carried out to determine whether any frame-type led to an increase or decrease in angular deviation of the drawn line relative to the model line. The ANOVA included a between participants factor of group (WS, TD) and within participant factors of line-type (vertical, horizontal, oblique) and frame congruence (the difference between the angle of the to-be-drawn line and the angle of the frame, e.g. for 0° frame congruence is provided by the 0° frame for horizontal and vertical lines, but the 45° frame for oblique lines). Frame congruence had eleven levels: baseline, 0°, 5°, 15°, 25°, 35°, 45°, -35°, -25°, -15°, -5°.

Figure 3

There was a significant main effect of group, $F(1,32) = 4.20$, $p = .05$, $\eta_p{}^2 = .12$ as the WS group ($M = 23.09°$, $SE = 2.63°$) drew with significantly more angular deviation than the TD group ($M = 15.48°$, $SE = 2.63°$). A significant effect of line-type, $F(2,64) = 7.30$, $p = .001$, $\eta_p{}^2 = .19$ resulted from greater angular deviation in oblique lines ($M = 26.80°$, $SE = 3.61°$) compared to both vertical ($M = 14.49°$, $SE = 2.07°$, $p = .001$) and horizontal lines ($M = 16.57°$, $SE = 2.22°$, $p = .02$), but no difference between vertical and horizontal lines ($p = .46$). There was a significant effect of frame congruence, $F(10,320) = 6.64$, $p < .001$, $\eta_p{}^2 = .17$. This is best explored within the context of the significant interaction between line-type and frame congruence, $F(20, 640)=20.10$, $p=.003$, $\eta_p{}^2 =.06$. There was a main effect of frame congruence for all three line types: Horizontal, $F(10, 320)=3.63$, p<.001, $\eta_p{}^2 =.10$; Vertical, $F(10, 320)=5.12$, p<.001, $\eta_p{}^2 =.14$; Oblique, $F(10, 320)=3.15$, p=.001, $\eta_p{}^2 =.09$. Sidak corrected pairwise comparisons demonstrated that for Horizontal and Vertical lines this was due to less angular deviation in the baseline (no frame) condition than a number of the frame conditions (Horizontal: baseline < 15°, 25°, -35°, -25°, -15°; Vertical: baseline < 15°, -25°, -15°), but no difference across frame conditions (p>.05 for all). The main effect of frame congruence for oblique lines did not reveal a systematic pattern; the baseline condition did not differentiate from the frame conditions (p>.05 for all; the source of the interaction). There was also less angular deviation at a frame congruence of -35° than at -15° (p=.01). This most likely demonstrates that the difficulty with drawing oblique lines (Beery 1997) introduced sufficient variance to overshadow any effects of the frame of reference. All remaining interactions were non-significant, $p > .05$.

Although not supported by a significant interaction, observation of Figure 3 demonstrates angular deviation in the oblique drawn lines of the WS group to the extent that these lines were drawn to closely resemble a horizontal or vertical line (i.e. 45° angular deviation; p>.05 for one sample t-tests against 45° for 0°, 5°, 15°, -25°, -15°, -5° frame congruence). This is most apparent with greater frame congruency and begs the question as to whether the apexes of the frame are being used by this group rather than the frame edges. However, without this a significant interaction, this remains a tentative suggestion.

In order to determine whether the effects of incongruency for vertical and horizontal lines was related to experience and / or level of non-verbal ability, a variable was created to reflect the mean angular deviation from ±15° to 45° frame incongruence across horizontal and vertical line-type trials. Correlations were carried out between this mean angular deviation variable and both chronological age (CA) and RCPM score. This demonstrated no significant relationship between incongruency and CA (WS: p=.41; TD: p=.16), but a significant relationship between incongruency and RCPM in the WS group only (WS: r=-.65, p=.005; TD: r=-.38, p=.13). Thus, with increasing non-verbal ability, the WS group were able to draw lines with less angular deviation.

2.4. Discussion

Both the WS and TD groups were influenced by a frame when drawing a single line, although overall the WS group drew with greater angular deviation. Note that there were no group differences for baseline horizontal or vertical lines which demonstrates that both groups had comparable motor control, and hence that any group differences in angular deviation cannot be accounted for by differences in fine motor ability. For both groups, oblique lines resulted in significantly more angular deviation than non-oblique line-types, and a frame of reference had no systematic influence on this poor ability. Gentaz et al. (2001) suggest that the ability to reproduce oblique orientations is impacted by a perceptuo-motor bias to use vertical and horizontal orientations as a frame of reference. This is supported by evidence that orientation detectors for vertical and horizontal orientations are stronger than for oblique orientations (Dick & Hochstein, 1989). This could explain why our imposed spatial frame of reference had little effect on the reproduction of oblique lines. The current data, therefore, reinforce the comparative difficulty that participants experience when encoding, planning and executing oblique lines: the ‘oblique effect’ (Appelle, 1972; Chen & Levi, 1996; Farran & Dodd, 2015).

For horizontal and vertical lines, drawing was impacted once the frame was 15° or more incongruent with the line. This suggests that participants were unable to inhibit the frame, and thus their drawings were biased towards the frame axes (e.g. Beh et al., 1971; see **Error! Reference source not found.**), with the effect of reduced drawing accuracy relative to the no-frame baseline condition. Interestingly, this suggests that the WS group, like the TD participants, were using a field-dependent, global processing style in order to copy the model line. This refutes a local processing bias in WS as participants were influenced by the surrounding orientation cues provided by the frame, rather than using a field independent, local processing style which would allow for drawing in isolation of the influence of a frame.

Processing style was also related to level of non-verbal ability in the WS group. Those individuals with a higher RCPM score were more able to overcome the influence of the frame on their ability to draw a horizontal or vertical line, than those with a lower RCPM score. Whilst the association was also negative for the TD group, it failed to reach significance. The TD group had a reduced spread of angular deviation scores relative to the WS group. Coupled with the small sample sizes, a lack of power might account for the apparent differences in associations across the groups. The pattern observed in the WS group is reminiscent of reports in the literature that 'disembedding' (for example, as measured by the Children's Embedded Figures Test; Witkin, Oltman, Raskin, & Karp, 1971) score is related to IQ in both typical (e.g. Remy & Giles, 2014) and atypical (Autism) populations (Courchesne, Meilleur, Poulin-Lord, Dawson & Soulières, 2015). This has been attributed to more efficient problem solving with increased IQ. In the current context, it likely reflects an active effort to try to disembed their line from the frame, as opposed to a more passive influence of the frame on drawing (see Remy & Giles, 2014 for a similar argument). Despite this, even those with the highest RCPM scores, still showed angular deviation of drawn lines thus demonstrating the pervading influence of global information.

3. Experiment Two: Drawing Whole Shapes

3.1. Introduction

Data from the DOT suggest that WS and TD groups were both similarly affected by orientation cues provided by a frame when drawing a single line; both groups demonstrated evidence of a field-dependent, global processing style. Given the influence of a frame on single line drawing, Experiment 2 assessed the influence of a frame when drawing whole shapes (squares and diamonds) when the frame was congruently or incongruently orientated with the shape. Because drawing accuracy becomes increasingly atypical in WS, with increased complexity (Hudson & Farran, 2011), this study aimed to determine whether drawing complexity (i.e. drawing a shape in Experiment 2, relative to drawing a line in Experiment 1) influences the ability to use a spatial frame of reference in WS.

Drawing was hypothesised to be most accurate when the model shape and frame were congruently orientated (such as a square within a square frame), and least accurate when the orientation of the model and frame were incongruent (such as a diamond within a square frame). A circular, neutral frame was also used which should not have influenced drawing ability as no common orientations were shared between the models and the circular form, therefore drawing was entirely self-guided.

The WS group were hypothesised to show greater angular deviation of figures relative to TD controls (in line with the findings from the DOT). If the WS group are influenced by the frame, as in Experiment one, they should benefit from the congruence of the model and frame, and be negatively influenced by incongruence between the model and frame. This would further refute a local processing bias hypothesis. If drawing accuracy is similarly poor for diamonds in Experiment 2, as for oblique lines in Experiment 1, it is possible that this ‘oblique effect’ (Appelle 1972) will overshadow any effect of the frame.

A further possible behaviour which might be observed, is an over-reliance on cues provided by the frame. This would be manifested in a response in which participants trace around the inner edge of the frame, and is commonly seen in TD 4 to 5 year-olds (McIntosh, Ambron & Della Sala, 2008). This behaviour is referred to as Closing-In Behaviour (CIB; Mighter-Gross, 1935). The age at which CIB is observed maps onto the age of our TD control group, and by default the non-verbal mental age of the WS group and so the presence of CIB will be investigated in this study. CIB is a form of constructional apraxia and describes copying excessively close to an item that is being copied (tracing around the inner edge of the frame in the current experiment). CIB is observed more frequently when figures are complex

(Lee et al., 2004) and is a means of overcoming difficulties with the maintenance of perceptual analysis of the model (Serra, Fadda, Perri, Caltagirone & Carlesimo, 2010). Because drawing of whole shapes requires integration of many lines, which is difficult for individuals with WS (e.g. Hudson & Farran, 2011), the WS group were anticipated to show increased use of CIB (i.e. draw larger figures), relative to the TD group due to inflation of drawings towards the frame, in an effort to benefit more directly from the orientation cues provided by the frame.

3.2. Method

3.2.1. Participants

Eighteen participants with WS were recruited from the Williams Syndrome Foundation UK (11 female, seven male; 11 right-handed, five left-handed, two ambidextrous), 10 of which had taken part in Experiment One approximately one year previously. A diagnosis of WS had previously been confirmed by a clinician and a positive FISH test. Eighteen TD non-verbal ability matched control participants were recruited from primary schools in Berkshire, UK (13 female, five male; 16 right-handed, two left-handed. TD and WS participants were matched using RCPM (Raven, 1993). Matching of groups was successful as there was no significant difference in RCPM score between groups, $t(34)=.03$, $p=.98$. Table 2 illustrates chronological age and RCPM scores for both groups. There were no between group differences in sex or handedness, $p > .05$.

Table 2

3.2.2. Apparatus and Materials

Three frames were constructed from A4-sized black card with an aperture cut centrally that was square, diamond (a square orientated at 45°) or circular in shape (all apertures had an area of 5184mm^2). Participants drew through this aperture in the frame and onto a piece of A4 paper in landscape orientation that was secured beneath the frame using a clipboard. The model figures were a 36mm x 36mm line-drawn diamond or square form, presented in a portrait orientation on A4 paper, and were copied using an HB pencil.

3.2.3. Procedure

Participants first completed two practice trials in which they traced a square and diamond shape; a sheet of tracing paper was placed over the model and participants were instructed to draw over the lines. For experimental trials the participants were told that they would be shown some shapes and that a piece of paper would be placed under a piece of card with a hole in it and that the task was to draw the shape inside the hole in the card onto the paper below. This was demonstrated to participants by the experimenter in a familiarisation phase. Participants watched as the experimenter copied a triangle shape (this model was not used during the experimental trials) inside the circular frame. Once the experimenter was satisfied that the participant understood the task, the test trials commenced.

A model (diamond or square) was placed on a table in front of the participant and then the clipboard was given to the participant with the piece of paper, overlaid by the frame, attached. Participants were then instructed to copy the model exactly on the paper beneath the frame. The order of presentation of diamonds and squares and the frame-types was randomised for each participant. Participants completed 12 experimental trials (the diamond and square were each drawn twice within each of the three frames). Participants could correct any perceived errors but only final drawings offered by participants were analysed. The angular deviation and length of each line drawn-line was recorded for each figure.

3.3. Results

3.3.1. Tracing of Squares and Diamonds

To determine that angular deviations of traced figures was minimal, a group (WS, TD) by shape (square, diamond) ANOVA was performed on the average absolute angular deviation of lines (the angular deviation of all four lines of each figure was averaged). There was a significant effect of shape, $F(1,34) = 4.29$, $p = .05$, $\eta_p^2 = .11$, due to greater angular deviation of traced lines in diamonds ($M = 2.29°$, $SE = .36°$) compared to squares ($M = 1.63°$, $SE = .25°$). However, note that angular deviations were small and that the difference across shapes was less than 1° of angular deviation, therefore tracing of both shapes was generally accurate. There was no effect of group or interaction of group by shape, $p > .05$. Both groups therefore had comparable, adequate motor control to complete the experimental trials.

3.3.2. The Influence of a Frame on Diamond- and Square-Drawing

In some instances participants traced along the inside edge of the frames in congruent and also incongruent conditions, therefore drawing was not self-initiated. Participants that traced all frames and their corresponding matched participants were excluded from analyses (four individuals with WS and one participant from the TD group, removing a total of four matched pairs of participants from the sample). After this exclusion there were fourteen participants in each group and no significant difference between groups in RCPM scores (WS: $M = 17.64$, $SD = 1.52$; TD: $M = 17.71$, $SD = 1.52$; $t(26) = .03$, $p = .97$).

3.3.3. Angular Deviation of Lines

A group (WS, TD) by frame congruence (congruent, incongruent, neutral) by shape (diamond, square) ANOVA was performed on the angular deviation of drawn lines (°). There was no significant difference in the angular deviation of drawn lines between groups (WS: $M = 18.28°$, $SD = 1.36°$; TD: $M = 15.46°$, $SD = 1.36°$; $F(1,26) = 2.15$, $p = .16$, $\eta_p^2 = .08$). There was a significant effect of congruence ($F(2,52) = 5.92$, $p = .005$, $\eta_p^2 = .19$) as a result of angular deviation of lines drawn in incongruent frames ($M = 20.14°$, $SD = 1.76°$) being significantly greater than angular deviation in congruent (*M* = 14.41, *SD* = 1.09°, *p* = .009) and neutral (*M* = 16.05°, *SD* = 1.19°, *p* = .02) frames. There was no significant difference in angular deviation between congruent and neutral frames *p* = .05. Diamonds (*M* = 22.84°, *SD* = 1.29°) were drawn with significantly greater angular deviation than squares (*M* = 10.90°, *SD* = 1.05°), $F(1,26) = 78.05$, $p < .001$, $\eta_p^2 = .75$. There was an interaction of shape by group, $F(1,26) = 20.44$, $p < .001$, $\eta_p^2 = .44$ (see Figure 4), resulting from the WS group drawing diamonds (*M* = 27.30°, *SD* = 8.62°) with significantly greater angular deviation than the TD group (*M* = 18.38°, *SD* = 4.25°), but no group differences in drawing of squares, $p > .10$ (WS: *M* = 9.25°, *SD* = 4.22°; TD: *M* = 12.55°, *SD* = 6.62°). All other interactions were non-significant, $p > .05$.

In line with Experiment 1, to determine whether variation in the effect of the incongruent frame on the ability to draw squares and diamonds was related to experience and / or level of non-verbal ability, correlations were carried out between angular deviation for the two incongruent conditions (squares drawn in a diamond frame and diamonds drawn in a square frame) and both CA and RCPM score. As in Experiment 1, CA was not related to angular deviation for either group (p>.05 for all). For RCPM score, there was a marginal relationship with the ability to draw diamonds in a square frame for the WS group only (diamond in square frame: WS, r=-.50, p=.07; TD, r=-.10, p=.73; square in diamond frame: WS, r=-.24, p=.40; TD, r=.08, p=.79).

Figure 4

3.3.4. Line Length

Line length was analysed as a measure of the influence of the frame on drawing. A group (WS, TD) by frame congruence (congruent, incongruent, neutral) by shape (diamond, square) ANOVA was performed on the length of drawn lines (mm). The WS group (M = 36.43mm, SD = 2.62mm) drew significantly longer lines overall than the TD group (M = 25.03mm, SD = 2.62mm), $F(1,26) = 9.44$, $p = .005$, $\eta_p^2 = .27$. A significant effect of congruence ($F(2,52) = 8.00$, $p = .001$, $\eta_p^2 = .24$) resulted from longer lines drawn in congruent frames (M = 34.09mm, SD = 2.56mm) relative to incongruent (M = 29.33mm, SD = 1.73mm, $p = .006$) and neutral (M = 28.78mm, SD = 1.70mm, $p = .003$) frames. Diamonds (M = 29.14mm, SD = 1.95mm) were drawn using significantly longer lines compared to squares (M = 32.33mm, SD = 2.01mm), $F(1,26) = 5.26$, $p = .03$, $\eta_p^2 = .17$. All other interactions were not significant, p>.05.

3.3.5. Evidencing CIB-like drawing.

As a direct measure of CIB-like drawing, we determined the relative size of the drawn line (mm) compared to the frame. Average line lengths were expressed as a ratio of the length of the drawn line to the length of the inside edge of the frame (72mm for congruent and incongruent frames, 62.93mm for neutral frames which is the maximum chord length to draw a square/ diamond of equal size lengths). A frame to line-length ratio score of 1.00 therefore denoted tracing around the interior edge of the frame (e.g. for a square drawn line 72mm/ frame line length 72mm= 1). Replication of a line within the frame with the same proportional size as the line length of the model within the line length of the frame resulted in a ratio of .50 for congruent and incongruent frames (36mm model line length/72mm frame length) and .57 for neutral frames (36mm model line length/ 62.93mm maximum chord length).

Ratios of the drawn line to the frame were significantly different from 1 and 0 in all trials completed by both groups, $p < .001$ for all. This suggests that both groups were able to draw figures in a self-initiated manner without exclusively tracing the frames. The ratio of drawn lines to the frame was compared for each shape to the “exact size” using one-sample *t*-tests with a test value of .50 for congruent and incongruent frames and .57 for neutral frames (the ‘exact size’), see Figure 5. Analysis showed that the WS group did not display CIB-like drawing. In all instances there was no significant difference between the ratio of the drawn line to frame and the ‘exact size’ ($p > .05$ for all). In the TD group lines were drawn significantly smaller than the model in all conditions ($p < .05$) with the exception of a diamond model inside a congruent frame, which was drawn accurately ($p > .05$); this behaviour appears to be the inverse of CIB where participants actively shrink their copy from the frame.

Figure 5

3.4. Discussion

This experiment investigated the influence of a frame of reference on whole-shape drawing to a more fine-grained level than previous studies (i.e. Naeli & Harris, 1976). We have shown that congruence of a model and frame influenced both angular deviation and length of drawn lines. Congruence of a frame and model influenced lines to be drawn longer than in incongruent and neutral frames, indicating that participants attempted to exploit the orientation cues provided by the frame by drawing lines that were relatively closer to the frame boundary. Note, however, that this difference in line length across frame types was not sufficient to significantly increase the size of drawn shape relative to the model shape for congruent trials. This suggests that although the frame was useful, the size of the model was also an important cue. Incongruence of the model and frame led both groups to draw more angularly deviant lines compared to drawing in both congruent and neutral frames, demonstrating an inability to inhibit the incongruent information provided by the frame when drawing. The congruent model and frame condition is likely to have reduced the planning demands when drawing as participants were guided by the frame in determining line length and turning points of lines of the figure. Hudson and Farran (2013b) have shown that drawing in WS and TD groups can be facilitated by provision of cues to line length and changes in direction of lines when drawing whole shapes. Indeed the WS and TD groups both drew figures with comparable angular deviation, contrary to the findings of the DOT where the WS group drew single lines with greater angular deviation than the TD group. Perhaps the structure of a 2D shape provides additional scaffolding than that of a 1D line in WS. However, without further empirical investigation, this is speculation. Note also that direct comparison across tasks is confounded by other design differences. That is, there was a larger proportion of trials in Experiment 2 that used a congruent frame (1/3rd) compared to Experiment 1 (1/11th), and the oblique effect overshadowed some of the effects of congruence on angular deviation. These two differences might have had an effect of bringing group performance closer together in Experiment 2, but this cannot be determined based on the current data. The incongruent model and frame conditions, conversely, are likely to have increased planning demands as participants had to actively inhibit orientation cues provided by the frame. As with the DOT, the results of this experiment are indicative of a global, field-dependent processing style and provide evidence against a local processing bias in WS, even for comparatively complex drawings. Interestingly, in contrast to Experiment 1, there was little evidence that the effects of incongruency were related to non-verbal ability in the WS group. Again, this likely reflects the relative complexity of this task compared to the DOT.

An unexpected finding of this experiment was the reduced line-lengths of the TD group. Analysis of the ratios of line lengths to the model revealed that, with the exception of drawing a diamond in a congruent frame, the TD group drew figures significantly smaller than the model. This might be indicative of the demands of drawing the diamond shape (Chen & Levi, 1996) and so participants attempted to use the frame’s orientation cues to guide drawing. The TD group might have drawn smaller figures as a result of switching between spatial frames of reference encoded for the model on the page and then using the cardboard frame as the frame of reference. This would suggest that the TD group attempted to use the model page as a frame of reference in a manner that was not seen in the WS group. This represents a form of a boundary extension scaling error (Chapman, Ropar & Mitchell, 2005), which in this case involves retention of information about the relative size of the model on a page when copying the model in a smaller area through the cardboard aperture. Further research is needed to understand the nature of this scaling bias in TD children. Perhaps this was not evident in the WS group because they made fewer looks to the model, as observed by Hudson and Farran (2013) and Hoffman, Landau and Pagani (2003). In this experiment, the WS group might have relied more on verbal coding than visual coding, by labelling the to-be-drawn shape as a square or a diamond, thus reducing the requirement to reference the model. The use of verbal coding is not unusual as a compensatory strategy in WS (e.g. Farran, Blades, Tranter & Boucher, 2010).

Landau and Hoffman (2005) proposed that atypical drawing in WS might reflect an inability to effectively use spatial frames of reference in order to understand the relation of parts within a model and to transfer this to a drawing space. In the current experiment the WS group demonstrated typical patterns and levels of drawing performance, when compared to the TD group when drawing squares. This demonstrates that individuals with WS can use a spatial frame of reference. However, for drawing diamonds, which is an arguably more difficult shape to draw on account of the oblique lines, the WS group showed reduced accuracy relative to the TD group. Thus although spatial frames of reference are useful for individuals with WS, they cannot be used to overcome differences in the relative difficulty of drawing different shapes. This is reminiscent of Farran & Dodd (2015), where effects of drawing facilitation (in this case colour cues) was reduced for oblique lines in WS relative to their TD peers.

5. General Discussion

The results of these experiments provide clear evidence against the local processing hypothesis as an explanation for drawing performance in WS. When drawing single lines and whole shapes both WS and TD groups displayed evidence of a global, field-dependent processing style. The introduction of a rigid frame of reference affected drawing accuracy in WS and TD groups, suggesting that individuals with WS are sensitive to spatial frames of reference. For both Experiments, there was no difference between performance in the neutral condition (Experiment 1: baseline; Experiment 2: circular frame) and the use of a congruent frame. The difference was observed between the neutral condition and when the spatial frame of reference was incongruent to the to-be-drawn line or shape. This had a negative impact on performance in both Experiments. This suggests that, whilst a spatial frame of reference is useful, it is automatically encoded from the environment around us (e.g. the edge of a page) and does not need to be imposed (cf. Broderick & Laszlo, 1987, 1988; Gentaz et al., 2001). In contrast, when a spatial frame of reference that is incongruent is imposed, it is very difficult to inhibit.

Although the WS group were influenced by spatial frames of reference, on the DOT, drawings were more angularly deviant in the WS group than the TD group, which emphasises the extent of the deficit in drawing in WS. A similar group effect was observed for drawing diamonds only in Experiment two; this might be a reflection of the complexity of integrating oblique lines to form a diamond in WS (e.g. Hudson & Farran, 2011). The results of experiment Two also suggested that the WS group were not susceptible to scaling biases in the same way as the TD group and so the WS and TD groups are likely to have used orientation cues provided by the frame in a differing manner. Further research is required to determine what this subtle difference might be, but perhaps the TD group are more able to use the environment (in this case, the page) to obtain a frame of reference. Nonetheless, we have provided the first assessment of the role of spatial frames of reference in drawing in WS, which has demonstrated that frames of reference can be used by individuals with WS. Furthermore, we have also provided tentative evidence that the ability to actively problem solve, in an effort to overcome the influence of spatial frames of reference, increases with increased non-verbal ability in WS. The nature of such problem solving cannot be determined within the current context, but these findings open up an interesting avenue for further research.

Data from the current experiments do not align with previous research in WS that suggests atypical use of spatial frames of reference (Brown et al., 2003; Nardini et al., 2008). Perhaps this relates to the nature of measurement. Here, the frame was explicit, and presented in the same space as the participant's drawing output. The data demonstrated that the main impact was when the frame of reference created conflict. Previous studies relied on congruent frames of reference only and required participants to select a frame of reference, and to integrate visual scenes, which is arguably a more complex set of requirements (e.g. use of attentional and working memory systems). It is highly possible that there is a difference in the ability of individuals with WS to show an effect of a given spatial frame of reference, compared to being able to *select* a useful frame of reference (and to use it effectively). Recent evidence has demonstrated that individuals with WS often select inappropriate landmarks when navigating (Farran et al., 2016); this tentatively supports the notion that the ability to select an appropriate frame of reference is impaired in WS.

The current results contribute to the explanation for impaired drawing ability in WS by demonstrating that this deficit cannot be accounted for by a local processing bias. Given this, we now turn to other potential determining factors. The particularly poor drawing accuracy for diamonds in the WS group (Experiment 2) supports previous research which suggests that the ‘oblique’ effect is more difficult to overcome in WS than for TD children, and is less receptive to facilitation techniques (e.g. the congruent frame in Experiment 2 and colour cues in Farran & Dodd, 2016). It is also possible that the WS group were not attending to the model as much as the TD children. This suggestion is tentatively supported by the scaling bias that was observed in the TD group, but not the WS group, and is consistent with Hudson and Farran (2013a). Other contributing factors, not measured here on account of the relative simplicity of the model image, are a difficulty in reproducing the spatial relations between the parts of an image and atypical replication strategies (Farran & Dodd, 2015; Hudson & Farran, 2011; 2013b). An interesting finding from Experiment Two was the scaling bias seen in the TD group, potentially evidencing a form of boundary extension. This finding warrants further research to understand the nature of the frames of reference that TD participants were using. Participants’ drawings did not differ in size compared to the model when drawing a diamond in a congruent frame so when drawing a demanding figure such as this, orientation cues are exploited in a unique manner compared to the other combinations of frame-types and shapes. It would be of interest to repeat this task with a TD group using differing sizes of model and frame to assess whether the scaling bias is pervasive regardless of frame size or whether this phenomenon is peculiar to the stimuli that we used. This would give insight into the typical development of use of spatial frames of reference for drawing. It is hoped that other researchers use the DOT and the whole-shape drawing task in clinical groups such as individuals with constructional apraxia or autism to investigate use of spatial frames of reference when drawing.

In summary, these experiments demonstrated that both WS and TD groups used frames of reference when drawing. The data from both experiments refute a local processing preference in WS as participants with WS were able to use the global cues provided by frames when drawing.

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Table 1

WS and TD Participants' Chronological Age and RCPM Scores for the DOT.

	Williams Syndrome (*N*=17)		Typically Developing (*N*=17)	
	Mean(SD)	Range	Mean(SD)	Range
CA (years; months)	25;01 (13;00)	9;10-44;07	6;05 (2;01)	4;01-11;08
RCPM Score (maximum possible=36)	18.59 (4.95)	10-28	18.82 (6.39)	10-31

Table 2.

WS and TD Participants' Chronological Age and RCPM Scores for Experiment Two

	Williams Syndrome (*N*=18)		Typically Developing (*N*=18)	
	Mean(SD)	Range	Mean(SD)	Range
CA (years; months)	24;10 (11;02)	8;06-43;02	5;08 (0;03)	5;05-6;07
RCPM Score (maximum possible=36)	17.06 (5.56)	10-28	17.11 (5.47)	11-28

Figure Captions

Figure 1. Biasing of a line towards the nearest gravitation axis of a frame in the *Drawing Orientation Task* (adapted from Beh, Wenderoth & Purcell, 1971).

Figure 2. Example stimuli from practice and experimental trials from the Drawing Orientation Task.

Figure 3. Angular deviation of drawn lines in each frame in the WS and TD groups from the Drawing Orientation Task.

Figure 4. The interaction of angular deviation of lines from shapes by group from Experiment Two.

Figure 5. The ratio of drawn lines to the frame for each model and frame type in both groups from Experiment Two.

Fig. 1.

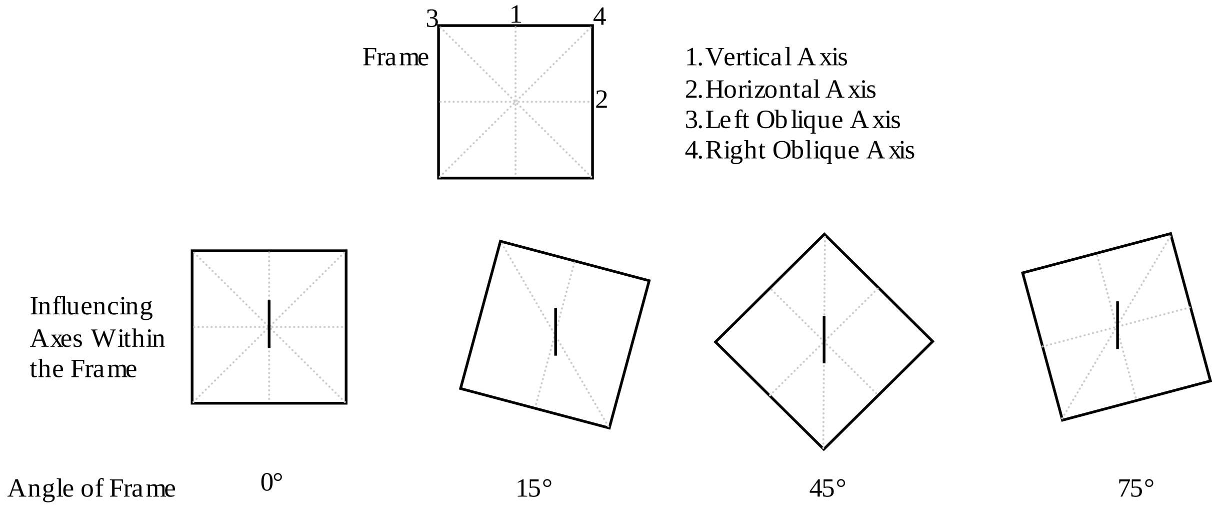

3
1
4
Frame
2
1.Vertical Axis
2.Horizontal Axis
3.Left Oblique Axis
4.Right Oblique Axis
Influencing Axes Within the Frame
Angle of Frame
0°
15°
45°
75°

Fig. 2.

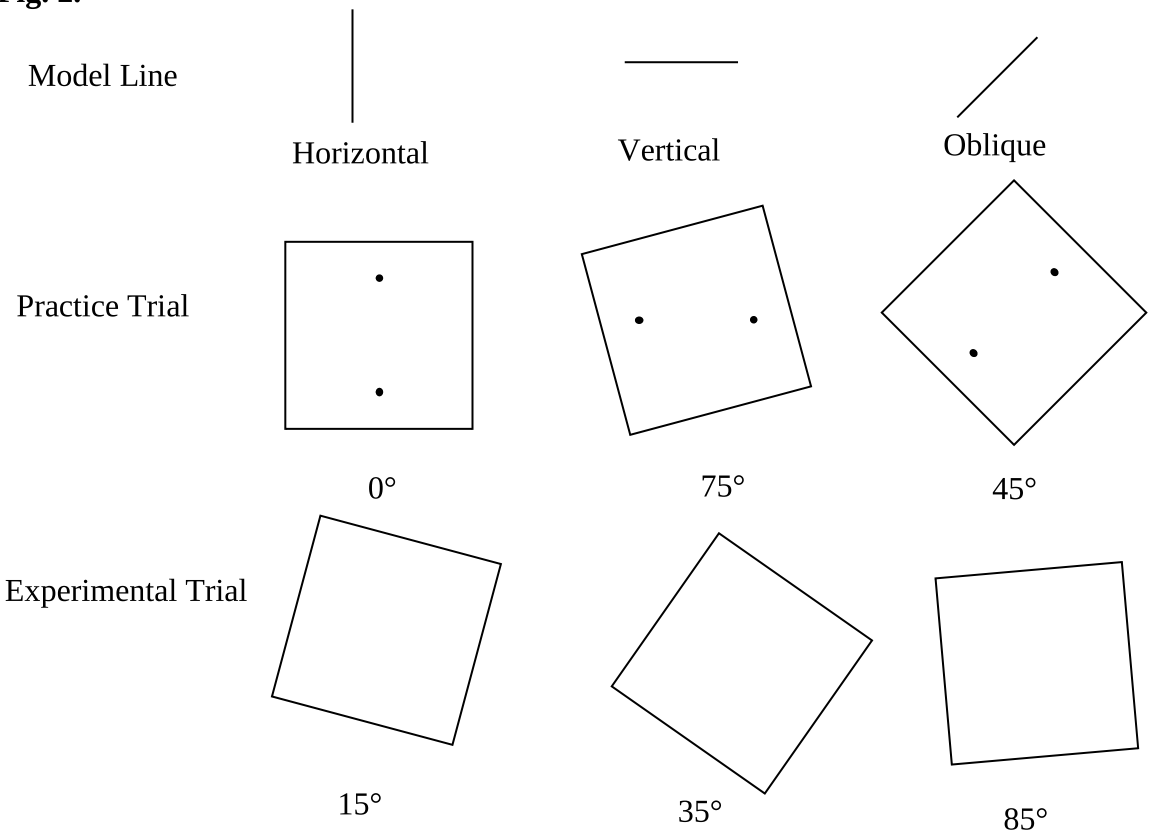

Model Line
Horizontal
Vertical
Oblique
Practice Trial
0°
75°
45°
Experimental Trial
15°
35°
85°

Fig. 3.

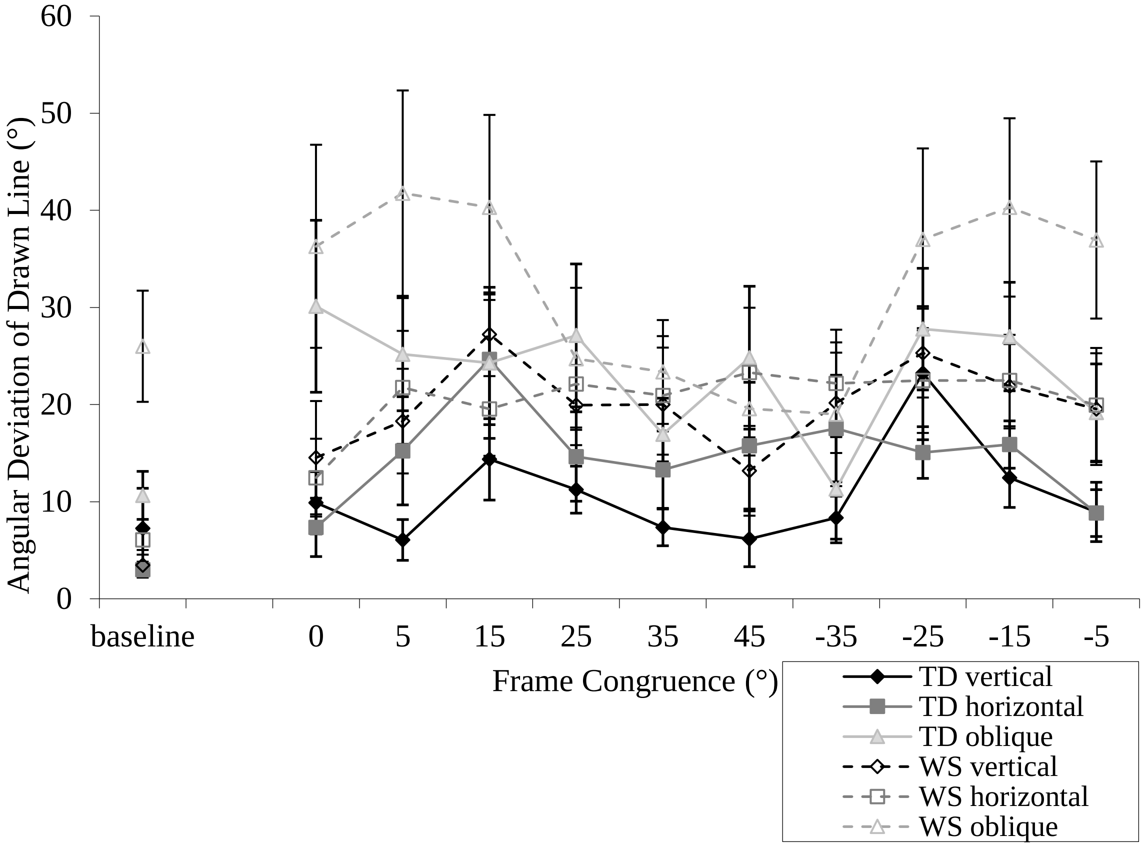

60
50
40
30
20
10
0
Angular Deviation of Drawn Line (°)
baseline
0
5
15
25
35
45
-35
-25
-15
-5
Frame Congruence (°)
TD vertical
TD horizontal
TD oblique
WS vertical
WS horizontal
WS oblique

Fig. 4.

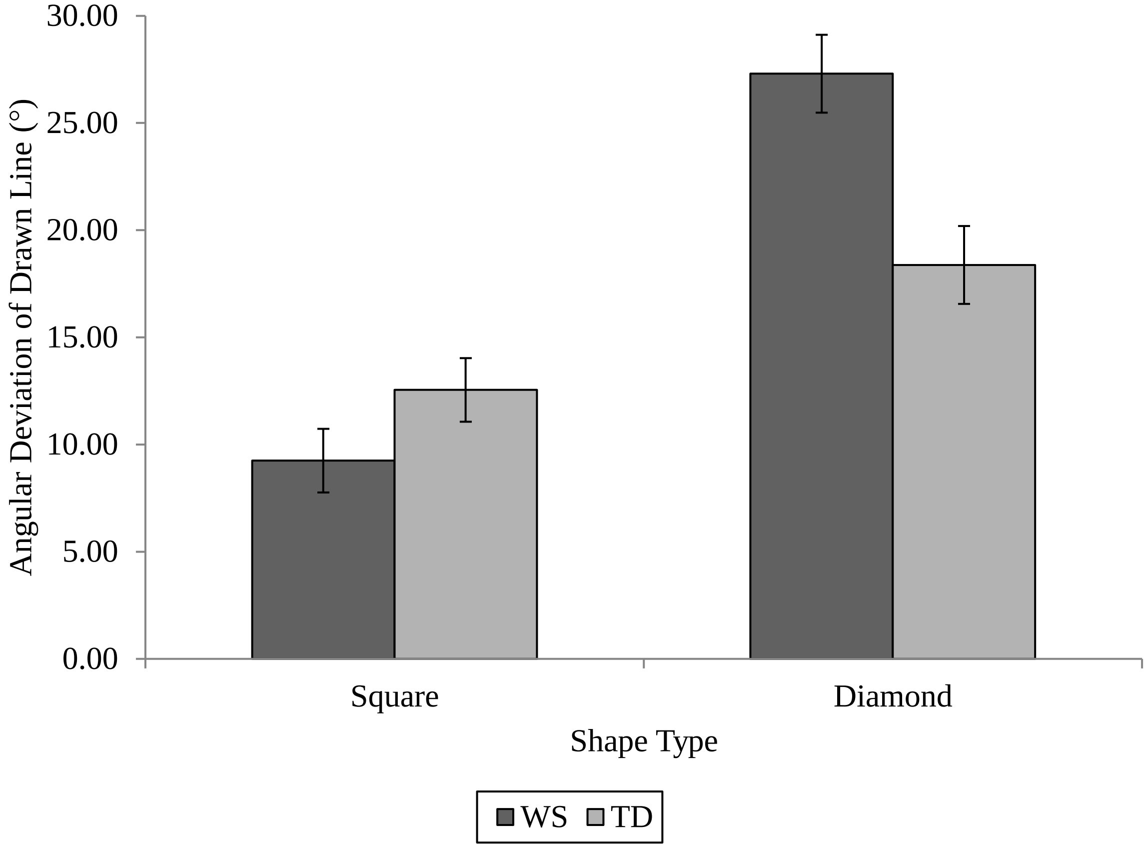
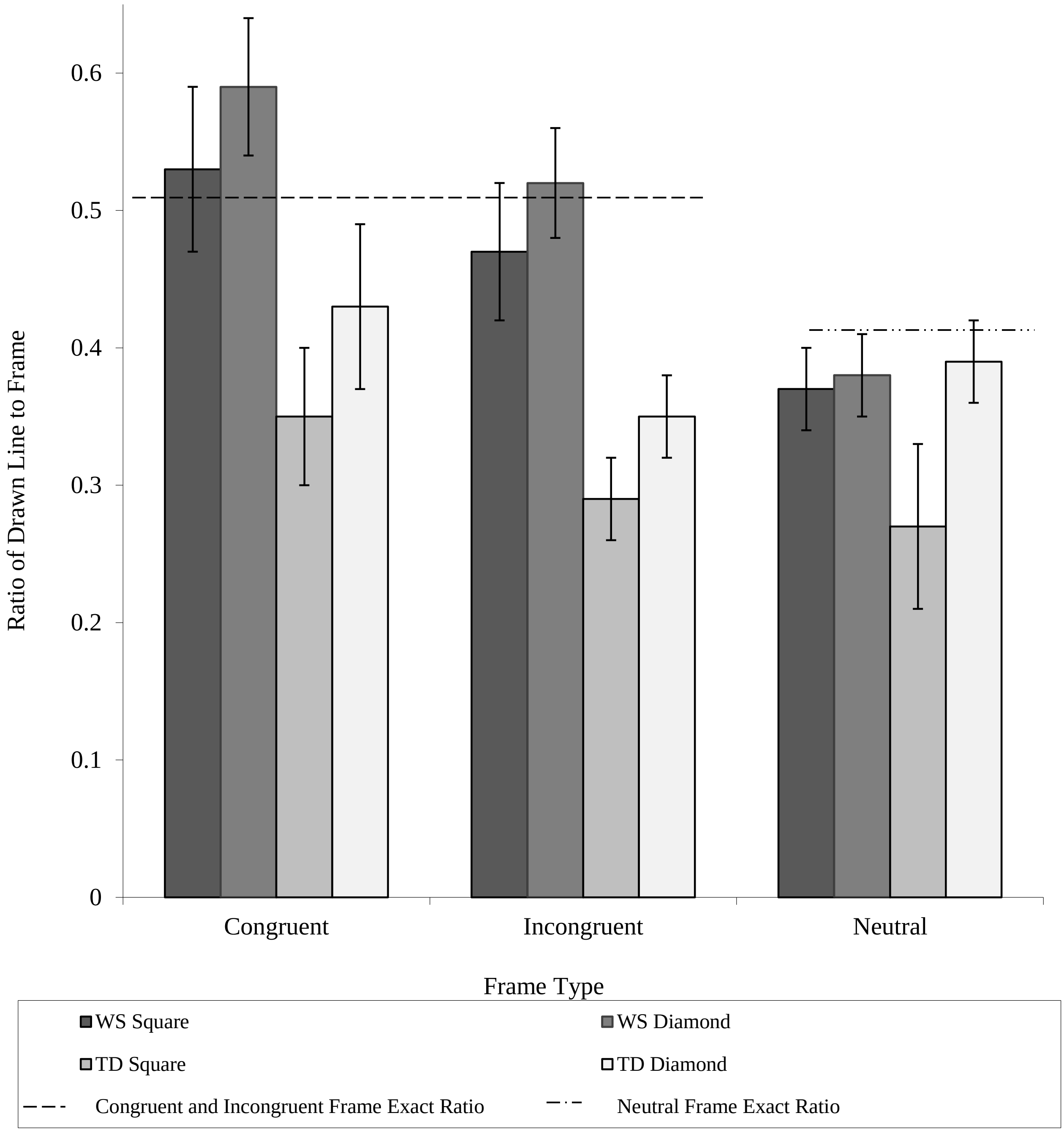

30.00
25.00
20.00
15.00
10.00
5.00
0.00
Angular Deviation of Drawn Line (°)
Square
Diamond
Shape Type
WS
TD

Fig. 5


0.6
0.5
0.4
0.3
0.2
0.1
0
Ratio of Drawn Line to Frame
Congruent
Incongruent
Neutral
Frame Type
WS Square
WS Diamond
TD Square
TD Diamond
Congruent and Incongruent Frame Exact Ratio
Neutral Frame Exact Ratio