Linguistic Processes in Visuospatial Representation: Clarifying Verbal Interference Effects

Judith Bek (j.bek@sheffield.ac.uk)
Department of Human Communication Sciences, University of Sheffield, UK

Mark Blades (m.blades@sheffield.ac.uk)
Department of Psychology, University of Sheffield, UK

Michael Siegal (m.siegal@sheffield.ac.uk)
Department of Psychology, University of Sheffield, UK, and University of Trieste, Italy

Rosemary Varley (r.a.varley@sheffield.ac.uk)
Department of Human Communication Sciences, University of Sheffield, UK

Abstract

Verbal interference in visuospatial information processing has been interpreted as showing either that verbal coding supplements visuospatial representation (Meilinger, Knauff, & Bulthoff, 2008; Walker & Cuthbert, 1998), or that language mechanisms are necessary for integrating featural and spatial information (Hermer-Vazquez, Spelke, & Katsnelson, 1999). However, previous studies have used verbal interference tasks varying in linguistic demands, making it difficult to identify which linguistic processes are involved in visuospatial representation. We compared the effects of verbal shadowing tasks with and without lexical and syntactic demands on performance of visuospatial construction and memory tasks and a reorientation task. The shadowing task with lexical and syntactic content did not selectively disrupt performance on any of the tasks, suggesting that core language mechanisms are not required for visuospatial representation.

Keywords: Reorientation; Verbal shadowing; Spatial representation.

Introduction

Verbal coding processes have been implicated in the representation and maintenance of featural visual information, but there is less evidence that language is involved in spatial representation (Postle, D'Esposito, & Corkin, 2005; Simons, 1996; Vuontela et al., 1999). These findings are consistent with the proposed dissociation between the cognitive mechanisms supporting processing of featural and spatial visual information (Baddeley & Hitch, 1994).

Although verbal interference has typically not been found for spatial information, there is some evidence to suggest that language aids the integration of featural information with location or shape-based information. Walker and Cuthbert (1998) reported effects of verbal interference (articulatory suppression) and nameability on memory for conjunctions of shape and colour from separate objects. Similarly, Postma and de Haan (1996) reported that articulatory suppression interfered with memory for object-location conjunctions, though Dent and Smyth (2005) failed to replicate this result, finding the effect to be restricted to memory for object identity. Also, Postma and de Haan used stimuli thought to be low in nameability, suggesting that interference was not due to language-specific mechanisms.

Navigation tasks requiring encoding of featural and location information have shown different effects of verbal interference. Garden, Cornoldi, and Logie (2002) found equivalent performance on a physical navigation task whether participants were engaged in a concurrent verbal (syllable repetition) task or a spatial (tapping) task, while a map-based navigation task was disrupted more by the spatial than the verbal task. Meilinger, Knauff, and Bulthoff (2008) found both spatial (sound localisation) and verbal (lexical decision) secondary tasks to impair adults' ability to learn a new route in a virtual environment containing landmarks, while a visual imagery task had no effect. Meilinger et al. proposed that dual spatial and verbal representations exist for location information. Hermer-Vazquez, Spelke, and Katsnelson (1999) found concurrent prose shadowing to interfere with spatial reorientation. The reorientation task required participants to relocate a hidden object within a room after being disoriented, success at which relied on the use of geometric (room shape) and featural (wall colour) cues. Participants had no difficulty with this task on its own. However, during verbal shadowing they appeared only to use geometric information to reorient, similar to how young children have been reported to perform in such tasks (Hermer & Spelke, 1996). Hermer-Vazquez et al. (1999) proposed that lexical and syntactic properties of language enable the integration of featural and geometric cues. According to this proposal, language is the medium of representation for feature-location conjunctions. This is different from the suggestion that dual-coding of visuospatial stimuli involves both verbal and visual representations, either of which may be sufficient on its own (Meilinger et al., 2008; Paivio, 1991).

The variation in verbal interference findings might be attributable to the nature of the verbal tasks used in the above studies. Meilinger et al.'s (2008) verbal task required lexical processing, and Hermer-Vazquez et al.'s verbal shadowing task involved repeating meaningful prose, whereas other researchers (e.g., Garden et al., 2002) used articulatory suppression tasks, which involve repeating a single letter or syllable, or a series of meaningless verbal tokens. While articulatory suppression likely engages phonological resources, thus potentially preventing covert verbal naming or rehearsal, it does not necessarily involve any syntactic or lexical processing. If lexical and syntactic properties of language are involved in forming integrated representations of feature-location conjunctions, it is possible that the absence of verbal interference in several studies may be due to the use of verbal tasks that did not disrupt deep linguistic processes.

Although Hermer-Vazquez et al. (1999) found meaningful prose shadowing to impair reorientation, subsequent studies have shown weaker or insignificant effects of prose shadowing on the use of spatial cues to reorient (Hupbach et al., 2007; Ratliff & Newcombe, 2008), suggesting that rather than being necessary for integrating featural and geometric information, language may have a more minor role in supporting spatial representation, providing a supplementary level of coding. Rhythm shadowing (Hermer-Vazquez et al., 1999) and spatial tasks (Hupbach et al., 2007; Ratliff & Newcombe, 2008) have also been shown to disrupt reorientation, so it also seems possible that general cognitive demands were responsible for interference in these dual-task studies.

By comparing the effects of a verbal task involving core linguistic components with one that engages phonological, but not syntactic and lexical resources, it might be possible to determine whether interference in visuospatial representation is due to the prevention of supplementary verbal coding or due to the occupation of core language resources needed for integrating featural and spatial information.

To investigate the two proposals – that language provides an optional supplementary code for visuospatial information or provides a medium for integrating featural and spatial information – we compared the effects of two verbal interference tasks, differing in linguistic demands, on three visuospatial tasks. The verbal tasks required participants to shadow either continuous prose, expected to engage lexical and syntactic resources, or a series of non-word syllables, minimising lexical and syntactic demands. In Experiment 1 we examined the effects of prose and syllable shadowing on visuospatial construction and memory, using a block design task and a complex figure task. In Experiment 2 we compared performance on a reorientation task based on Hermer-Vazquez et al. (1999) during concurrent shadowing of prose or syllables. The reorientation task, as described above, requires the use of featural and geometric cues to retrieve the location of a hidden object after disorientation.

If core linguistic mechanisms are involved in visuospatial construction or memory, accuracy in the complex figure (construction, memory) and block design (construction) tasks should be reduced more by prose than by syllable shadowing; otherwise the two shadowing tasks should have similar effects. Similarly, if lexical and syntactic resources are required for representing feature-location conjunctions, performance in the reorientation task should be reduced during prose shadowing relative to syllable shadowing. If language has only a supplementary role in supporting feature and location representations (e.g., subvocal naming or rehearsal), both verbal tasks should disrupt reorientation performance.

Experiment 1

Participants Ninety-one healthy adults (64 female, 27 male) aged 18 to 33 years (*M* = 21 years) participated in exchange for course credit or payment.

Materials The visuospatial tasks were the Rey-Osterreith Complex Figure Test (Rey, 1941; Osterreith, 1944), and the block design subtest of the Weschler Adult Intelligence Scale (WAIS-R; Weschler, 1981). The complex figure test involves visuospatial construction and memory, and contains potentially nameable elements (Ropar & Mitchell, 2001). Participants are required to copy the figure using pencil and paper and then draw it again from memory following a time delay. The full test includes both immediate and delayed recall, but for this experiment only copy and delayed recall were tested. The block design task is a test of online visuospatial construction that requires participants to reconstruct two-dimensional designs using red and white plastic blocks. Nine designs (5 small, 4 large) are presented in order of increasing difficulty.

The material for the prose shadowing task, based on those reported by Hermer-Vazquez et al. (1999) and Ratliff and Newcombe (2008), was a recording of political news articles read at a rate of 2.7 syllables per second. The syllable shadowing material was a recording of randomised sequences of 8 non-word syllables (4 with long vowel sounds, 4 with short vowel sounds) at a rate of approximately 1 per second. Shadowing stimuli were played through headphones and participants' responses were recorded. Performance on the two shadowing tasks was found to be equivalent in a pilot study, in which 10 participants shadowed each of the two recordings in counterbalanced order, without any concurrent task. Accuracy rates were 98.6% for prose shadowing and 97.8% for syllable shadowing.

Design Participants completed the block design and complex figure tests during prose shadowing, syllable shadowing or without shadowing (control group). Half of the participants in each shadowing group shadowed during copying of the complex figure and the other half shadowed during the recall stage, to compare effects on encoding and retrieval. This resulted in five conditions: prose-copy, prose-recall, syllable-copy, syllable-recall and control. There were 15 participants in each shadowing condition (except prose-recall in which there were 16), and 30 control participants.

Procedure Participants first copied the complex figure, while continuously shadowing (prose-copy and syllable-copy conditions) or as a single task (prose-recall, syllable-recall and control conditions). The block design task was introduced next, and the first two small designs were given as practice items without shadowing. Participants (excluding controls) then began shadowing again and completed the rest of the block design task. Finally, complex figure recall was tested, either with concurrent shadowing (prose-recall and syllable-recall conditions) or without (prose-copy, syllable-copy and control conditions). The delay interval between copy and recall was approximately 10 minutes and participants were not pre-warned about the recall task.

Scoring and Analysis Verbal shadowing accuracy was calculated as the percentage of stimulus items (syllables or words) correctly repeated. Participants with shadowing scores exceeding 2 standard deviations below the mean for each task were excluded from further analyses (N = 3 for the complex figure, N = 4 for block design). Mean completion times in the block design task were calculated for small and large designs. Complex figure copy and recall drawings were scored out of 36 in accordance with the manual guidelines, and completion times were recorded. Response times greater than two standard deviations from the mean for complex figure copy and recall stages, and for block design small and large means, were replaced with the next longest completion time plus one (as per Dancey & Reidy, 2004), resulting in four replacements for each of these measures.

Performance on each of the shadowing tasks (prose vs. syllables) was compared for each visuospatial task using independent t-tests. For the complex figure test, a multivariate analysis of covariance was run to examine the effects of shadowing type (prose/syllables/none), shadowing stage (copy/recall/none) and sex on each of the response measures, with time delay between copy and recall entered as a covariate (having been found to correlate with recall accuracy). For the block design, the effects of shadowing type and sex on mean completion times for small and large designs were examined by multivariate analysis of variance.

Results

Verbal Shadowing Verbal shadowing scores were not obtained for 6 participants due to recording error. Participants shadowing prose had a mean accuracy rate of 93.1% for the complex figure and 91.1% for block design, and the mean syllable shadowing rates were 92.8% for the complex figure and 88.3% for block design. Accuracy in the two shadowing tasks did not differ for the block design ($t(52) = 0.811$; $p > 0.4$) or the complex figure ($t(52) = 0.113$; $p > 0.9$).

Block Design There was no effect of shadowing type on mean response times for small ($F(2,90) = 0.25$; $p > 0.7$) or large ($F(2,90) = 0.745$; $p > 0.4$) designs, and no interaction of shadowing type with sex for small ($F(2,90) = 0.841$; $p > 0.4$) or large designs ($F(2,90) = 1.06$; $p > 0.3$). There was an effect of sex on mean completion time for large designs ($F(1, 90) = 6.03$; $p = 0.016$) and a marginal effect of sex on

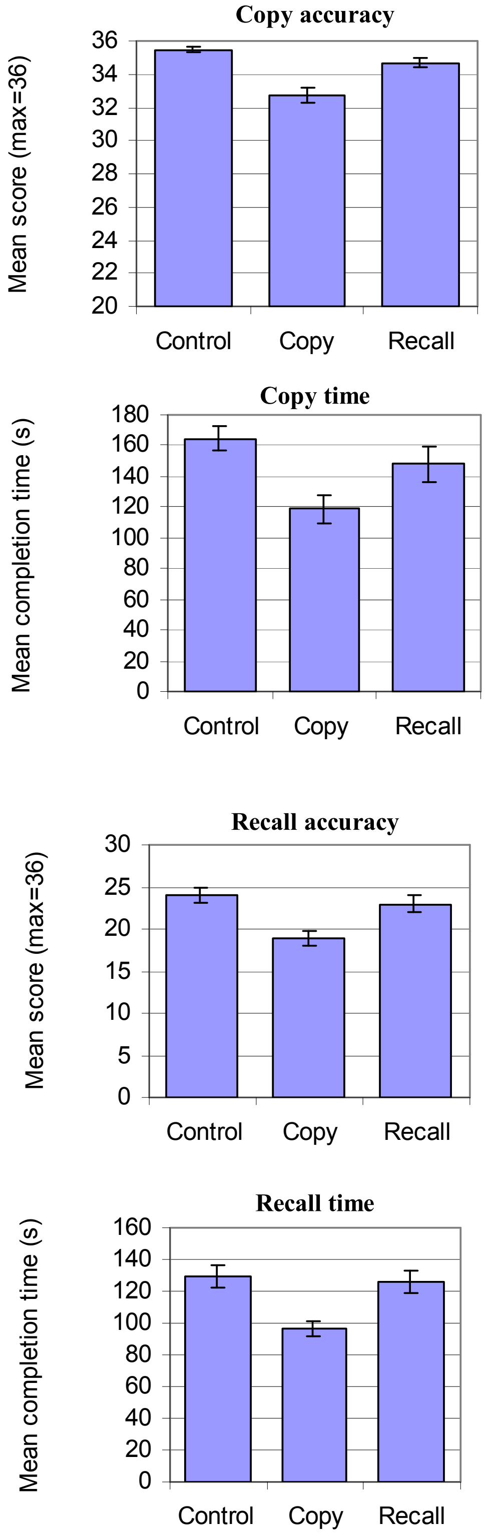

Figure 1. Complex Figure Test performance by shadowing stage (control/during copy/during recall). Error bars show standard errors.

small design completion times ($F(1, 90) = 3.35$; $p = 0.071$), with males being quicker at completing designs of both sizes.

Complex Figure Test Shadowing type affected recall time ($F(1,89) = 4.08$; $p < 0.05$), with syllable shadowing associated with quicker recall than either the control condition ($p < 0.05$) or prose shadowing ($p < 0.05$). There were no other effects of shadowing type (all *p*s > 0.2).

Shadowing stage affected copy accuracy ($F(1,89) = 15.1$; $p < 0.001$), recall accuracy ($F(1,89) = 12.3$; p < 0.001) and recall time ($F(1,89) = 13.7$; $p < 0.001$), with a marginally significant effect on copy time ($F(1,89)=3.39$; $p = 0.069$). As illustrated in Figure 1, shadowing during the copy stage resulted in less accurate copy and recall, and shorter recall times, relative to shadowing during recall or not shadowing. Copy times were shorter for participants shadowing during the copy phase than the control group.

There were no main effects of sex (all *p*s > 0.1), but a marginally significant interactive effect of sex and shadowing type on recall time ($F(1,89) = 3.51$; $p = 0.065$), with males completing the recall task more quickly in the syllable shadowing condition than the other conditions. There were no other significant interactions between shadowing type, stage and sex (all *p*s > 0.1).

Discussion

Verbal shadowing did not affect performance on the block design task, which does not require retention of visuospatial information and does not contain highly nameable features. Males were quicker at completing designs, in line with previous reports of sex differences in this task (Ilai & Willerman, 1989). Participants who shadowed while copying the complex figure showed reduced copy and recall accuracy relative to those shadowing during the recall stage, whose performance did not differ from controls. This suggests that verbal interference affected encoding of the figure but not retrieval (if encoding had occurred in the absence of shadowing).

The interference with visuospatial construction in the complex figure test, but not the block design, may have been due to the nameability of complex figure elements (e.g., 'cross', 'triangle'). Shadowing may have prevented access to subvocal naming mechanisms that might otherwise have supported task performance. The lack of interaction with shadowing type shows that syllable and prose shadowing affected performance to a similar extent, though syllable shadowing was associated with quicker complex figure recall. Although previous research has shown a male advantage for the complex figure test (Gallagher & Burke, 2007) we found no main effect of sex on complex figure performance.

Experiment 2

Participants Twenty-six healthy adults (24 female, 2 male) aged between 18 and 23 years ($M = 19.4$ years) participated for payment or course credit.

Materials The room used for the experiment was a rectangular enclosure measuring 164 x 255cm; 190cm high. Black curtains enclosed the space, which had a black ceiling and dark grey carpet. Four 25w lights and a video camera were located in the centre of the ceiling. Four identical silver-grey coloured cylindrical tins (diameter 12.5cm, height 15cm) with lids were placed in the corners of the room and served as hiding locations for the target object (a pocket watch). A wheelchair was used for the disorientation procedure, during which participants wore a blindfold. Participants wore headphones in all conditions, through which the verbal shadowing recordings (syllable shadowing and prose shadowing conditions) or white noise (baseline condition) were played. In the two shadowing conditions, a sheet of glossy white poster paper, measuring 91 x 142cm, was attached to the short wall opposite the entrance to the enclosure, serving as a directional landmark.

Design and Procedure The design and procedure were similar to that of Hermer-Vazquez et al. (1999), except that conditions were completed in a counterbalanced order. A within-participants design was used, with each participant completing four trials in each of three conditions: prose shadowing, syllable shadowing and geometric baseline. In all conditions, geometric information was provided by the rectangular shape of the room. In the two shadowing conditions, featural information was also provided by the white paper landmark. In the geometric baseline condition, no featural information was available and participants had to rely on the geometric cues to reorient. The purpose of the geometric baseline condition was to check that disorientation was effective; disoriented participants would be expected to reorient equally to the two corners providing the same geometrically correct information. In the two conditions containing the featural cue, participants should be able to integrate this with geometric information to reorient correctly.

At the beginning of a trial, the participant was seated in the wheelchair and placed in a predetermined starting position. They were then shown the object, watched the experimenter hide it, and were asked to put on the blindfold. The wheelchair was pushed around in four rotations, incorporating two direction changes, and was then stopped in a predetermined position. The experimenter then removed the blindfold, and asked the participant "where did I hide the watch?", and the participant indicated their choice of corner by pointing. The object was then retrieved and the participant repositioned to begin the next trial. Between conditions, participants waited outside the room briefly while it was prepared for the next condition. The object was hidden in a different corner in each of the four trials of each condition, and the participant's position at the start and end of each trial was randomised.

Scoring and Analysis Verbal shadowing accuracy was scored as the percentage of stimulus items (syllables or words) correctly repeated. Two participants scored more than two standard deviations below the mean on both shadowing types and their data were excluded from further analyses. Reorientation accuracy was scored out of four for each condition, and performance in the two shadowing conditions was compared against a chance level of 25%. For the geometric baseline condition, paired t-tests were used to compare responses to the two geometrically equivalent corners (to check that orientation had not been maintained), and to compare responses to geometrically correct versus incorrect corners. An analysis of variance was then run for the two shadowing conditions, with shadowing type (prose/syllables) as the within-participants factor and condition order as the between-participants factor.

Results

Mean shadowing accuracy was 91.8% for prose and 92.4% for syllables. In the geometric baseline condition, responses to the two geometrically correct corners were more frequent than to the incorrect corners ($t(23) = 12.1$; $p < 0.001$), and responses to the two geometrically corners did not differ from each other ($t(23) = 1.04$; $p > 0.3$), indicating that disorientation was effective. Accuracy in both shadowing conditions exceeded the 25% chance level (syllables, $t(23) = 8.67$; $p < 0.001$; prose, $t(23) = 12.4$; $p < 0.001$). Shadowing type had a marginally significant effect on reorientation accuracy ($F(1,21) = 3.48$; $p = 0.076$), with lower accuracy in the syllable shadowing condition (see Figure 2). There was no main effect of order ($F(2,21) = 1.76$; $p > 0.1$), and no interaction of order with shadowing condition ($F(2,21) = 1.41$; $p > 0.2$)).

Discussion

Neither shadowing task reduced reorientation accuracy to chance levels, though there was a tendency towards poorer performance on the reorientation task with syllable shadowing than with prose shadowing. This suggests that participants may have found syllable shadowing more demanding than prose shadowing, despite it having fewer lexical and syntactic demands than the prose task. We did not include a condition in which both featural and geometric cues were included and without a secondary task, as previous experiments have consistently demonstrated high accuracy rates in such conditions. Single-task accuracy was 81 and 93% in Hermer-Vazquez et al. (1999) and Ratliff and Newcombe (2008) respectively. In Experiment 2, accuracy during prose shadowing was similar to levels in previous studies (82.3%), while syllable shadowing was associated with poorer accuracy (68.8%).

General Discussion

We investigated verbal interference in visuospatial tasks in relation to two theories about the role of language in visuospatial representation. One proposal is that language provides a supplementary or secondary code to support visuospatial memory (Meilinger et al., 2008; Paivio, 1991). Our results are consistent with this theory to some extent in that both shadowing tasks (prose and syllables) likely reduced the availability of phonological resources for subvocal naming and rehearsal, and both reduced encoding of visuospatial information in the complex figure task. It was suggested that the lack of shadowing interference in the block design task may have been due to the low nameability of test items, such that supplementary verbal coding is not normally engaged by this task.

The second proposal, that lexical and syntactic mechanisms are required for the integration of feature and location information, was not supported. Prose shadowing did not selectively interfere with visuospatial task performance; in fact the opposite pattern was observed in Experiment 2, with reorientation accuracy lower during syllable shadowing than with prose shadowing.

A further possible explanation for the results presented here is that language is not involved at all in the visuospatial tasks we investigated, and that the interference observed is due to the increase in general attentional demands conferred by dual-tasking (e.g., Pashler, 1994). Nonverbal tasks used in previous studies (Hermer-Vazquez et al., 1999; Ratliff & Newcombe, 2008) also disrupted reorientation. However, neither rhythm shadowing nor spatial tasks fully match the non-linguistic demands of the verbal task. While we attempted to match non-linguistic demands of the prose and syllable shadowing tasks, the tendency for greater interference in reorientation by the syllable task indicates that it may be more attentionally demanding, and although the prose task was more linguistically demanding it involves a greater degree of predictability than non-word repetition.

Previous research (e.g., Salter, 1973) has suggested that processing of other linguistic information can occur during

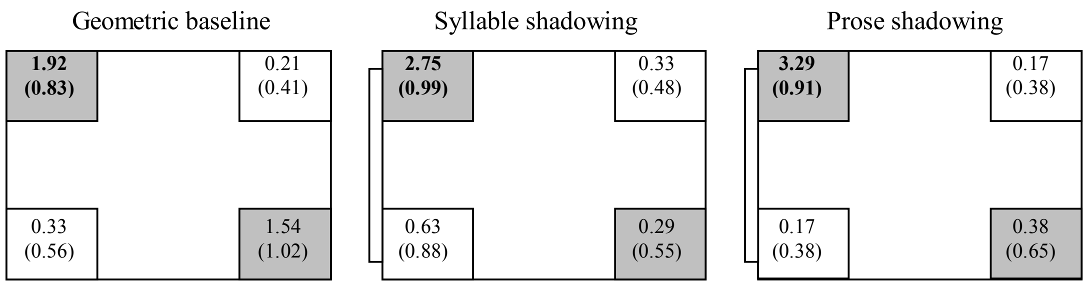

Figure 2. Reorientation task performance: mean response rates (and standard deviations) for each corner in the three conditions of Experiment 2. The correct corner (different on each trial) is shown in bold. Geometrically equivalent corners (sharing the same geometric properties) are shaded.

shadowing, and it is possible that, contrary to assumptions made in previous studies (e.g., Hermer-Vazquez et al., 1999), prose shadowing does not fully occupy core language resources. This is an important consideration due to the number of claims about the role of language in cognitive processes that have been based on verbal interference experiments. Claims of the involvement or absence of language in visuospatial cognition have been based on verbal interference tasks with different levels of linguistic demands (e.g., Garden et al., 2002; Meilinger et al., 2007; Walker & Cuthbert, 1998). However, little is known about which linguistic resources different verbal tasks occupy, and to what extent. Further research should therefore examine the extent to which different shadowing tasks disrupt online processing of syntactic and lexical information.

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