COMMUNICATING ENVIRONMENTAL KNOWLEDGE
The Impact of Verbal and Spatial Abilities on the Production and Comprehension of Route Directions

ERIC J. VANETTI *is enrolled in the Ph.D. program in industrial/organizational psychology at Old Dominion University in Norfolk, Virginia. His primary interest is in personnel research.*

GARY L. ALLEN *is an Assistant Professor in the Department of Psychology at the University of South Carolina. He has a long-standing research interest in spatial cognition, focusing particularly on how children and adults acquire and use environmental knowledge.*

ABSTRACT: The impact of verbal and spatial abilities on the communication of route information was investigated using a two-part procedure. Initially, subjects were selected for inclusion in four groups based on their combination of spatial and verbal abilities. Subsequently, the performance of high spatial-high verbal, high spatial-low verbal, low spatial-high verbal, and low spatial-low verbal subjects was measured on tasks requiring the comprehension and production of route directions. No differences were found with regard to subjects' abilities to comprehend route directions. However, the results suggested that spatial abilities are very important in the production of efficient route directions and that verbal abilities are related to subjects' tendency to conform to certain proposed linguistic conventions regarding the communication of route knowledge.

AUTHORS' NOTE: *Requests for reprints should be directed to Gary L. Allen, Department of Psychology, University of South Carolina, Columbia, SC 29208.*

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The communication of route knowledge refers to a complex process that involves both the production and the comprehension of route directions (Klein, 1980). Because of practical and theoretical significance, giving and comprehending directions are problems attracting the attention of researchers interested in person-environment relations (e.g., Ward et al., 1986). From a practical perspective, the communication of spatial knowledge is a common activity that serves the important function of keeping an individual oriented in the environment during navigation. At a theoretical level, research on this topic can provide useful insight into the processes by which information about the spatial environment is organized and communicated as procedural knowledge.

According to Edelman et al. (1977), communicating spatial information involves the interactive function of four factors: (a) the addressor, or the individual being asked to supply the information; (b) the object of representation, or the environment to which the information pertains; (c) the medium of representation; and (d) the addressee, or the individual to whom the information will be provided. The present experiment is concerned primarily with the cognitive abilities of the addressor and the addressee.

When asked for directions, the addressor must access environmental knowledge from memory and produce a coherent set of verbal directions based on that knowledge (Edelman et al., 1977). It is reasonable to posit that a combination of spatial and verbal abilities is involved in this process. Spatial abilities would play a role in accessing the addressor's stored knowledge of spatial relationships among environmental features and in tracking changes in the traveler's perspective of these features as a route is traversed; verbal abilities would play a role in generating the lexical conventions that adequately and accurately convey the spatial information specifying the route.

The task of the addressee would presumably also involve spatial and verbal abilities. The addressee must initially produce a request that effectively conveys the need for information and then comprehend the incoming verbal statements from the addressor (Wunderlich and Reinelt, 1982). Critical to navigational success is the ability to match the comprehended verbal message with perceptual experience in the environment during route navigation.

To date, the interaction of spatial and verbal skills in the communication of route knowledge is largely a matter of speculation. The present study was designed to produce initial empirical evidence concerning this issue. The approach used for this experiment involved the identification of the following four groups on the basis of their combinations of abilities: high spatial-high verbal, high spatial-low verbal, low spatial-high verbal, and low spatial-low verbal. A very conservative approach to examining the roles of spatial and verbal abilities was taken, in the sense that these abilities were assessed using widely available psychometric instruments rather than specific experimental measures of route learning skill and facility with spatial terminology. Accordingly, the term *spatial abilities* refers to those generic skills necessary to anticipate the appearance of visual stimuli following prescribed internal transformations (visualization) and to remain oriented to a stimulus following prescribed perspective transformations (spatial relations). The term *verbal abilities* refers to the extent of the lexicon and efficiency in its access. This conservative approach to assessing cognitive skills was taken to ensure the conclusiveness of positive results. In other words, interpretation of confirmed hypotheses would not be constrained by the argument that the findings held only for specialized macrospatial skills rather than for more generalizable cognitive abilities.

The comprehension of route directions was studied by measuring the efficiency of subjects' navigation in a real-world environment after they had received directions to a specific location. The production of route directions was investigated by examining the verbal protocols produced by subjects when they were asked to provide directions to a specific location.

FRAMEWORK FOR EXAMINING ROUTE DIRECTIONS

Measuring the efficiency of movement in a spatial setting is a straightforward matter, but the method applied for scoring protocols requires some explanation. Subjects' route direction protocols were scored according to the Communication of Route Knowledge (CORK) taxonomy and accompanying simple rules devised by Allen (1983). The taxonomy and rules were derived from computer models of macrospatial knowledge (e.g., Kuipers, 1978), qualitative analysis of protocols obtained in real-world circumstances, and pilot studies involving children and adults. Basically, the taxonomy consists of communicative statements and delimiters. Communicative statements include (a) an activating query, which is the addressee's request for directions (e.g., "How do I get to the nearest post office?"); (b) directives, which are action statements (i.e., essential "go to" and "turn" commands) provided by the addressor (e.g., "Drive three more blocks and turn left."); and (c) descriptives, which are used by the addressor to specify a spatial relationship between the traveler and an environmental feature or between environmental features (e.g., "A vacant lot will be on your left and a service station on your right.").

Delimiters provide specificity for communicative statements. Included under this rubric are environmental features, such as landmarks and choice points, and spatial-relational constructs, such as direction designations, distance designations, and lexical conventions connoting spatial relationships (e.g., between, over). Environmental features provide concrete referents in the communication process, and spatial-relational constructs constrain or modify other delimiters or entire communicative statements.

Simple rules for the effectiveness of communication accompany these basic taxonomic components. First and most obvious, the communicative statements should be in the correct temporospatial order. In addition, the described route should be as direct or efficient as possible. Two other rules are concerned with the placement of descriptives and the placement of delimiters. Descriptives are most appropriate in conveying information about choice points (e.g., "At the intersection, a large red building will be to your left.") and as the final statement in route directions (e.g., "Our house will be the third on your right."). Descriptives are basically statements consisting of delimiters, and thus the concentration of delimiters should be greater in statements involving choice points than in other statements. However, the primary rule involving delimiters is that their frequency should increase as the destination is neared, simply because there is a greater need for specificity as the traveler reaches his or her objective.

Seven measures of the production of route directions were examined in the present study, including (a) the number of communicative statements included in the directions, (b) the number of delimiters, (c) the number of temporospatial ordering errors, (d) the efficiency of the described route (expressed as a ratio of the distance covered by the most efficient possible route to the distance covered by the described route), (e) the proportion of descriptives occurring in conjunction with choice points and statements of the final destination, (f) the proportion of delimiters occurring in the final one-third of the communicative statements, and (g) the number of head and hand gestures used in communicating route information.

HYPOTHESES FOR THE PRESENT STUDY

If both spatial and verbal abilities are equally important in the communication of route knowledge of route directions, then subjects' performances in the comprehension task and the production task would be better in the high spatial-high verbal group than in the low spatial-low verbal group, with the other two groups falling between these two. If spatial abilities are more important than verbal abilities, then the two high spatial groups would be expected to be superior to the two low spatial groups. Conversely, if verbal abilities are more important than spatial abilities, then the two high-verbal-ability groups would outperform the two low-verbal-ability groups. If neither spatial nor verbal ability is significant in the comprehension process, no group differences would appear. Superior performance in the comprehension task refers to more efficient movement. Superior performance in the production task specifically means greater efficiency of described route, more efficient placement of descriptives and delimiters, and fewer temporospatial ordering errors.

Of less importance than the rule-related predictions are the expectations that high verbal subjects (i.e., high spatial-high verbal and low spatial-high verbal) would produce a greater number of communicative statements and a greater number of delimiters than would low verbal subjects (i.e., high spatial-low verbal and low spatial-low verbal). Both of these CORK-based measures reflect the amount of information produced rather than its relevance or accuracy. In addition, a greater number of head and hand gestures might be found with low verbal subjects (i.e., high spatial-low verbal and low spatial-low verbal) than with high verbal subjects (i.e., high spatial-high verbal and low spatial-high verbal). This possibility was based on the proposition that subjects with low verbal skills might more readily employ gestures to compensate for slow or inefficient access to the terminology required for their route directions.

METHOD

SUBJECTS

Included in the analyses of route comprehension and route production measures were data from 10 subjects in each of the four following groups: high spatial-high verbal, high spatial-low verbal, low spatial-high verbal, and low spatial-low verbal. These 40 subjects were selected from a subject pool of 104 undergraduates who completed five tests, including the Campus Knowledge Inventory, two tests of spatial ability, and two tests of verbal ability (see Materials). Subjects' assignment to groups was based on a comparison of their test scores to the distributions of scores obtained from another group of undergraduates (n = 248) tested on these instruments in a separate research project. High and low spatial subjects scored one-half standard deviation above and below the mean of the comparison distributions, respectively, on both tests of spatial ability. High and low verbal subjects scored one-half standard deviation above and below the means of the comparison distributions, respectively, on both tests of verbal ability. All subjects demonstrated knowledge of the location of the building used as the destination in the task required the production of route directions.

MATERIALS

The materials involved in subject selection included the Campus Knowledge Inventory, the spatial relations test (CAP-S) and the verbal ability test (CAB-V) from the *Comprehensive Ability Battery* (1975), and the surface development test (VZ-3) and the vocabulary test ((V-1) from the *Kit of Factor-Referenced Cognitive Tests* (Ekstrom et al., 1976). The Campus Knowledge Inventory was designed specifically for the present experiment to survey subjects' knowledge of the spatial relationships among buildings on their university campus. The 24-item inventory included questions concerning the frequency with which buildings were visited and a map-referenced building identification task. All of the subjects selected for the direction production procedure correctly identified the building subsequently used as the destination in that procedure and had actually visited that building. The CAB-S test consists of multiple choice items that require subjects to determine which of several comparison figures represents a different perspective on a referent figure. The distribution of scores used for subject selection had a mean of 44.6, with a standard deviation of 17.2 ($n = 248$). The VZ-3 test requires subjects to indicate corresponding edges between intact three-dimensional drawings of figures and "unfolded" two-dimensional versions of the same figures. The distribution used for subject selection had a mean of 31.1, with a standard deviation of 16.5 ($n = 248$). The CAB-V test consists of two parts, the first of which involves a multiple-choice vocabulary test and the second of which involves the comprehension of aphorisms. The distribution used for subject selection had a mean of 15.2, with a standard deviation of 4.82. The V-1 test is a multiple-choice vocabulary test. The distribution used for subject selection had a mean of 21.6, with a standard deviation of 7.4.

Subjects' production of route directions were recorded on videotape for subsequent scoring of content and accompanying gestures. Subjects' comprehension of route directions was studied by first providing them directions to a specific office in the building in which they were being tested and subsequently recording their actions as they attempted to follow these directions. The same directions were presented by recording to each subject: These directions conformed with all of the rules mentioned in the context of the CORK taxonomy. Subjects' spatial behavior was recorded on floorplans of the building for later scoring.

PROCEDURE

The experiment consisted of a procedure for the selection of subjects and a procedure for testing the production and comprehension of route directions. The selection of subjects involved the administration of the Campus Knowledge Inventory and the battery of four psychometric tests to large numbers of subjects. All psychometric tests were administered and scored according to accompanying instructions. The initial 10 subjects that met all the criteria for inclusion in each group were selected for the route direction procedure.

Subjects were tested individually in the second procedure. Initially, they were asked to produce a set of verbal directions describing the route from the testing room where they were situated to a particular building on campus. They were asked to describe the most accurate and most efficient route possible. The direction-giving behavior was videotaped for later scoring.

After completion of the production task, subjects were told that they were to be provided with directions to a specific office in the building in which testing was taking place. They were instructed to listen as carefully as possible because they would be asked to follow these directions as closely as possible. After listening to the directions, each subject made his or her way to the target destination. The experimenter followed the subject, charting the course of movement. The proportion of the distance involved in the described route to the distance actually traveled by the subject served as a measure of route comprehension.

RESULTS

A multivariate analysis of variance (MANOVA) was performed to determine the presence of differences among the four experimental groups with regard to the one measure of comprehension and the seven measures of production. This analysis indicated a significant effect of ability combination according to either Wilks's Criterion (.34), approximate F (21, 86.7) = 1.86, or the Hotelling-Lawley Trace (1.34), approximate F (21, 86) = 1.84. The .05 criterion of statistical significance was applied to these and subsequent analyses in this experiment.

COMPREHENSIVE MEASURE

The ANOVA performed on the route efficiency measure derived from the distance subjects traveled in following route directions revealed no significant effect of ability combination, F (3, 36) = 1.17, MSe = .05. Subjects in all groups demonstrated considerable accuracy in this task; the mean proportion scores were as follows: .90 for the high spatial-high verbal group, .88 for the high spatial-low verbal group, .79 for the low spatial-low verbal group, and .75 for the low spatial-high verbal group. Higher scores indicated greater accuracy in following directions.

PRODUCTION MEASURES

Separate ANOVAs performed on each of the seven production measures revealed significant between-group differences on two of the seven dependent variables. Group differences were revealed in the consistency with which subjects conformed to the proposed rules regarding effective communication. The ANOVA performed on the efficiency of the described route (expressed as a proportion obtained by using the shortest possible distance as the numerator and the distance that would be traveled according to the subject's instructions as a denominator) indicated a significant group effect, F (3, 36) = 4.30, MSe = .007, as did the ANOVA performed on the proper placement of descriptives (i.e., the proportion of descriptives involving choice point and the final destination), F (3, 36) = 4.86, MSe = .06. The means from these analyses are shown in Table 1.

Scheffé comparisons performed on means from the analysis of the efficiency measure indicated that the routes described by high spatial-high verbal subjects and by high spatial-low verbal subjects were significantly more efficient than were those described by low spatial-low verbal subjects. The mean efficiency score of low spatial-high verbal subjects did not differ significantly from those two groups scoring higher and the single group scoring lower.

TABLE 1
Mean Values for Seven Dependent Measures from the Route Production Task as a Function of Spatial Ability-Verbal Ability Combinations

	Ability Combinations			
Dependent Measures	High Spatial-High Verbal	High Spatial-Low Verbal	Low Spatial-High Verbal	Low Spatial-Low Verbal
Efficiency of Directions*	.92[a]	.90[a]	.84[ab]	.79[b]
Placement of Descriptives*	.67[a]	.37[b]	.44[ab]	.28[b]
Placement of Delimiters	.47	.48	.52	.39
Temporospatial Errors	1.1	1.3	1.6	2.2
Communicative Statements	13.1	13.8	11.5	11.2
Delimiters	13.7	14.4	12.3	10.4
Gestures	13.1	16.3	14.0	15.5

a., b. Mean values with the same superscript did not differ significantly at $p < .05$.
*Significant differences among groups at $p < .05$.

Scheffé comparisons performed on means from the analysis of the placement of descriptions revealed no differences between high spatial-high verbal and low spatial-high verbal groups, with both groups conforming to the rule regarding placement more frequently than did the low spatial-low verbal group. The high spatial-low verbal group did not differ from the other three.

The ANOVA performed on the measure of proper placement of delimiters (i.e., the proportion of delimiters appearing in the final one-third of the protocols) indicated that group differences were not significant, F (3, 36) = 2.36, *MSe* = .01, p = .08. Inspection of the means reveals that low spatial-low verbal subjects tended to conform to the rule regarding delimiter placement less frequently than did subjects in the other three groups. The ANOVA performed on the number of temporospatial ordering errors indicated no differences among groups, F (3, 36) = 1.69, *MSe* = 1.36. As indicated in Table 1, subjects made few errors of this type.

Neither of the variables reflecting the amount of information produced showed group differences. The number of communicative statements, F (3, 36) = 1.02, *MSe* = 15.3, and the number of delimiters, F (3, 36) = 1.25, *MSe* = 24.9, did not vary reliably as a function of ability combination. In addition, the number of gestures did not vary across conditions, F (3, 36) = 0.20, *MSe* = 102.1. Within-group variability was large on this measure. Group means are shown in Table 1.

DISCUSSION

Overall, the results of this study advance significantly our understanding of the relative contributions of spatial and verbal abilities to the communication of environmental knowledge. As reflected in the predictions for this study, there was formerly little empirical basis for predicting how spatial and verbal abilities interact in direction-giving tasks. The current findings support the view that spatial and verbal abilities play important but distinct roles in the production of route directions. The evidence indicates that spatial abilities have a major impact on the efficiency of described routes. Both the high spatial-high verbal and the high spatial-low verbal subjects produced very accurate route descriptions. The performance of the low spatial-high verbal group represented an intermediate level of accuracy, significantly different from neither the more accurate high spatial groups nor the less accurate low spatial-low verbal group.

A different pattern emerged with regard to the placement of descriptives within route directions. Subjects with high verbal ability were more likely than those with low verbal ability to involve choice points and the final destination in descriptives. In this instance, the low spatial-high verbal subjects represented an intermediate level of performance in the sense that they did not differ significantly from either the other high spatial group or the two low verbal groups. The effect of ability combination only approached significance in the analysis of delimiter placement. The means suggested simply that low ability subjects tended to place a lower proportion of delimiters in the final one-third of their route direction protocol than did the other three groups.

Logically, the data on errors must be mirrored to some degree in the measure of efficiency, and in this case, that correspondence is clear. For the four groups, errors are perfectly negatively related to efficiency. However, the differences between groups were not significant on this variable, attributable perhaps to the fact that the campus was familiar to all subjects and the route was not extensive. The means suggest a "floor effect" with regard to this variable. Nevertheless, it is interesting to note that low ability subjects averaged one error more than did high ability subjects.

It is important to emphasize that the only differences found between groups involved the proposed rules for effective communication, which are the most theoretically interesting aspects of the CORK framework. Presumably, it is adherence to these conventions that determines successful communication: The structure of message components is necessarily as important as their production per se. Thus the fact that high verbal subjects did not produce a greater number of communicative statements or a greater number of delimiters should not be considered damaging failures to confirm important hypotheses. On the contrary, these findings suggest that the differences observed with regard to the effectiveness of the directions and the placement of descriptives and delimiters were not an artifact of greater verbosity on the part of high verbal subjects.

The notion that low verbal subjects would incorporate more gestures into their route description efforts was not supported. Individual differences were far greater than group differences in the case of gestures. Despite the small differences between groups, however, the low verbal groups did use an insignificantly greater number of gestures in producing directions.

In contrast to the findings concerning the production of route directions, the findings concerning route comprehension provided little insight into the role of spatial and verbal abilities in this task. There was a small trend toward more efficient route-finding on the part of the two high spatial groups, but within-group variability was great. A longer, more complex route may be necessary to reveal group differences in this type of task. Also, it is reasonable to speculate that differences in memory factors may play a more important role than differences in spatial and verbal skills in following route directions.

Although the findings of this experiment cannot be considered conclusive evidence for a particular model of the direction-giving process, they do suggest some profitable focal points for future research aimed at specifying such a model. Evidence indicating that the general ability to manipulate and maintain orientation with respect to figural stimuli is related to the efficiency of route directions points to the need for further investigation of the role of imagery in the direction-giving process. Representational theorists posit that environmental knowledge if organized as a coherent representation constructed over the course of repeated experience (Klein, 1980, 1982; Kuipers, 1978, 1980). Regardless of the format of this representation (analog versus propositional), converting environmental knowledge into a working image of what a traveler will perceive during the navigation of a prescribed route may be a critical source of individual differences in direction-giving skill.

After information about the environment has been accessed, producing route directions becomes a matter of applying linguistic conventions (Scotton, 1987). Evidence from analyses of the placement of descriptives and delimiters in route protocols suggests that verbal abilities are particularly important in this regard. Without denying the importance of high spatial ability, it again seems reasonable to posit that verbal ability facilitates the effective translation of spatial knowledge into verbal product. Of course, the importance of conforming to these conventions hinges on future studies demonstrating unequivocally the validity of the rules associated with the CORK framework.

Comprehending route directions presumably involves the same operations as production but in reverse order. Verbal abilities facilitate the comprehension of the incoming message, and spatial abilities are useful in coordinating the information obtained through the message to perceptual experience in the environment. Specifying the mechanisms whereby these abilities are pressed into service represents a challenging agenda.

It is noteworthy that the elements of route directions observed in Ward et al.'s (1986) study correspond nicely with components of the CORK taxonomy. However, the distinction raised by Ward et al. between competence and stylistic preference raises the question of whether the rules for effective communication that accompany the CORK taxonomy reflect communicative competence or a preferred mode of giving directions. At this point, we contend that the rules are concerned with competence and that stylistic preferences are expressed in terms of which CORK components are included in the directions (e.g., use of environmental features rather than distance designations as delimiters). The contention must be examined in future studies.

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