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# How Did You Get Here from There? Verbal Overshadowing of Spatial Mental Models

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## SUMMARY

This experiment investigated the reactive effects of verbal reports on spatial mental models. Participants studied a map marked with a route and then either verbalized their memory for the route or engaged in an unrelated verbal activity. Results showed that verbalization hindered performance on a measure of configural knowledge (straight-line distance estimations) but had no overall influence on a measure of featural knowledge (route distance estimations). In addition, verbalization differentially interacted with verbal ability on the memory measures. The implications for research on memory for spatial environments and the evidence for the existence of two distinct forms of memory representations (route versus configural) in spatial mental models are discussed. Copyright © 2002 John Wiley & Sons, Ltd.

The ability to determine how to get from a given point to another is a form of spatial reasoning thought to rely on distinct forms of mental representations. For example, at times we may call upon an overall picture of a familiar neighbourhood to aid in orientation, while at other times we may rely upon our memory for a route to get us from one point to another (Tversky, 1991). Conventionally, the former type of representation is described as a 'map in the head' (e.g. Kuipers, 1982) and is a type of configural knowledge that can aid in determining one's general course of direction. The latter is the more familiar 'route' knowledge used when one has to determine the best way to get from a certain location to another (e.g. make a left turn at Main Street, go two blocks; e.g. Lipman, 1991). In short, it seems that people can draw upon different memory representations and the question is, what are the conditions that determine our use of one form over the other.

One factor that can influence the use of a particular memory representation over another is verbalization. Verbal recall of a stimulus item can alter the type of knowledge individuals rely upon for associated recognition decisions (e.g. Brandimonte *et al.*, 1997; Schooler and Engstler-Schooler, 1990; Schooler *et al.*, 1997). For example, research in the area of face recognition demonstrates that verbalizing one's memory for a face can lead one to differentially rely on verbal and visual memories when later engaged in recognition of that face (e.g. Dodson *et al.*, 1997; Fallshore and Schooler, 1995; Schooler and Engstler-Schooler, 1990). More specifically, the act of verbalizing one's memory for a

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face negatively affects later recognition of that face—a phenomenon known as verbal overshadowing (e.g. Meissner *et al.*, 2001; Roediger, 1996; Schooler and Engstler-Schooler, 1990).

Given that verbal overshadowing occurs in situations where multiple memory representations may exist, it seems quite plausible that such effects could occur in spatial reasoning. The purpose of this study is to investigate whether verbalization similarly influences a particular type of spatial mental model, specifically, whether verbalizing one's memory for a map can later influence the use of that memory. Rather than investigating the influence of discourse on the construction of spatial mental models (e.g. Foos, 1980; Perrig and Kintsch, 1985; Tversky, 1991), or spatial situation models (e.g. Haenggi *et al.*, 1995; Rinck *et al.*, 1997), in this study we explored how *self-generated descriptions* of spatial mental models (i.e. memory for large-scale environments) may alter access to that representation. In short, this research was designed to extend the verbal overshadowing paradigm into the domain of spatial mental models. Unlike other perceptual domains in which verbal overshadowing has been explored, spatial mental models have a sequential component that is more readily verbalized (i.e. route knowledge). Thus, it may be that verbalization differentially interacts with route versus configural memories. As such, this study employed measures contrived to tap these two distinct components of spatial mental models. It was predicted that these distinct memory representations would differentially rely on the degree to which verbal and non-verbal knowledge was effectively utilized.

## TYPES OF SPATIAL MENTAL MODELS

Spatial mental models, or memory for an environment, have been classified in ways that juxtapose knowledge which could be argued to differentially rely on verbal and nonverbal knowledge, specifically, route versus configural representations (e.g. Hirtle and Hudson, 1991) and procedural versus survey knowledge (e.g. Taylor and Tversky, 1992; Thorndyke and Hayes-Roth, 1982). Essentially, a distinction can be made between representations relying on relatively more or relatively less verbal knowledge. Such representations may be based more on verbal/propositional knowledge or based more on visual/analogue knowledge (Kosslyn *et al.*, 1978).

Route knowledge consists of discrete chunks of information representing sequential locations rather than the representation of general interrelationships of items across the route (e.g. Hirtle and Hudson, 1991). Similarly, procedural descriptions are said to be acquired through direct navigation and result in a sequential record of the space traversed. Configural knowledge is made up of a more holistic representation and allows one to determine the locations of objects within a general frame of reference (e.g. Hirtle and Hudson, 1991), and survey knowledge is said to consist of a global representation that includes the location of objects relative to a fixed coordinate system (e.g. Tversky, 1991). In order to be consistent with previous verbal overshadowing work (e.g. Fallshore and Schooler, 1995), for the purposes of this paper, the term 'configural' will be used to discuss the more holistic or map-like representations and the term 'featural' will be used to discuss the more procedural or route-like representations.

Researchers investigating spatial mental models have provided various sources of evidence for these distinct forms of memory representations. For example, Hirtle and Hudson (1991) used the structure of ordered trees generated from recall trials as one indicator of configural knowledge. Participants who consistently recalled landmarks in a single order, and thus produced a uni-directional tree, showed poorer performance on measures of configural knowledge than participants who did not. Hirtle and Hudson maintained that recalling landmarks in a single order is consistent with a route representation, which would explain poorer performance on measures designed to test a configural representation. Thorndyke and Hayes-Roth (1982) used distance estimations for naturally and artificially learned spatial environments to show that participants learning via a map were more accurate on Euclidean or 'straight-line' distance estimations (judgements requiring configural knowledge) than were participants learning through navigational experience. In contrast, participants learning via navigation were more accurate on route distance estimations (judgements requiring featural knowledge) than were participants learning via a map. Others have used similar methods to distinguish between the accuracy and type of spatial representation (Evans and Pezdek, 1980; Hirtle and Jonides, 1985; Lipman, 1991; Lipman and Caplan, 1992; McNamara *et al.*, 1989; Taylor and Tversky, 1992; Thorndyke, 1981).

## VERBAL OVERSHADOWING

This distinction between configural and featural forms of representation has been similarly made in the verbal overshadowing literature and in other areas of cognition (Diamond and Carey, 1986; Fallshore and Schooler, 1995; Melcher and Schooler, 1996). Fallshore and Schooler (1995) suggested that the process of face recognition can focus to varying degrees on either the distinct individual features, known as featural processing, which is analogous to route processing, or on the interrelation of the features, known as holistic processing, which is analogous to configural processing. Research on the effects of verbalizing ones' memory for a face showed that verbalization led participants to focus on specific featural or propositional information at the expense of more configural or holistic information (Dodson *et al.*, 1997; Fallshore and Schooler, 1995; Schooler and Engstler-Schooler, 1990). Studies showing that verbalization disrupts the face recognition process suggest that it may have its effect by specifically impairing the configural processes thought to be associated with face recognition (Diamond and Carey, 1986).

Fallshore and Schooler (1995) demonstrated this effect by examining perceptual expertise in the face-recognition process. Expertise in face recognition, associated with same-race identification, is thought to be due to configural processing while non-expertise, associated with other-race identification, is thought to be due to featural processing (Diamond and Carey, 1986). Similarly, recognition of upright faces relies on configural processing while recognition of inverted faces relies on featural processing (Sergent, 1984). Fallshore and Schooler demonstrated that verbalization disrupts same-race upright face recognition while marginally improving other-race upright face recognition. When participants were given recognition tests with inverted faces, no effect of verbalization was found, implying that verbalization influences only upright face recognition. These results suggest that verbalization only impairs configural processes and that it has its effects on memory by overshadowing a given stimulus's holistic or configural representation with a more linear or featural representation.

This overshadowing caused by verbalization is not limited to face recognition and is evident in various forms of cognition that are thought to be dominated by dichotomous processes. Researchers have shown detrimental effects of verbalization on visual

(Schooler and Engstler-Schooler, 1990) and taste (Melcher and Schooler, 1996) memory, on visual image processing (Brandimonte *et al.*, 1992, 1997), on insight problem-solving (Schooler *et al.*, 1993) and on decision making (Wilson and Schooler, 1991). Collectively, this research demonstrated that participants who were forced to verbalize various processes performed more poorly on certain tasks or made less satisfactory decisions than participants who did not perform any type of verbalization. In each of these distinct areas of research, the relevant cognitive processes can be dichotomized into competing components and this study was designed to explore the effect of verbalization in yet another area of cognition where analogous distinctions exist—spatial mental models. Although configural knowledge can be described via certain forms of verbal descriptions, our argument is that the veridical properties of such knowledge (e.g. types of distances, angles, orientations) may be attenuated by the imprecision associated with such descriptions (e.g. cardinal directions such as 'Northwest'). Further, we argue that route knowledge does not similarly suffer by the use of verbal descriptions given that the properties of route knowledge may be more consistently represented.

## PRESENT STUDY

The purpose of this study was to determine how verbalization affects spatial mental models. It was hypothesized that the task of verbalizing one's memory for a large-scale environment would disrupt access to the configural aspects of the spatial mental model while encouraging access to featural or propositional aspects of the model. The discrete features of the mental model would thus become more salient at the expense of the overall configuration of the model. Encoding a spatial environment via a map was expected to be more likely to result in a configural representation, that is, in the absence of specific instructions participants may attend to cardinal directions and/or the overall orientation of landmarks within that environment. Accordingly, participants who verbalize their memory for a route on the map were expected to show, when compared to participants in a control condition, a detriment in performance on tasks designed to test configural knowledge (e.g. straight-line distance estimations), and show either an enhancement in performance, or no effect on tasks designed to measure featural knowledge (e.g. route distance estimations).

Because verbalization was expected to de-emphasize the configural representation, it was hypothesized that there would be a negative effect on Euclidean or straight-line distance estimations (e.g. Hirtle and Hudson, 1991; McNamara *et al.*, 1989; Thorndyke, and Hayes-Roth, 1982). Euclidean distance estimations have a substantial configural component so verbalization participants may fail to access the spatial knowledge necessary for this task because of their de-emphasis on the configural aspects of the route. Because verbalization was expected to emphasize the featural aspects of the representation, as was found with featural aspects of face recognition (e.g. Fallshore and Schooler, 1995), it was hypothesized that there would either be a positive effect or no influence of verbalization on route distance estimations.

## VERBAL ABILITY

An additional issue is the degree to which verbal ability interacts with the hypothesized verbal overshadowing effect. In recent studies, differences in verbal and nonverbal expertise have interacted with verbalization on a variety of tasks (e.g. Fallshore and Schooler, 1993; Melcher and Schooler, 1996; Schooler *et al.*, 'Knowing more than you can tell: The relationship between language and expertise', unpublished manuscript, 2002). For example, Fallshore and Schooler (1993) found that, on an artificial grammar learning task, the effect of verbalization was most pronounced for low verbal ability participants (as measured by SAT scores). Similarly, Melcher and Schooler (1996) showed, in a wine-recognition study, that participants with relatively high levels of verbal knowledge were not affected by verbalization. In addition, Ryan and Schooler (reported in Schooler *et al.*, 2002) found that the effects of verbalization on tests of face recognition were most pronounced for participants with low verbal ability. Ryan and Schooler also found those with relatively high perceptual ability showed a greater effect of verbalization than those with low perceptual ability. The converging lines of evidence from these studies suggests that individuals who are more likely to rely on verbal knowledge and/or exhibit some form of verbal proficiency, are less likely to show interfering effects of verbalization (Schooler *et al.*, 2002). In addition, although a number of studies investigating the development of spatial mental models attempt to account for various individual differences as they relate to spatial ability (e.g. 'Hidden Figures Test'), verbal ability is rarely considered (e.g. Allen *et al.*, 1996). To address these issues, a measure of general verbal ability was included to determine if such abilities differentially interact with verbalization and performance on tests of spatial memory. Last, although the influence of visual/perceptual ability on verbalization effects is not as pronounced, a measure of spatial ability was included in order to determine if relative spatial skills may also differentially interact with verbalization on these measures.

## METHOD

### Participants

Participants were members of introductory psychology courses who earned course credit for participation. In total 84 participants were run in the experiment. Procedural problems (e.g. some participants did not complete the experiment in the designated time) necessitated the exclusion of three participants, leaving 81 participants for the data analyses (40 in the Control Condition and 41 in the Verbalization Condition). There were 23 females and 17 males in the Control Condition and 24 females and 17 males in the Verbalization Condition. The mean age of participants was 21.5 years ($SD = 5.1$) in the Control Condition and 21.3 years ($SD = 4.4$) in the Verbalization Condition.

### Materials

A portion of the materials used in the experiment were those used by Hirtle and Hudson (1991). Participants were shown a map of a small town with a marked path containing 16 landmarks. The 16 landmarks were used to generate 60 landmark pairs for the distance estimations. A potential confound, not addressed in the literature, which results from using route and Euclidean distance estimations is that the two types of distances are themselves often correlated. Because of this, participants could rely on one form of representation, and still be somewhat accurate on distance estimations for the other. To correct for this, landmark pairs used in the distance estimations in this experiment were specifically designed to be uncorrelated, thereby enabling the independence of these two sources of spatial knowledge to be more fully investigated.

This independence was accomplished by first calculating a straight-line and route distance for each landmark pair. Then a correlational analysis was conducted on the landmark pairs to determine which landmark pairs were not highly correlated. The set of landmarks was broken down into two sets, each with 30 items: one to be used in the route distance estimations and the other to be used in the Euclidean distance estimations. The correlation between actual route distance and actual Euclidean distance was 0.20 ($p > 0.05$) in the route set and 0.21 ($p > 0.05$) in the Euclidean set.

### Procedure

Participants were run in groups of six or less and randomly assigned to either the verbalization or the control condition. In order to maximize initial encoding similarity to the standard verbal overshadowing face-recognition paradigm, instructions were worded such that participants paid attention to the overall configuration of the map while encoding. Participants were told the following: 'For this experiment, you will be shown a map depicting a small town. Your task will be to memorize the map in terms of the landmarks on the map and the distance between the landmarks. We want you to focus on 16 landmarks, each of which will be identified by a name on the map.' Following the initial presentation, participants were tested on their knowledge by having them place five randomly chosen landmarks on a blank map. The study and test phase were then repeated. The test phase was conducted to ensure that participants were acquiring spatial knowledge about the landmarks (Hirtle and Hudson, 1991). Participants studied the map for a total of 12 minutes.

Following the encoding phase, participants in the verbalization condition were instructed to write down everything they could remember about the route shown on the map and the landmarks along that route. We chose to emphasize verbalization of the route specifically because our hypotheses had to do with the manner in which featural descriptions could attenuate other aspects of the memory. Although one could argue that this limits the conclusions we could make from the experiment (i.e. because we did not solicit differing forms of verbalizations), we chose this type of instruction to maximize similarity to, and the generality of, verbal overshadowing. Participants in the control condition were given an unrelated verbal filler task—describing a specific memory lapse they had experienced. All participants were then given the route and Euclidean distance estimation tasks. Presentation of these tasks was counter-balanced across participants. For both the route and Euclidean distance estimation tasks, participants were presented with landmark pairs and instructed to make either straight-line distance judgements or route distance judgements. They were instructed to make these judgements assuming that the longest distance is '100 units' (see the Appendix for full instructions). Last, all participants were administered a mental rotations test and then the vocabulary portion of the Nelson–Denny Reading Test.

## RESULTS

There were no significant differences between verbalization and control participants on the individual differences measures. Therefore, it was assumed that participants in each condition were of relatively equal verbal and spatial ability. As mentioned, because verbal ability has sometimes mediated verbal overshadowing effects (Schooler *et al.*, 2002), participants were divided into high and low verbal ability based upon a median split of their vocabulary score (Mean High Verbal = 56%; Mean Low Verbal = 32%). In order to determine whether similar interactions might occur for spatial ability, comparable analyses were conducted using a median split on participants' mental rotations score (Mean High Spatial = 82%; Mean Low Spatial = 56%). Because data suggest that gender differences exist in both verbal and spatial abilities (e.g. Geary, *et al.*, 1992; Halpern and Wright, 1996; Hyde and Linn, 1988; Linn and Petersen, 1985), gender was included as a covariate in all reported analyses. Accuracy on the distance estimation tasks was determined by correlating the judged and actual distances. Correlational analyses have been used in a number of studies of memory accuracy for large-scale environments, in domains as varied as cognitive psychology (Thorndyke and Hayes-Roth, 1982), environmental psychology (Cadwallader, 1976; Hirtle and Hudson, 1991), and in virtual reality research of macro-spatial learning (Ruddle *et al.*, 1998). For this and subsequent analyses, correlations were converted to $z$-scores by means of Fisher's $r$ to $z$ transformation; the means reported here have been converted back to correlation coefficients.

### Euclidean distance estimations

Participants in the verbalization condition were significantly less accurate on Euclidean distance estimations than participants in the control condition. The mean correlation between the actual and the judged distance was 0.41 for participants in the verbalization condition and 0.52 for participants in the control condition. An analysis of variance conducted on the $z$-transformed values revealed a main effect for the verbalization condition, $F(1, 76) = 6.14$, $p = 0.015$. There was not a main effect of verbal ability nor did verbal ability interact with the verbalization condition on Euclidean distance estimations ($F\text{s} < 1$). There was not a significant effect of spatial ability, $F(1, 76) = 2.51$, $p = 0.12$, nor did spatial ability interact with the verbalization condition on Euclidean distance estimations ($F < 1$).

### Route distance estimations

Participants in the verbalization condition were no more accurate on the route distance estimations than participants in the control condition ($F < 1$).[1] The mean correlation between the actual and the judged route distance was 0.78 for participants in the verbalization condition and 0.79 in the control condition. There was a main effect of verbal ability, $F(1, 75) = 5.62$, $p = 0.020$, with high verbal participants (M = 0.83) significantly more accurate than low verbal participants (M = 0.70). There was also an interaction between verbal ability and verbalization condition, $F(1, 75) = 4.03$, $p = 0.048$ (see Figure 1). *Post-hoc* analyses showed that, when considering participants in the verbalization condition, high verbal participants were significantly more accurate than low verbal ability participants, $F(1, 38) = 7.35$, $p = 0.010$. There was no such difference between high and low verbal participants in the control condition ($F < 1$). In addition,

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[1] One participant had a score greater than three standard deviations from the mean and was excluded from the analyses.

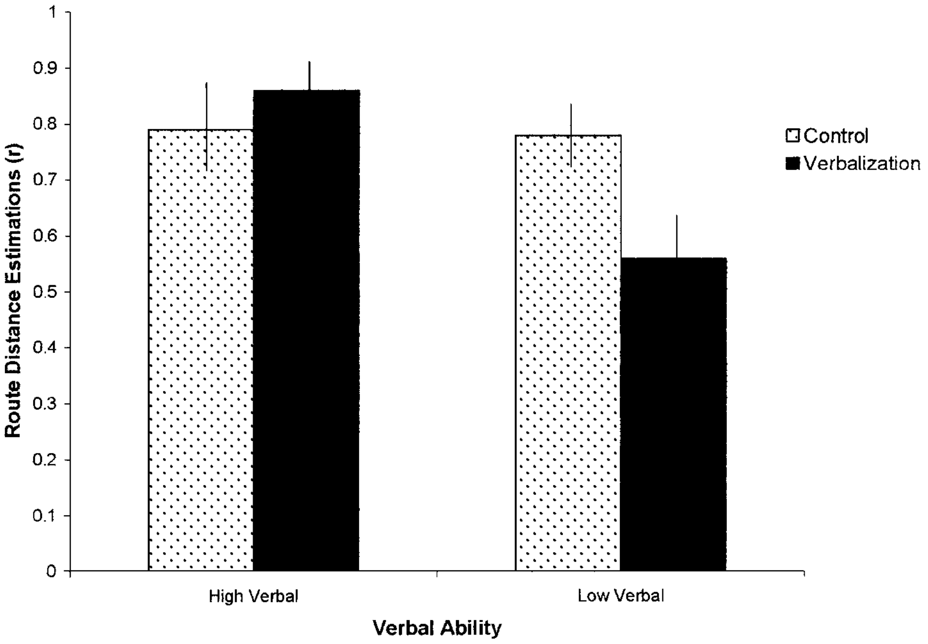

Figure 1. Route distance estimations broken down by verbal ability and verbalization condition

compared to the control participants, verbalization impaired low verbal participants, $F(1, 34) = 4.12$, $p = 0.05$. There was no such effect on the performance of high verbal participants ($F < 1$). There was no effect of spatial ability, $F(1, 75) = 1.49$, $p = 0.226$, nor did spatial ability significantly interact with the verbalization condition on route distance estimations, $F(1, 75) = 2.82$, $p = 0.097$.

## DISCUSSION

### Evidence for effects of verbalization on configural knowledge

The results provide evidence that verbalization negatively affected certain aspects of spatial mental models. It was hypothesized that the task of verbalizing one's memory for a spatial environment would disrupt access to the configural aspects of the spatial mental model while encouraging access to the featural or propositional aspects of the model. Participants who verbalized their memory for the route were less accurate on Euclidean distance estimations than control participants. Given the substantial configural component of the Euclidean distance estimations, verbalization seems to have hindered access to the critical spatial information necessary for this task. Thus, verbalization may have biased access, or disrupted access, to configural aspects of the spatial mental model (Schooler *et al.*, 1997). Also, consistent with other research using individual differences measures (e.g. Lorenz and Neisser, 1986), there was no significant relation between this measure and spatial ability. This represents further evidence suggestive that configural environmental knowledge may be somewhat independent of spatial ability as measured by some psychometric tests (see Allen *et al.*, 1996, for a discussion). Nonetheless, some caveats are warranted with respect to these findings. First, only a single measure of configural knowledge was used to find evidence for verbal overshadowing. Although this is consistent with traditional investigations of verbal overshadowing, the domain of spatial mental models has a number of assessments for configural knowledge that can be explored in future research (e.g. orientation questions, Hirtle and Hudson, 1991; see also Montello, 1991). Second, alternative and additional measures of individual differences in spatial and/or verbal ability could be applied to better converge on the degree to which such factors may moderate verbal overshadowing in this domain.

## Evidence for effects of verbalization on route knowledge

The results provide evidence that the effects of verbalization on route memory are somewhat benign. It was hypothesized that the task of verbalizing one's memory for a spatial environment would either be minimal (cf. Fallshore and Schooler, 1995) or perhaps even increase access to the featural aspects of the spatial mental model thereby potentially aiding in assessment of distances along the route. Overall, there was little evidence for the negative effects of verbalization on the route measure. Nonetheless, there was evidence that verbalization hindered performance for low verbal participants on the measure of route knowledge (discussed next). The differential effects of verbalization on route vs. configural memory thus help to further support the notion that verbalization particularly disrupts perceptual experiences that are especially difficult to verbalize (Schooler *et al.*, 1997).

## Verbalization and individual differences

This study also adds to the growing body of literature showing how the effects of verbalization may be moderated by verbal ability (e.g. Schooler *et al.*, 2002). Specifically, previous research suggests that an individual's inherent reliance on verbal knowledge and/or their verbal proclivity may, in certain situations, help overcome the deleterious effects of verbalization (e.g. Melcher and Schooler, 1996; Schooler *et al.*, 2002). Although there was not a main effect of verbalization on route memory there were effects dependent upon verbal ability. Verbalization hindered the performance of low verbal participants on route distance estimations. This suggests that the effects of verbalization on route memory are benign, but only to the degree one has an adequate level of verbal ability.

When verbal ability is relatively low even route memory performance may suffer from verbalization, possibly as a consequence of less effective verbalizations. This finding is consistent with other studies of verbal overshadowing in both face memory (Ryan and Schooler, reported in Schooler *et al.*, 2002) and in artificial grammar learning (Fallshore and Schooler, 1993). Further, this finding is consistent with a developmental study of young children's memory for a familiar route (Matthews, 1985). Matthews noted that performance depended on whether map construction or verbal recall was employed, stating that 'verbal reporting appears to inhibit the young child severely' (p. 274). His results showed that, when verbal recall was employed, young children's performance was markedly inferior when compared to their performance on a map-drawing task. In the context of the present study, Matthews' findings can be interpreted from a verbal overshadowing perspective. Because young children may be less inclined to rely on verbal reasoning and/or apparently lack the vocabulary to articulate their spatial knowledge, forcing them to describe that knowledge resulted in poorer performance compared to measures allowing them to illustrate that knowledge. Likewise, low verbal ability participants in this study may similarly have been less inclined or less able to rely on verbal reasoning and thus were differentially affected by the verbalization manipulation. Furthermore, these results are unique given that verbal ability is rarely, if at all, used as an individual differences measure in studies of memory for large-scale environments (e.g. Allen *et al.*, 1996; Thorndyke and Stasz, 1980). Thus, despite the prevalence of measures of route-like knowledge in such studies, little attention has been paid to verbal ability. This main effect of verbal ability, coupled with the interaction between verbalization and verbal ability, suggests that investigations of environmental learning (e.g. Golledge, 1985; Siegal *et al.*, 1978; Siegal and White, 1975) need to consider such abilities in addition to those typically assessed.

We had expected that verbal ability might also interact with verbalization for configural judgements. However, verbalization impaired the performance of both high and low verbal participants on the measure of configural knowledge. One reason why verbal ability apparently failed to insulate the high verbal participants from the disruptive effects of verbalization is that these participants may be particularly prone to alter the type of knowledge on which they rely as a function of verbalization. The notion that verbalization may dampen access to configural knowledge is quite consistent with a variety of recent findings suggesting that verbalization may not simply reduce the quality of the memory, but alters the type of memories upon which individuals are inclined to rely (Schooler *et al.*, 1997).

## The relation between language and spatial memory

The present findings also have important implications for conceptualizing the relationship between language and spatial memory. This has long been a topic of some debate (e.g. Glenberg and McDaniel, 1992). Indeed, a number of researchers interested in text processing and mental models have investigated the *construction* of spatial mental models using different types of verbal descriptions as the independent measure (e.g. Franklin *et al.*, 1992; Oakhill and Johnson-Laird, 1984; Perrig and Kintsch, 1985; Taylor and Tversky, 1992). This research often juxtaposed route versus configural descriptions to determine the nature and accuracy of the spatial mental model. Route descriptions contain text emphasizing sequential relations, whereas configural descriptions contain text about an environment in geographic terms. Such research sometimes shows differential performance on measures of spatial knowledge dependent upon the wording of the text. Others have investigated the construction of spatial situation models in order to understand how readers integrate information contained in a narrative (e.g. Haenggi, *et al.*, 1995; Rinck *et al.*, 1996). Such studies show, for example, how readers make inferences about spatial relations so as to continuously update their situation model and thus facilitate text comprehension (Haenggi *et al.*, 1995).

Note, though, that these text processing studies involved the verbal manipulation taking place at encoding, not following encoding. Specifically, the aforementioned researchers were determining how language could be used to construct a spatial mental model, *not* how language could influence an already constructed mental model of a large-scale environment. Thus, their participants' exposure to the environment was essentially verbally based and, as previously mentioned, was experimentally biased by the text towards a particular spatial representation. The present study is distinct from, and, to some degree, extends upon, the aforementioned research because the verbal processing takes place subsequent to the encoding rather than during, and because the 'text' in the present design is entirely self-generated. Therefore, any influence of verbalization would be the result of a self-generated description of an already learned representation. Thus, this study demonstrates the influence of language, not during encoding (e.g. Perrig and Kintsch, 1985; Taylor and Tversky, 1992), but following encoding, suggesting that verbalization may interfere with access to an already acquired spatial mental model.

### Implications of the reactive effects of verbalization for research on spatial mental models

Last, an important aspect of this research is the implications for studies of spatial mental models that employ either some form of free-recall task as a dependent measure or elicit verbal protocols from their participants (e.g. Fishwick and Vining, 1992; Giovanna *et al.*, 1988; Golledge, 1985; Lipman and Caplan, 1992; Thorndyke and Stasz, 1980). Specifically, because verbalization was shown to influence participants' performance on different memory measures, then articulating some aspect of spatial knowledge could differentially influence performance depending upon when it takes place in the experimental procedure. For example, consider that, until recently, problem solving was thought to be invulnerable to verbalization and was characterized as readily lending itself to verbal exposition (e.g. Ericsson and Simon, 1993). But, Schooler *et al.* (1993) found that both retrospective and concurrent verbalization impaired participants' ability to find solutions to certain problem types. Thus, verbal exposition during problem solving is not as innocuous a measure as it is often considered.

In the context of spatial mental models a similar caution may be warranted. Though any given dependent measure has the potential to influence one's memory, the potential for reactivity due to some form of verbalization (e.g. free recall) is considerable. Given that such measures are employed in investigations of memory for large-scale environments, there is also the potential for interference from verbalization. For example, after an initial encoding phase where a spatial environment has been presented, if the order of dependent measures is counter-balanced, participants who free-recall before another dependent measure may be more inclined to rely on that verbal recollection of the environment than their more veridical visual representation. Thus, the potential for order effects may be increased due to the reactive nature of verbalizing one's memory when some form of free-recall task is employed. As such, caution is warranted when designing studies to investigate such spatial mental models and the relative benefit of free-recall needs to be balanced against the potential costs.

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## APPENDIX: DISTANCE ESTIMATION INSTRUCTIONS

### Euclidean distance estimations

We are now going to ask you to judge distances between landmarks in the town. On each trial you will be given two landmark names. Please judge the distance between the landmarks using straight-line distances or 'as the crow flies' distances. You should make your judgements assuming that the longest distance is 100 units.

### Route distance estimations

We are now going to ask you to judge distances between landmarks along the route. On each trial you will be given two landmark names. Please judge the route distance between the landmarks—that is, how far apart the landmarks would be if you walked along the route. You should make your judgements assuming that the length of the route is 100 units.