Running header: SPATIAL LANGUAGE CUES AND FEATURE CONJUNCTIONS

Children's ability to bind and maintain colour-location conjunctions: the effect of spatial language cues

Emily K. Farran

Brigid O'Leary

Department of Psychology and Human Development, Institute of Education, University of London

Address correspondence to:

Emily Farran

Department of Psychology and Human Development

Institute of Education

25 Woburn Square

London WC1H 0AA

Tel: +44(0)207 6126272

E-mail: E.Farran@ioe.ac.uk

Abstract

Sixty 4-year-olds were shown a target square, divided in half by colour, and, after a one second delay, were asked to find an identical square in a test array. Seven to ten days later, control children (N=19) completed the same task again, one experimental group heard a descriptive spatial language cue when shown the target (e.g. “yellow is on the top”) (N=21) and the other heard and verbalized the same cue (N=18). Spatial language cues significantly improved the performance of both experimental groups when compared to the control group, but this was dependent on children demonstrating knowledge of the spatial language terms used. Verbalizing a linguistic cue yielded no additional benefit over just hearing a linguistic cue. The current results suggest that hearing a spatial language cue encourages children who have an understanding of spatial language terms to change from a visual to a verbal strategy to encode colour-location feature conjunctions in visual stimuli.

Children's ability to bind and maintain colour-location conjunctions: the effect of spatial language cues

Introduction

The manner in which language can influence our ability to process spatial information has long been an active area of research. Previously, research has presented a dichotomous view that the structure of spatial language may affect perception of the world (Whorf, 1956) or that our perception of spatial relationships may shape our spatial language (e.g. Li & Gleitman, 2002). A more pragmatic recent development has been to focus on how spatial language can be used to influence our ability to process and use spatial information efficiently. Current theories hypothesise that language acts as a “toolkit” by providing the concepts and strategies to support visual representations (Gentner & Goldin-Meadows, 2003).

Loewenstein and Gentner (2005) found that spatial language terms could be used as cues with 3- to 5-year-olds, to scaffold performance on tasks that require spatial reasoning. In their spatial mapping task, children watched a winning card being placed in a location in a ‘hiding’ box, and were asked to find a second winning card in the exact location in a ‘finding’ box. The use of ‘top’, ‘middle’ and ‘bottom’ cues positively impacted performance. They suggest that spatial language helps children to encode spatial information and improves their conceptual understanding of spatial relations, as well as helping to draw children’s attention towards the task. Important for the current study, they point out that this depends “…on children knowing the meanings of the spatial terms we use.” (page 321). The extent to which knowledge of the spatial language terms is required to be stable, however, is brought into question by Dessalegn & Landau (2008; 2013), who used feature binding as a case study to assess this relationship.

Feature binding involves the grouping together of features from the same object (e.g. red and shiny) and the ability to maintain them as feature conjunctions in memory (Allen, Baddeley & Hitch, 2006). Although a small piece of the jig-saw with reference to spatial cognition, it is an essential component of our ability to make sense of our visual environment. Feature binding represents an ideal case study to assess the impact of spatial language cues on performance because, developmentally, forming and maintaining feature conjunctions shows a gradual improvement with age (Lorsbach & Reimer, 2005) and thus in young children it is a strong candidate for the effective use of facilitation cues.

Processing feature conjunctions accurately requires focused attention (Treisman & Gelade, 1980), a skill that is still developing at four/five years (Ruff & Capozzoli, 2003). Dessalegn and Landau (2008) proposed that difficulty in young children's ability to form and maintain feature conjunctions may be due to a weak attention faculty. They used a delayed matching task which involved squares that were divided horizontally, vertically or diagonally into two colours. One could argue that the task did not involve feature binding in the traditional sense because colour and location did not vary independently; the design required a simpler form of binding which was developmentally appropriate for 4-year-olds. Four-year-olds who received linguistic directional cues (e.g. the red is on the left), displayed stronger performance than those who received no cue, other linguistic (e.g. the red is touching the green) or a non-linguistic cue (e.g. the red part flashed on and off). Dessalegn and Landau (2013) further demonstrated that the effect of linguistic directional cues persisted for both a 1 second and a 4 second delay between the target and test items. They suggest that directional language provides a modulation of attention which supports a temporary representation of the visual stimulus. Particular significance is attached to their finding that the directional cues seemed to improve performance even when the children's explicit knowledge of “left” and “right” was not yet stable. When spatial terms were not understood, they suggest that children acquired a temporary understanding which improved their representation of the target and helped them maintain the colour-location conjunction. One aim of the current study is to further explore the relationship between spatial language knowledge and facilitation by spatial language cues, also using feature conjunctions.

Developmental factors associated with working memory might also affect performance on spatial tasks (Allen et al., 2006). Hitch et al. (1988) report that between 5 and 7 years, children typically rely on their visual memory to recall visual information in working memory tasks while ten-year-olds tend to verbally code the visual information and mentally rehearse it. However, when the younger children were prompted to verbally name each figure, their accuracy improves significantly. Thus, although verbal coding is not employed spontaneously in young children, it is available when prompted and is associated with improved performance.

An important difference between the studies discussed above relates to whether children hear the verbal cue from an experimenter, as in Dessalegn and Landau (2008; 2013), or whether children verbally label the object themselves, as in Hitch et al. (1988). No study has hitherto explored whether one strategy is more effective than the other. Palmer (2000) suggests that the extent to which a child’s attention is engaged in the labelling process will influence how effectively they use sub-vocal rehearsal. If verbal labelling by children directs more attention to the task than hearing a verbal label, then it might be a more effective way to improve performance. The second aim of the current study was to compare the effect of spatial language cues when provided solely by the experimenter, to cases in which spatial language cues were provided by the experimenter and subsequently repeated by the child.

We investigated 4-year-old's ability to maintain colour-location conjunctions, whether spatial language labels had an effect on performance and whether there was an association between knowledge of spatial language terms and task performance. We adapted Dessalegn and Landau's (2008; 2013) design by first using a within-participants design to investigate the impact of directional language cues. A within-participants design is more powerful than a between-participants design as any effects of condition are not due to individual differences because one is directly comparing the performance of the same children with and without language scaffolding. Second, we assessed the comprehension and production of the spatial terms employed. Unlike Dessalegn and Landau (2008) this was carried out using stimuli which were identical to the experimental stimuli, in order to assess their language knowledge as required by the task. As an additional between-participants factor at testing time 2, we considered whether the effect of language cues was different for those who just heard the experimenter verbalize the language cue (as in Dessalegn & Landau, 2008) versus those who were asked to verbalize the language cue themselves, with prompting by the experimenter (as in Hitch et al., 1988). Children were predicted to show weaknesses in maintaining colour-location conjunctions. The use of a linguistic cue was predicted to improve performance. If stable knowledge of spatial language terms is important, this effect was predicted to be associated with knowledge of the labels employed. That is, the effect of the use of "top/bottom" language cues (which are typically understood by 3 years [Clarke, 1980]) will be present for all children, but "left/right" language cues (which may not be firmly established until between 8 and 10 years [Belmond & Birch, 1963]) will only be effective for those children with some understanding of these terms. Finally, if it is important for children to verbalize the cue themselves to direct attention to the task then children who verbalized the cue were predicted to perform better than those who simply heard the experimenter label the cue.

Method

Participants

Sixty 4-year-olds from Cambridgeshire UK took part. Children all had normal/corrected to normal vision and spoke English as a first language. Verbal ability was assessed using the British Picture Vocabulary Scale II (BPVS II; Dunn, Dunn, Whetton & Burley, 1997). The BPVS is a British version of the Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 1997); children are asked to point to a picture, from a choice of 4, which matches a single word given by the experimenter.

Participants were randomly divided into three groups for the purposes of time 2 testing (detailed below): a control group and two experimental groups (Table 1). One experimental group was given a descriptive cue only (ED) and the other experimental group was given a descriptive cue and then required to verbalize it (EV). All children completed two sets of tasks, separated by seven to ten days. One child in the control group was excluded because they did not complete all tests and one child in the EV group performed at ceiling in the first set of control tasks and so was also excluded from final analysis. There were no significant differences between the groups for chronological age, F(2, 55=1.01, p=0.37, $\eta_p{}^2$=0.04, or verbal ability (BPVS II), F(2,55)=1.64, p=0.20, $\eta_p{}^2$=0.05.

Design and Procedure

At time 1 (t1), all children completed the control trials. In each control trial, a target object appeared on a 14 inch computer screen, horizontally centred at the top of the screen (Figure 1b). The experimenter said: “Look at this. I want you to help me find one that is exactly the same”. As in Dessalegn and Landau (2008), the target was displayed for four seconds then disappeared and, after a one second delay, the test array appeared (Figure 1c). The children were asked to select the one that was: “exactly the same as the one that you just saw”.

Children first performed six practice trials which involved; matching target animals or shapes to test items (3 trials); and matching target symmetric shapes (a circle, a triangle and a pentagon) split in half by colour, with test items that included the target, its reflection and a second distracter (3 trials). All children passed the practice trials. Children's colour knowledge was also tested; all children could confidently identify yellow and blue. .

For the test trials, targets were 7cm squares, split in half by colour (blue and yellow) along one of three axes (horizontal, vertical or diagonal, hereafter referred to as horizontal targets, vertical targets or diagonal targets). In total, eight targets were used (Figure 1a). Test arrays comprised of three 7cm squares: the target; a reflection of the target (divided along the same axis as the target, but colours reversed); and a square divided by colour along a different axis (hereafter, the distracter). Each target was presented on three trials, position counterbalanced, for a total of 24 randomly ordered trials. Test arrays timed out if no response was selected after 20 seconds (this occurred on 1.05% of trials).

Figure 1

Seven to ten days after t1, children completed time 2 (t2). For the control group, the design, stimuli and procedure were identical to t1. For the ED group, when the target appeared, the experimenter said: "Look at this. The yellow is…" and the sentence was completed appropriately by the experimenter, e.g.: "The yellow is on the top". For vertical targets, color location was described using "left" and "right", and for horizontal targets, "top" and "bottom" were used. For diagonal targets half were labelled "top" and "bottom" and half were labelled "left" and "right". The children in the EV condition heard the same language cue as the ED condition and, after the sentence was completed by the experimenter, children were asked to repeat the sentence while looking at the test object. As in t1, all three groups of children took part in 24 trials and the target was displayed for four seconds before disappearing, followed by the test array after a one second delay. For the EV group, repetition of the cue sometimes extended into the one second pause between target and test arrays but there was sufficient time for children to finish verbalising before the test array appeared. For all groups, as in t1, the experimenter said: “I want you to help me find one exactly the same”. When the test array appeared they were asked to find one: “exactly the same as the one you just saw”.

Seven to fourteen days after t2, children completed the BPVS II and spatial language term comprehension and production tasks. For the comprehension task, children were presented with replicas of the target squares (horizontal and vertical division only) and were asked to point to the top, bottom, left or right of the square. For the production task, children were presented with the same target squares and one side of the square was pointed to by the experimenter; children were asked to label the position as top, bottom, left or right. For both comprehension and production, children completed 16 trials.

Results

Feature-conjunction task

Time 1 (t1, no language cues) served as a baseline measure of children’s ability to maintain feature conjunctions. Children chose the correct match 49% of the time (chance =33%). Choosing the reflection or distracter accounted for 74% and 26% of errors respectively.

ANOVA on the proportion of trials correct at t1, with one between participant factor of Condition (control, ED, EV) and one within participant factor of Target type (horizontal, vertical, diagonal) showed no significant main-effects for Condition ($F(2,55)=1.28$, $p=.29$ $\eta_p^2=.04$) or Target type ($F(2,110)=1.70$, $p=.19$, $\eta_p^2=.03$) and no significant interaction between Target type and Condition ($F<1$). Thus, performance at t1 provided a suitable baseline measure for comparison with performance at t2.

We next considered whether language cues had a significant impact on performance, and whether verbalizing the cue had a stronger impact than hearing it. At time 2 (t2) the control group selected the correct match 53% of the time while the ED and EV group both selected the correct match 74% of the time. Errors were predominantly accounted for by choosing the reflection, as in t1 (control: 69%; ED: 69%; EV 61%).

To compare t2 performance to the flat pattern of performance observed at t1, ANOVA was carried out on the proportion of trials correct, with one between participant factor of Condition (control, ED, EV) and two within participant factors of Target type (horizontal, vertical, diagonal) and Time (t1, t2), as shown in Figure 3. This revealed a main effect of Time, $F(1, 55)=175.21$, $p<.001$, $\eta_p^2=.76$ (t2>t1), and a main effect of Target type, $F(2,112)=16.77$, $p<.001$, $\eta_p^2=.23$, which was modulated by Time $F(1.7, 104)=8.13$, $p<.001$, $\eta_p^2=.13$ (using Greenhouse-Geisser adjusted degrees of freedom to accommodate lack of sphericity in the data). The main-effect of Condition was not significant, $F(2,55)=2.33$, $p=.11$ $\eta_p^2=.08$, but interacted with Time, $F(2, 55)=30.93$ $p<.001$, $\eta_p^2=.53$, and with Time and Target type, $F(3.4, 92)=2.92$, $p=.03$, $\eta_p^2=.10$. Because we know that there were no significant effects at t1, these interactions were driven by significant effects at t2.

ANOVA of Condition (control, ED, EV) by Target type (horizontal, vertical, diagonal) at t2 showed a significant main effect of Target type, $F(2,110)=30.66$, $p<.001$, $\eta_p^2=.36$, due to higher scores on horizontal targets than diagonal targets and vertical targets ($p<.001$ for both; bonferroni corrected) but no difference between scores on vertical and diagonal targets ($p=.36$; bonferroni corrected). There was a main effect of Condition, $F(2,55)=16.49$, $p<.001$, $\eta_p^2=.38$ which interacted with Target type,

$F(4,110)=4.48$, $p=.002$, $\eta_p^2=.14$. There was a pattern of higher proportions of correct matches in the EV and ED conditions than the control condition, but for horizontal and diagonal targets only (vertical: $F(2,55)=1.02$, $p=.37$, $\eta_p^2=.04$; horizontal: $F(2,55)=19.71$, $p<.001$, $\eta_p^2=.42$ [ED=EV, $p=.48$; ED, EV > control, $p<.001$ for both]; diagonal: $F(2,52)=13.32$, $p<.001$, $\eta_p^2=.33$ [ED=EV, $p=.87$; ED, EV > control, $p<.001$ for both]).

The above analyses split the data by Time. To explore the interactions with reference to the effects of Time, paired t-tests of t1 compared to t2 were calculated for each target type for each condition. This demonstrated improved performance for children in the experimental conditions only (control condition, p>.05 for all), for all target types (p<.05 for all), with the exception of vertical targets in the EV condition (p=.091). Thus, although the ANOVA above showed an advantage for horizontal and diagonal targets, over vertical targets, this did not preclude improvement (as seen in the ED condition) in responses to vertical targets from t1 to t2.

Figure 2

The effects of spatial language cues were further explored by analyzing the pattern of results for diagonal targets at t2 in the experimental conditions, half of which were labelled with top /bottom and half with left/right. ANOVA with Condition (ED, EV) as a between-participant factor and Label (top/bottom, left/right) as a within-participant factor showed a main effect of Label, $F(1,37)=6.92$, $p=.01$, $\eta_p^2=.16$; children chose the correct match significantly more often with the top/bottom label (ED: mean =75 % s.d. =19; EV: mean =79 %, s.d.=49) than the left/right label (ED: mean=67 % s.d. =19; EV: mean=61%, s.d. =24). There was no main effect for Condition, $F<1$ or interaction between Condition and Label, $F(1,37)=1.24$, $p=.27$, $\eta_p^2=.03$.

Spatial language knowledge

All children performed at ceiling for their knowledge of top and bottom in the spatial language knowledge tests. For the group as a whole, scores of left and right production (mean=58%, s.d.=0.29) and comprehension (mean=61%, s.d.=0.25) were similar. To compare spatial language knowledge of left and right across the three groups in the feature-conjunction task ANOVA was carried out with Condition (control, ED, EV) as a between-participant factor and Test (comprehension, production) as a within-participant factor. This showed no main effect of Test, $F(1,55)=1.46$, $p=.23$, $\eta_p^2=.03$, or Condition, $F<1$, and no significant interaction, $F(2, 55)=1.65$, $p=.20$, $\eta_p^2=.06$.

Correlational analyses

We analysed whether, for children in the experimental conditions only (ED and EV), L-R knowledge was positively correlated with improvement at t2 (language cue trails) relative to t1 (control trials) on vertical target trials. On account of the analysis above, Left-right (L-R) knowledge scores were collapsed across comprehension and production tasks to produce a score out of 16 and children in the ED and EV groups were treated as one experimental group.

Children were classified as having: "good L-R knowledge" (a score of greater than 50%) or "poor L-R knowledge" (a score less than or equal to 50%). This classification assumes knowledge of the axial organisation (based on Landau & Hoffman, 2005), and preserves a higher level of power than more conservative categorization methods. Fifteen children had "poor L-R knowledge" and 24 had "good L-R knowledge". Difference scores (t2 minus t1) were calculated to identify the benefit of using languages cues on children's accuracy at matching vertical targets. For children with good L-R knowledge, a significant correlation was identified between difference scores for vertical targets and L-R knowledge, $r(24)=.51$, $p=.01$. For children with poor L-R knowledge, L-R knowledge was not associated with difference scores for vertical targets, $r(15)=0.06$, $p=0.83$.

Figure 3

Discussion

The aim of this study was to explore the hypothesis that language can be used as a “toolkit” to bolster spatial representations (e.g. Gentner & Goldin-Meadows, 2003). Feature conjunctions were used as an example of spatial relationships which young children find difficult to encode, and which have been shown to be susceptible to facilitation by spatial language cues. Other examples include spatial navigation, spatial mapping during block building or jig-saw puzzle completion, and landmark use when locating hidden objects (e.g. Hermer-Vasquez, Moffet & Munkholm, 2001).

Specifically, this study investigated young children’s ability to maintain colour-location conjunctions, and whether spatial language could support their performance on such tasks. Results showed that 4-year-olds experience difficulty in maintaining colour-location conjunctions, but that spatial language can support this ability. Importantly, we showed that spatial language cues are only effective when children have knowledge of the spatial language terms used. This was demonstrated in three ways. First, spatial language cues facilitated performance when identifying horizontal targets (which were cued by top/bottom language cues) to a greater extent than vertical targets (which were cued by left/right cues). Second, diagonal targets which were cued by top/bottom showed an advantage over diagonal targets that were cued by left-right. Finally, for those children in the experimental groups who had relatively strong knowledge of left and right spatial language terms, knowledge of these terms was positively correlated with accuracy difference scores (the difference in accuracy between cued and non-cued conditions) for vertical targets, but not for those children whose knowledge of left and right was relatively weak. The current findings do not appear to support Dessalegn and Landau’s (2008; 2013) assertion that children gain a temporary understanding from spatial language cues and that this can facilitate performance without stable knowledge of spatial language terms. However, we do concede that there is evidence that children can assign meaning to non-words that have been assigned spatial relational meaning, albeit within a simultaneous matching context (Christie & Gentner, 2010). Note that in our data there was an effect of cueing for vertical targets in the ED condition (but not the EV condition), albeit significantly attenuated relative to the same effect for horizontal targets. This could be interpreted as children assigning meaning to left and right as a result of hearing the cues. This interpretation is not supported by the correlational analysis however, which demonstrates a linear relationship between the extent of any cuing advantage for vertical targets and level of Left-Right knowledge.

Dessalegn and Landau (2008; 2013) found weak knowledge of left and right spatial terms. However, with the exception of one correlation, which they account for with two outliers, they found no correlation between knowledge of left and right and performance on vertically split matching. It is possible that this was because all children were included in their analysis and so the lack of variability in the data from those with no knowledge of left and right might have masked any developmental patterns in the remaining data. In the current study, when the participants were split into “good LR knowledge” and “poor LR knowledge” groups, a significant correlation was found between knowledge of left and right and change in scores on the vertical targets for the good LR knowledge group, but not for the poor LR knowledge group.

Dessalegn and Landau (2008; 2013) report an overall advantage of using directional language cues which was replicated in the current study. Dessalegn and Landau (2008) also report that, in their Experiment 2, the experimental group was more accurate when responding to horizontal targets (cued with top/bottom) than vertical targets (cued with left/right). These results appear to be consistent with the notion that facilitation *is* reliant on knowledge of the terms employed. However, in their Experiment 4, and in their later study (Dessalegn & Landau, 2013) no such effect is evident; level of performance was facilitated by cues in a consistent manner across target types, i.e. top/bottom cues were as effective as left/right cues. It is not clear why this difference in the patterns of results emerges across their studies (type 2 errors cannot be ruled out given that each of their groups had an N of 12), but they suggest that knowledge of language cues does not impact facilitation effects. The current study demonstrates a discrepancy between horizontal and vertical target performance in cued conditions. Furthermore, group comparisons at both between and within participant levels show no facilitation for vertical targets, but a strong facilitation for horizontal targets. This suggests that children are not acquiring temporary linguistic knowledge of left and right. The lack of consistent improvement on vertical targets in our data suggests that language cues only provide support when participants are familiar with the directional terms. The correlation in the "good L-R knowledge" group between the positive effect of spatial language cues and left-right knowledge is consistent with Ratterman and Gentner (1998) who found that the positive effect of using relational terms such as bigger and smaller on size judgments was related to children's familiarity with the language terms used. Furthermore, Hermer-Vazquez et al. (2001) report a significant relationship between Left-Right production ability in 5- and 6-year-olds, and performance on a spatial reorientation task. The current data lends support to the idea that linguistic cues support the maintenance of feature-conjunctions by helping children to verbally encode the visual stimulus.

Hitch et al. (1998) required children to verbally label a target object themselves, rather than hearing the experimenter say the label. They proposed that verbalizing a linguistic cue may require more attention to be directed to the target object or may be a more effective way to encourage sub-vocal rehearsal in working memory. The current study assessed whether children's ability to maintain feature conjunctions would receive an additional benefit from verbalizing, rather than just hearing a spatial language cue. We found that children did not show any additional benefit from verbalizing linguistic cues. This suggests that hearing or hearing and verbalizing the cue have similar effects on attention, and possibly on rehearsal strategies in working memory. However, because this study used a delay between target and test presentation of just one second, it is possible that any advantage of sub-vocal rehearsal is not apparent. If this is the case, a longer delay period might differentiate between the children who heard and verbalized the cues from those who just heard the cues.

When no spatial language cues were used, the correct target was chosen 47% of the time. This is reliable evidence of a difficulty in maintaining feature-conjunctions in young children, and is consistent with similar studies (Hoffman et al., 2003; Dessalegn & Landau, 2008; 2013). In those studies, 4 and 5-year-olds were able to accurately represent the internal geometry of a target object (i.e. the axis of the division), but were not able to accurately pair colour to location. This kind of task, although not varying features independently as in adult feature binding tasks, represents an age-appropriate measure of young children's ability to pair colour to location. Consistent with this, the current study also found that the majority of errors were a result of children choosing the reflection of the target.

A challenge of research in this area is to understand what factors underlie children's ability to maintain feature conjunctions. Furthermore, there is relatively little research which considers whether, and how, young children's ability to maintain visuo-spatial conjunctions can actually be supported. Indeed, Dessalegn and Landau (2008; 2013) employed a myriad of techniques, to conclude that verbal labels of spatial relations are the most effective and enduring support.

The current findings suggest that spatial language cues significantly improve performance on feature-conjunction tasks, but only when children have knowledge of the terms used. This is consistent with the idea that language acts as a "toolkit" by providing the concepts and strategies to support visual representations (Genter & Goldin-Meadows, 2003). Palmer (2000) suggests that introducing a verbal cue encourages young children to rely on both visual-spatial working memory and the phonological loop of verbal working memory. Alternatively, it may be that an unambiguous verbal cue allows children to focus on one colour-location conjunction, rather than trying to store yellow and blue simultaneously. Spivey et al. (2001) suggest that linguistic cues provide a focus for visuo-spatial processing and reduce attentional demands.

In summary, spatial language can provide effective support for young children's ability to maintain colour-location conjunctions. However, the effect is only evident when children have an understanding of the language used. This research does not support earlier findings that spatial language labels scaffold performance when children do not have a stable understanding of the terms used.

References

Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2006). Is the binding of visual features in working memory resource-demanding? *Journal of Experimental Psychology, 135*(2), 298-313.

Belmont, L., & Birch, H. G. (1963). Lateral dominance and left-right awareness in normal children. *Child Development, 34*(2), 257-270.

Christie, S., & Gentner, D. (2010). Where hypotheses come from: Learning new relations by structural alignment. *Journal of Cognition and Development*, *11*(3), 356-373.

Clarke, E. V. (1980). Here's the "Top:" Nonlinguistic Strategies in the Acquisition of Orientational Terms. *Child Development*, *51*(2), 329-338.

Dessalegn, B., & Landau, B. (2008). More than meets the eye: the role of

language in binding and maintaining feature conjunctions. *Psychological Science*, *19*(2), 189-195.

Dessalegn, B., & Landau, B. (2013). Interaction between language and vision: It’s momentary, abstract, and it develops. *Cognition 127*, 331–344Dunn, L., &

Dunn, L. (1997). Peabody Picture Vocabulary Test III. Circle Pines, MN: American Guidance Service.

Dunn, L. M, Dunn, L. M, Whetton, C. & Burley, J. (1997). British Picture Vocabulary Scale II (BPVS II). London: NFER-Nelson.

Gentner, D., & Goldin-Meadow, S. (2003). Whither Whorf. In Gentner, D & Goldin-Meadow, S. (Eds.), *Language in mind: Advances in the study of language and* *thought* (pp. 3-14). Cambridge, MA: MIT Press.

Hermer-Vasquez, L.,Moffet,A.,&Munkholm,P.(2001).Language,space, and the development of cognitive flexibilityin humans: The case of two spatial memory tasks. *Cognition, 79,* 263–299.

Hitch, G. J., Halliday, M. S., Schafstall, A. M., & Schraagen, J. M. (1988). Visual working memory in young children. *Memory & Cognition, 16*(2), 120-132.

Hoffman, J., Landau, B., & Pagani, B. (2003). Spatial breakdown in spatial construction: Evidence from eye fixations in children with Williams syndrome. *Cognitive Psychology, 46*, 260-301.

Li, P., & Gleitman, L. (2002). Turning the tables: language and spatial reasoning.

Cognition, *83*, 265-293.

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50,* 315-353.

Lorsbach, T. C., & Reimer, J. F. (2005). Feature binding in children and young adults. *The Journal of Genetic Psychology, 166*(3), 313-327.

Palmer, S. (2000). Working memory: A developmental study of phonological recoding. *Memory, 8*(3), 171-193.

Ratterman, M. J., & Gentner, D. (1998). The effect of language on similarity:

The use of relational symbols improves young children's performance on a mapping task. In Holyoak, K., Gentner, D. & Kokinov, B. (Eds.), *Advances in analogy research: Integration of theory & data from the cognitive, computational and neural sciences* (pp. 274-281). Sophia: New Bulgarian University.

Ruff, H. A., & Capozzoli, M. C. (2003). Development of attention and distractability in the first 4 years of life. *Developmental Psychology, 39*(5), 877-890.

Spivey, M. J., Tyler, M. J., Eberhard, K. M., & Tanenhaus, M. K. (2001). Linguistically mediated visual search. *Psychological Science, 12*(4), 282-286.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97-136.

Whorf, B. L. (1956). The relation of habitual thought and behavior to language. In J. B. Carroll (Ed.), Language, thought and reality: selected writings of Benjamin Lee Whorf. Cambridge, MA: MIT Press.

Table 1: Participant details

Condition	**N(N of girls)**	**Chronological Age: Years;Months**	**Verbal Mental Age: Years;Months**
		Mean (S.D.)	
Control	19 (10)	4;06 (0;03)	6;01 (12;00)
Experimental Descriptive (ED)	21(10)	4;05 (0;04)	6;01 (12;01)
Experimental Verbal (EV)	18(11)	4;05 (0;04)	5;10 (12;01)

Figure captions

Figure 1. Target types and examples of target object and test array displays.

Figure 2. Mean (standard error) proportion of correct targets chosen at Time 1 and Time 2 for Control, Experimental Descriptive (ED) and Experimental Verbal (EV) conditions.

Figure 3. Correlation between left-right (LR) knowledge and difference scores for vertical targets, collapsed across Experimental Descriptive (ED) and Experimental Verbal (EV) conditions at Time 2.

Figure 1

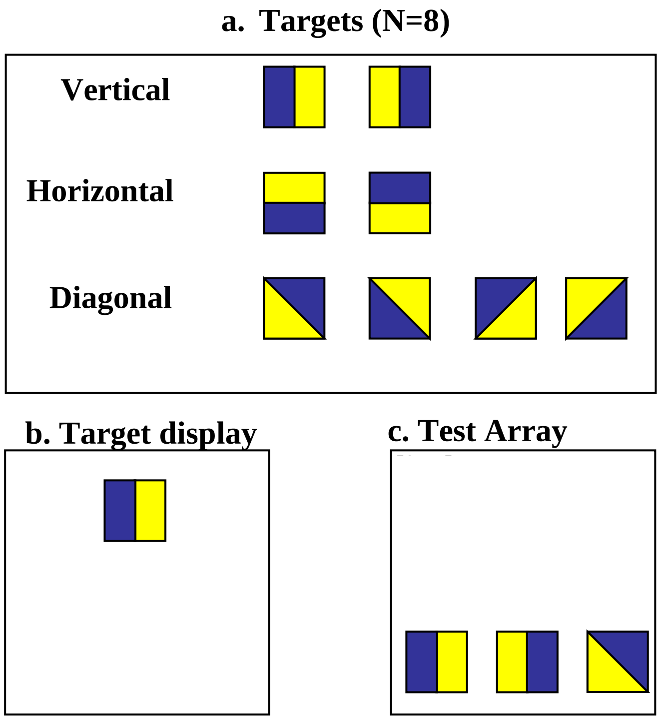

a. Targets (N=8)
Vertical
Horizontal
Diagonal
b. Target display
c. Test Array

Figure 2

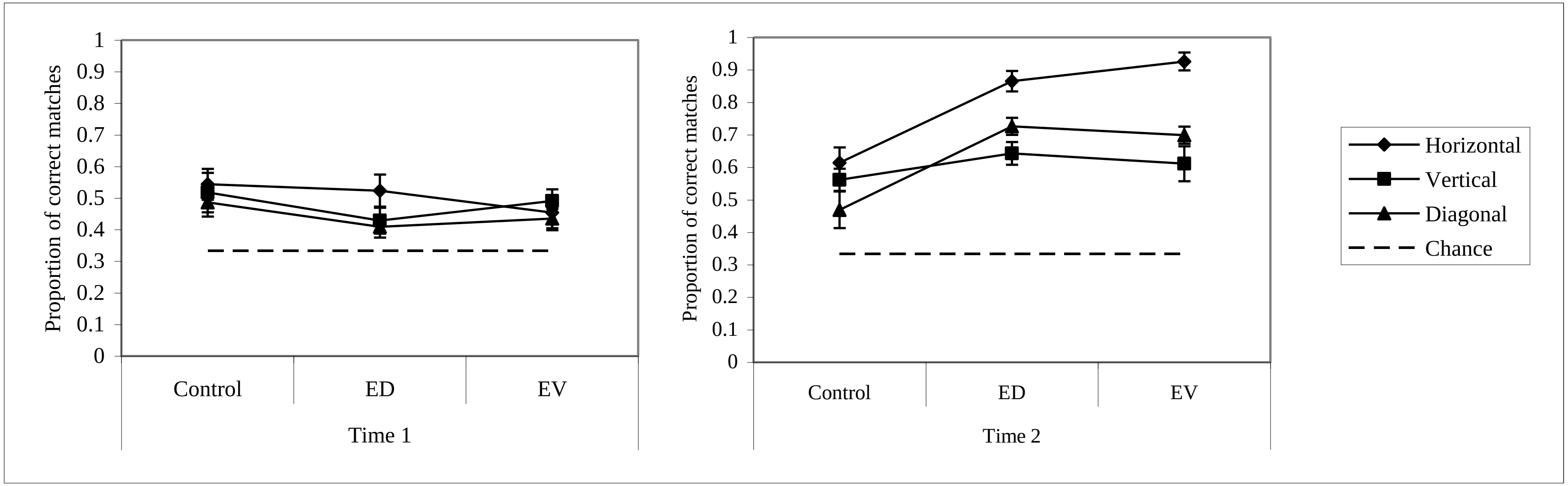
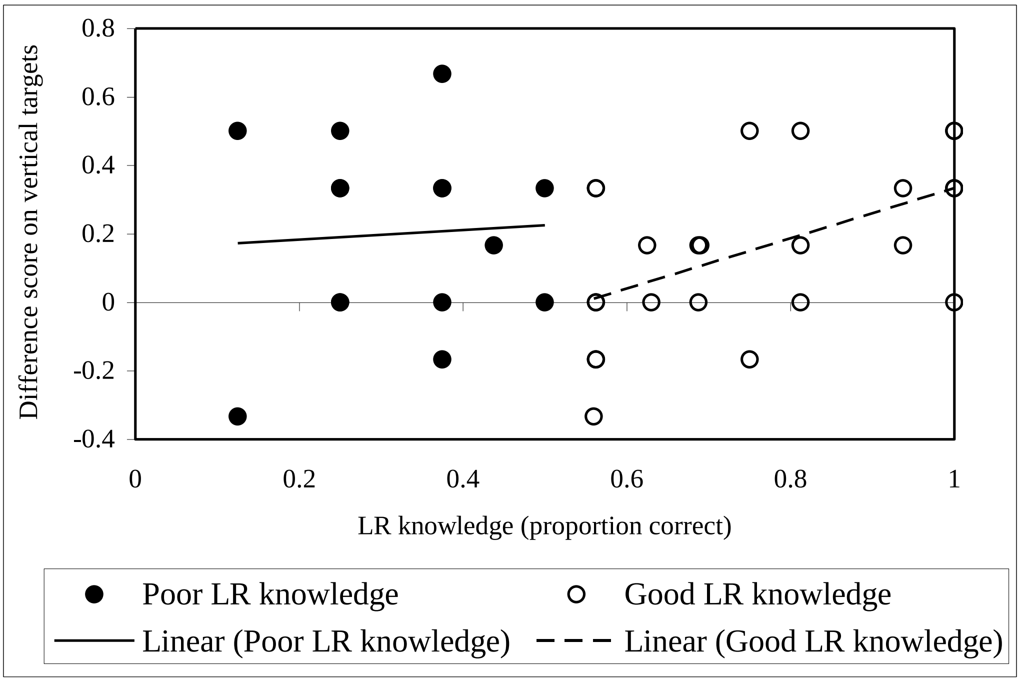

Proportion of correct matches
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Control
ED
EV
Time 1
Time 2
Horizontal
Vertical
Diagonal
Chance

Figure 3


Difference score on vertical targets
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
LR knowledge (proportion correct)
Poor LR knowledge
Good LR knowledge
Linear (Poor LR knowledge)
Linear (Good LR knowledge)