This paper has been accepted for publication in *American Journal on Intellectual and Developmental Disabilities*

Block design performance in Williams syndrome: Visuospatial abilities or task approach skills?

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Short running title: Task approach skills in Williams syndrome

Conflict of Interest: No conflict of interest has been declared.

Acknowledgements:

We would like to thank all the participants who took part in the research as well as Dr Susie Formby, Kate Ross Lonergan, and Carolina De Horna for their help with data collection and data preparation.

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Abstract

The Block Design task (BDT) is a visuospatial measure which individuals with Williams syndrome (WS) perform poorly on. However, it is unclear what underlies their impaired performance. This study investigated whether poorer performance is a result of visuospatial difficulties, executive function (EF) difficulties, atypical looking strategies or a combination of these. Eleven individuals with WS participated alongside Mental Age (MA) and Chronological Age (CA) matched control groups. Eye-movements were recorded whilst they undertook the BDT. Dwell times and visits to areas of interest in WS differed from CA, but not MA groups. Findings suggest that BDT abilities of individuals with WS are delayed, but not atypical. Delays result from visuospatial and attention switching difficulties rather than atypical looking strategies.

Keywords: Visuospatial abilities, Executive function, Williams syndrome, Eye movements, Block Design

Introduction

Williams syndrome (WS) is a rare genetic disorder that affects 1 in 7,500-20,000 births (Semel & Rosner, 2003; Stromme et al., 2002). It is caused by a microdeletion on 7q11.23. The IQ of individuals with WS is generally between 50 and 70 and there is an uneven cognitive profile with relatively good language skills but poor visuospatial abilities (Donai & Karmiloff-Smith, 2000).

The Block Design task is part of the Wechsler Abbreviated Scales of Intelligence (WASI; Wechsler, 1999, 2011) and similar block / pattern construction tasks are used in other standardised batteries for assessing visuospatial difficulties in children and adults (e.g., Pattern Construction task in British Ability Scales; Elliot et al., 1996, and Differential Ability Scales; Elliot, 2007). It is a visuospatial task that requires both perception and representation of the spatial relationships within and between the blocks of the model. The original Block Design task involves presenting participants with three-dimensional red and white cubes with some sides being red, white, or half red-half white (an arrangement of two colours). After participants familiarise themselves with the cubes, the experimenter models the picture in the assessment book using cubes for the first four trials and then participants are asked to copy the same pattern design from the book using their own cubes, as quickly as possible.

People with WS perform extremely poorly on Block Design tasks, typically at the level of a 4 year old child (see Farran & Jarrold, 2003 for a review). Although performance on this task improves with age in WS, it does so at a slower rate compared to language abilities (Jarrold et al., 1998; Van Herwegen et al., 2011). Mervis et al. (2000) characterised the Williams Syndrome Cognitive Profile (WSCP). This included four profile criteria, three of which included the Patten Construction task (which is similar to the Block Design task) of the Differential Ability Scales (DAS). That is, to meet the WSCP criteria, performance on the Pattern Construction had to be below the 20^{th} percentile, below the mean standardised score for other subtests in the DAS, and below performance on the Digit Recall subtest of the DAS. Mervis et al. (2000) demonstrated very high sensitivity and specificity to WS. This highlights that poor performance on Block Design type tasks is a hallmark of the WS phenotype. As such, it is surprising that the reason or reasons for impaired performance in WS on the Block Design task are unclear and under-researched.

Explanations for poor block construction performance in WS are that their visuospatial difficulties are due to incorrectly encoding the spatial relationships between the blocks (Farran & Jarrold, 2005; Hoffman et al., 2003). It has also been argued that spatial representations on this task interact with executive processes. For example, Ballard et al. (1997) showed that typically developing adults do not build a complex representation of the model to be copied but rather solve the Block Design task one block at the time. This suggests that adults do not need detailed information about the global configuration of the model once they have mentally decomposed it into a set of subtasks to be carried out. Adults switch their attention from the model to the copy in order to establish pointers which allows them to reduce working memory demands and constantly update their spatial representations. Therefore, both spatial working memory and executive processes are required with respect to how attention is allocated to their own cubes, the model from the book, and the experimenter’s model. Moreover, impaired executive processes would prevent one from establishing sub-goals and monitoring one’s progress. For example, in the Block Design task one needs to look at the example to be copied, search for the correct blocks, once the correct block has been selected one has to re-examine the example to see where the block should be placed, after placing the block one has to verify the outcome and finally correct the copy if needed.

Individuals with WS have been shown to have poorer visuospatial working memory abilities (Jarrold et al., 1999) and this has also been found in a spatial memory task when the information to be recalled is presented in a spatial-simultaneous presentation rather than a spatial-sequential (one at a time) format (Caretti et al., 2015). Executive function difficulties in WS has been well documented (e.g., Hudson & Farran, 2011). Therefore poor working memory and executive function in WS could contribute to their Block Design impairment. Farran and Jarrold (2004) suggest that individuals with WS perform extremely poorly on the Block Design task as a result of impaired mental imagery. Mental rotation skills have consistently been shown to be poor in WS, with performance often at or below the level of a 5 year old (e.g. Broadbent et al., 2014; Farran & Jarrold, 2004; Stinton et al., 2008). Due to their impaired mental imagery abilities, unlike typically developing (TD) children, Farran and Jarrold (2004) demonstrated that individuals with WS do not draw on mental imagery to mentally rotate or mentally transform the blocks as a strategy for mapping the block faces onto the model image.

Finally, it has been argued that individuals with WS show sticky fixation or fail to move their attention from one item to another in a typical manner (see Brown et al., 2003 & Van Herwegen, 2015). Therefore, it can be predicted that if sticky fixation is an issue, participants with WS would move their attention overall less (have a longer dwell time), and not just look less at the model before placing a block, but fixate less on the different areas overall and move less forward and backwards between the model and part-finished solution which would result in a higher working memory load. Therefore, atypical looking strategies as opposed to vision difficulties (see Atkinson et al., 2001) could be an explanation for difficulties with visuospatial tasks in WS. Moreover, visuospatial abilities may develop atypically in WS, however little is known whether this is still the case for adults with WS.

As there are different reasons for why individuals with WS might fail a Block Design task, eye tracking methodology can provide further insight into where people with WS pay attention and thus whether their task approach is the same or different from TD controls. A previous study by Hoffman et al. (2003) has already suggested that children with WS showed atypical looking behaviour during the Block Design task in that they fixated the model to copy (as measured by whether placing a block was preceded by a look at the model), as well as their own partial solutions, less frequently (also see Hudson & Farran, 2013 for a similar finding). Hoffman et al. (2003) argued that this atypical looking behaviour is caused by impaired spatial representations rather than by impaired executive processes. This was evidenced by the fact that participants with WS performed similarly to controls on simple puzzles, which according to the authors require the same executive processes as complex ones. However, it could be argued that complex puzzles include more subtasks and require a greater working memory capacity than simple puzzles. Furthermore, there was a decrease in fixations on the model for complex puzzles that contained more than three pieces as well as a decrease in accuracy on these models. In contrast, TD children increased their fixations on the model for difficult items in order to cope with the difficulty to understand the spatial relationships. Research has demonstrated that individuals with WS have difficulty with replicating figures with multiple spatial representations (Hudson & Farran, 2011) and so complexity is likely to play a role. Moreover, the study by Hoffman et al. (2003) was screen-based and the participants only had to select the correct blocks and drop them in the correct place, whereas in the original Block Design task participants have to manipulate and rotate the blocks in order to select the correct one and then place it in the correct location. Therefore, the original Block Design task includes additional executive function (EF) demands compared to the task used by Hoffman et al. (2003) and thus, deficits in EF might be more apparent during the traditional Block Design task. In addition, Hoffman and colleagues only measured looking patterns just before each drop. Consequently, for the current study it was decided not to divide the task into drop cycles but rather to analyse the number of times the example and participants' own model were fixated on per trial. This would allow investigation of whether sticky fixation, an aspect not examined by Hoffman and colleagues (2003), would provide an explanation for the fact that people with WS struggle with the Block Design task.

The current study expands on Hoffman et al.'s (2003) study but rather than using a computerised programme, we used the actual table top block design task from the WASI-II (Wechsler, 2011), providing a more realistic insight into what causes difficulties in the Block Design task. Research has shown that interactivity does influence performance in that interacting with the materials might change the perception of the problems to be solved (Vallée-Tourangeau & Vallée-Tourangeau, 2014). For example, the actual process of manipulating the blocks to construct a particular design can then prompt new ways of completing the item. In addition, the current study examined looking behaviours in older individuals with WS (16 years and over) since previous research (Hoffman et al., 2003) has only investigated eye movements in children with WS. Examination of older participants with WS would allow further insight into how difficulties and strategies change across development.

Eye-tracking is an important measure to use in conjunction with the Block Design task as it can show whether different strategies are being used (Hayes et al., 2011). The question being addressed is whether weak performance on the Block Design task could be explained by different task approach strategies, such as atypical looking or EF difficulties, as opposed to visuospatial difficulties being the only explanation.

It was predicted that if poor performance is caused by atypical looking strategies then individuals with WS should have different looking patterns during the task compared to TD individuals, such as longer dwell times (time spent looking at either the examples or their own blocks) due to 'sticky fixation'. Switching is defined as the number of times participants switched their attention from their own cubes to the example shown and vice versa. As a lack of switching may reflect a greater reliance on EF (e.g., working memory), it was hypothesized that if we see reduced switching in the WS group, this may point to EF challenges as an underlying reason for their performance differences. Finally, if spatial coding is generally impaired then individuals with WS would show similar frequency of visits (number of times looking at examples or their own blocks) and switching but performance would still be impaired on the Block Design task.

Method

Participants

Seventeen participants with WS between the ages of 16 and 47 years were recruited via the Williams syndrome Foundation, UK. However, useable data could only be obtained from 11 WS participants (mean chronological age= 29 years old, range from 16 to 47 years old). Two participants did not want to complete the task, data from one participant was lost due to technical issues, and for three other participants no accurate calibration could be obtained (this could have been caused by the fact they were wearing corrective glasses) and thus their eye movement data was not reliable and excluded from the analyses. All participants had normal or corrected to normal vision. There were two control groups of TD individuals, the first group were individually matched to the WS participants on mental age (MA, mean chronological age= 6 years old, range from 6 to 12 years old) and the second group were individually matched on chronological age (CA, mean chronological age= 28 years old, range from 16 to 50 years old). The MA group matched the participants with WS for their raw score (plus or minus 2 points) on the Raven's Coloured Progressive Matrices (RCPM). This task was chosen as previous studies have found that participants with WS show a typical error pattern (Van Herwegen et al., 2011). One participant with WS could not be individually matched to an MA control as performance on RCPM was too low (raw score of 10).[1] and that is equivalent to a 4 years and 2 months old TD child. We did recruit 4 year olds but they could not be accurately calibrated as the Tobii glasses are made for older children and adults. An independent sample *t*-test was carried out on RCPM scores comparing WS and MA groups and a Welch one-way ANOVA was undertaken comparing groups (WS, CA, MA) on chronological age. See Table 1 for participant characteristics, RCPM scores and statistics for each of the groups. Moreover, the T-scores from the Block Design task suggest that both control groups (CA and MA) were in the typical range. The mean T-score for the MA group was 44.4 and the mean T-score for the CA group was 47.73. The average T-score is 50 (SD= 10).

Insert Table 1 here

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[1] Analyses were carried out with and without this participant and similar results were obtained. All analyses in the results section use data from that participant nonetheless.

Materials and Procedure

The study was approved by the Faculty ethics committee at Kingston University and informed consent was given by parents of participants prior to their inclusion in the study. Participants completed the Block Design task from the WASI-II (2011) whilst wearing Tobii glasses that monitored participants' eye movements. This standardised task was chosen as it is commonly used to assess the visuospatial abilities of individuals with WS. Each session began with calibration of the eye tracker. Participants stood 1 meter away from a white wall and were asked to follow a marker on the wall with their eyes. A researcher gently held the participant's head to reduce the likelihood that they would make head movements during the calibration process. Participants fixated nine calibration points. After successful calibration, the participant was guided to the assessment table.

In the Block Design task participants were shown and subsequently given 3-dimensional red and white cubes with some sides being red, white or half red-half white along the vertical/horizontal axis. After familiarising themselves with the cubes, the researcher modelled the picture in the book and then participants were asked to copy the same pattern design from the book using the cubes. The booklet was about 40 cm away from the participant and lay flat on the table. The researcher's model remained visible next to the assessment book throughout the participant's trial for the first four items. All participants started with item one and testing finished once the participant failed to complete two consecutive items or when all 13 items had been completed. Participants' completion times were recorded and each item had a specified time limit in accordance with the WASI-II manual.

The video recordings were coded for overall dwell time in a specific area of interest (AOIs) and number of visits in that area using Observer Noldus XT 11 programme. The number of switches participants made between the different areas of interest was calculated as the number of times participants switched their attention from their own blocks to the example and vice versa. This number of switching was calculated as a proportion score: the number of switches made in the time they completed the item.

AOIs included the example (the book as well as researcher's model), participants' own cubes, or elsewhere (including any other place they looked at). Overall dwell time to AOIs, number of visits, and number of switches were calculated as a proportion of the total time it took participants to complete the item.

The first item of the Block Design task was not analysed as this includes a simple puzzle with block faces being of a single colour. Therefore, item one was considered as a practice item. The analyses focused on items 2, 3 and 4 as these were the only items that all participants successfully completed and thus could directly be compared across the three groups. This is because participants with WS typically do not exceed item 4 and fail successive items. Item 2 is a complex design using 2 blocks and items 3 and 4 are complex designs using 4 blocks. The simple (single colour) and complex (arrangement of two colours in a half-half design that requires orientating) designs follow the same definition as Hoffman et al. (2003). The WASI task finishes once the participant has failed two consecutive items or when all items were completed (which did not occur in the current study). Analyses also looked at these last two items that participants failed. A failed items analysis was undertaken and participants' first and second failed items were chosen and these could have been different items. This still allowed examination of whether failing the Block Design task could be explained by atypical visual strategies.

One-way ANOVA's were used to examine group differences and Bonferroni corrected pairwise comparisons were used to examine any post-hoc effects. In cases where Levene's test was significant Welch ANOVAs were carried out and Games-Howell multiple comparisons methods were used to assess group differences.

Results

Performance data

All participants performed the example (item 1) correctly, showing that they understood the task and could copy patterns using 3-dimensional cubes. A one-way Welch ANOVA was carried out on Block Design raw scores across the three groups (WS, CA, MA) and a one-way ANOVA was carried out on final item completed across the three groups (WS, CA, MA). Performance data (means, standard deviations and statistical values) are presented in Table 1.

Eye movement data

As we only report eye tracking data for those who had performed the item correctly and some participants did not pass all trials (three participants failed item 3 and three participants failed item 4), the number of participants reported for each analysis differed slightly.

Dwell times

Dwell times to the example, their own cubes, or elsewhere for items completed correctly were analysed using separate one-way ANOVA's comparing groups (WS, CA, & MA) for items 2, 3, and 4 as well as for *failed* items 1 and 2. Means, standard deviations, and statistical values are presented in Table 2.

Insert Table 2 here

Frequency of visits

Frequency of visits to the example, their own cubes or elsewhere, were analysed for *correct* items and separate one-way ANOVA's (Group- WS, CA, MA) were carried out for items 2, 3, and 4 as well as for *failed* items 1 and 2. See Table 3 for means, standard deviations, and statistical values for correct and failed items.

Insert Table 3 here

Switching data

A two-way ANOVA was carried out on Item and Group for correct items[2]. There was a significant main effect of Group, $F(2, 27) = 8.061$, $p < .001$, $\eta^2_p = .563$, but there was no significant main effect of Item, $F<1$, and no significant interaction between Item and Group, $F<1$. Bonferroni pairwise comparisons revealed that the CA group has a higher switching proportion than the MA ($p < .001$) and WS group ($p < .001$). However, there was no significant difference in switching between WS and MA groups ($p = 1.00$). See Figure 1 for mean proportions and standard errors for switching.

Insert Figure 1 here

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[2] A switching analysis could not be carried out for failed items as participants completed different items and as switching increases with difficulty of the item, switching could not be compared for the failed items.

Discussion

To summarise, this study replicated Hoffman et al.'s (2003) work but used a direct Block Design assessment rather than a screen-based task, included an older sample and included an additional looking measure. The study found a number of different looking behaviours between the WS, MA and CA groups. With regards to overall dwell times for failed items individuals with WS looked less at the example than the CA group but were similar to the MA group, showing that looking patterns are delayed rather than atypical. For visits, WS and MA groups looked less often at the example and at their own cubes than the CA group for both correct and failed items. Moreover, the switching analysis, which only included correct items, showed that individuals with WS and MA controls switch less than the CA group. Therefore, individuals with WS switch their attention from the example to their own cubes and vice versa to the same extent as the MA matched participants but not to CA group which suggests a different task approach in comparison to the CA group. The CA group did of course complete more difficult items which may have required them to look at the example more often. Yet, the switching differences and how participants looked at their own cubes applied to correct items which were all completed by the three groups. This provides evidence that switching and attention during the Block Design task is different in WS and in younger MA matched children.

Therefore, the current findings may have useful implications for clinical practice. First of all, when matching WS participants to TD controls who have similar mental ages, we now know that they use similar strategies on the visuo-spatial task and that performance can be compared in a useful way. The findings may also imply an important role for switching as if individuals with WS switch their attention less then they need to keep more information in their working memory and this might explain their poorer performance. This suggests that to improve their performance they need to look more often at the example in order to reduce the demand on their working memory.

There was no evidence of sticky fixation or atypical looking in individuals with WS as they did not have longer dwell times compared to control participants for correct items. This corroborates with previous research that has not found sticky fixation in older participants with WS (Van Herwegen et al., 2019). It has been suggested that sticky fixation patterns may change with age and that only young children with WS show sticky fixation, especially on tasks that involve social stimuli or faces (Riby & Hancock, 2008; Van Herwegen, 2015). Therefore, if participants fail to build a global picture of the example to be copied, it may be driven by other contributing mechanisms such as impaired spatial relations (Farran & Jarrold, 2005), impaired mental imagery (Farran & Jarrold, 2004) or difficulties with WM or EF (Hudson & Farran, 2011; Jarrold et al., 1999), rather than scanning issues.

Findings support the account that poorer performance on the Block Design task may be partly due to EF issues (Hudson & Farran, 2011), if it is inferred that individuals with WS (who switched attention less than the CA controls) had to rely more heavily on their EF skills. Furthermore, they checked the example and their own cubes less often than the CA group suggesting they have a different task approach to the Block Design task. As suggested by Ballard et al. (1997), switching appeared to be an important factor for the successful performance of the CA group as they were better at the Block Design task than the other groups and this could be because they switched their attention more from the example to their own cubes and vice versa.

Previous studies that have used eye-tracking to examine the underlying causes of poor Block Design task performance in WS, had only used a computerised version

(Hoffman et al., 2003) which reduced the EF demands for individuals with WS as participants only had to select the correct picture from a number of options. In the current study, participants had to manually rotate the blocks to find the right arrangement and thus keeping track of whether they rotate the block in the correct way to find new possibilities which added a further step to complete the task and thus working memory capacity. As such, the current study expanded upon Hoffman et al.'s study by using three dimensional cubes as well as examining performance in individuals with WS over the age of 16 and showed that adults with WS fail the Block Design task not only due to impaired visuospatial abilities but also because of the EF demands of the task. Therefore, implications of these findings include designing interventions to teach individuals with WS to switch their attention more to the example, as this would reduce working memory demands of the task. Subsequently, this type of intervention would benefit other real-world activities such as in classroom settings where students often need to switch their attention from what the teacher is saying or showing on the whiteboard to completing their own work. Therefore, performance on tasks can potentially be improved by developing the ability to continuously switch their attention from one entity to another in copying tasks.

Limitations and Future Directions

This study has demonstrated that interactivity with blocks offers important information regarding block design task performance and that screen-based block design studies may not provide the same insight. Despite this strength, there were some limitations that should be mentioned. It is important to acknowledge that the Block Design task is just one of many tasks that measure visuospatial abilities and that the use of another task may yield different results for being a more 'pure' test of visuospatial abilities such as a mental rotation task. However, studies using other spatial tasks have also found that children with WS perform similarly to younger children (Farran & Formby, 2012). A further limitation concerns matching by RCPM. There was a small to moderate effect (albeit non-significant) group difference between WS and MA groups in the RCPM and this should be taken into consideration when interpreting those comparisons. RCPM is, however, a suitable matching measure: Van Herwegen et al. (2011) found that children with WS make typical errors on this task that are similar to typically developing children and thus we are confident that performance on the RCPM is delayed but not atypical in our WS sample. Another limitation of the study is the small number of participants that were included in the analyes, therefore caution must be taken with respect to the generalisability of these findings. However, this was due to a combination of the rarity of WS and obtaining high quality eye-tracking data. Nevertheless, these results should be viewed as preliminary and replication with larger samples would be highly desirable.

Findings suggest that visuospatial abilities cannot be studied in isolation, there is a need for future studies to incorporate measures of attention, EF, motor abilities and level of task difficulty, and to explore how these variables interact. Moreover, investigating developmental trajectories in both typical development and in other neurodevelopmental disorders across the lifespan will help elucidate the relative contribution of different task approach skills and whether visuospatial abilities are delayed or atypical. For example, individuals with autism are known to have superior visuospatial abilities so comparing their performance to TD individuals across the lifespan would be informative about the development of this ability.

To conclude, Block Design abilities of individuals with WS are MA appropriate and do not appear to be atypical. Delays are more likely to be caused by attention switching difficulties which may impact on spatial difficulties. However, atypical looking strategies such as sticky fixation were not observed and thus, do not seem to play a role.

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Table 1: Participant characteristics, including chronological age (CA) and Gender, Mean (and SD) for raw score on Raven's Coloured Progressive Matrices (RCPM) and performance on Block Design Task

	WS N=11 Male/female=5/6	CA N=11 Male/female=3/8	MA N=10 Male/female= 3/7	Group Difference
CA	29.10 (11.73)	28.76 (11.83)	6.76 (1.97)	F(2,14.115)= 35.065, p < .001, η^2_p = .546, WS = CA, p>.1; MA< CA & WS, p<.001
RCPM	17.91 (4.41)	N/A	19.50 (2.95)	t(19)= -.960, p = .349, d = .423, WS = MA
Block Design raw score	5.45 (3.86	45.55 (12.18)	8.80 (7.15)	F(2,16.143)= 52.043, p < .001, η^2_p = .837, WS=MA p>.1; CA>WS & MA, p<.001
Final item completed	5.18 (1.72)	12.09 (.094)	6.30 (1.57)	F(2, 29)= 71.746, p < .001, η^2_p = .832, WS=MA, p>.1; CA> WS & MA, p<.001.

Table 2: Dwell times (proportions) across participant groups for correct and failed items

		Group									
		WS			CA			MA			
Item	Place	N	Mean	SD	N	Mean	SD	N	Mean	SD	Group Difference
Item 2	Example	9	.29	.23	11	.29	.16	10	.29	.19	$F(2,29)= .004$, $p = .996$, $\eta^2_p = .000$
	Own cubes	9	.50	.38	11	.55	.28	10	.49	.33	$F(2,29)= .106$, $p = .900$, $\eta^2_p = .008$
	Elsewhere	9	.20	.31	11	.12	.25	10	.15	.15	$F(2,29)= .300$, $p = .743$, $\eta^2_p = .022$
Item 3	Example	8	.21	.12	11	.17	.12	9	.16	.14	$F(2,27)= .460$, $p = .637$, $\eta^2_p = .035$
	Own cubes	8	.69	.21	11	.75	.15	9	.70	.25	$F(2,27)= .280$, $p = .758$, $\eta^2_p = .022$
	Elsewhere	8	.07	.14	11	.08	.11	9	.14	.21	$F(2,27)= .482$, $p = .623$, $\eta^2_p = .037$
Item 4	Example	8	.26	.13	11	.21	.20	9	.19	.11	$F(2,27)= .772$, $p = .473$, $\eta^2_p = .058$
	Own cubes	8	.64	.21	11	.69	.20	9	.60	.22	$F(2,27)= .445$, $p = .646$, $\eta^2_p = .034$
	Elsewhere	8	.10	.13	11	.10	.22	9	.14	.09	$F(2,27)= .193$, $p = .825$, $\eta^2_p = .015$.

Failed 1	Example	11	.22	.11	11	.42	.09	10	.24	.11	*F*(2,31)= 11.618, $p < .001$, $\eta^2_p = .445$ WS=MA, *p*>.1; CA> WS & MA, p<.001
	Own cubes	11	.66	.20	11	.55	.11	10	.63	.17	*F*(2,31)= 1.200, $p = .316$, $\eta^2_p = .076$
	Elsewhere	11	.10	.15	11	.03	.05	10	.12	.14	*F*(2,31)= 1.733, $p = .195$, $\eta^2_p = .107$
Failed 2	Example	10	.18	.12	11	.45	.14	8	.33	.23	*F*(2,28)= 6.939, $p = .004$, $\eta^2_p = .348$ WS=MA, *p*>.1; CA>WS & MA, *p*<.01
	Own cubes	10	.67	.26	10	.53	.15	8	.48	.20	*F*(2,27)= 2.046, $p = .150$, $\eta^2_p = .141$
	Elsewhere	11	.14	.31	11	.03	.05	10	.11	.22	*F*(2,28)= .996, $p = .394$, $\eta^2_p = .069$

Table 3: Frequency of visits (proportions) across participant groups for correct and failed items

		Group									
		WS			CA			MA			
Item	Place	N	Mean	SD	N	Mean	SD	N	Mean	SD	Group difference
2	Example	9	.27	.11	11	.69	.38	10	.38	.12	*F*(2,17.180)= 7.016, p = .006 WS = MA, p>.1; CA > WS & MA, p <.05
	Own cubes	9	.28	.17	11	.72	.47	10	.28	.28	*F*(2,29)= 6.297, p = .006, η^2_p = .318 WS = MA, p>.1; CA > WS & MA, p <.05
	Elsewhere	11	.33	.50	11	.12	.20	10	.17	.16	*F*(2,18.062)= .802, p = .464
3	Example	9	.34	.25	11	.46	.25	9	.24	.19	*F*(2,28)= 2.141, p = .138, η^2_p = .141
	Own cubes	9	.27	.16	11	.58	.30	9	.24	.06	*F*(2,28)= 8.540, p = .001, η^2_p = .396 WS = MA, p>.1; CA > WS & MA, p<.01
	Elsewhere	9	.09	.14	11	.06	.09	9	.14	.10	*F*(2,28)= 1.279, p = .295, η^2_p = .090
4	Example	7	.29	.19	11	.53	.44	10	.22	.19	*F*(2,27)= 2.847, p = .077, η^2_p = .186

	Own cubes	7	.29	.17	11	.51	.13	10	.20	.11	*F*(2,28)= 15.777, $p < .001$, $\eta^2_p = .558$ WS=MA, $p>.1$; CA>WS & MA, $p<.01$
	Elsewhere	7	.09	.12	11	.15	.32	10	.12	.06	*F*(2,15.482)= .375, $p = .705$
Failed 1	Example	11	.31	.130	11	.49	.11	10	.20	.10	*F*(2,31)= 16.574, $p < .001$, $\eta^2_p = .533$ WS = MA, $p>.1$; CA > WS & MA, $p<.01$
	Own cubes	11	.28	.102	11	.50	.11	10	.21	.10	*F*(2,31)= 22.831, $p < .001$, $\eta^2_p = .612$ WS = MA, $p>.1$; CA > WS & MA, $p<.001$
	Elsewhere	11	.08	.109	11	.03	.05	10	.11	.11	*F*(2,31)= 2.144, $p = .135$, $\eta^2_p = .129$
Failed 2	Example	10	.25	.15	11	.46	.09	9	.23	.09	*F*(2,29)= 13.534, $p < .001$, $\eta^2_p = .501$; WS = MA, $p>.1$; CA > WS & MA, $p<.001$
	Own cubes	10	.22	.16	11	.47	.08	9	.22	.09	*F*(2,29)= 16.356, $p < .001$, $\eta^2_p = .548$ WS = MA, $p>.1$; CA > WS & MA, $p<.001$
	Elsewhere	10	.05	.06	11	.04	.06	9	.15	.09	*F*(2,29)= 7.687, $p <.01$, $\eta^2_p= .363$ WS = MA, $p> .1$; WS < MA ($p <. 05$) CA < MA ($p < .01$).

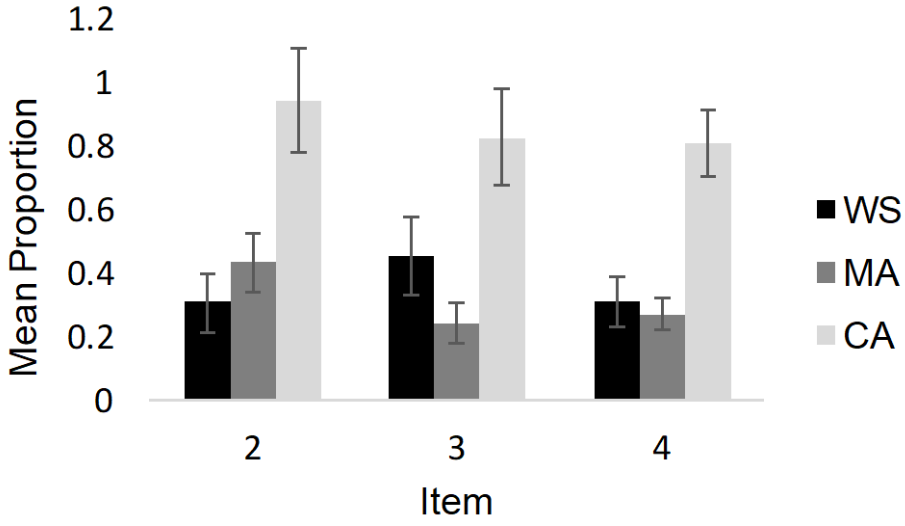

Figure 1. Mean proportions and standard error bars for switching across items and groups