Looking around houses: Attention to a model when drawing complex shapes in Williams syndrome and typical development

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Highlights

1. Poor drawing in Williams syndrome (WS) may be due to inefficient looking behaviour.

2. WS and typically developing (TD) groups drew larger features before smaller parts.

3. Drawing errors were unrelated to frequency of looking at the model and copy.

4. Individuals with WS produce less complete drawings than TD controls.

5. Drawing and tracing strategies in WS are similar to TD controls, but delayed.

Abstract

Drawings by individuals with Williams syndrome (WS) typically lack cohesion. The popular hypothesis is that this is a result of excessive focus on local-level detail at the expense of global configuration. In this study, we explored a novel hypothesis that inadequate attention might underpin drawing in WS. WS and typically developing (TD) non-verbal ability matched groups copied and traced a house figure comprised of geometric shapes. The house was presented on a computer screen for five second periods and participants pressed a key to re-view the model. Frequency of key-presses indexed the looks to the model. The order that elements were replicated was recorded to assess hierarchisation of elements. If a lack of attention to the model explained poor drawing performance, we expected participants with WS to look less frequently to the model than TD children when copying. If a local-processing preference underpins drawing in WS, more local than global elements would be produced. Results supported the first, but not second hypothesis. The WS group looked to the model infrequently, but global, not local, parts were drawn first, scaffolding local-level details. Both groups adopted a similar order of drawing and tracing of parts, suggesting typical, although delayed strategy-use in the WS group. Additionally both groups drew larger elements of the model before smaller elements, suggested a size-bias when drawing.

Keywords: Drawing, Williams syndrome, attention, developmental disability, strategy use.

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1. Introduction

Producing an accurate drawing of a to-be-copied model relies on the ability to attend to the model. This enables one to identify and replicate elements and place parts in the correct spatial arrangement. Drawing accuracy is greatest when attention is frequently switched between the model and copy, and attention is both sustained and focussed on a small area of the model (Coen-Cagli et al., 2009; Cohen, 2005; Miall & Tchalenko, 2001). This type of attention facilitates drawing by reducing working memory (WM) load; small amounts of information are processed and so memory stores are not overburdened (Ballard, Hayhoe & Pelz, 1995). Training typically developing (TD) children aged four to eight years old to attend closely to a model when copying can increase the detail and accuracy of drawings significantly more than children not instructed to selectively attend to the model (Sutton & Rose, 1998; Vlach & Carver, 2008). This suggests an important role for attention when drawing that may not be spontaneous in TD children. In support of this, evidence has shown that drawing ability improves throughout development as children learn to pay close attention to comparison of the model and copy (Del Guidice et al., 2000).

Comparing a model and copy is also an important feature of accurate drawing that features in conceptual models of the drawing process. The models of drawing proposed by Grossi and Angelini (1991 cited by Grossi & Trojano, 1999) and Roncato et al. (1987) both include a checking component in the latter stages of drawing production. Attention to the model therefore not only permits encoding of the spatial relations of parts of the model, but is also used to check between the model and copy for the spatial arrangements and properties of the replication with respect to the model. This too acts to reduce WM burden.

Drawings produced by individuals with the rare genetic disorder Williams syndrome (WS), typically lack cohesion, approximately 77% of drawings by individuals with WS show evidence of serious disorganisation (e.g. Bellugi, Lichtenberger, Jones, Lai, & St. George, 2000; Bertrand, Mervis & Eisenberg, 1997; Georgopoulos, Georgopoulos, Kuz, & Landau, 2004); for example when drawing a bicycle attempts may be made to draw the wheels, saddle and handlebars but these elements may be scattered around the page and not grouped into a recognisable global configuration (Bellugi et al., 2000). Furthermore, poor attention is frequently reported in this group (Leyfer et al., 2006). Despite this, poor attention has hitherto not been associated with drawing ability in WS although attention to the model may be an important mediating factor in drawing behaviour in WS.

WS results from a hemizygous 1.6 Mb microdeletion of approximately 28 contiguous genes on chromosome 7q11.23 (Osbourne, 2012) that affects approximately one in 20,000 live births (Morris, Demsey, Leonard, Dilts, & Blackburn, 1988). WS results in short stature, facial dysmorphology, connective tissue abnormality, hypersociability, neuromorphological abnormality, gastrointestinal problems and cardiovascular dysfunction (e.g. Morris et al., 1998). At a cognitive level, WS is characterised by mild to moderate learning difficulties (average IQ between 50 and 60), executive dysfunction and an unusual cognitive profile typified by relatively strong linguistic ability and poor visual-spatial performance (Ewart et al., 1993; Farran & Karmiloff-Smith, 2012; Ferrero et al., 2007; Hudson & Farran, 2012; Mervis & John, 2008; Smoot, Zhang, Klaiman, Schultz, & Pober, 2005).

Early theories of visual-spatial ability in WS posited a preference for processing local-level information of a visual scene; that is, when drawing, individuals with WS correctly draw detail elements but fail to integrate these parts into a cohesive, global organisation (e.g. Bellugi, Sabo, & Vaid, 1988). A local-level element is defined as a detail component of a to-be-drawn-object, for example the handlebars or saddle of a bicycle. However it is now recognised that a local-level bias in WS does not fully capture all aspects of visual-spatial ability. Performance of individuals with WS on the *Children's Embedded Figures Test* (Witkin, Oltman, Raskin, & Karp, 1971) shows a typical balance of local and global processing (Farran, Jarrold, & Gathercole, 2001; 2003, also see Deruelle, Rondan, Mancini, & Livet, 2006; Pani, Mervis, & Robinson, 1999). In this task participants find a local element (e.g. a triangle) within a global image (e.g. a child's pram), if individuals with WS did show a local-level bias one would expect rapid responses to this task if the participants is not having to inhibit processing of the global image's configuration. Therefore it is unlikely that atypical drawing behaviour in individuals with WS reflects a local bias in perception; it more likely reflects factors such as impairments in mental imagery (e.g., Farran et al., 2001) and/ or difficulty replicating multiple spatial relations (e.g. Hudson & Farran, 2011).

An alternative proposition is that individuals with WS show an apparent bias towards local elements when drawing due to inefficient attention to the model and infrequent checking between the model and copy; this would result in parts of the model being produced with incorrect spatial organisation. Poor attention may be underpinned by abnormal eye movements (saccades and fixations), which have been reported in WS (Montfoort, Frens, Hooge, Lagers-van Haselen & van der Geest, 2007; Van der Geest et al., 2004). Atypical eye movements (such as excessive corrective saccades) might influence fixations to a target, as well as parsing and memorisation of the spatial localisation of local elements which is compounded by WM deficits. Ultimately this might impact upon gaze-frequency (rate of switching between the model and copy), leading to disorganised drawings.

Hoffman, Landau and Pagani (2003) demonstrated that when completing a block construction task participants with WS showed a reduced instance of looking to the model when placing parts, relative to TD adults and mental-age matched TD children. This was especially so when models contained many parts; where TD children and adults increased the number of fixations to the model, individuals with WS significantly decreased fixations. Infrequent looking by the WS group led to errors (potentially due to WM load) and was exacerbated by less checking of the final solution with reference to the model, particularly for the most complex models, compared to the TD groups. Hudson and Farran (2011) have shown that as models become more complex individuals with WS produce less accurate and strategically-produced drawings. When considered with Hoffman et al.'s (2003) findings this could potentially be due to atypically fixations to the model.

Ballard et al. (1995) suggested that the dorsal stream may be responsible for positioning and monitoring of saccade locations, which then impacts upon looking behaviour; dorsal stream dysfunction has also been posited in WS (e.g. Eckert et al. 2006). To successfully replicate a part, complex coordination and control of fixations is needed. That is, one must allocate attention to select an element to draw and maintain refixations to the target element (Ballard et al., 1995). There is evidence to suggest that individuals with WS have an inability to plan rapid saccades ("sticky fixations") that is evident from infancy (Brown et al., 2003). This has been related to poor rapid processing of configural information (Karmiloff-Smith, 2009).

Atypical eye movements may be a limiting factor of attention in WS, with downstream detrimental effects on drawing behaviour. Furthermore, because of the relationship between attention to the model and WM load when drawing, this cascading series of effects is likely to be compounded by more general memory and executive function deficits in WS (Menghini et al., 2010; Rhodes et al., 2010; Vicari, Bellucci & Carlesimo, 2001). That is, less spatial information can be retained in working memory in individuals with WS, relative to TD individuals. However to date the relationship between attention to a model and drawing performance has not been investigated in WS.

The salience of elements can be traced by the serial order of appearance of elements in the drawing sequence (Picard & Vinter, 2005); this can be used as an online measure of attention paid to the model. Features that are deemed important for a particular object are replicated early in the drawing sequence. An example of this is when drawing a house; TD children start by drawing the main house outline, followed by the roof, door or windows and then add peripheral features. Picard and Vinter (2005) suggested that this ordering may be a form of size-biasing, by starting with large features and progressing to smaller elements. However, it is also possible that production of the larger global elements serves as an anchor for local features and provides a scaffold for spatial localisation of smaller parts of the model. In this sense Picard and Vinter's (2005) size-biasing may represent a useful strategy for producing a cohesive replication of a model. A means of examining the disparity between salience of features and using features as anchors is to compare drawing and tracing, as in the current experiment. If children abide by rigid graphic schema as Picard and Vinter (2005) suggest then the means of producing a figure should be stable between copying and tracing. However, less demand for self-generated planning is educed by tracing as elements are already provided and decisions do not need to be made in order to anchor parts or plan for spatial localisation (e.g. van Sommers, 1989). As a result the size bias may not be evident in tracing as there is less need to use hierarchical drawing schemes as the model is in view at all times and so spatial relations are already provided for the drawer.

This study aimed to assess the frequency of looks to a model as a factor affecting drawing ability in WS and TD groups. If attention to the model is infrequent and drawings are poorly constructed then this may indicate that attention training for graphomotor tasks inline with Sutton and Rose (1998) and Vlach and Carver (2008) may benefit individuals with WS. We were also interested in participants' ability to draw local and global elements as the local processing hypothesis would suggest that local elements were drawn with poor global organisation; however Hudson and Farran (2011, 2013) have suggested that a local processing hypothesis does not characterise drawing in WS. We used a house as the to-be-copied model; Bertrand et al. (1997) suggested that a house figure was complex and contained many embedded parts and is thus ideal to determine hierarchical drawing ability. A house figure has been used previously in WS research and has shown that individuals with WS produce fewer global elements and produce seriously disorganised figures, relative to mental age-matched and chronological age-matched controls (Bertrand et al., 1997; Stiles et al., 2000; Wang & Bellugi, 1993). We hypothesised that the WS group would look to the model less frequently and make more errors than a TD control group; infrequent looks to the model could be the root of poorer replications of the model. A tracing condition was included because tracing ability would not be affected by inattention to the model (the model and replication occur in the same space), and eliminates any planning demands. This also provided a control measure of motor control.

Use of a complex model permitted investigation of the effect of attention on drawing of local and global elements of the model. Adequate attention to the model in the TD group would result in no relationship between the frequency of looking and replication of local and global parts when drawing. When copying it was hypothesised that if individuals with WS showed a local-level processing preference then local elements of the house would be drawn first (such as windows or features of the door). Should a local processing preference not be evidenced in individuals with WS then the drawing order will resemble that of TD controls. That is, in both the WS and TD groups, global features will be replicated first (the main outlines of the house and roof) in order to scaffold part-relations between local-level elements, i.e. a size bias (Picard & Vinter, 2005). The size bias should be less evident in the WS group compared to the TD group as larger elements represent global features that scaffold local elements. Drawing of larger, global elements in the WS group argues against a local processing bias in this group. Although it is likely that individuals with WS will be able to perceive local- and global-level information in line with Farran and Jarrold (2001; 2003) but may not be able to evidence this in drawing (e.g. Bertrand et al., 1997). This study is therefore the first of its kind to assess looking behaviour during drawing and how this impacts upon drawing strategies in WS and TD groups.

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). Diagnosis of WS in all participants had previously been confirmed 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). No participant had known comorbid diagnoses. Verbal and written consent was gained from each participant and their parent/ carer.

Seventeen TD non-verbal ability individually matched control participants (nine male, eight female; sixteen right-handed, one left-handed) were recruited through advertisements to parents at the University of Reading, UK. Written consent was obtained from parents and verbal consent was given by participants to take part in the study. Matching of participants was achieved using *Raven's Coloured Progressive Matrices* scores (RCPM; Raven, 1993). RCPM is a standardised measure of non-verbal reasoning (fluid intelligence, *g*) and visuospatial perception, and has previously been used successfully as a matching measure for visuospatial 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). RCPM consists of three sets of twelve items, within each set the trials become progressively more difficult. Participants are shown a coloured pattern with a missing area and are asked to select the correct missing segment from six options. Individuals with WS have been shown to show a typical pattern of errors on this task (Van Herwegen, Farran & Annaz, 2011). The two groups did not differ in RCPM scores (equivalent to that expected from a TD 6.7 year old), suggesting that matching was adequate, $t(32) = .12$, $p = .91$.

Both groups also completed the *British Picture Vocabulary Scale II* (BPVS-II) (Dunn, Dunn, Whetton & Burley, 1997) which assessed verbal ability (receptive vocabulary). This allowed for a fuller picture of each participant's cognitive ability to be gained. In this task participants must match a spoken word from the experimenter to one of four images depicting possible meanings of the word; target words include animals, parts of speech and emotions. The WS group's BPVS-II 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' chronological age, BPVS-II and RCPM scores. There were no between-group differences in sex or handedness, $p > .05$. All participants had normal or corrected to normal vision.

Table 1 about here

Table 1
WS and TD Participants' Chronological Age, BPVS-II and RCPM Scores.

2.2. Materials and Apparatus

The house model was constructed in 2D using combinations of basic geometric shapes (Figure 1). The house shape was presented to participants on a 15.6 inch laptop using Superlab Pro at approximately 60cm from the participant. The house was presented initially for five seconds. The model was then replaced onscreen with instructions that the space bar should be pressed in order to view the house again. If the space bar was pressed then the house was presented for a further five seconds. Participants copied the model on an A4 piece of paper in a portrait orientation, using an HB pencil. Participants were free to view the house as frequently as was required to accurately replicate the model.

Button presses were used as a proxy for actual fixations as use of traditional eye tracking techniques in combination with drawing were likely to be problematic, especially in children and individuals with a neurodevelopmental disorder. Head-mounted eye trackers in concert with chin rests would have impeded normal head movement when drawing and made the act of mark-making challenging. Additionally this set-up may not have been tolerated by the WS group, whilst use of screen-based eye-trackers would have presented methodological issues due to repeated fixation away from the screen. A button press measure provides a gross index of switching of attention between the model and copy.

For the tracing condition, the model was composed of dashed lines presented in a portrait orientation printed on an A4 sheet of paper. This condition simulated tracing in participants as they were required to join the dashed lines in order to replicate the house, using an HB pencil.

Figure 1 about here

Figure 1. House figure used as the model for drawing and tracing.

2.2. Procedure

Ethical approval for the study to proceed was gained from the Research Ethics Committee of the University of Reading, UK; all data were collected by KH.

2.2.1. Drawing condition. The drawing condition was always presented first to reduce the influence of memory and familiarity with the model from tracing that might have reduced attention to the model. Participants were instructed that they would see a house shape and that the figure was to be copied exactly. Participants were informed that the model would be presented for a short time and would then disappear. By pressing the space bar participants could view the house again to continue copying. Participants were observed during the task to ensure that they attended the screen subsequent to each button press. These instructions were delivered verbally and were also presented on the computer screen. The task was explained until it was clear that participants understood the task. Participants commenced drawing when they were ready and indicated when drawing was completed. Participants were permitted to correct any perceived errors and only final solutions were analysed. Total drawing times and number of button-presses were derived from Superlab Pro. These were used to calculate the mean duration of time between looks to the model (total drawing time divided by the number of button presses). During each participant's drawing the experimenter noted the order that parts of the model were drawn.

2.2.2. Tracing condition. Participants were given a piece of A4 paper with the house model depicted in dashed lines. It was explained to participants that the house could be copied by tracing over the dashed lines of the model. The experimenter recorded tracing time and the order of tracing of each element of the figure.

2.3. Data Analysis

In order to assess drawing and tracing of hierarchical levels within the model, elements of the house were categorised as global, mid- and detail-level parts. A global-level part was defined as an external feature of the house namely the path, outline of the main house, roof, chimney pot and partially occluded circles (smoke). Mid-level features were defined as the window frames, door frame and top of the door. A detail-level feature was determined as an internal feature of mid-level elements of the house model; window panes, door window and door knob.

In line with Picard and Vinter (2005), this study also examined the influence of the size of elements on the drawing order. The order of size of elements based on area (mm^2) was as follows, 1) house frame, 2) roof, 3) path, 4) smoke, 5) door frame, 6) door top, 7) window frames, 8) door window, 9) chimney pot, 10) window panes and 11) door knob.

Comparison of the percentage of global, mid- and detail-level parts that were drawn and traced was used to determine whether participants with WS had difficulty drawing global elements, but were able to trace the parts when these were provided. The order in which elements were drawn or traced determined hierarchisation

(Mottron et al., 1999). If a local processing preference in WS stands then the WS group should prioritise mid- and detail-level elements with less of a preference for drawing the global features.

3. Results

Given that the mean duration between looks to the model measure was derived from button presses and total drawing time, Table 2 presents average tracing and drawing times as well as average total button presses for both groups.

Table 2 About Here

Table 2
Average Tracing Time, Drawing Time and Button Presses for WS and TD Participants

3.1. Frequency of Looking

The frequency of looking during drawing was assessed by dividing the total drawing time by the number of button-presses (looks to the model). This determined the average length of time between looks throughout the time spent drawing, regardless of total drawing time. Tests of normality revealed that the frequency of looking measure was not normally distributed in the WS group ($D(17) = .39$, $p < .001$; TD: $D(17) = .11$, $p = .20$) therefore a non-parametric test was applied. A Mann-Whitney U test to compare the frequency of looks between groups showed that the WS group looked significantly less frequently at the model than the TD group, $U = 36.00$, $p < .001$ (WS: $M = 32.59$s between looks, $SD = 42.54$s between looks; TD: $M = 8.83$s between looks, $SE = 2.95$s between looks). Of note is the variability seen in frequency of looks in the WS group when compared to the TD group (evidenced by standard deviation). This suggests that looks to the model during drawing is far more consistent in the TD group than in the WS group, in which looks to the model varies widely across participants.

3.2. Correlations between Looking Frequency and Total Drawing Omissions

This analysis aimed to determine if completeness of a copy depended on looking frequency. If so, the percentage of omissions in drawing should decrease as a function of looking frequency. Spearman's rho correlations are presented due to lack of normality of the looking measure. The correlation between total drawing omission and looking frequency was not significant for either group (WS: $r = -.09$, $n = 17$, $p = .71$; TD: $r = -.15$, $n = 17$, $p = .42$). When this analysis was split into global-, mid- and detail-level elements there were no significant correlations between omissions at each level and looking frequency in either group, $p > .05$.

3.3. Drawing of Global-, Mid- level and Detail Elements

Analysis determined whether the WS group differed from the TD group in depiction of mid-, detail-level and global-level parts of the model when drawing and tracing. Unsurprisingly, there were some ceiling effects in the tracing condition. These were observed for the TD group only, for global-level and detail-level parts ($p > .05$ for both), but not mid-level parts. There were no ceiling effects for the WS group for either condition, or for the TD group in the drawing condition. Examples of drawings and tracings of the model can be seen in Figure 2. This figure demonstrates that participants with WS produced cohesive images that resembled the model.

Figure 2 about here

Figure 2. Examples of drawings and tracings of the house model.

A group (WS, TD) by condition (drawing, tracing) by level (global, mid-level and detail) Analysis of Variance (ANOVA) was conducted on the percentage of parts of the model that were drawn or traced at each feature level. There was a marginal effect of group, $F(1, 32) = 3.90$, $p = .06$, $\eta_p^2 = .11$ due to the TD group ($M = 89.74\%$, $SE = 3.31\%$) drawing and tracing marginally more elements than the WS group ($M = 80.49\%$, $SE = 3.31\%$). There was a significant effect of condition $F(1, 32) = 4.97$, $p = .03$, $\eta_p^2 = .13$ as significantly more elements were traced ($M = 89.25\%$, $SE = 2.91\%$) than were drawn ($M = 80.98\%$, $SE = 3.06\%$). A significant effect of the level of feature, $F(2, 64) = 13.16$, $p < .001$, $\eta_p^2 = .29$, resulted from significantly fewer detail elements ($M = 75.74\%$, $SE = 3.97\%$) being produced than global ($M = 90.88\%$, $SE = 2.24\%$, $p = .03$) or mid-level features ($M = 88.73\%$, $SE = 2.43\%$, $p = .03$).There was a marginal interaction of condition by group, $F(1, 32) = 3.52$, $p = .07$. This was due to significantly less accurate drawings in the WS group ($M = 72.88\%$, $SE = 5.40\%$) compared to the TD group ($M = 89.09\%$, $SE = 2.89\%$, $p = .01$), but no difference between groups when tracing (WS: $M = 88.10\%$, $SE = 3.71\%$; TD: $M = 90.39\%$, $SE = 4.49\%$), $t(32) = 0.39$, $p = .70$. A significant interaction of the level of feature by group, $F(2, 64) = 5.26$, $p = .01$, $\eta_p^2 = .14$, resulted from significantly fewer detail elements being drawn by the WS group ($M = 65.20\%$, $SE = 5.64\%$) compared to the TD group ($M = 86.28\%$, $SE = 5.57\%$, $p = .01$), but no group differences for global (WS: $M = 90.00\%$, $SE = 3.21\%$; TD $M = 91.76\%$, $SE = 3.12\%$, $p = .70$) or mid-level features (WS: $M = 86.27\%$, $SE = 3.78\%$; TD $M = 91.18\%$, $SE = 3.07\%$, $p = .32$). There was a significant interaction of level of feature by condition $F(2, 64) = 3.13$, $p = .05$, $\eta_p^2 = .09$ that was due to tracing of significantly more global and detail features than were drawn ($p < .05$ for both), but no difference between the percentage of mid-level features that were drawn and traced ($p = .84$). There was a significant three-way interaction of condition by level of feature by group, $F(2, 64) = 6.68$, $p = .002$, $\eta_p^2 = .17$, due to the WS group ($M = 48.04\%$, $SE = 9.89\%$) drawing significantly fewer detail elements than the TD group ($M = 87.25\%$, $SE = 5.63\%$, $p = .002$), but no other difference between groups for any other level of feature for drawing or tracing conditions ($p > .05$ for all).

3.4. Strategies Used to Complete the Model

In order to compare completion strategies between drawing and tracing, the mean position in the replication sequence that each feature was completed was calculated for each condition. Spearman's correlations of the average position in the drawing sequence of each feature between conditions for each group revealed that in the WS group ($r = .89$, $n = 17$, $p < .001$) and TD ($r = .83$, $n = 17$, $p < .001$) the order of production of parts was comparable between drawing and tracing. This suggests that completion strategies were comparable between drawing and tracing in both groups.

Given that within group completion strategies were similar, analysis next compared both group's mean order of occurrence of features to determine whether similar strategies were used across groups when drawing and when tracing the model. When drawing there was a significant correlation between groups' mean order of drawing of parts, $r = .68$, $n = 17$, $p = .003$, suggesting that both groups used a comparable order of sequencing of parts when drawing the model. When tracing, both groups appeared to use a marginally comparable strategy to complete the house, $r = .48$, $n = 17$, $p = .054$.

Next, we asked whether features that occurred earlier in the drawing sequence were more likely to be drawn or traced, thus indicating core features in drawing of a house. When drawing and tracing, for the WS group, features that occurred earlier in the drawing sequence were significantly more likely to be drawn (r = .77, n = 17, p < .001) and traced (r = .70, n = 17, p = .002). In the TD group the mean position of occurrence of features did not correlate with the frequency of occurrence of the feature in the drawing condition, r = .14, n = 17, p = .60, but did correlate in the tracing sequence, r = .65, n = 17, p = .005. Figure 3 depicts drawing and tracing orders for completion of the model in both groups plotted against the average occurrence of each feature in the completion sequence.

Figure 3 about here

Figure 3. Drawing and tracing strategies used to complete the model in WS and TD groups. Key: Colours: Black Bold- Global element, Grey- Mid-Level element, Black- Detail element. Abbreviations: H- House Frame, R- Roof, S- Smoke, C- Chimney, P- Path, ULW-Upper Left Window, ULWP- Upper left Window Panes, URW- Upper Right Window, URWP- Upper Right Window Panes, LLW- Lower Left Window, LLWP- Lower Left Window Panes, LRW- Lower Right Window, LRWP- Lower Right Window Panes, D- Door, DT- Door Top, DW- Door Window, DK- Door Knob.

3.5. The Effect of the Size of Feature on Drawing and Tracing Orders

The following analysis determined whether there was a selective bias towards replicating larger elements of the model early in the drawing and tracing sequence in the WS and TD groups, similar to drawing a global-level feature. Participants with WS may have produced less detail elements (reminiscent of detail-level elements) as these are smaller, therefore less attention to the model may have meant that larger elements of the model were preferentially drawn and traced earlier in the replication sequence.

Elements from the model were ranked in order of size, based on area in mm². This was then correlated with the mean order of position that elements were drawn and traced in both groups. Spearman's correlations revealed a significant relationship between the size of the element and its position in the drawing and tracing order in both groups (WS Drawing $r = .66$, $n = 17$, $p = .004$; WS Tracing $r = .52$, $n = 17$, $p = .03$; TD Drawing $r = .67$, $n = 17$, $p = .004$; TD Tracing $r = .56$, $n = 17$, $p = .02$). In both groups and in both conditions larger elements were replicated earlier in the replication sequence than smaller parts.

4. Discussion

This study revealed that individuals with WS looked significantly less frequently to the model when drawing and produce less accurate drawings than TD controls. This is the first time that attention to a model has been investigated in drawing in WS, although attentional factors have been posited to underpin performance on block construction tasks in WS (Hoffman et al., 2003). Participants with WS may be attending to the model less frequently due to poor switching between the model and copy, or the copy may have been attended to more than the model.

By looking less frequently to the model, individuals with WS place excessive load on already atypical WM ability (Menghini et al., 2010). This is because more information must be stored and used to guide drawing, increasing the likelihood of drawing errors and disorganisation (Ballard et al., 1995; Cohen, 2005). In order to accurately copy and position parts of a model, looks between the spatial area of the model that is being copied and the corresponding copy must be tightly yoked (Coen-Cagli et al., 2009). Further to this, drawing accuracy in TD adults is greater when looks to the model are consistent and sustained, relative to drawers that infrequently attend to the model and do not focus looks to small portions of the model (Miall & Tchalenko, 2001). However in the current study looking frequency did not correlate with the number of elements that were omitted at global, local or detail levels in the either group; thus completeness of a drawing is not solely reliant upon frequency of looks. Despite the relative infrequency of looks in the WS groups, the less frequent drawing of detail features in the WS group cannot be attributed to attention to the model. Participants with WS that looked less frequently were no less likely to draw detail-level elements than individuals that looked to the model frequently. The lack of any relationships between feature levels and looks to the model in the WS group may be the result of the large variability seen in looking behaviour. The variability that is reported in drawings by individuals with WS, such as by Bertrand et al. (1997), may be a reflection of individual differences in looking behaviour in individuals with WS; in the current study some participants with WS looked frequently while others looked only occasionally. It is possible that looking behaviour can influence drawing performance by guiding where to attend and what information is extracted and stored in memory (i.e. Ballard et al., 1995). Future research could utilise mobile eye tracking devises to understand the yoking of inspection of the model and the parts that are drawn. The current study is limited in that we know how frequently participants look to the model but we do not know exactly where participants are attending on the model. This would provide greater insight into the variability in looking behaviour in WS and could be used to form the basis of an attention training strategy.

Ballard et al. (1995) argued that the dorsal visual stream is important for allocation of saccade locations. The proposed dorsal stream vulnerability in WS (Atkinson et al., 1997, 2001) may therefore underlie the difficulty that individuals with WS have with allocation of attention when drawing. One could argue that the higher chronological age of the WS group relative to the TD group could have led to less need to attend to the model due to greater familiarity with the subject of the model. However, the WS group drew houses that resembled the model and not generic depictions of a house; suggesting that the model was attended to in order to extract information about the identity of the elements. Additionally, the geometric shapes used in the model form part of a house and can therefore be assigned a meaning (and thus a verbal label), which might have benefitted the WS group to a greater extent than the TD group. Sheppard, Ropar and Mitchell (2005) have suggested that when figures have a meaning, drawing accuracy is increased relative to when the same elements were combined into a less meaningful configuration. It would be of interest to repeat the study with the same elements, but arranged in to a meaningless configuration to determine whether WS and TD groups differed in their approach to drawing, and accuracy of drawing. Indeed the study would benefit from a greater number of models to understand how participants construct drawings in more depth. One would expect that the WS group would still show a reduced attention to the model, but the means of scaffolding of parts may differ between groups as a less meaningful configuration of parts might lead to less rigid ordering of elements due to less ease of assigning verbal labels to parts.

The current data fail to support a local processing bias. Participants with WS produced cohesive images that did not differ in the depiction of global and mid-level features when compared to the TD group. This suggests that individuals with WS were able to draw global features without a selective bias towards local-level elements (such as mid- and detail-level features). When drawing, the WS group drew detail elements significantly less frequently than the TD group, however this difference was not present when tracing. Despite non-significant correlations between looks to the model and the number of detail elements that were drawn, a major difference between drawing and tracing is that when tracing both the model and copy are constantly in view. This means that the need to switch attention between the model and copy is circumvented in a manner that is not possible when drawing. The lack of detail elements in WS drawings, such as drawing of the window panes cannot be the result of the inability to draw these parts. Hudson and Farran (2011) demonstrated that individuals with WS could draw intersecting lines in a developmentally sophisticated manner; the lack of drawing of this feature (which contains intersecting lines) in the house was not related to poor graphic ability.

Completion strategies were comparable between drawing and tracing in both WS and TD groups suggesting that the means of depicting the model were stable between task-demands. Additionally, drawing and tracing strategies were broadly similar between groups. This is despite reported poor drawing in WS (e.g. Bertrand et al., 1997); these data suggest that individuals with WS can utilise typical, although delayed, strategies to draw and trace a model. This finding is reminiscent of the findings of Hudson and Farran (2011) in which typical drawing strategies were observed in a WS group, however this was only observed in simple, intersecting figures and was not seen in complex, embedded figures.

It is interesting that omissions were frequently made in the tracing condition in the WS group. Elements such as the door and doorknob were absent in tracings by some participants; this counters our original assertion that when tracing, the model is under continuous viewing. As such, poor attention to the model cannot explain these omissions. There is potentially an alternative type of inattention at work in this condition, which is perhaps of a spatial origin or related to executive dysfunction.

This might be a demonstration of ineffective set-shifting as participants might have difficulty mentally updating elements that have been traced and those that are yet to be traced. Menghini et al. (2010) suggest that set-shifting (between letters and numbers) in WS is poor when spatial relations need to be interpreted and produced. These abilities are clearly necessary when drawing. Alternatively this may be evidence of atypical eye movements in the WS group (e.g. Brown et al., 2003). When individuals with WS are looking at the model scan paths and localisation of fixations may be inefficient. Therefore the relatively long duration between looks in the WS impact drawing all the more if information is being extracted from the model or copy less efficiently.

In the WS group features that were more frequently drawn were more likely to occur earlier in the drawing and tracing sequence; drawing and tracing sequences were almost identical. When drawing and tracing, parts that occurred earliest in the completion sequence were generally global features whilst mid-level features were more likely to occur later in the drawing sequence. Conversely, when drawing, the TD group did not show a correlation between the average position of occurrence in the drawing sequence and the frequency with which the part was drawn; this is most likely due to low variation in frequency of drawing of parts rather than a qualitative difference between groups. However, global features appeared early in the drawing sequence, with mid-level details later. When the TD group traced the house, more frequently occurring parts also occurred earlier in the completion sequence, global parts occurred early in order of completion sequence, followed by mid-level elements. Overall global features and a door and window represented core features of the house as these were drawn and traced frequently and relatively early compared to mid- and detail-level elements in both groups. This supports Picard and Vinter's (2005) finding that features that are deemed important for identifying an object are replicated early in the drawing sequence. Picard and Vinter (2005) reported that TD children drew the main house outline, the roof, door or windows and then additional peripheral features, resembling the current data.

Alternatively, Picard and Vinter (2005) suggested that the reliance that children make on the depiction of core features early in a drawing sequence may represent a form of size-biasing. The core features of the house follow a progression from larger elements to smaller parts. Drawing may not be based upon features that are known to be necessary for recognition of the model as an example of its class, but instead represents a selective depiction of parts in order of size, beginning with the largest. This type of strategy would aid hierarchical depiction of parts as the larger global elements scaffold smaller, detail parts.

The current results support Picard and Vinter's (2005) notion of a size bias as both groups drew and traced larger elements earlier in the sequence of replication than smaller parts. This suggests that individuals with WS do not bias toward local elements and actively seek to scaffold and embed local elements in global arrays in a manner akin to TD controls. This is an important finding and illustrates the inability of a local processing bias to explain drawing behaviour in WS. It would be interesting to examine this in embedded figures of varying size in which no knowledge of the parts was possible. It may be that both WS and TD groups selectively draw larger elements earlier in the drawing sequence even when the parts do not have meaning, as in the house model verbal labels could be attached to each part.

In summary, this study provides the first evidence to suggest that poor drawing ability in WS may be subserved by infrequent or inefficient looks to a model, relative to TD controls. By looking to the model less frequently the WS group place excessive load on WM and so increase the likelihood of poorly depicting spatial relations between parts. It is therefore likely that the difficulty that the WS group possess with replication of multiple spatial relations is the result of poor attention to the model, leading to less accurate depiction of the relations of parts due in part to overburden of WM. Further research is needed to determine whether attention training when drawing may benefit individuals with WS in terms of drawing accuracy, such as drawing detail elements of a model. Both groups used comparable drawing and tracing strategies, suggesting that individuals with WS can show typical completion strategies for their level of non-verbal ability. The WS group were less likely to draw details of the house model, although this was unlikely to be the result of the inability to draw these elements, relative to the TD group. The WS group therefore made use of more generic and salient features of a house; in both groups this may be the result of a selective bias in drawing elements in order of size, as opposed to the assigned meaning of the part. These findings may be useful for devising graphomotor remediation strategies in WS as typical strategies can be used and strategies used in TD individuals may also be applicable in WS groups (e.g. Hudson & Farran, 2013). Results also argue against a local processing bias in WS as participants copied global features as frequently as the TD group and also actively embedded elements in a typical manner. However, in the WS and TD groups the frequency of looks was unrelated to the frequency of global, mid- and detail-elements that were drawn. Overall, the results suggest that attention to the model and copy is an important feature of the process of producing a drawing, but cannot entirely explain drawing accuracy.

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Table 1
WS and TD Participants' Chronological Age, BPVS-II and RCPM Scores.

	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
BPVS-II Score (maximum possible= 168)	102.4 (24.92)	52-142	76.22 (12.75)	56-112

Table 2

Average Tracing Time, Drawing Time and Button Presses for WS and TD Participants

	Average Tracing Time (s)	Average Drawing Time (s)	Average Number Button Presses Whilst Drawing
WS	114.37s (*SD* = 56.33s)	101.71s (*SD* = 54.81s)	5.53 (*SD* = 5.51)
TD	92.08s (*SD* = 46.13s)	104.06s (*SD* = 33.74s)	12.65 (*SD* = 4.55)

Figure Captions.

Figure 1. House figure used as the model for drawing and tracing.

Figure 2. Examples of drawings and tracings of the house model.

Figure 3. Drawing and tracing strategies used to complete the model in WS and TD groups. Key: Colours: Black Bold- Global element, Grey- Mid-Level element, Black- Detail element. Abbreviations: H- House Frame, R- Roof, S- Smoke, C- Chimney, P- Path, ULW-Upper Left Window, ULWP- Upper left Window Panes, URW- Upper Right Window, URWP- Upper Right Window Panes, LLW- Lower Left Window, LLWP- Lower Left Window Panes, LRW- Lower Right Window, LRWP- Lower Right Window Panes, D- Door, DT- Door Top, DW- Door Window, DK- Door Knob.

Fig. 1.

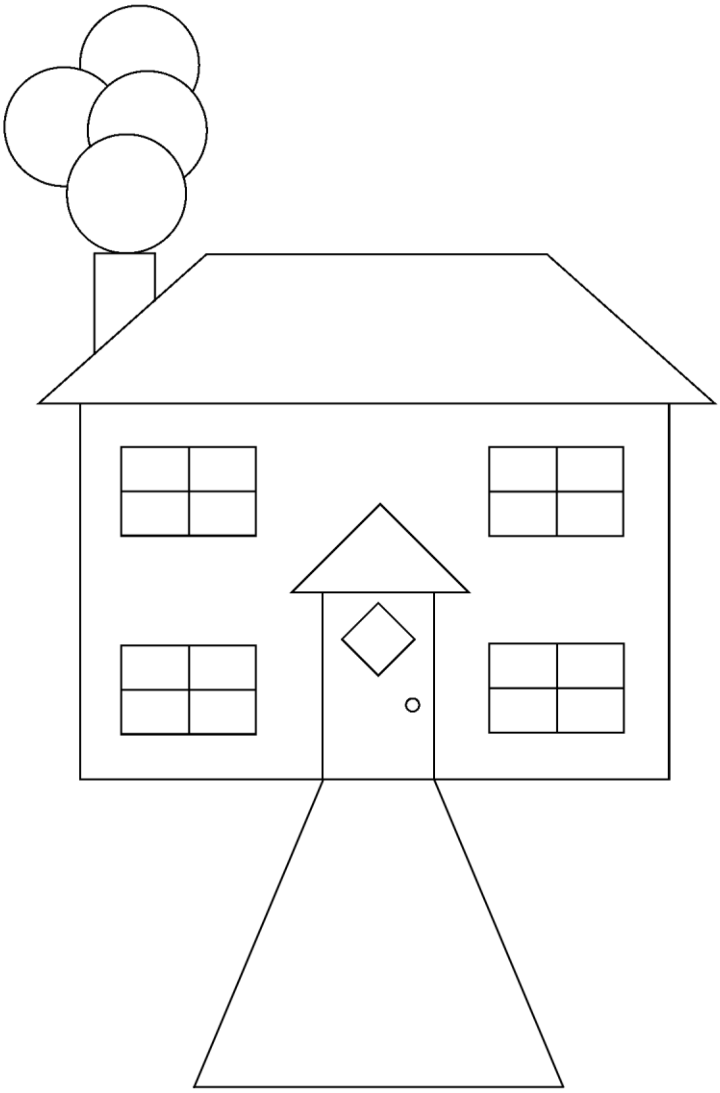
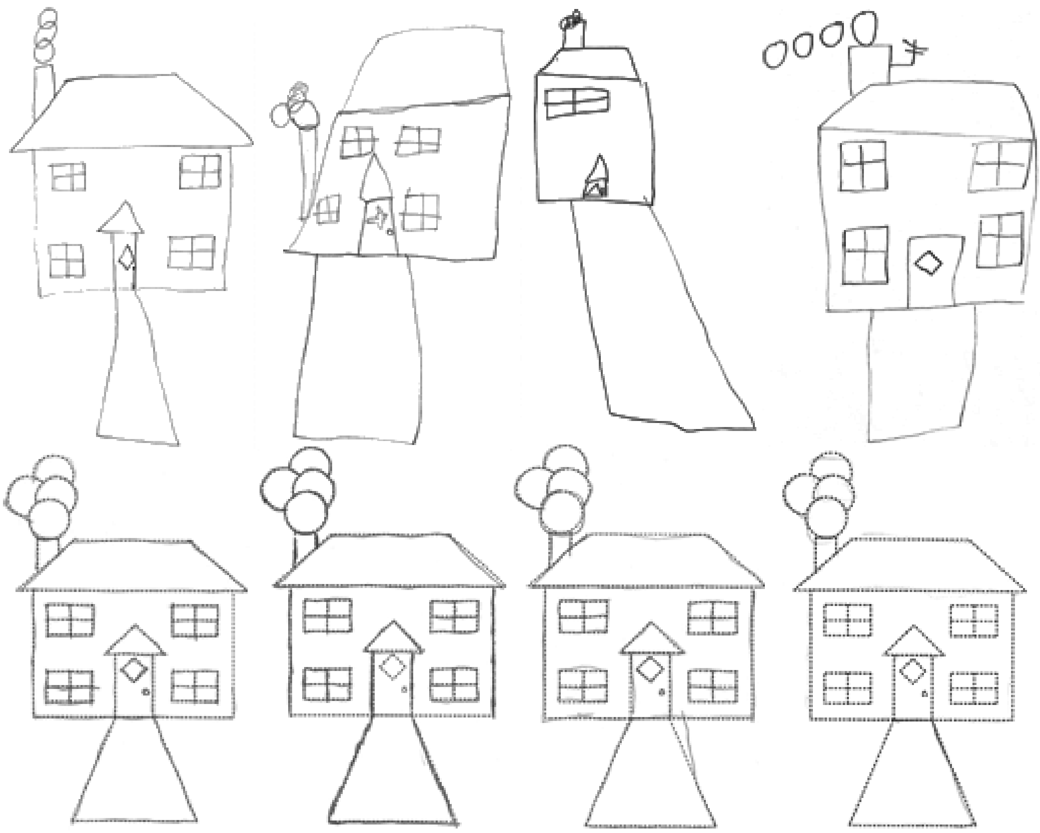


Fig. 2.

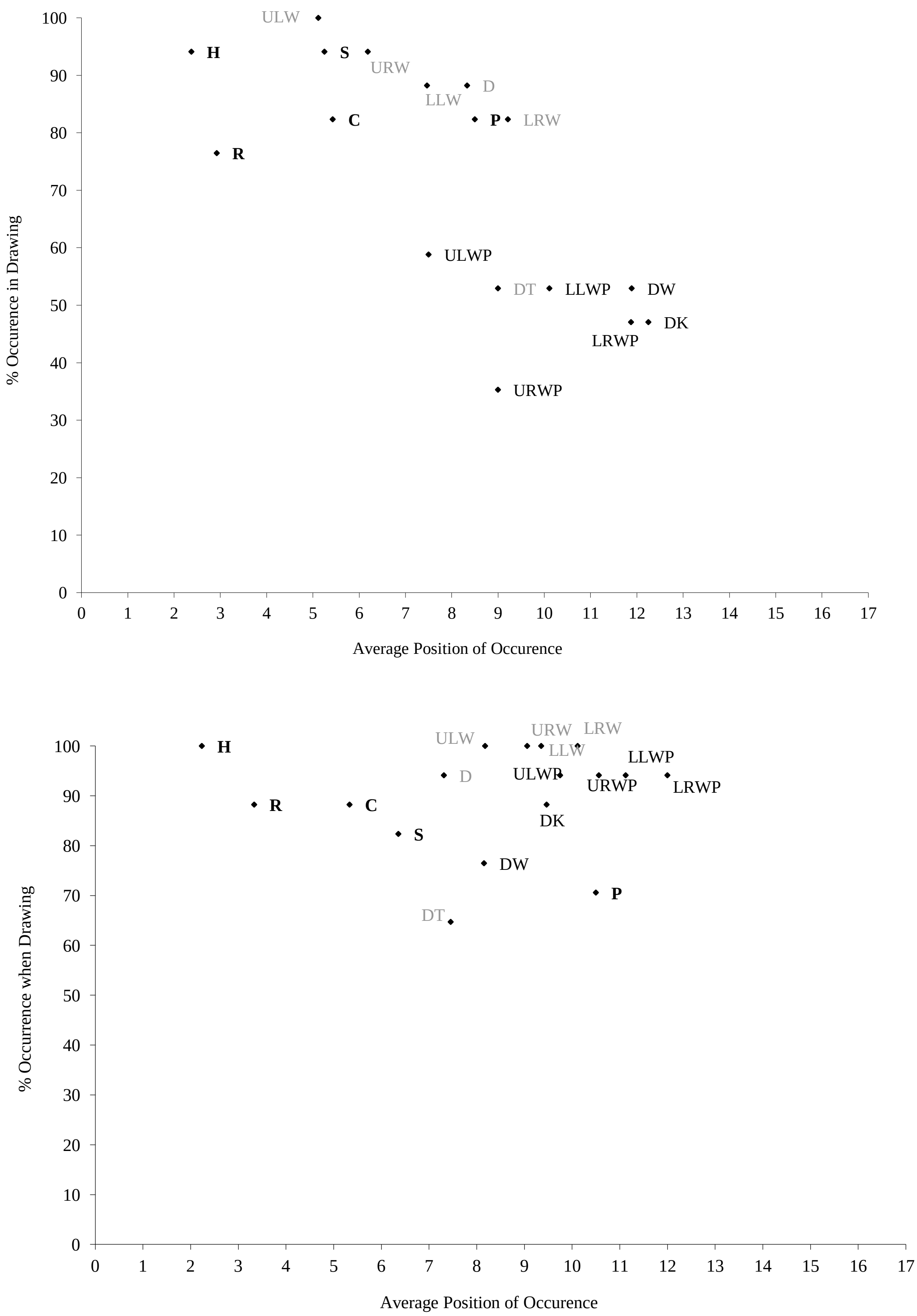


Drawing

Tracing

TD	TD	WS	WS
11;07 years; months	6;04 years; months	10;09 years; months	44;05 years; months
RCPM 24	RCPM 14	RCPM 20	RCPM 28

Fig. 3.


% Occurence in Drawing
Average Position of Occurence
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URW
LLW
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C
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DT
LLWP
DW
LRWP
DK
URWP
% Occurrence when Drawing
Average Position of Occurence
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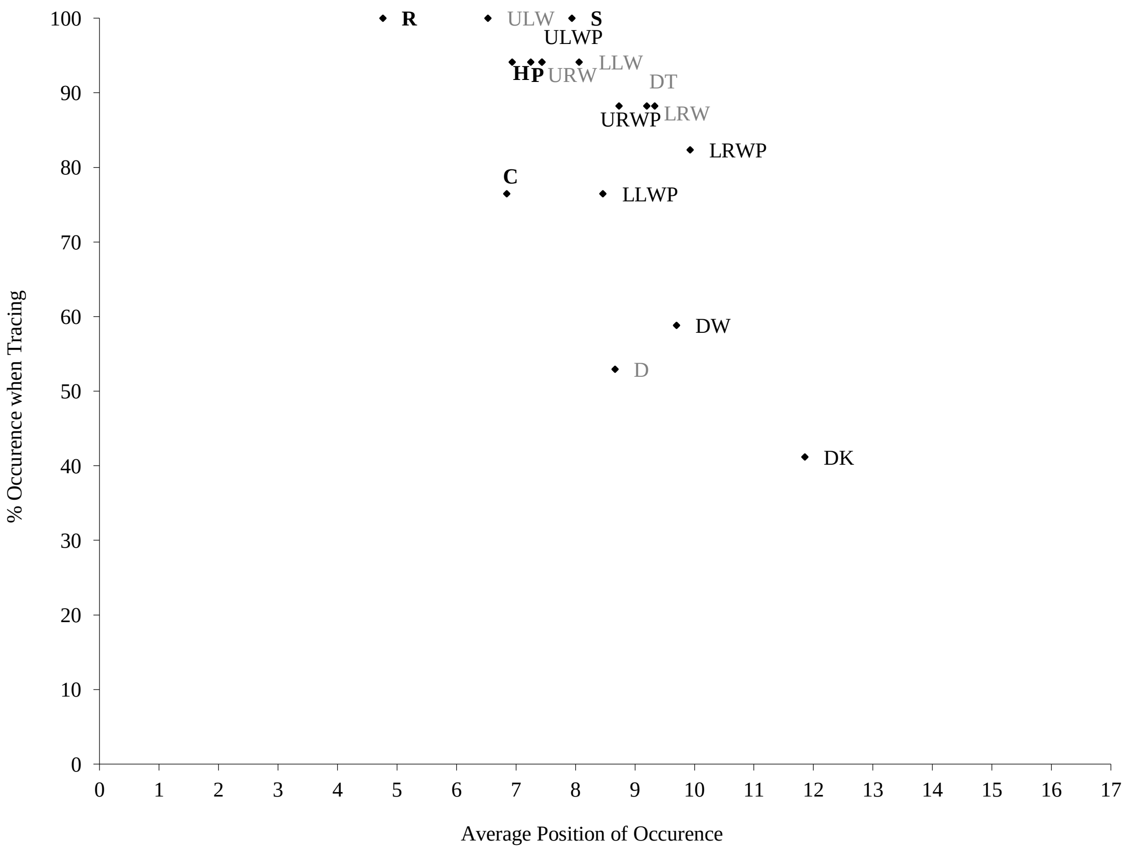
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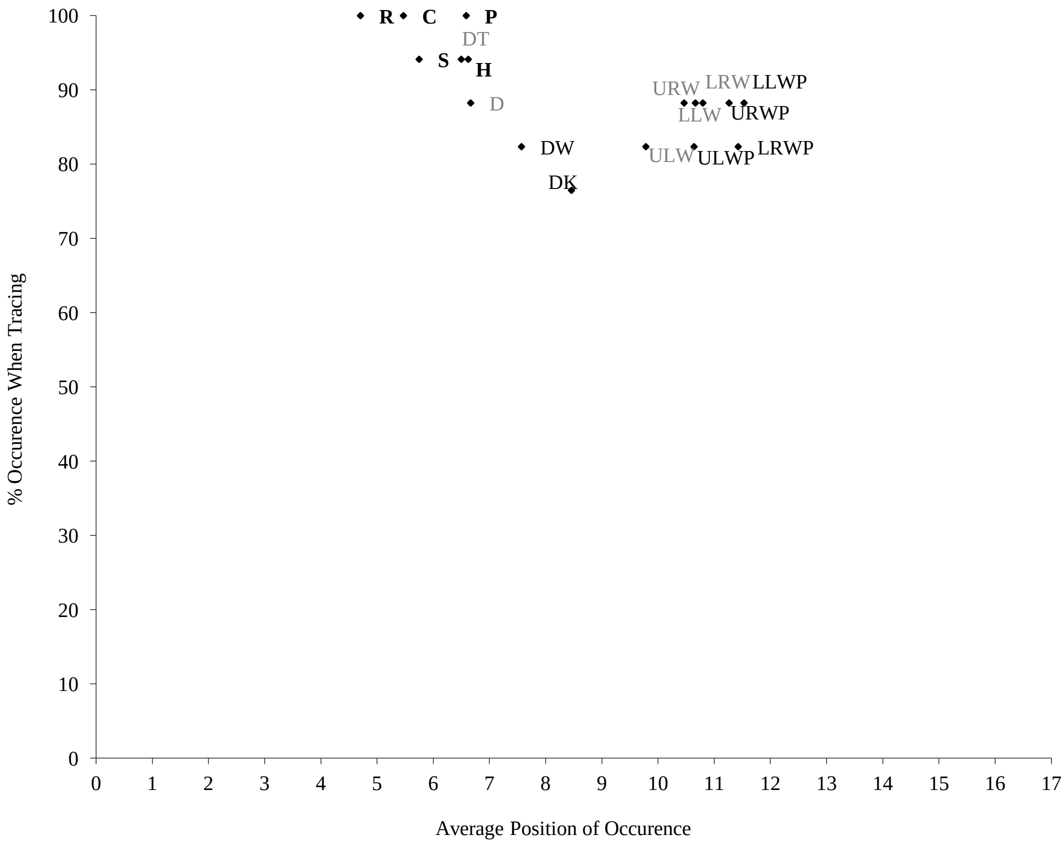
% Occurence when Tracing
Average Position of Occurence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% Occurence When Tracing
Average Position of Occurence