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Principles and Practices for Communicating Route Knowledge

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SUMMARY

A series of experiments was conducted to examine the effect of several principle-based practices hypothesized as being important in communicating route knowledge. Results indicated that remembering and following route directions were facilitated by the practice of (a) presenting the directions in correct temporal–spatial order, consistent with the principle of natural order, (b) concentrating information in statements concerned with choice points, consistent with the principle of referential determinacy, and, to some extent, (c) using spatial designations with which most listeners are facile, consistent with the principle of mutual knowledge. In all studies, women had more difficulty than men in following the route from verbal directions. Possible avenues for explaining this sex-related difference are suggested. Copyright © 2000 John Wiley & Sons, Ltd.

The production and comprehension of wayfinding directions has considerable potential value as a focus for scientific inquiry. Most of the early work on this problem was done by psycholinguists focusing on semantic and pragmatic aspects of the task (see Klein, 1982, 1983; Johnson-Laird, 1983; Wunderlich and Reinelt, 1982; Scotton, 1987; Talmy, 1975). More recently research has been focused on the communication of spatial knowledge as a vehicle for examining important issues in the representation of spatial knowledge and the relationship between verbal and spatial processes (Couclelis, 1996; Denis, 1996, 1997; Freundschuh *et al.*, 1990; Taylor and Tversky, 1992a; Vanetti and Allen, 1988).

The potential theoretical richness of this problem stems from the series of transformations required in the context of communication. In the case of route directions, spatial knowledge of a large-scale environmental area, which itself is the product of perceptual and perceptual-motor experience, is transformed into a set of verbal productions. In comprehending and following route directions, the listener constructs an action plan from the set of verbal productions and refers to this plan during travel. Thus, comprehending and following route directions are outcomes of a collaborative, goal-directed communication process (Clark, 1992, 1996; Golding *et al.*, 1996). Interestingly, empirical research (Daniel and Denis, 1998) as well as day-to-day experience provide ample evidence that route communication episodes do not always result in wayfinding success and route directions vary in terms of their quality and

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effectiveness. The obvious question arises as to what differentiates good route directions from poor ones.

This question cannot be addressed meaningfully without prior consideration of the structure and components of route directions. A route communication episode may be divided into four phases: initiation, route description, securing, and closure (Wunderlich and Reinelt, 1982). In terms of conveying spatial information, the route description phase is at the core of the communication episode. Route descriptions involve specific components, most importantly, environmental features, delimiters, verbs of movement, and state-of-being verbs. Principles and practices influencing the relative effectiveness of route directions are concerned with the organization and distribution of these components. Thus each component requires a brief description.

Environmental features are nominals that refer to objects, both artificial and natural, or attributes of objects that can be experienced observed along the path of movement. Landmarks, pathways, and choice points are the most common environmental features used in route descriptions. Although a satisfactory definition is somewhat elusive (see Presson and Montello, 1988), a landmark may be described as an environmental feature that can function as a point of reference (Lynch, 1960). In essence, landmarks serve as sub-goals that keep the traveller connected to both the point of origin and the destination along a specified path of movement. Pathways are nominals that refer to actual or potential channels of movement such as streets, sidewalks, or trails (Lynch, 1960). Choice points are nominals that obviously refer to places affording options with regard to pathways, with intersections being the most typical example. The concept of choice points is similar to that of Lynch's (1960) nodes, but the latter term connotes major strategic points within a city's organization. Not all choice points are of such importance, but they all provide an opportunity for mistakes to be made.

Delimiters are verbal devices that constrain or define communicative statements or provide discriminative information about environmental features (Allen, 1997; Wunderlich and Reinelt, 1982). Distance designations specify spaces separating points of reference in terms of standard units (for example, miles), conventional non-standard units (for example, city blocks), temporal units (for example, minutes), or even vague judgements (for example, 'not far from here'). Direction designations specify spatial relations in terms of an abstract frame of reference (for example, cardinal directions), an environment-based or object-based frame of reference (for example, 'toward the church'), or a body-based frame of reference (for example, left or right). Direction designations include relational terms, which are prepositions used to specify a spatial relationship between the traveller and environmental features or between different environmental features. They include terms such as 'toward', 'away from', 'between', 'in front of', 'beside', 'behind', and 'across from'.

Verbs of movement and state-of-being verbs yield different types of communicative statements. Verbs of movement, which can be distilled semantically into either 'go' and 'turn', connote directives, which prescribe where the traveller is supposed to go (for example, 'Go toward the church'). State-of-being verbs, which are reducible to 'is', connote descriptives, which provide the traveller with information about relations among environmental features along the route (for example, 'A sign is in front of the library'). Another common form of descriptive refers to perceptual experience (for example, 'You will see a stop sign'). Directives and descriptives can be used to provide the traveller with different perspectives along the route (see Tversky, 1996).

Given this basic information about the components of route descriptions, it is appropriate to return to the question of what characteristics or qualities of route directions facilitate successful wayfinding efforts. Two empirical approaches have been used to address this question. Denis and his colleagues have employed a strategy of reduction to essentials (Daniel and Denis, 1998; Denis, 1997; Denis *et al*., in press), in which a description consisting only of essential statements is obtained by having judges familiar with a geographic area eliminate all superfluous statements from a composite route description consisting of all statements made by the participants in a study. The validity of the resulting ‘skeletal descriptions’ has been established by studies in which raters assessed the communicative value of these descriptions as route directions (Daniel and Denis, 1998) and by field studies examining their effectiveness in real-world wayfinding situations (Denis *et al*., in press). Thus, this interesting and imaginative approach has captured the essence of good directions. The next step in this strategy may involve a formal description of the structure and components of these skeletal descriptions, which consist of a combination of directives and descriptives as described previously.

An alternative approach, one that incorporates a strategy of identifying ‘best practices’, is described in the experiments that follow. The literature from psycholinguistics and discourse processing (e.g. Clark, 1992, 1996; Landau and Gleitman, 1985; Levelt, 1989; Levinson, 1983; Talmy, 1995) provides the basis for deriving a number of principles highly relevant to route communication episodes. Practices based on these principles provide testable hypotheses regarding the characteristics or qualities of good wayfinding instructions.

Three principle-based practices were examined in the experiments that follow. The first practice involved the temporospatial ordering of communicative statements. According to the principle of natural order (Levelt, 1989), the order in which information is expressed should be consistent with the natural sequence of its content. Ample empirical evidence indicates that sequential descriptions that match the order in which objects or actions are encountered generally facilitate comprehension of or memory for those objects or actions in children and adults (Clark, 1970, 1973; Fraisse, 1964). Thus, it is reasonable to hypothesize that route directions that mention movement and environmental features in the order in which they are to be performed or experienced will lead to more successful wayfinding efforts than will route directions that violate natural temporospatial order.

Another practice suggested by principle is concerned with reducing uncertainty at choice points along the route. The challenge of giving useful instructions is to establish and maintain ‘common ground’ between interlocutors (Clark, 1992, 1996; Clark and Wilkes-Gibbs, 1990), despite the obvious fact that the person seeking wayfinding information lacks the knowledge that he or she needs to reach a destination. ‘Common ground’ while understanding and following route directions is in jeopardy when multiple courses of action are possible, as at intersections, for example. Maintaining ‘common ground’ by reducing uncertainty suggests a principle of referential determinacy. Including a number of direct definite references (Clark, 1992) in describing choice points is one way to achieve referential determinacy by making it clear exactly what environmental features will be encountered by the traveller at choice points and how he or she should respond. This principle suggests two practices for conveying effective wayfinding information, one involving the concentration of delimiters in communicative statements involving choice points, and the other involving the use of descriptives in conjunction with choice points. These facilitate orientation and correct path selection at choice points and increase the likelihood of arrival at the specified destination.

A third practice that was investigated concerned the selection of delimiters. Following Clark's (1992) emphasis on the role of shared knowledge in facilitating 'common ground' during communication, the principle behind this practice is referred to as the principle of mutual knowledge. The delimiters included in route descriptions should be appropriate for the environment and for the traveller. For example, city blocks are more useful than meters as a unit of distance if an urban area is laid out in a square grid, and references to cardinal directions may not be useful if a traveller is either not accustomed to or not facile with such a frame of reference.

The experimental studies that follow tested the principle-based practices as hypotheses. The central question in each study concerned the extent to which the practices facilitated participants' remembering and following route instructions. The general method employed was the same in each study. Specifically, participants were read directions specifying a route approximately one km in length for the purpose of following the route. An elaborated rationale for the practice being examined accompanies the description of each experiment.

EXPERIMENT 1

The first principle-based practice for effective communication of route information is that communicative statements should be presented in veridical temporospatial order, in other words, the events included in the description should reflect the events as they occur in the environment. This practice reflects in large part on the linearization inherent in spoken language (Levelt, 1981). During speech acts, the speaker's ordering of information is constrained by culturally based knowledge of expected order and by inherent limitations of working memory (Levelt, 1981). It may be assumed that these same constraints affect the listener to some extent. It is interesting to note that violation of typical sentence order has been shown to have little impact on some aspects of prose memory and comprehension (Kintsch *et al.*, 1977), and a scrambled presentation of scenes from a walk has been shown to result in relatively accurate knowledge of distances along the pictured route (Allen, 1988). Yet, prose that violates normal order appears to make comprehension more effortful and mistake-prone, whether the task is discourse comprehension (Kieras, 1978; Ohtsuka and Brewer, 1992; but see also Einstein *et al.*, 1984), or image construction (Denis and Cocude, 1992; Ehrlich and Johnson-Laird, 1982).

The effects of violating temporospatial order should be considered in light of Dixon's (1987) view that following directions involves parallel tasks, one being the comprehension of the instructions and the other the development of a hierarchically organized action plan. Comprehending instructions involves memory for propositional and relational information (Dixon, 1987; Einstein *et al.*, 1984). Instructions that violate temporo-spatial order affect the latter more than the former, and it is this impact on relational information that would be expected to decrease the precision of the resulting action plan.

In this experiment, the wayfinding performance of participants who received route directions consisting of communicative statements in veridical temporo-spatial order was compared to that of participants who received route directions in which the order of communicative statements was altered so that it was structurally inconsistent with temporo-spatial order. Specifically, altered directions featured the non-veridical presentation of portions of the route, with proper order maintained among communicative statements within each portion. This manipulation is analogous to dividing a story into a number of passages – while preserving sentence order within each passage – and then randomizing the order in which the passages are presented. It was predicted that this manipulation would result in poorer wayfinding performance because it violated expectations about linearity and placed demands on working memory that were far beyond those normally encountered.

Method

Participants

Data were collected from 30 male and 30 female undergraduate students, who earned research participation credit in psychology courses as a result of their voluntary involvement in the study. All participants were either freshmen or first-year transfer students at the time of the experiment, and none of them resided in a dormitory, house, or apartment that bordered the route used in the study. Furthermore, individuals were included in the study only if they responded that they knew 'very little' or 'nothing' about the neighborhood in which the route was located when they were asked to rate their knowledge on a 5-point scale.

Materials

A route description was developed to specify a walk that began on the participating students' campus, continued through a residential area, and ended in a commercial district (see Figure 1). The route, which was approximately 1 km in length, included twelve changes in heading. The route description was composed of 63 communicative statements organized into 21 units, which included from two to five communicative statements (see Appendix). Each unit described the proximal situation that could be observed at a particular standpoint along the route (for example, the corners at an intersections). These units were read to the participants as a realistic exercise in direction giving rather than as a memory task involving individual statements.

Two scripts were developed for the study. The logically sequenced route description included the 21 units in their proper temporo-spatial order. The scrambled route description included the same 21 units, but these units were combined into five roughly equidistant parts, which were randomized with two constraints. The first constraint was that the first part of the logically sequenced description was not allowed to be the first part of the scrambled description; the second was that the final part of the logically sequenced description was not allowed to be the final part of the scrambled description. These constraints yielded the following order: units 1–3 in the scrambled presentation were units 15–17 in the properly ordered presentation; units 4–8 in the scrambled presentation were units 6–10 in the properly ordered presentation; units 9–13 in the scrambled presentation were units 1–5 in the properly ordered presentation; units 14–17 in the scrambled presentation were units 18–21 in the properly ordered presentation; and units 18–21 in the scrambled presentation were units 11–14 in the properly ordered presentation. The two scripts are presented in the Appendix.

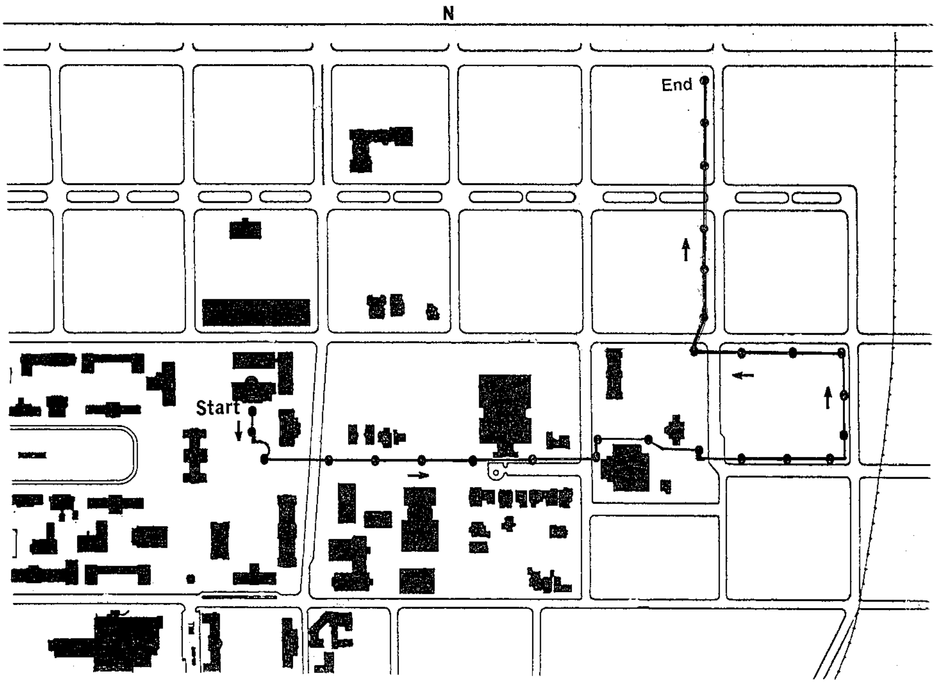

Figure 1. Map showing the route used in Experiments 1, 2, 4, and 5

The route that each participant followed after hearing the script was charted on a sketch map of the route, which the experimenter carried on a clipboard. The course and associated notations were marked on the sketch map in pencil.

Procedure

The procedure consisted of three phases. In the introductory phase, participants were met by the experimenter in the lobby of a building that was near the beginning of the route. The general nature of the study was explained and informed consent to participate was obtained. Participants were then asked to verify how long they had been enrolled in the university, to indicate where they lived in relation to the campus, and to rate their familiarity with areas in the immediate environment. If the participant met the criteria for inclusion, they were included in the remaining phases of the procedure.

In the route description phase of the study, participants were informed that they would be listening to a description of a route that began on campus and continued for about a quarter of a mile. They were told that they should listen to the description carefully and remember as much of it as possible because they would subsequently be asked to walk the route exactly as it was described. Additionally, participants were informed that the route description might be in normal order just as any sensible directions should be, or they might be in scrambled order so that they would have to unscramble or re-order the directions in memory in order to reach the specified destination. To facilitate their understanding of what was involved in scrambled directions, an example of logically sequenced and scrambled directions for making a cup of instant coffee were provided.

In the route-execution phase of the study, participants were asked to walk the route they had heard specified in the route description. They were instructed to follow the exact route without changing it in any way. If they had doubts about which way to go at any point in the walk, they were to guess the correct pathway on the basis of what they remembered from the description. If they remembered nothing of relevance regarding the continuation of the path, they were to inform the experimenter. During route execution, the experimenter walked to the right of and one step behind the participant, recording the path of movement on a map of the area. When the participant deviated from the route or did not know where to go next, the experimenter marked the location along the route on the map. In instances in which the participant indicated he or she did not know where to go next, the experimenter asked the participant to indicate which way he or she would go if forced to continue. This response was recorded. Participants who walked off-course were allowed to progress only ten steps before being escorted back to the point at which they had left the designated route.

After the participant had either indicated which way they would go if forced to continue or been escorted back to the route, the experimenter faced him or her and read the next two units from the directions that were relevant to the corresponding location along the route. The experimenter then moved to the above-mentioned position slightly behind the participant and continued to record the path of movement. Data collection ended when the destination specified in the last information unit had been reached. Participants were debriefed as they were escorted back to the beginning of the route, where they were thanked for their participation and dismissed.

Results and discussion

The first step in analysing the data was to determine the legitimacy of combining deviations from the route with incidents in which participants indicated that they did not know where to go next into a single dependent measure called information failures. Only four of the 60 participants in the study actually deviated from the route, three of whom did so more than once. However, all participants at some point in the route-execution phase of the procedure indicated that they had insufficient information to continue. A 2 (direction condition: veridical versus scrambled order) $\times$ 2 (sex of participant) between-subjects analysis of variance (ANOVA) performed on the proportion of correct choices under these circumstances yielded no significant main effects or interactions, all F's < 1.40. The $p < 0.05$ criterion for statistical reliability was applied to all analyses throughout these experiments. The overall mean proportion correct was 0.43.

In an effort to determine whether participants' accuracy in selecting where to go next differed reliably from chance-level selection, a determination was made with regard to how many pathways were available to each participant at each place where it was indicated that he or she had insufficient information to continue. The proportion of correct selections ranged between 0.31 and 0.54 for the 60 participants, and the proportion that represented chance-level performance ranged between 0.36 and 0.41. Tests of differences between two proportions revealed no instances in which the proportion of correct selections exceeded chance level, all z's < 1.20. These findings indicated that participants' responses that they did not know where to go next were valid reflections of insufficient information and, therefore, could legitimately be combined with deviations from the route into a single measure representing information failures.

A 2 (direction condition: normal versus scrambled order) × 2 (sex of participant) × 3 (portion of route: first one-third, middle one-third, or final one-third of the route) mixed ANOVA performed on the number of information failures yielded reliable main effects for condition, $F(1,28) = 17.45$, $MSe = 0.77$, sex, $F(1,28) = 15.50$, $MSe = 0.77$, and route portion, $F(2,56) = 39.90$, $MSe = 0.19$, as well as a reliable condition by route portion interaction, $F(2,56) = 20.52$, $MSe = 0.19$. The main effect of portion of the route is considered in the context of the interaction between condition and route portions.

Tukey tests indicated basically two patterns of performance in terms of the distribution of information failures across different portions of the route. Both patterns feature a low rate of information failure in the initial portion of the route. However, in the pattern indicated by superscript a in Table 1, the middle and final portions each result in a higher number of information failures than in the initial portion, with no difference between these two (that is, initial < middle = final). In the pattern indicated by superscript b in Table 1, the number of information failures in the middle portion is higher than is the case in the initial portion, but the final portion resulted in a decrease compared to the middle portion, such that it does not differ from the initial portion (that is, initial = final < middle). The first pattern characterized performance for normally order directions, and the second pattern characterized performance for scrambled directions.

Table 1. Mean number of information failures in each portion of the route as a result of normal versus scrambled route directions in Experiment 1

	Type of route directions	
Portion of route	Normal[a]	Scrambled[b]
Initial	0.4	1.5
Middle	1.7	2.5
Final	1.3	1.7

[a]Initial < middle = final, $p < 0.05$.
[b]Initial = final < midle, $p < 0.05$.

The purpose of Experiment 1 was to test the prediction that, although individuals can make sense of scrambled prose, route directions that are sequenced in veridical order should result in more accurate route execution than should route directions that are presented in incorrect temporo-spatial order. The prediction was verified, and the pattern of results also provided useful insight into the processes involved in following route directions from memory. This pattern suggests that participants in both conditions attempted to construct an action plan based on a linear-order representation of the route. Put another way, participants were aided by their knowledge that the information units described a path of travel linking a series of environmental features between a definite point of origin and a definite destination.

Although the more frequent information failures in the first and second portions of the route for participants receiving scrambled presentations signified a heavier burden on working memory (see Allen, 1988), the generally good performance under these circumstances – the highest mean number of information failures was 2.5 out of 7 possible for the middle portion – indicates that a sensible route representation was acquired. This outcome is not too surprising in view of the fact that the scrambled description involved violating the order of five parts of the description, with the veridical order of statements within each part preserved. Inspection of where errors occurred within the three portions of the route indicated that the increased frequency of information failures with the scrambled presentation was due to problems at choice points where there was discontinuity in the scrambled description. In other words, transitions between segments were difficult but continuity within segment posed little difficulty.

Accounting for the condition by route portion interaction observed in this task evokes references to the historical controversy between associative chaining (Hull, 1935; Lepley, 1934) and spatial/ordinal position (Koffka, 1935; Ebenholtz, 1963) explanations of serial position effects in list learning. The associationist position attributed recall failures primarily to the accumulation of proactive interference. Accordingly, it would predict that, because executing the route from directions necessitates serial recall of the units, information failures should be significantly more frequent in the middle and final portions of the route than in the initial portion. The pattern of performance exhibited by participants with logically sequenced directions is adequately described in terms of such a primacy effect.

However, the primacy effect observed with scrambled directions cannot be attributed to an absence of interference because the information units describing the initial portion of the route were not presented first under these circumstances. The significantly better performance in the final portion of the route than in the middle portion is also inconsistent with the pattern of results typically found with serial recall. The recency and primacy effects observed with scrambled directions were apparently due to the unique spatial/ordinal positions of the point of origin and destination. Similar 'end-anchor' effects have been described in work involving judgements along linear-order representations (see Maki, 1981; Potts, 1974). Borrowing from Harcum's (1975) analysis of serial learning, it appears that multiple processes are responsible for the order effects observed in participants' efforts to follow directions from memory.

EXPERIMENT 2

The next three experiments tested the hypothesis that choice points, as the basic organizational components of listeners' representation of the route, should be better specified than non-choice points in wayfinding instructions. Although there is some variation in connotation, the term 'anchor' has been used recently to refer to such components (see Couclelis *et al.*, 1987; Ferguson and Hegarty, 1994). The cost of errors in wayfinding can be quite high; consequently, the importance of identifying choice points and differentiating the potential locomotor options at these junctures is paramount. In light of this importance, a traveller following directions in an unfamiliar environment may inspect more physical features at choice points than at other points along the route and may, in fact, slow down or stop movement altogether to facilitate such inspection.

The practice of including descriptives rather than directives at choice points is analogous to the act of stopping at a choice point. Rather than advancing the traveller along the path of movement the way directives do, descriptives in route direction protocols provide a static portrayal of spatial relations from a particular viewpoint. Experiment 2 tested the hypothesis that descriptives should be concerned with choice points rather than with non-choice points. To test this hypothesis, the placement of descriptives was manipulated in two scripts so that in one script they were concerned with choice points, while in the other script they were concerned with non-choice points. It was expected that information failures would be more frequent for participants who listened to the script that contained descriptives at non-choice points along the route. The effects reflecting sex difference and differences among route portions were also anticipated for this study.

Method

Participants

Data were collected from 30 male and 30 female undergraduate students, who earned research participation credit in psychology courses as a result of their voluntary involvement in the study. The criteria for inclusion in the study were the same as those mentioned in Experiment 1.

Materials

The walk described in the route directions was the same one that was used in Experiment 1. Two scripts were used in this study. The script with descriptives at choice points was the same as the logically sequenced route description used in Experiment 1. In the second script, descriptives were included at non-choice points only. The two scripts are presented in the Appendix. As in the previous experiments, the route that each participant followed after hearing the script was charted in pencil on a sketch map of the route.

Procedure

The procedure consisted of the introductory phase, the route-description phase, and the route-execution phase as described for Experiment 1. The only difference between the procedures was that no reference was made to a scrambled presentation in the introductory phase of Experiment 2.

Results and discussion

Only four of the 60 participants in the study actually deviated from the route, two of whom did so more than once. However, all participants at some point in the route-execution phase of the procedure indicated that they had insufficient information to continue. A 2 (direction condition) $\times$ 2 (sex of participant) between-subjects ANOVA performed on the proportion of correct choices under these circumstances yielded no significant main effects or interactions, all F's < 1.50. The overall mean proportion correct was 0.48. The proportion of correct selections when participants indicated they did not know where to go next ranged between 0.38 and 0.56 for the

60 participants, and the proportion that represented chance-level performance ranged between 0.36 and 0.41. Tests of differences between the two proportions revealed no instances in which the proportion of correct selections exceeded chance level, all z's < 1.25. These findings indicated that participants' responses that they did not know where to go next were valid reflections of insufficient information and could be combined with deviations from the route into a single measure of information failures.

The number of information failures was subjected to a 2 (direction condition: descriptives at choice points versus descriptives at non-choice points) $\times$ 2 (sex of participant) $\times$ 3 (portion of route) ANOVA, which yielded significant main effects of direction condition, $F(1,28) = 21.99$, $MSe = 0.49$, sex of participant, $F(1,28) = 31.00$, $MSe = 0.49$, and portion of route, $F(2,56) = 20.27$, $MSe = 0.20$, as well as a significant two-way interaction involving sex of participant and portion of route, $F(2,56) = 3.97$, $MSe = 0.20$, and a significant three-way interaction involving direction condition, sex of participant, and portion of route, $F(2,56) = 6.48$, $MSe = 0.20$.

Overall, the number of information failures was greater when descriptives were concerned with non-choice points than choice points along the route (1.5 versus 0.8 per route portion). Men exhibited fewer information failures than did women (0.8 versus 1.5). The main effect of route portion and the two-way interaction involving sex of participant and route portion are most economically considered in the context of the three-way interaction.

Tukey tests performed on the means from the three-way interaction shown in Table 2 revealed basically three patterns of information failures across the route portions. In both route direction conditions, men showed the pattern in which information failures were less frequent in the initial portion of the route than in either the middle or final portions, with no difference between the latter two. When descriptives were concentrated at non-choice points, women showed the pattern in which information failures were less frequent in the initial and final portions of the route than in the middle portion, with no difference between the earlier two. When descriptives were concentrated at choice points, information failures for women did not vary as a function of route portion.

The focus of this study was on the location of descriptives in route direction protocols, investigating the validity of the principle-based practice of including them at choice points rather than non-choice points. The findings support the validity of

Table 2. Mean number of information failures in each portion of the route, as a result of having descriptives concerned with choice points versus non-choice points in Experiment 2

	Placement of descriptives			
	Choice points		Non-choice points	
Portion of route	Men[a]	Women	Men[a]	Women[b]
Initial	0.1	0.9	0.5	1.4
Middle	0.8	1.3	1.1	2.8
Final	0.7	1.2	1.4	1.8

[a]Initial < middle = final, $p < 0.05$.
[b]Initial = final < middle, $p < 0.05$.

this practice, while further indicating that the advantage of having descriptives concerned exclusively with choice points may be apparent only in latter parts of the route where memory demands are greatest.

It is tempting to point to the three-way interaction in speculating that women are more reliant on descriptives than are men in the middle portion of the route where interference is potentially great and differentiation is presumably poor. However, it must be pointed out that this interaction was in large measure caused by the unusually good performance by men in the middle portion of the route under the condition in which descriptives were concerned with non-choice points. There is no ready explanation for this high level of performance under such circumstances, and consequently, a speculative account of sex differences based in part on this sub-group seems unwise.

EXPERIMENT 3

The previous two experiments provided general support for the proposed practices for effective route communication. However, the same route was involved in both studies. To increase confidence in the generalizability of these findings, Experiment 2 was selected for replication involving a different route. Experiment 3, then, tested the hypothesis that information failures would be fewer if descriptives were concerned with choice points rather than with non-choice points, using a route that was different from that used in originally validating this hypothesis.

Method

Participants

Data were collected from 20 male and 20 female undergraduate students, who earned research participation credit in psychology courses as a result of their voluntary involvement in the study. The criteria for inclusion were the same as those mentioned in the previous experiment, with the additional condition that none of the participants had worked in the area through which the route passed.

Materials

The walk described in the route directions began on a college campus, continued for approximately seven blocks through an urban commercial area, and ended after a one-block segment through the grounds adjacent to a large church. It was 1.4 km in length and included 13 changes in heading. The route description was composed of 72 communicative statements organized into 24 units, which included from two to five communicative statements. Each unit described the proximal situation that could be observed at a particular standpoint along the route. Two scripts were used in the study. The script with descriptives at choice points resembled the logically sequence route described in Experiment 1. The other script included descriptives in the middle of blocks rather than at choice points, as with script C in the Appendix.

Procedure

The procedure consisted of the introductory phase, the route-description phase, and the route-execution phase as performed in Experiment 2.

Results and discussion

As in the previous studies, a preliminary examination indicated that it was legitimate to combine instances in which participants deviated from the route with instances in which participants indicated that they did not know where to go next. Four participants (three men and one woman) travelled off the route at some point during the route-execution phase.

The number of information failures was subjected to a 2(direction condition: descriptives at choice points versus descriptives at non-choice points) $\times$ 2(sex of participant) $\times$ 3(portion of route) ANOVA, which yielded significant effects of direction condition, $F(1,18) = 5.50$, $MSe = 0.52$, sex of participant, $F(1,18) = 6.20$, $MSe = 0.52$, and portion of route, $F(2,36) = 4.84$, $MSe = 0.36$, as well as a significant direction condition by portion of route interaction, $F(2,36) = 3.67$, $MSe = 0.36$. No other interactions were significant.

The number of information failures was greater when descriptives were concerned with non-choice points than with choice points (1.0 versus 2.1 per route portion). Men exhibited fewer information failures than did women (0.9 versus 2.2). The main effect of portion of route is considered in the context of the two-way interaction. Tukey tests performed on the means shown in Table 3 indicated that this interaction occurred because the number of information failures differed as a result of descriptive placement for the middle and final portions of the route, but not for the initial portion of the route. Nevertheless, for both direction conditions the pattern of information failures over route portions was the same; there were more in the middle and final portions of the route than in the initial portion, with no difference between the middle and final portions.

Table 3. Mean number of information failures in each portion of the route as a result of having descriptives concerned with choice points versus non-choice points in Experiment 3

	Placement of descriptives	
Portion of route	Choice points[a]	Non-choice points[a]
Initial	0.4	0.8
Middle	1.4	2.1
Final	1.9	2.6

[a]Initial < middle = final, $p < 0.05$.

The results of this experiment replicated the essential main effects from Experiment 2. The specific interaction observed in this study was not found in Experiment 2, in which the three-way interaction involving direction condition, sex, and portion of route was significant, but the two-way interaction observed in this case was sensible and readily interpretable. The results are consistent with the idea that placement of descriptives becomes more important in latter portions of the route, when memory is taxed. Overall, the study suggests that the findings generated with the route used in Experiments 1 and 2 may be reasonably generalized to other routes.

EXPERIMENT 4

The purpose of this study was to evaluate the principle-based practice of concentrating delimiters in statements involving choice points along the route rather than in statements involving non-choice points. It should be pointed out that the descriptive statements manipulated in Experiments 2 and 3 contained delimiters. Thus, this experiment examined the influence of including those delimiters in clauses and phrases attached to statements specifying movement (that is, directives) rather than in statements describing static spatial relations (that is, descriptives). It is possible that more information might be retained from descriptive statements because they correspond to a temporary cessation of movement; such a pause might provide a better means of parsing or organizing the information from the route directions.

It was expected that information failures would be more frequent if directions violated the practice of placing delimiters at choice points. Also, on the basis of the results from previous experiments, it was anticipated that men would have fewer information failures than would women and that such failures would be more frequent in the middle and final portions of the route than in the initial portion.

Method

Participants
Data were collected from 30 male and 30 female undergraduate students, who earned research participation credit in psychology courses as a result of their voluntary involvement in the study. The criteria for inclusion in the study were the same as those mentioned in previous experiments.

Materials
The walk described in the route directions was the same as that used in Experiment 1. Two scripts were used in this study. The script with references to delimiters concentrated at choice points was the same as the logically squenced route description used in Experiment 1. The second script differed from the first only in terms of where references to delimiters were concentrated. In the second script, such references were more common at non-choice points than at choice points. The two scripts are presented in the Appendix. As in Experiments 1 and 2, the route that each participant followed after hearing the script was charted in pencil on a sketch map of the route.

Procedure
The procedure consisted of the introductory phase, the route-description phase, and the route-execution phase as described for Experiments 2 and 3.

Results and discussion

Only two of the 60 participants in this study actually deviated from the route, both of whom did so more than once. However, all participants at some point in the route-execution phase of the procedure indicated that they had insufficient information to continue. A 2 (direction condition) $\times$ 2 (sex of participant) between-subjects ANOVA performed on the proportion of correct choices under these circumstances yielded no significant main effects or interactions, all F's < 1.16. The overall mean proportion correct was 0.46. The proportion of correct selections when participants indicated they did not know where to go next ranged between 0.33 and 0.56 for the 60 participants, and the proportion that represented chance-level performance ranged between 0.36 and 0.41. Tests of differences between two proportions revealed no instances in which the proportion of correct selections exceeded chance level, all z's < 1.28. These findings indicated that participants' responses that they did not know where to go next were valid reflections of insufficient information and could be combined with deviations from the route into a single measure of information failures.

The number of information failures was subjected to a 2(direction condition: delimiter concentration at choice points versus delimiter concentration at non-choice points) $\times$ 2(sex of participants) $\times$ 3(portion of route) ANOVA, which yielded main effects for direction condition, $F(1,28) = 13.70$, $MSe = 0.73$, sex, $F(1,28) = 10.39$, $MSe = 0.73$, and portion of route, $F(2,56) = 21.74$, $MSe = 0.17$. None of the interactions was significant, all F's < 2.15.

The mean number of direction failures when delimiters were concentrated in statements including choice points was fewer than that when they were concentrated in statements referring to non-choice points (0.8 versus 1.5 per route portion). On average, men had fewer information failures than did women (0.9 versus 1.4 per route portion). Tukey tests performed on the means involved in the significant effect of portion of route showed that there were fewer information failures at the beginning of the route (0.8) than in the middle (1.4) or the end (1.3), with the latter two not differing significantly.

These findings support the practice of placing delimiters in statements involved with choice points along the route. Such placement decreased information failures in this case and, accordingly, resulted in more accurate route execution. The results clearly suggest that the specific form of the statements including delimiters is of little consequence. The delimiters attached to directive statements in this study gave rise to about the same frequency of information failures as did the delimiters within descriptive statements in Experiments 2 and 3.

The finding that men exhibited fewer information failures than did women was replicated again in this study. The data also showed that information failures were more frequent in the second and third portions of the route than in the initial portion. The small number of failures near the beginning of the walk may be attributed to the point of origin's role as an anchor point in a linear-order representation, a lack of proactive interference in the serial recall of information, and the relative familiarity of that area of the walk. Differentiating among these possible influences would be a desirable research objective in the future.

EXPERIMENT 5

Route-communication episodes often involve individuals with limited knowledge of each other. Thus, a person giving directions may be challenged to establish the 'common ground' necessary to convey the needed spatial information, particularly when it comes to the use of mutual knowledge. Understanding various delimiters, such as direction and distance designations, provides a good example of potential deficiencies in mutual knowledge. Previous research has indicated that in producing route direction protocols based on information from maps, participants tended to include more references to relations among environmental features than to metric distance (e.g. mileage) and cardinal direction information (Ward *et al*., 1986). Also, Ward *et al*. (1986) found that women tended to include more references to environmental features than did men, while men tended to include more references to metric distances and cardinal directions than did women.

These findings raise the question of whether these tendencies are related to effectiveness in remembering and following route directions. Specifically, does the less frequent inclusion of metric distance and cardinal direction information as delimiters indicate that route directions emphasizing such information would result in less accurate performance than would route directions involving delimiters that emphasize environmental features? In addition, would women's and men's performance in the route following task be differentially affected by the type of delimiters included in the directions?

This experiment was designed to address these questions by comparing men's and women's performance under the two route direction conditions mentioned above. It was predicted that directions emphasizing relational terms and environmental features as delimiters would result in fewer information failures than would directions emphasizing metric distance and cardinal direction information as delimiters. Furthermore, it was expected that with route directions emphasizing environmental features, women would perform as accurately as men. With route directions emphasizing metric distance and cardinal direction information, however, it was expected that men would exhibit fewer information failures than would women.

Method

Participants

Data were collected from 30 male and 30 female undergraduate students, who earned research participation credit in psychology courses as a result of their voluntary involvement in the study. The criteria for inclusion in the study were the same as those mentioned in previous experiments.

Materials

The walk described in the route directions was the same as that used in Experiments 1, 2, and 4. Two scripts were used in this study. The script emphasizing environmental features was the same as the one used as the logically sequenced route description in Experiment 1, which contained no references to cardinal direction or metric distances. The script emphasizing metric distance and cardinal direction information included metric distance and cardinal direction information in both directives and descriptives. Mention of environmental features was generally constrained to street names and buildings. The two scripts are presented in the Appendix. As in previous experiments, the route that each participant followed after hearing the script was charted in pencil on a sketch map of the route.

Procedure

The procedure consisted of the introductory phase, the route-description phase, and the route-execution phase as described previously.

Results and discussion

Preliminary analyses indicated that it was reasonable to combine instances in which participants reported that they did not know where to go next with instances in which participants deviated from the prescribed route to form a single dependent measure called information failures. The number of information failures was subjected to a 2 (direction condition: emphasis on environmental features versus emphasis on direction and distance information) $\times$ 2 (sex of participant) $\times$ 3 (portion of route) ANOVA, which yielded significant main effects of direction condition, $F(1,28) = 4.20$, $MSe = 0.88$, sex of participant, $F(1,28) = 25.71$, $MSe = 0.88$, and portion of route, $F(2,56) = 39.28$, $MSe = 0.23$, as well as a significant direction condition by sex of participant interaction, $F(2,56) = 3.62$, $MSe = 0.23$. None of the other interactions was found to be significant.

Overall, directions emphasizing environmental features resulted in significantly fewer information failures than did directions emphasizing distance and direction information (1.9 versus 2.3 per route portion), and men exhibited fewer such failures than did women (1.7 versus 2.5). Tukey tests performed on the means from the various route portions verified the familiar pattern of fewer information failures in the initial portion of the route (1.4) than in either the middle (2.4) or final (2.3) portions, with no difference between the latter two.

Other Tukey tests performed on the means involved in the significant interaction revealed that women's, but not men's, accuracy was differentially impacted by direction condition. For men, directions emphasizing distance and direction information (1.8) produced the same number of information failures as did the directions emphasizing environmental features (1.6). For women, directions emphasizing distance and direction information (2.8) produced more information failures than did those emphasizing environmental features (2.2). The difference between sexes was significant in both conditions.

These results indicate that the relative frequency of different types of delimiters spontaneously produced in route direction protocols may indeed be related to participants' efficacy in using these different types of delimiters in attempting to follow route directions. In Ward *et al.*'s (1986) study, participants included more references to environmental features than to metric distance and cardinal directions in their route protocols; in the present study, route directions that emphasized environmental features led to more accurate performance than did those that emphasized distance and direction information. In Ward *et al.*'s (1986) study, women were more likely than men to refer to environmental features in their route protocols; in the present study, women were more successful when their instructions emphasized environmental features than when they emphasized direction and distance information. However, although Ward *et al.* (1986) found that men included more references to metric distance and cardinal direction information in their protocols, men did not perform more accurately with directions emphasizing direction and distance information in the present study.

GENERAL DISCUSSION

The purpose of this study was to provide a foundation of empirical support for the idea that principle-based practices in part determine effective route directions. The results of Experiments 1 indicated that effective wayfinding behaviour is enhanced by the veridical temporal–spatial ordering of communicative statements, consistent with the principle of natural order. Findings from Experiments 2, 3, and 4 validated the practices of including descriptives and concentrating delimiters at choice points, consonant with the principle of referential determinacy. Data from Experiment 5 suggested that the effectiveness of instruction depends to some extent on the selection of delimiters that are understood well by both interlocutors, consistent with the principle of mutual knowledge.

Taken together, these findings are consistent with a constructivist interpretation of how route directions are remembered and followed. When a traveller prepares to receive wayfinding information, his or her general knowledge of environmental structure and of spatial terminology is activated or primed. In this study, general knowledge of environmental structure included information about urban layout and environmental objects, natural and artificial, that comprise such settings. Knowledge of spatial terminology refers to the comprehension of spatial prepositions (e.g. across, between), as well as facility with distance (e.g. blocks, miles) and direction (e.g. cardinal directions, left–right distinctions) terminology. As verbal information arrives, the listener constructs a linear-order representation that corresponds to a traveller's perceptual experience along a path of observation (see Johnson-Laird, 1983; Morrow *et al.*, 1989; Taylor and Tversky, 1992b). This constructivist account basically represents the reciprocal of the cognitive activities (representation, transformation, and symbolization) underlying the production of route directions, as identified by Couclelis (1996).

Constructing representations from route directions is a constrained instance of discourse processing as question-answering (Golding *et al.*, 1996) in that the listener must consistently adopt the perspective of the protagonist, which is implicitly the listener, as he or she negotiates a route through the environment (see Franklin & Tversky, 1990; O'Brien and Albrecht, 1992). The structural 'anchors' for this representation consist of choice points specified by environmental features in directive and descriptive statements; the greater the specificity, the more secure the 'anchor'.

When relying on such a representation to reach the designated destination, the traveller must rely on stored information sufficient to approach each choice point in succession. It is worth while to note that, as in many practical cognitive tasks, what is required is just enough specificity to discriminate among possibilities rather than extensive memory for the details of the entire route. The traveller is aided by a type of word-scene recognition priming; places that seem familiar on the basis of hearing a verbal description are approached. The principle is the same as that described in the wayfinding model of Cornell *et al.* (1994), except that in their model, approach is elicited by familiarity based on prior visual experience rather than on a verbal description. The practice of including descriptive statements and extra delimiters at choice points and during the final segments of the route reflects the need to provide an expanded basis for potential recognition of features at these points. The better specified these choice points, the more likely it is that they will serve as 'anchors' during wayfinding activity (Couclelis *et al.*, 1987; Ferguson and Hegarty, 1994).

Information failures in direction-following activity can arise as the result of problems at the time of encoding or at the time of retrieval. The construction of a mental or situation model of a route places considerable demands on working memory, particularly under the typical circumstances of environmental unfamiliarity.

If the task load becomes unmanageable because of a lengthy set of instructions or because of an unusual environment, some of the information may simply never be encoded. Individuals may differ significantly in their ability to manage task demands under such circumstances, a possibility to be addressed in future research.

On the retrieval side, task performance is potentially hindered considerably by interference, both proactive and retroactive. Additionally, response competition may be the consequence of similar features at different intersections. In the present experiment, the absence of overt responses in instances of information failure makes it impossible to differentiate among these possibilities. It may be necessary to examine these issues using a more artificial procedure in which environmental information can be easily manipulated and the cost of making an error is perceived as smaller.

It is important to mention that although the role of environmental factors in the communication of route knowledge was not the focus of these experiments, it must not be overlooked. It is reasonable to posit that structure in the environment can significantly lower task demands, with the consequence of reducing reliance on those communication principles and practices dedicated to maintaining 'common ground' between interlocutors under challenging circumstances.

Sex-related differences in performance

The finding that men exhibited fewer information failures than did women appeared consistently in these experiments. This difference was unanticipated, and, consequently, attempts to account for this result must be speculative and *post hoc*. Three broadly construed factors that could have played a role in creating this difference between the sexes are wayfinding and orientation skills, modes of representation, and social-personality factors. Sex-related differences on wayfinding and orientation tasks are found infrequently (see Evans, 1980). The most commonly found difference in this ability domain is concerned with sense of direction, particularly cardinal directions (Bryant, 1982; LaGrone, 1969), perhaps attributable to experiential factors such as frequency of independent travel and map use (Newcombe *et al.*, 1983; Ward *et al.*, 1986). It is possible that the sex difference observed in the present studies was primarily the result of men's greater experience in wayfinding activities, which ostensibly would afford them greater efficiency in translating the direction protocol into an action plan. This possibility can be easily addressed in subsequent studies.

Different representational modes is a second candidate factor in explaining the sex difference. Some investigators have reported that in wayfinding tasks women tend to rely more on proximal landmark-to-landmark sequential information than on distal or configurational information, with the opposite tendency being observed in men (Baker, 1981; Bever, 1992). However, an examination of route learning in itself indicated that men and women tend to rely on the same representational strategy (Galea and Kimura, 1993). At this time, the case for different modes of representation is not substantial but is worthy of careful empirical examination.

The third factor that could be important in accounting for the observed sex difference involves social-personality variables. A number of activities requiring outdoor orientation and wayfinding have been found to be categorized as stereotypically masculine by young adults (Crawford *et al.*, 1989; Newcombe *et al.*, 1983). Herrmann *et al.* (1992) found that, consistent with predictions based on gender stereotyping data, women performed more poorly than men on a task requiring memory for route directions but outperformed men on a task requiring memory for objects on a shopping list. In a related vein, anxiety about wayfinding and the prospects of becoming disoriented in unfamiliar surroundings has been found by some researchers to be greater in women (Lawton, 1993; but see also Bryant, 1982). Such anxiety could plausibly interfere with effective information-processing activities. These possibilities can be addressed in the future by assessing social desirability and anxiety about wayfinding problems in the context of direction-following tasks.

Conclusion

Remembering and following route directions involves the construction of a representation from a verbal presentation. This representation is basically a mental or situation model consisting of a sequence of actions-in-context. At a basic level, the construction of such representations is affected by some well-known influences on associative learning, such as proactive interference. Higher-order procedures based on knowledge of typical environments, spatial concepts, and communication principles serve to facilitate the organization of relational information within the representation.

Route direction protocols that are consistent with certain principle-based practices result in greater wayfinding success than do protocols that are inconsistent with these practices, thus validating a 'best practices' approach to addressing the question of what characteristics or qualities differentiate good route directions from poor ones. This approach provides a useful complement to others, especially the reduction to essentials approach used by Denis *et al.* (in press), in developing a comprehensive theory of how wayfinding information is communicated through language.

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APPENDIX

A. Route directions that conform to principle-based practices (Experiments 1, 2, 4, and 5).

1. Exit Barnwell by the front doors, and go directly down the steps.
2. Walk a few steps to a circular walkway that surrounds a small grassy area encircled by wooden benches.
3. Take the walkway to the left, and continue for about one-fourth of the way around the circle.
4. Then turn left onto a broad sidewalk. Light brown university buildings will be just ahead, Sloan – the art building – to your left and Laconte – the math building – to your right.
5. Walk straight ahead on the sidewalk, which passes over a street.
6. After you pass over the street, continue straight down the sidewalk.
7. The sidewalk is divided by large planters at this point; walk on the left side of the planters.
8. You will pass university buildings to your left and to your right.
9. Walk straight until the sidewalk ends at Barnwell Street. House-style university buildings will be on your left and right; the one on your left will be the Student Alumni Association. A very tall dormitory building called Capstone will be in front of you.
10. Use the crosswalk when crossing the street, then take a few steps to the left.
11. Then turn right so that you will walk straight alongside Capstone, with the dorm on your right and a parking lot on your left.
12. After you walk past the dorm on the right, a large house-style building will be on your left. Continue walking forward until you reach a street named Gregg Street.
13. Turn right on Gregg Street, and walk just a few steps to where another street goes off to your left. This is called College Street.
14. Turn left onto College Street, and walk to the end of the block, where College Street intersects with Laurens Street. Townhouses will be on your right and a large house with white columns will be on your left. Straight ahead is a large sidewalk that crosses railroad tracks.
15. Turn left onto Laurens and walk one block. The first street on your left will be Pendleton Street.
16. Turn left onto Pendleton Street. On your left at the corner is a medium-sized stucco house, on the right is a big tan-colored house with brown trim.
17. Walk one block to Gregg Street. On your left will be a little white house, and on your right will be a very large brown house.

18. Turn right onto Gregg Street, and walk two blocks. As you cross Senate Street, a large high-rise building will be on your left.
19. Continue walking straight on Gregg Street.
20. When you get to the end of the block, you will be at Gervais Street. It is a busy street with businesses on both sides of the street.
21. Turn left. The building you will be facing is white with brown lettering on the sign. The name of the business is Fine Arts Framing, which is the end of the walk.

B. Scrambled route directions with correct temporospatial order indicated in brackets (Experiment 1).

1 [15]. Turn left onto Laurens and walk one Block. The first street on your left will be Pendleton Street.
2 [16]. Turn left onto Pendleton Street. On your left at the corner is a medium-sized stucco house, on the right is a big tan-colored house with brown trim.
3 [17] Walk one block to Gregg Street. On your left will be a little white house, and on your right will be a very large brown house.
4 [6]. After you pass over the street, continue straight down the sidewalk.
5 [7]. The sidewalk is divided by large planters at this point; walk on the left side of the planters.
6 [8]. You will pass university buildings to your left and to your right.
7 [9]. Walk straight until the sidewalk ends at Barnwell Street. House-style university buildings will be on your left and right; the one on your left will be the Student Alumni Association. A very tall dormitory building called Capstone will be in front of you.
8 [10]. Use the crosswalk when crossing the street, then take a few steps to the left.
9 [1]. Exit Barnwell by the front doors, and go directly down the steps.
10 [2]. Walk a few steps to a circular walkway that surrounds a small grassy area encircled by wooden benches.
11 [3]. Take the walkway to the left, and continue for about one-fourth of the way around the circle.
12 [4]. Then turn left onto a broad sidewalk. Light brown university buildings will be just ahead, Sloan – the art building – to your left and Laconte – the math building – to your right.
13 [5]. Walk straight ahead on the sidewalk, which passes over a street.
14 [18]. Turn right onto Gregg Street, and walk two blocks. As you cross Senate Street, a large high-rise building will be on your left.
15 [19]. Continue walking straight on Gregg Street.
16 [20]. When you get to the end of the block, you will be at Gervais Street. It is a busy street with businesses on both sides of the street.
17 [21]. Turn left. The building you will be facing is white with brown lettering on the sign. The name of the business is Fine Arts Framing, which is the end of the walk.
18 [11]. Then turn right so that you will walk straight alongside Capstone, with the dorm on your right and a parking lot on your left.
19 [12]. After you walk past the dorm on the right, a large house-style building will be on your left. Continue walking forward until you reach a street named Gregg Street.

20 [13]. Turn right on Gregg Street, and walk just a few steps to where another street goes off to your left. This is called College Street.
21 [14]. Turn left onto College Street, and walk to the end of the block, where College Street intersects with Laurens Street. Townhouses will be on your right and a large house with white columns will be on your left. Straight ahead is a large sidewalk that crosses railroad tracks.

C. Route directions with descriptives at non-choice points, indicated by italicized additions and notations of deletions (Experiment 2).

1. Exit Barnwell by the front doors, and go directly down the steps. *A light brown university building – Sloan, the art building – will be just ahead to the left.*
2. Walk a few steps to a circular walkway that surrounds a small grassy area encircled by wooden benches.
3. Take the walkway to the left, and continue for about one-fourth of the way around the circle.
4. Then turn left onto a broad sidewalk. [Deletion.]
5. Walk straight ahead on the sidewalk, which passes over a street. *There are small planters in the center of the sidewalk.*
6. After you pass over the street, continue on the sidewalk. *Brick house-style buildings will be on your left and brick high-rise university buildings – the Humanities Building and Gambrell – will be on your right.*
7. The sidewalk is divided by large planters at this point; walk on the left side of the planters.
8. You will pass university buildings; *a large brick high-rise building – the Business Administration Building – will be to your left and a series of house-style buildings to your right.*
9. Walk straight until the sidewalk ends at Barnwell Street. [Deletion.]
10. Use the crosswalk when crossing the street, then take a few steps to the left.
11. Then turn right so that you will walk straight alongside the high-rise dormitory named Capstone. *There will be a parking lot to the left, the dorm to the right, and the back of a house straight ahead.*
12. Continue walking forward until you reach a street named Gregg Street. [Deletion.]
13. Turn right on Gregg Street, and walk just a few steps to where another street goes off to your left. This is called College Street.
14. Turn left onto College Street, and walk to the end of the block, where College Street intersects with Laurens Street. [Deletion.]
15. Turn left onto Laurens and walk one block. *Large traditional-style homes will be on both sides of this tree-lined street.* The first street on your left will be Pendleton Street.
16. Turn left onto Pendleton Street. [Deletion.]
17. Walk one block to Gregg Street. [Deletion.]
18. Turn right onto Gregg Street, and walk two blocks. [Deletion.]
19. Continue walking straight on Gregg Street. *A parking lot will be on your left, and houses will be on your right. The walk is down a rather steep hill at this point.*
20. When you get to the end of the block, you will be at Gervais Street. [Deletion.]
21. Turn left. The building you will be facing is white with brown lettering on the sign. The name of the business is Fine Arts Framing, which is the end of the walk.

D. Route directions with delimiters at non-choice points, indicated by italicized additions and notations of deletions (Experiment 4).

1. Exit Barnwell by the front doors, and go *between the large white pillars* directly down the steps.
2. Walk a few steps *on a tree-lined brick sidewalk* to a circular walkway that surrounds a small grassy area encircled by wooden benches.
3. Take the walkway to the left, and continue for about one-fourth of the way around the circle.
4. Then turn left onto a sidewalk. University buildings will be ahead, Sloan to your left and LaConte to your right. [Deletion.]
5. Walk straight ahead on the sidewalk, *which contains planters and* which passes over a busy street.
6. After you pass over the street, continue on the sidewalk *that passes a brick house-style buildings on your left and brick high-rise university buildings – the Humanities Building and Gambrell – on your right.*
7. The sidewalk is divided; walk on the left side. [Deletion.]
8. You will pass *beside a large brick high-rise building – the Business Administration Building – to your left and a series of house-style buildings, including the Financial Aid Office and Women's Studies, to your right.*
9. Walk until Barnwell Street. University buildings will be on your left and right, and a dormitory building called Capstone will be in front of you. [Deletion.]
10. Use the crosswalk when crossing the street, then take a few steps to the left.
11. Then turn right so that you will walk straight alongside the building named Capstone Hall. [Deletion.]
12. After you walk past the dorm on the right, a large house-style *brick* building *with white columns* will be on your left. Continue walking forward until you reach a street named Gregg Street.
13. Turn right on Gregg Street, and walk just a few steps *beside the pavement* where another street goes off to your left. This is called College Street.
14. Turn left onto this street, College Street, and walk *past townhouses on the right and a large house with columns on the left* to the end of the block, where it intersects with Laurens Street. Townhouses will be on your right and a house on your left. Straight ahead is a sidewalk. [Deletion.]
15. Turn left onto Laurens and walk *past large traditional-style homes along the tree-lined street* for one block.
16. Turn left onto Pendleton Street. Houses will be on your left and your right. [Deletion.]
17. Walk one block *past large two-storey houses on your left and right until you get* to Gregg Street. [Deletion.]
18. Turn right onto Gregg Street, and walk two blocks *past more large two-storey houses with large front yards.* [Deletion.]
19. Continue walking straight on Gregg Street *past a parking lot on your left and houses on your right. The walk is down a rather steep hill at this point.*
20. When you get to the end of the block, you will be at Gervais Street. There are businesses of both sides of the street. [Deletion.]
21. Turn left. The building you will be facing is white with brown lettering on the sign. The name of the business is Fine Arts Framing, which is the end of the walk.

E. Route directions involving metric distance and cardinal direction information, indicated by italicized additions and notations of deletions (Experiment 5).

1. Exit Barnwell by the front doors. *You will be facing south*. Go directly down the steps.
2. Walk *about 40 yards* to a circular walkway. [Deletion.]
3. Take the walkway to the left, and continue *for about 25 yards*. [Deletion.]
4. Then turn *east* onto a broad sidewalk. Light brown university buildings will be just ahead, Sloan – the art building – the *north* and Laconte – the math building – the *south*.
5. Walk straight ahead on the sidewalk, which passes over a street.
6. After you pass over the street, continue straight *for about 75 yards*.
7. The sidewalk is divided by large planters at this point; walk on the *north* side of the planters.
8. Continue walking straight for another *175 yards or so, facing due east*. [Deletion.]
9. After this distance, you will be at Barnwell Street. *University buildings will be to the north and to the south of you, and a large dormitroy – Capstone – will be immediately to the east*. [Deletion.]
10. Use the crosswalk when crossing the street, then go about *25 yards* to your left, *facing north*.
11. Then turn *to face east again*, so that you will walk straight alongside the dorm called Capstone. [Deletion.]
12. Walk *east for about 100 yards* until you reach a street named Gregg Street. [Deletion.]
13. Turn *south* on Gregg Street and walk *about 25 yards* to where another street goes off *to the east*. This is called College Street.
14. Turn *east* onto College Street, and walk to the end of the block, where College Street intersects with Laurens Street. Townhouses will be to the *north* and a large house to the *south*. [Deletion.]
15. Turn left *to face north* onto Laurens and walk *about 100 yards* to the intersection with Pendleton Street.
16. Turn *west* onto Pendleton Street. To the *south* is a medium-sized house and to the *north* is a big house. [Deletion.]
17. Walk *about 50 yards* to the intersections with Gregg Street. To the *south* will be a little house and to the *north* is a very large house. [Deletion.]
18. Turn right on Gregg Street and *face north*.
19. Walk straight on Gregg Street for two blocks, *about 200 yards*. As you cross Senate Street a high-rise building will be *to the west*.
20. At the end of the block, you will be at Gervais Street. It is a busy street with businesses on both sides of the street.
21. *Face west*. The building you will be facing is Fine Arts Framing, which is the end of the walk. [Deletion.]