Applied Cognitive Psychology, *Appl. Cognit. Psychol.* **26**: 182–193 (2012)
Published online 31 May 2011 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/acp.1805

Remembering Routes: Streets and Landmarks

ARIANE CECILE TOM[1]* and BARBARA TVERSKY[2]

[1]*INRETS-LCPC-LEPSIS, Paris Cedex 15, France*
[2]*Stanford University-Psychology, Stanford, USA*

Summary: Route directions are often given on request in situ, requiring the inquirer to remember the directions. Previous work has shown that landmarks are more memorable than street names. However, in those studies, the names of landmarks were more vivid and distinctive than the street names. In two experiments, we disentangled vividness/distinctiveness from landmark/street. The major factor in memorability of routes was vividness/distinctiveness, with a slight advantage to streets. Route directions were remembered better when either the landmarks, the street names or both were more vivid and distinctive. Those high in mental imagery read the descriptions faster and remembered them better. Thus, vividness in the stimuli and visual imagery in the mind augment constructing and remembering spatial mental models because forming spatial mental models relies in part on spatial structure but also on associative learning, and vividness and visual imagery promote associative learning. The findings have implications for learning in general. Copyright © 2011 John Wiley & Sons, Ltd.

INTRODUCTION

Who has not stopped a stranger in a new environment for instructions to a destination? And who of those has gotten good route directions? What makes route instructions effective? Numerous studies have demonstrated that people can form spatial mental models from language (e.g. Lee & Tversky, 2005; Mani & Johnson-Laird, 1982; Taylor & Tversky, 1992). Spatial mental models are more easily established when the descriptions are coherent and complete (Mani & Johnson-Laird, 1982). At their most abstract, routes are ordered sets of links and nodes (e.g. Tversky & Lee, 1998, 1999). Route directions impose a discourse structure on the ordered set of links and nodes (Denis, 1997a, b). Route instructions consist of a succession of segments, each of which begins with a start point, then a reorientation, then an action, and finally an end point, which may serve as the start point for the next segment. Observing this format results in more effective route directions, even in difficult cities like Venice (Denis, Pazzaglia, Cornoldi, & Bertolo, 1999).

In many cases, the turning points that link node to node can be described either by referring to the pathways or streets connecting the nodes or by referring to the landmarks at the nodes. Which is better? Research comparing the effectiveness of streets versus landmarks found an advantage to landmarks (Tom & Denis, 2004). That research compared two kinds of route directions, one based on landmarks and one based on street names. The same words were used to refer to streets and landmarks; for example, Hospital Street or a hospital. There was a clear advantage to landmarks; that is, route descriptions based on landmarks were better remembered than route descriptions based on streets.

However, this study had a confounding. The landmarks were highly vivid and distinctive, whereas the streets were not. Hospital conjures an image of a large utilitarian building whereas Hospital Street is simply a street that somewhere probably has a hospital on it. It is well known that vividness and distinctiveness improve memory (e.g. Paivio, 1990) so that the advantage of landmarks might not be due to landmark status *per se* but rather to vividness. Vividness can be defined as forming clear or striking mental images; vivid route directions thus bring strikingly realistic or lifelike images to the mind and consequently enhance memory (e.g. Katz, 1995; Marks, 1983).

The present project investigates that possibility by disentangling the effects of vividness from the type of environment feature that scaffolds the route, landmark or street. The first study replicated the study of Tom and Denis (2004) but reversed the relationship between vividness and environmental feature. Streets were vivid and distinctive, but landmarks were not. If vividness is the key factor, then a route based on streets should be better remembered than a route based on landmarks. Conversely, if environmental feature is key, a route based on landmarks should be better remembered.

The second study addressed the same question, vividness versus environmental feature, in a different way. Participants studied either vivid or non-vivid route directions consisting of both streets and landmarks. Here, the vivid directions should be remembered better than the non-vivid. In both cases, will there be an advantage to streets or landmarks in recall?

Landmarks are typically thought of as point-like entities and streets as one-dimensional entities extending in space (e.g. Talmy, 1983; Gale, Golledge, Pellegrino, & Doherty, 1990). Because streets extend in space and explicitly carry directional information, unlike landmarks, streets may form a better mental framework or scaffolding for route memory than landmarks.

Another factor of interest is individual differences, specifically in mental imagery. Fernandez (1999) found that good imagers recalled descriptions better, although the effects were eliminated when imagery was explicitly suggested as a strategy.

EXPERIMENT 1: RECALL OF ROUTES WITH VIVID STREETS OR NON-VIVID LANDMARKS

In previous work (Tom & Denis, 2004), participants remembered routes based on landmarks better than routes based on streets. However, in that study, the landmarks were

*Correspondence to: Ariane Cecile Tom, INRETS-LCPC-LEPSIS, 58 Boulevard Lefebvre Paris Cedex 15 75732, France.
E-mail: arianectom@yahoo.fr

vivid and the streets were not. The present study replicated the earlier one, but in this case, streets were vivid and landmarks were not.

Method

Participants
Forty Stanford University undergraduates in Psychology, 20 women and 20 men, with a mean age of 20.03 years participated in the experiment for pay ($10). They were randomly assigned to one of the two experimental groups, with constraint that there were equal numbers of men and women in each group. The participation was individual.

Design and materials
The experimental design involved the description (street or landmark) as a two-level, between-participant factor and the number of read–recall trials (first, second, third) as a three-level within-participant factor.

Two sets of directions were composed describing the same route, one set based only on streets and the other only on landmarks. The fictitious route joined a park to a train station. For the street route, each statement was accompanied by a visual description, referring to salient features located all along the streets. These vivid descriptions differed from one another, making the streets distinctive from one another. The vivid street descriptions either described the border ('a path edged with a row of gigantic redwood trees') the surface ('a street paved with antique cobblestones') or the geometry of the street ('a road that zigzags sharply the entire way'). At most, two statements of the same kind appeared in a row in the set of directions. By contrast, each landmark was a building or building-like (e.g. a complex, a business), rendering the landmarks visually similar. Further, each landmark was accompanied by a factual description that rendered it conceptually but not visually distinctive (e.g. 'privately financed', 'owned by local investors'). Some of these factual statements were adapted from Lee & Tversky (2005).

The lengths of the landmark and street statements, as measured by the number of syllables, were strictly equated between the two sets. Each set was composed of 219 syllables. The number of references to streets or landmarks located to the left or to the right of the traveler (either encountered by the traveler or intended to signal a reorientation) was equated within each set, with five right-located and six left-located items.

Finally, each set of route directions contained 20 statements, of which 11 were common to both sets, and nine differed between the two sets. Except for the introduction of the start and end points, the common statements were mostly prescriptions of actions (e.g. 'turn right', 'continue walking'). The different statements contained both locative and descriptive information about the landmarks or streets. Full descriptions are given in Table 1.

Procedure
The experiment was conducted on a G3 Macintosh (400 MHz), with a 15-inch monitor operated by PSYSCOPE 1.2.5 software (Carnegie Mellon University, Pittsburgh, Pennsylvania, USA) (Cohen, MacWhinney, Flatt, & Provost, 1993). The statements appeared one at a time, centered on the computer screen, in black 18 font (Arial) print on a white background. Participants pressed the space bar to advance to the next statement. Each statement remained on the screen until the next press. Only forward reading was possible. Reading times per instruction were recorded, allowing comparisons between and within descriptions.

First, the participants read a practice route, composed of four statements, and drew a map of it. If participants had no question about this procedure, they were asked to press the Tab key. This made the experiment instructions appear on the screen. Participants were instructed to read the description at their own pace and to pay attention as they would be asked to draw a map of the route described. After reading the experiment instructions, participants pressed the space bar to read the first route statement.

After the last route statement, a message appeared on the screen requesting participants to tell the experimenter they were done. The experimenter then asked participants to draw a map of the route on a blank sheet of paper with a blue pen. The experimenter told participants they could write down the names of streets or landmarks that they remembered but could not locate. After participants finished drawing their maps, the experimenter took the maps, and asked participants to press the Tab key on the keyboard. This allowed participants to read the route directions a second time. After the second trial, participants were given back their maps and were asked to modify or complete them with a green pen; if needed, they could draw a new map. The reading/drawing phases were repeated once more; this time, the sketch was drawn with a red pen. A previous study had shown that three trials were sufficient to learn this amount of information (Tom & Denis, 2004).

Then, participants completed two tests of spatial ability, namely, the Mental Rotation Test (MRT) (Vandenberg & Kuse, 1978) and the Money's Standardized Road-Map Test of Direction Sense—below referred to as the Money Test (MT) (Money, Alexander, & Walker, 1965). The order was counterbalanced. The MRT consists of a set of 20 items. Each item is made of a criterion figure and of four alternatives in a different orientation. All figures are three-dimensional objects. The participants had to find which two of the four alternatives could be rotated in correspondence with the criterion figure.

In the MT, participants were given a street map of a city. First, a short practice route with only three turns was drawn on the map. Participants had to imagine traveling on this route and to say aloud whether they had to turn left or right at each corner, without turning the map. After practice, the same map was given to the participants, with a longer route drawn on it. It consisted of 32 turns, with an equal number of left and right turns. The participants' task remained the same. A time limit was set for 20 seconds; participants were required to go as far as possible within this limit without sacrificing accuracy.

Results

Reading task
Although the landmark and street directions were equated in length, reading times in milliseconds per syllable were

Table 1. Route directions used in Experiment 1

	Street description		Landmark description
1	Leave the park	1	Leave the park
2	Follow the path that is straight ahead	2	Follow the path that is straight ahead
3	Go down this path which *is edged with a row of gigantic redwood trees*	3	Go down this path *which leads to a building that was privately financed*
4	You will then see on your left *a very bumpy and stony dirt road*	4	You will then see on your left *an office building with small companies*
5	On your right, there is *a road that zigzags sharply the entire way*	5	On your right, there is *a business operated by a young couple*
6	Turn right	6	Turn right
7	Go to the end of the road	7	Go to the end of the road
8	The road ends *on a path that goes through an emerald-green horse pasture*	8	The road ends *at a building occupied by insurance companies*
9	Turn left here and continue walking	9	Turn left here and continue walking
10	On your left, there is *a road bordered by a community of tiny garden cottages*	10	On your left, there is *a complex donated to the town by a women's organization*
11	Turn left and continue walking	11	Turn left and continue walking
12	On your right, you will see *a street paved with antique cobblestones*	12	On your right, you will see *a lawyers' building that faces south*
13	Turn right	13	Turn right
14	You come to *an avenue lined with ornate gas lampposts*	14	You come to *a building reopened just 3 weeks ago*
15	Continue straight on	15	Continue straight on
16	On your right, you will see *a street that has a steep slope which goes down*	16	On your right, you will see *a building owned by local investors*
17	On your left, there is *a wider road with buildings under construction on both sides*	17	On your left, there is *a federal office building that lacks air-conditioning*
18	Turn left	18	Turn left
19	Go straight ahead on this street	19	Go straight ahead on this street
20	The station will be in front of you	20	The station will be in front of you

computed to allow comparisons both within description and across trials. An analysis of variance (ANOVA) was performed on the data, with a 2×3 mixed design (two descriptions: street or landmark; three trials). Figure 1 shows the mean reading times for each trial in each description.

Overall, participants took 500.83 milliseconds per syllable to read the landmark statements ($SD = 150.41$) and 444.76 milliseconds to read the street statements ($SD = 263.39$), a difference that was not significant: $F(1, 38) < 1$. Reading times overall decreased from Trials 1 to 3: $F(2, 76) = 4.88$, $p = .01$. Tukey *post hoc* analyses showed that this decrease was significant between the first and third trials ($p < .01$). The trial × description interaction was not significant: $F(2, 76) = 2.03$, $p > .05$. Nonetheless, Tukey *post hoc* analyses showed an interesting effect. Reading times remained stable across trials in the landmark condition (all ps$ > .05$), whereas they decreased between Trials 1 and 3 in the street condition ($p < .01$). Moreover, a linear trend was found significant only for the street condition: $F(1, 38) = 10.84$, $p < .005$.

Further analyses were conducted to distinguish processing of the locative (street or landmark location descriptions) versus action statements. The type of statement was treated as a two-level within-subject factor. Overall, reading times per syllable were longer for the locative ($M = 554.46$, $SD = 143.16$) than for the action statements ($M = 390.17$, $SD = 308.36$): $F(2, 76) = 5.40$, $p < .01$. The description × type

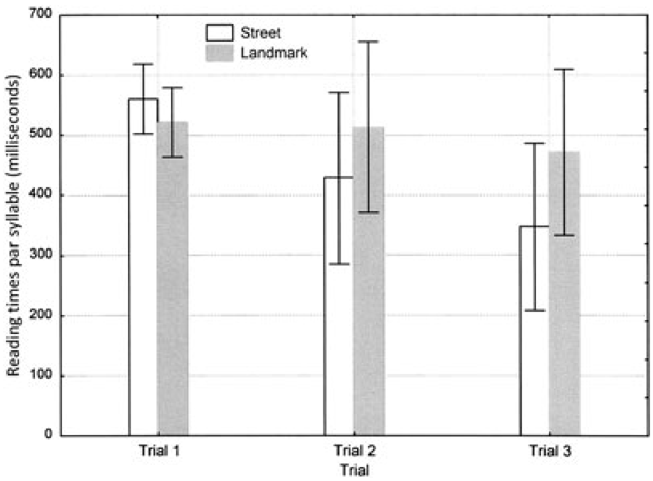


Figure 1. Reading times per syllable for each trial in each description (Experiment 1)

of statement interaction was not significant: $F(2, 76) = 2.18$, $p > .05$. Reading times were longer for the locative statements for both street and landmark conditions, as attested by Tukey *post hoc* analyses (both *p*s $< .05$). The trial × type of statement interaction was significant: $F(2, 76) = 9.36$, $p < .0005$. Detailed analyses showed that reading times linearly decreased from Trials 1 to 3 for the locative statements [$F(1, 38) = 50.95$, $p < .00001$] but stayed stable for the action statements: $F(1, 38) < 1$. Finally, the description × type of statement × trial three-way interaction was not significant: $F(2, 76) < 1$.

Analyses of the maps

The maps that participants drew were first analyzed by counting the amount of information recalled after each trial. Computerized sketches of the routes are shown in Figure 2.

A maximum of 11 items (streets or landmarks) could be recalled, that is the nine items that differed between the two descriptions plus the start and end points. As only very few participants ($n = 3$) made a list of the items whose locations were forgotten, only the items that were drawn were included in the following analyses. Figure 3 shows the mean number of items recalled after each trial for each description.

Overall, participants recalled more items in the vivid street condition ($M = 9.88$, $SD = 1.49$) than in the non-vivid landmark condition ($M = 8.07$, $SD = 1.97$): $F(1, 38) = 10.83$, $p < .005$. The amount of information recalled increased from Trials 1 to 3: $F(2, 76) = 77.84$, $p < .00001$. The description × trial interaction was significant: $F(2, 76) = 7.14$, $p < .001$. Tukey *post hoc* analyses showed that this increase was significant across the three trials in the landmark condition (for all three pairwise comparisons: *p*s $< .005$). In the street condition, the comparison between the number of items recalled after Trials 2 and 3 was the only comparison that did not reach significance, most probably because of a ceiling effect. We also considered the percentage of participants who recalled all items on their maps. Results showed that the cumulative percentages of items recalled was higher in the street condition than in the landmark condition, after each of the three trials (30%, 65% and 85% vs 0%, 20% and 55%, respectively).

Another interesting result was how the participants labeled the items they recalled. As participants were required not to learn the statements word for word, some of them used synonyms. Of the labels that were distorted, 100% were synonyms in the street condition (e.g. 'rocky road' stood for 'stony road'), but only 65% were synonyms in the landmark condition. The remaining 35% were errors that could be explained by interference from other statements (e.g. 'small businesses' came from both 'small companies' and 'business').

Correctness of recall

Another series of analyses focused on the correctness of the location of the items recalled. The first analysis considered only the locally correct locations, that is those items that were correctly located relative to the previous one in the description (to the right, to the left or in front of it). Just as the participants in the street condition recalled more items, they also recalled the locations more accurately. Thus, conditional frequencies were computed (see Tom & Denis, 2004). Figure 4 shows the mean frequency of items correctly located after each trial in each description.

Overall, participants recalled the spatial locations of streets more accurately than those of landmarks ($M = 0.85$, $SD = 0.12$ vs $M = 0.75$, $SD = 0.15$). The frequency of correctly located items increased over trials: $F(2, 76) = 12.75$, $p < .0001$. Tukey *post hoc* analyses showed that this frequency increased between Trials 1 and 2 and between Trials 1 and 3 (both *p*s $< .05$) but only marginally increased between Trials 2 and 3 ($p = .06$). Finally, the description × trial interaction was not significant: $F(2, 76) = 2.37$, $p > .05$. Tukey *post hoc* analyses showed that the difference between the street condition and the landmark condition was significant only after the first trial ($p < .005$). The frequency of items correctly located linearly increased in the landmark condition [$F(1, 38) = 15.80$, $p < .0005$] but increased only marginally in the street condition [$F(1, 38) = 3.74$, $p = .06$]. This last result can here again be explained by a ceiling effect in the street condition.

The second type of analysis performed on these data took into account the global correctness of maps. First, we considered only maps that included all items in the correct location. Results first showed that cumulative percentages of correctness were higher in the street condition than in the landmark condition, after each of the three trials (20%, 25% and 40% vs 0%, 15% and 35%, respectively). Although there were differences between the two conditions, especially after the first two trials, the major result was that most of the participants failed to recall all the items in their correct spatial locations. We then used a less stringent criterion, focusing only on the items that would be essential if someone actually had to navigate; choice points are known to have this characteristic (e.g. Allen, 2000; Michon & Denis, 2001). So, only the correct *routes* (as opposed to the correct *maps*) were taken into account in this new analysis. Results showed that in the street condition the cumulative percentages of correct routes were the following: 25%, 45% and 75% for each of the three trials. In the landmark condition, the data were the following: 15%, 25% and 70%. This last analysis indicated that the differences between the two groups for the global correctness of the maps were evident in the first two trials. Again here, information based on streets leads to the best performance.

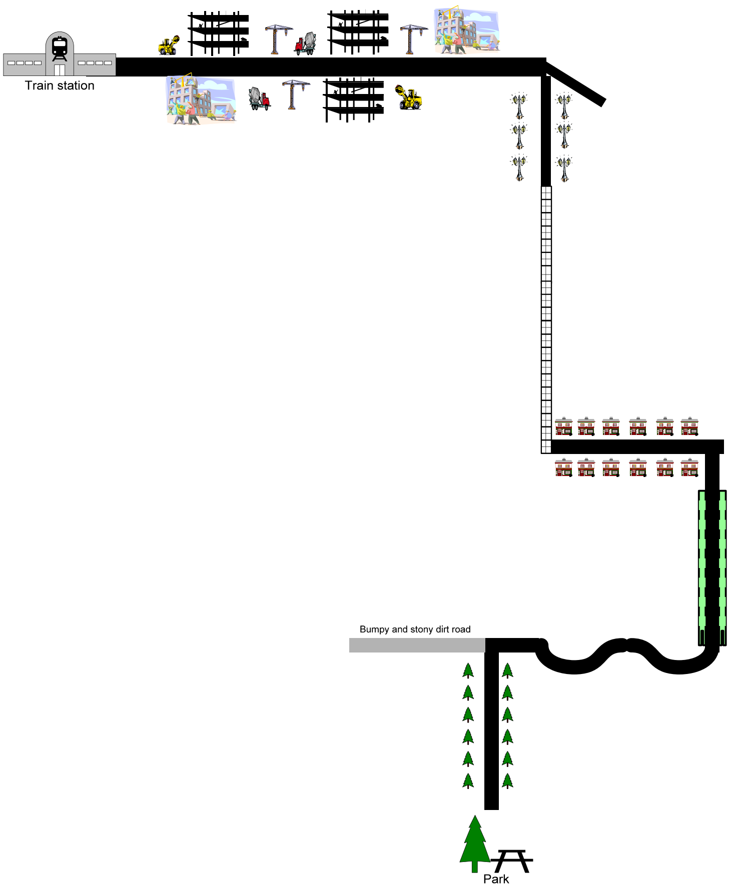
Individual differences

Individual differences were studied by computing correlations between the score obtained for each test and other relevant variables. Correlations were computed for each condition. Those high in mental rotation read faster [$r(38) = -.61$, $p < .005$] and remembered more items [$r(38) = .56$, $p < .01$] in the vivid street condition. The frequency of correctly located items was correlated with MT scores but only in the landmark condition [$r(38) = .58$, $p < .01$]. These last results show a new contrast between streets and landmarks, which thus extend beyond mean differences shown before.

Gender differences

There were no differences between men and women on speed of reading [$F(1,36) < 1$], recall of instructions [$F(1,36) < 1$] or correct placement of items [$F(1,36) = 1.58$, $p > .05$].

(a) Street-based condition



(b) Landmark-based condition

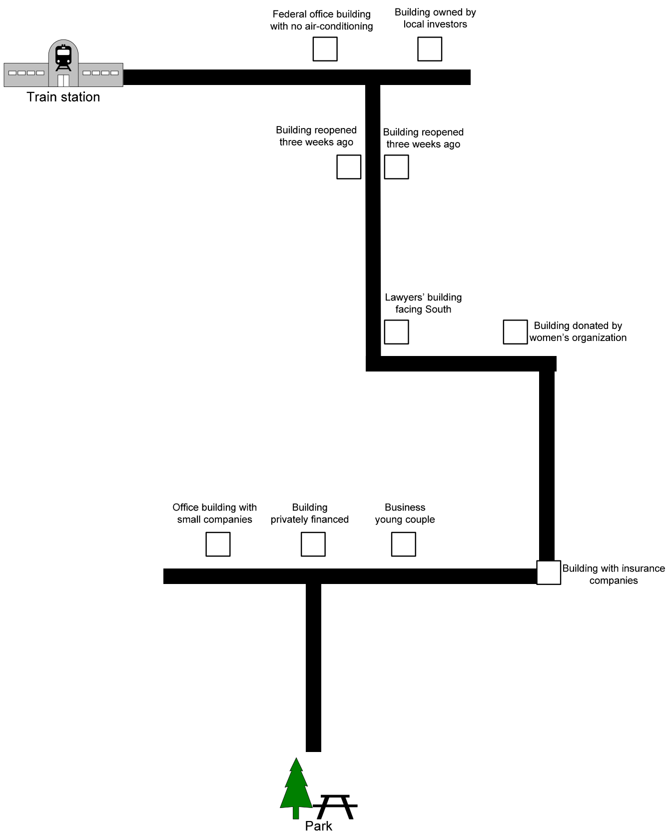


Figure 2. Real sketches of routes used in Experiment 1. (a) Street-based condition. (b) Landmark-based condition

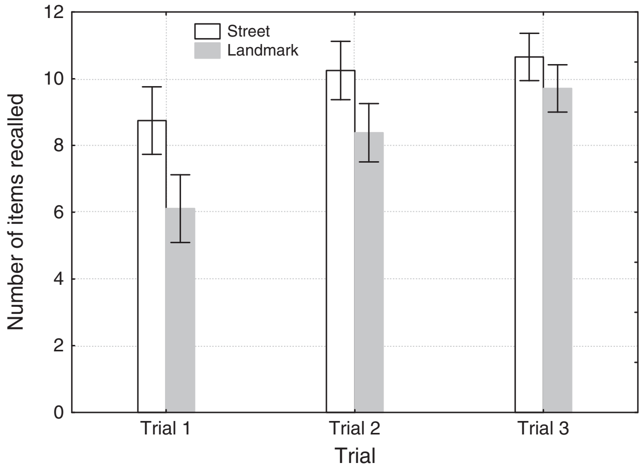


Figure 3. Number of items recalled for each trial in each description (Experiment 1)

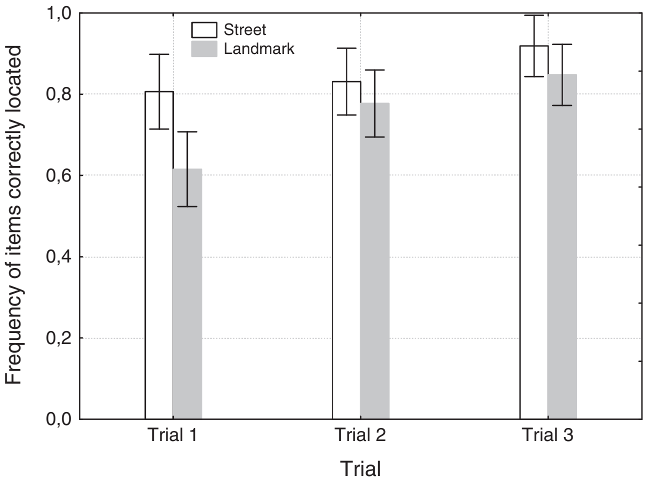


Figure 4. Frequency of items correctly located for each trial in each description (Experiment 1)

Discussion

Previous research had suggested that route directions based on landmarks were better remembered than directions based on streets (Tom & Denis, 2004). However, in that study, landmarks were vivid. In the present study, streets or paths were vivid, and directions based on streets were better recalled. Together, the experiments indicate that route directions based on vivid items are better remembered. Vivid materials trigger strong mental images and thereby provide effective anchors for memory. Considerable research has shown positive effects of vividness on recall, notably the work of Paivio (1990) but also many others (e.g. Collins, Taylor, & Wood, 1988; Shedler & Manis, 1986). Nonetheless, vividness promotes memory when vivid elements are logically consistent with the central ideas of the message; when vivid elements are distracting, recall decreases (Frey & Eagly, 1993). In the present research, because the vivid information was logically linked to the route directions, it enhanced recall.

EXPERIMENT 2: COMPARING VIVIDNESS AND ENVIRONMENTAL FEATURE

Vividness has a powerful effect on recall of routes. Will environmental feature, whether landmark or street, affect recall when vividness is equated? The present experiment addresses that question with two routes consisting of both landmarks and paths, one route with only vivid items and the other route with only non-vivid items. Because streets extend in space, they provide a more complete representation of a route than point-like landmarks do and are expected to be better remembered.

Method

Participants

Forty Stanford undergraduates in Psychology, 20 women and 20 men, with a mean age of 20.08 years participated in this second experiment for pay ($10). They were randomly assigned to one of the two experimental groups, with constraint that there were equal numbers of men and women in each group.

Design and materials

The experimental design involved the description (vivid or non-vivid) as a two-level, between-participant factor and the number of read–recall trials (first, second, third) as a three-level within-participant factor and the type of information (streets or landmarks) as a two-level within-participant factor.

The computer software was the same as in Experiment 1. Two sets of directions were designed describing the same route, one set based only on vivid information and the other only on non-vivid information. As before, the fictitious route joined a park to a train station. For the vivid description, landmarks and streets were selected from the previous experiment and research (Tom & Denis, 2004) to be vivid and distinctive from one another. We selected those of the landmarks which were conceptually most independent from each other. Five landmarks were selected; their proximity evaluated in a conceptual space was low. Actually, the intercorrelations computed to evaluate the conceptual proximity comprised the following interval: [0.02; 0.14].

For the non-vivid description, the landmarks and their factual descriptions also come from Experiment 1. The streets were named after the most frequent first names of people in the USA (source: 1990 US census) with the constraint that the number of syllables match those of the vivid description street names. We thus selected five first names: Robinson (rank, 20); Smith (rank, 1); Anderson (rank, 11); Williams (rank, 3); Jones (rank, 4).

Pairs of vivid/non-vivid instructions were strictly equated in length: both descriptions have a total of 188 syllables. Both descriptions are shown in Table 2.

Based on the results of the first experiment, we kept the two tests used (MRT and MT). In addition, we selected a questionnaire, the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). A review of the literature (McKelvie, 1995) attests to its reliability and validity (in particular, criterion validity). In addition, the notation scale of the

Table 2. Route directions used in Experiment 2

	Vivid description		Poorly vivid description
1	Leave the park	1	Leave the park
2	Follow the path that is straight ahead	2	Follow the path that is straight ahead
3	Go down this path which leads to a *hospital*	3	Go down this path which leads to *Robinson Street*
4	You will then see on your left *a very bumpy and stony dirt road*	4	You will then see on your left *an office building with small companies*
5	On your right is a *church*	5	On your right is *Smith Street*
6	Turn right	6	Turn right
7	Go to the end of the road	7	Go to the end of the road
8	The road ends on a *path that goes through an emerald-green horse pasture*	8	The road ends at a *building occupied by insurance companies*
9	Turn left here and continue walking	9	Turn left here and continue walking
10	On your left, there is a *road bordered by a community of tiny garden cottages*	10	On your left, there is a *complex donated to the town by a women's organization*
11	Turn left and continue walking	11	Turn left and continue walking
12	On your right, you will see a *theater*	12	On your right, you will see *Anderson Street*
13	Turn right	13	Turn right
14	You come to a *market*	14	You come to *Williams Street*
15	Continue straight on	15	Continue straight on
16	On your right, you will see a *street that has a steep slope which goes down*	16	On your right, you will see a *building owned by local investors*
17	On your left is a *school*	17	On your left is *Jones Street*
18	Turn left	18	Turn left
19	Go straight ahead on this street	19	Go straight ahead on this street
20	The station will be in front of you, on a long *street lined with ornate gas lampposts*	20	The station will be in front of you, *next to a lawyers' building that faces south*

questionnaire was reversed because in the American version (but not in the French version), the highest score corresponds to the lowest vividness. The VVIQ consists of four items. Each item includes four sub-items, each one referring to a different detail (for example, the sun, the sky, the clouds, a rainbow). For each item, the participant was asked to first visualize a scene as precisely as possible (for example, a sunrise), then attend to a particular detail in the visual image and, finally, to evaluate the image for its degree of clarity and vividness on a Likert scale from 1 to 5.

Procedure

The VVIQ was administered first since it has been shown that participants increase their estimates if they think they performed well on a prior task (McKelvie, 1995).

Then, procedures of Experiment 1 were followed. Participants read the route description three times, each time followed by sketching a map of the route.

MT and MRT were administered in counterbalanced order. Following these timed tests (20 seconds for the MT and 6 minutes for the MRT), participants were asked to write down the route directions they had previously studied. The time between reading the instructions and the final recall was approximately 10 minutes.

Results

Reading task

As noted, the number of syllables of two descriptions was equated. Nevertheless, as for Experiment 1, we calibrated these reading times (in milliseconds) to carry out, without changing measuring unit, comparisons between the trials as well as within-description comparisons. An ANOVA was carried out on these data, with a $2 \times 2 \times 3$ mixed design (two descriptions: vivid or non-vivid; two types of information: streets or landmarks; three readings).

Overall, the participants needed 680.12 milliseconds per syllable to read the non-vivid description ($SD = 343.75$) and 702.90 milliseconds to read the vivid description ($SD = 344.72$). This difference was not significant: $F(1, 38) < 1$. The reading times decreased overall from Trials 1 to 3: $F(2, 76) = 19.66$, $p < .0001$. Tukey *post hoc* analyses showed that this decrease was significant between the first and the second trials ($p < .0005$) but was not significant between the second and the third trials ($p > .05$). The description × trial interaction was not significant: $F(2, 76) < 1$.

The description × trial × type of information interaction was significant: $F(2, 76) = 8.05$, $p < .001$. The corresponding results are shown in Figure 5. The comparisons of the partial effects carried out by means of the *post hoc* honestly significant difference *Tukey* test were significant only for the first trial. Thus, for Trial 1, we found that for the non-vivid description, reading times were higher for the streets than for the landmarks ($p = .0001$). For the vivid description, reading times were higher for the landmarks than for the streets ($p = .0009$). Further, for the information based on streets, the reading times were higher for the non-vivid description than for the vivid description ($p = .04$). Finally, it was found that for the information based on landmarks, reading times were higher for the vivid description than for the non-vivid description ($p = .0001$).

Analyses of maps

Computerized sketches of the routes are shown in Figure 6.

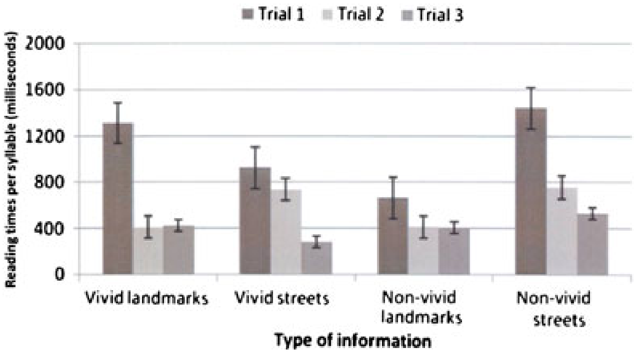


Figure 5. Reading times per syllable for each trial, each description and each type of information in Experiment 2

Quantity of information recalled

A maximum of 12 items could be recalled, namely the five streets and the five landmarks that constituted the descriptions plus the starting and arrival points.

Overall, the participants recalled more items from the vivid description ($M = 10.88$, $SD = 1.09$) than from the non-vivid description ($M = 8.95$, $SD = 2.87$): $F(1, 38) = 8.15$, $p < .01$. The quantity of information recalled increased from Trials 1 to 3: $F(2, 76) = 56.28$, $p < .00001$. The description × trial interaction was not significant: $F(2, 76) = 2.12$, $p > .05$. In addition, the type of information memorized determined the amount recalled: $F(1, 38) = 4.25$, $p < .05$. The streets were indeed recalled more frequently than landmarks (respectively: $M = 9.22$, $SD = 2.49$ vs $M = 8.56$, $SD = 3.46$). However, a more detailed analysis highlighted the fact that this effect varied with the trials and description type; that is, the interaction description × type of information × trial was significant: $F(2, 76) = 3.12$, $p < .05$. Figure 7 illustrates this interaction. The analysis of the partial effects showed that for each of the three trials, the number of recalled streets did not differ from the number of landmarks recalled for the vivid description (all ps > .05). On the other hand, for the non-vivid description, the number of streets recalled was higher than that of landmarks for the second ($p = .003$) and third trials ($p = .03$).

Finally, we analyzed the percentages of participants with perfect recall. The results show that these percentages were always higher for the vivid description for each trial.

Correctness of recall

A new series of analyses considered the correctness of the locations of the items using conditional frequencies. Overall, the participants recalled the locations of the items from the vivid description better than from the non-vivid description ($M = 0.81$, $SD = 0.15$ vs $M = 0.63$, $SD = 0.27$): $F(1, 38) = 7{,}21$, $p < .05$. The frequency of the correctly located items increased from trial to trial: $F(2, 76) = 60.02$, $p < .0001$. The *post hoc* Tukey analyses showed that this frequency increased between Trials 1 and 2 and also between Trials 2 and 3 (ps < .005). The interaction description × trial was not significant: $F(2, 76) < 1$. Lastly, there were no main effects or interactions with the type of information, street or landmark (all ps > . 05).

Written free recall

Descriptions of routes recalled in writing were transcribed. Overall, there were two kinds of organizations in the recall: a list of instructions each preceded by a bullet or a number or a compact textual description. See Table 3 for examples of each. About half the participants used each, and the frequency of each was about the same for vivid and non-vivid descriptions.

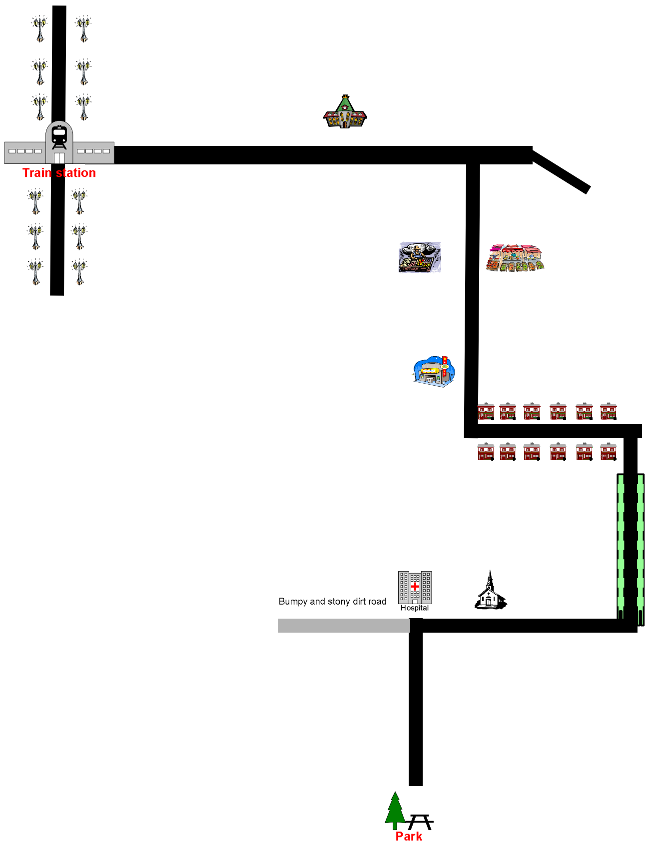
We conducted two series of quantitative analyses relative to the recalled descriptions of routes, first counting the number of words recalled. Participants who had read the vivid description wrote more words than those who had read the non-vivid description ($M = 124.80$, $SD = 28.82$ vs $M = 100.85$, $SD = 33.78$): $F(1, 38) = 5.53$, $p < .05$. All participants omitted some of the original information. The number of words recalled was less than the original number of words both for the vivid description (152 words, $p < .0005$ unilateral) and for the non-vivid description (143 words, $p < .00001$ unilateral).

Next, we examined whether the memory loss differed for streets and for landmarks. To answer this question, the percentage of forgotten streets and landmarks was calculated. The percentage of items forgotten was higher for the non-vivid descriptions than for the vivid descriptions ($M = 13.92$, $SD = 10.85$ vs $M = 8.01$, $SD = 5.78$); this difference was marginally significant: $F(1, 35) = 3.66$, $p = .06$. The effect of the type of information was not significant: $F(1, 35) < 1$. Lastly, the interaction description × type of information was marginally significant: $F(1, 35) = 3.78$, $p = .06$. The *post hoc* Tukey test highlighted that more landmarks were forgotten for the non-vivid description than for the vivid description ($p = .009$).

Individual differences

Imagery measures. First, correlations among the three imagery measures (MRT, MT and VVIQ) were computed. Scores on MRT and MT were moderately correlated: $r(38) = 0.48$, $p < .005$. Scores on MRT and VVIQ were not correlated: $r(38) = -0.05$, $p > .05$, and neither were scores on MT and VVIQ: $r(38) = 0.19$, $p > .05$. Men performed higher than women on the MRT: $F(1,38) = 5.54$, $p < .05$, as is typical (Voyer, Voyer, and Bryden, 1995). There were no gender differences for the MT: $F(1,38) < 1$ or the VVIQ: $F(1,38) = 1.13$, $p > .05$.

Second, for each of the three measures, MRT, MT and VVIQ, participants were split at the median into two groups. Participants whose scores were on the median were discarded from the analyses. A new series of ANOVAs was then carried *(a) Vivid condition*



(b) Non-vivid condition

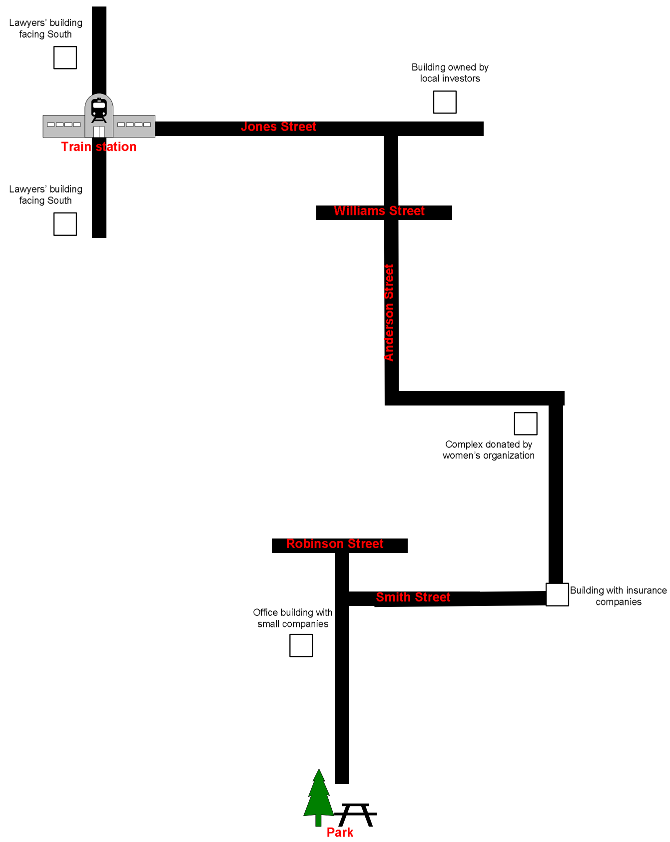


Figure 6. Real sketches of routes used in Experiment 2. (a) Vivid condition. (b) Non-vivid condition

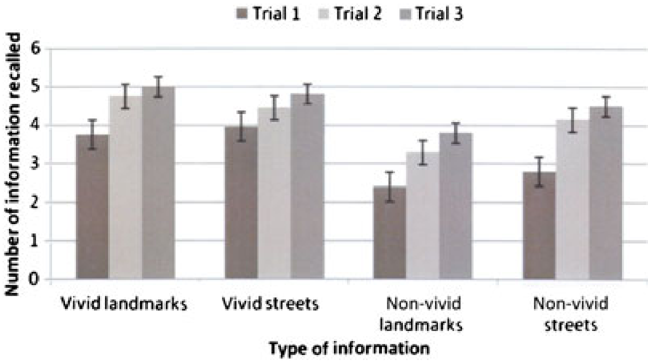


Figure 7. Number of information recalled for each trial, each description and each type of information in Experiment 2

Table 3. Examples of route directions freely recalled in Experiment 2

	Vivid condition	Non-vivid description
Series of instructions	1. Leave the park and go straight down the path that leads to the hospital	• Take the path from the park to Robinson Street and go straight
	2. You will encounter a stony, bumpy path on your left; take this path, turn left	• You will come to an office building of small companies, and Smith Street will be on your right
	3. On your right there will be a church and also a road; take this road, turn right	• Go right
	4. Follow this path to the end until you reach a green horse pasture; there will be a road to your left surrounded by green country cottages; take this road, turn left, make another left	• The road ends at an insurance company building
	5. You will encounter a movie theater on your right, turn right onto a road next to it	• Go left
	6. You will pass through a market	• When you reach a building donated by the women's association, go left
	7. After the market, there will be a steep slope to your right with a path leading down it; take this path, turn right	• Go right on Anderson
	8. There will be a school on your left; turn left	• Go left on Jones
	9. Past the school, there is a road with ornate lights (lampposts)	• The station will be in front of you with a lawyer's building that faces south next to it
	10. The station is on this road that you will encounter by going straight	
Compact text	You start at the park. There is a path leading straight out of the park, towards the hospital. Before you reach the hospital, you will come to an intersection. On your left is a dirt road, and on your right is a church. Turn right by the church. Follow this path straight until the end of the road. At the end of the road, it turns into a path through a pasture, turn left here. Follow the road until you come to a road on your left which is surrounded by small cottages. Turn left at that road. Follow it until you come to a theater on your right. Turn right at the theater. Go straight on this road. You will come to a market. Continue to go straight. You will come to an intersection. On your right is a road going steeply downhill. On your left is a school. Turn left at the school. Follow this road straight until you come to the station. Near the station you should see some old-fashioned lamp posts on either side of the road	Start at the park. Walk straight ahead to Robinson St. On your left you will see an office building with small companies. On your right you will see Smith St. Turn right. Continue on Robinson. It will dead end in front of an office complex. At the end of the road, at the dead end, go left. On your left you will see a building that was donated by a women's organization. Go left, continue walking. On your right you will see Anderson Street. Turn right. Ahead, you will see Williams Street. Continue walking. On your left you will see Jones Street. Turn left. Continue walking ahead. The station will be in front of you next to a lawyer's corporation. The station faces south

out on the same dependent variables as previously, with the addition of one of the imagery measure.

On the whole, participants high on any of the imagery measures read the descriptions more quickly. We found that MRT+ participants needed 565.23 milliseconds to read an instruction ($SD = 287.26$), whereas MRT− participants needed 817.79 milliseconds ($SD = 348.10$): $F(1,36) = 6.53$, $p < .05$. The same pattern appeared with the MT: MT+ participants needed 571.43 milliseconds to read an instruction ($SD = 294.50$), whereas MT− participants needed 804.91 milliseconds ($SD = 357.43$): $F(1,32) = 4.82$, $p < .05$. Finally, VVIQ+ participants needed 563.52 milliseconds to read an instruction ($SD = 202.36$), whereas VVIQ– participants needed 838.76 milliseconds ($SD = 406.50$): $F(1,31) = 6.49$, $p < .05$. In addition, participants high in mental rotation had better recall of the low vivid description after the first trial, as stated by the *post hoc* Tukey test ($p < .05$).

Gender differences

There were no differences between men and women on speed of reading [$F(1,36) = 1.24$, $p > .05$]. Men ($M = 10.57$, $SD = 1.30$) recalled more items of the non-vivid description than women ($M = 9.27$, $SD = 2.97$): $F(1,36) = 4.26$, $p < .05$. Tukey *post hoc* test also revealed that men ($M = 0.79$, $SD = 0.27$) located items better than women ($M = 0.70$, $SD = 0.16$) after the second ($p = .05$) and third trials ($p < .0005$) for both descriptions.

Discussion

In the present study, participants read either vivid or non-vivid route instructions consisting of landmarks and paths. Vivid streets and landmarks were remembered better than non-vivid, consistent with previous research (Paivio, 1990). Those higher on imagery had a dual advantage: they read spatial descriptions faster, and they remembered them better. This finding suggests that those higher in imagery establish mental models from descriptions both more quickly and more accurately than those lower in imagery. In addition, there was a slight advantage to streets over landmarks. This may be because the pattern of streets provided a more complete mental framework for the route than point-like landmarks. The streets allow one to build a mental model of a route based on a network of connected paths, whereas landmarks can be seen as a series of dots which have to be progressively interconnected in order to form a route.

There were gender differences in recall but only for the non-vivid descriptions, which are harder to memorize. In that case, men recalled more information than women. Making the information vivid benefited both genders and eliminated any differences. Men were also slightly better at globally locating information than women. These differences are consistent with some previous research, but it must be remembered that there are other studies that do not find gender differences (e.g. Halpern, 2000; Voyer, et al., 1995; Wolbers & Hegarty, 2010).

GENERAL DISCUSSION

Despite advances in technology, sometimes people simply need to remember something by relying on their own unaided minds. One familiar case is asking directions to find one's way. Remembering route instructions can be challenging, as the sheer quantity of information may tax working memory. Crafting more memorable instructions should help. What makes route directions memorable? The present studies have found that vividness is key. People remember directions better when streets and landmarks are given vivid descriptions than when streets and landmarks are described non-vividly. In the present research, we showed that when streets are described vividly, they are remembered better than landmarks; a previous study had shown that when landmarks are described vividly, they are remembered better than streets (Tom and Denis, 2004). Here, we found that route directions in which both streets and landmarks are vivid are remembered better than route directions in which streets and landmarks are not described vividly. Thus, vividness increases memory for routes, just as it increases memory for paired associates and lists (e.g. Paivio, 1990). The benefits of rich visual imagery extend to individual differences in imagery ability. Those high in mental imagery both read route descriptions faster and remember them better. Presumably, it is easier for those high in mental imagery to form visuospatial mental representations. Men, who typically are better at mental rotation, outperformed women when the descriptions were not vivid. When streets and landmarks are not vivid, comprehension and memory rely primarily on spatial information. Importantly, gender differences disappeared for vivid descriptions. The vivid descriptions contained rich visual information, and women are not at a disadvantage for visual information. Together, the results indicate that vivid visual information and vivid mental imagery facilitate spatial memory and thinking. Why might this happen, that is, why does the visual augment the spatial?

One way to cope with the cognitive overload that route directions can impose is to form mental models of the routes from the directions. Mental models are compact integrations, in this case, of lengthy verbal texts. Forming mental models in the case of route directions requires understanding a variety of kinds of information, spatial information, perspective changes, visual information and more, and integrating those multiple kinds of information into a coherent and complete representation (e.g. Lee & Tversky, 2005; Tversky, 2005). Routes are composed of nodes—landmarks—and paths—streets—between them, where the paths have directions from the nodes (e.g. Denis, 1997a, b; Tversky & Lee, 1998, 1999). The structure of a mental model of a route maps the sequence of nodes and the directions of the paths from the nodes into a spatial structure. Forming and connecting the links between the nodes and the paths and their directions, that is, constructing a mental model, requires establishing a spatial structure and associating the specific information, in this case, about streets and landmarks to it. Associative learning is facilitated by vivid visual information (e.g. Paivio, 1990). Thus, forming spatial mental models has at least two components: spatial thinking and associative connections.

These findings, that the visual promotes the spatial in forming mental models and remembering route instructions, illustrate more general phenomena in memory. First, they highlight the flexibility of memory, that mental representations can be established in different ways. Spatial structure and associative learning both contribute and are, to some extent, compensatory. Because of this flexibility, the advantage that men have in constructing mental spatial frameworks is eliminated when the elements of the spatial structure are vivid. These findings should also apply to learning routes from experience. Both verbal and experiential situations require forming mental models of the routes and mapping landmarks and streets and the directions between them, tasks that draw on both spatial and associative information. The finding that the visual and the spatial interact in the formation of mental models and that vividness of descriptions of streets and landmarks promotes memory for routes also has practical implications. It exhorts designers of directions, for routes certainly but most likely also for other kinds of instructions and explanations, to make descriptions vivid, perhaps even at the expense of greater length of description. Finally, the findings that the spatial, that is, the structure, and the visual, that is the specific content, interact in memory and that the visual supports the spatial have general implications for learning and memory. The conclusions apply to learning a range of other kinds of things, such as how things work and how to work things, in short, to anything that involves learning about structure and learning about behavior, process or causality, anything that involves integrating some sort of conceptual structure with specific content.

ACKNOWLEDGEMENTS

These data were collected while the first author was a post-doctoral fellow at Stanford University, CA, USA, under Grant # 9860830050 from the Délégation Générale de l'Armement (DGA) of France. The support of the following NSF grants for preparation of the manuscript is gratefully acknowledged: IIS-0725223, IIS-0855995, IIS-0905417, and REC-0440103.

REFERENCES

Allen, G. L. (2000). Principles and practices for communicating route knowledge. *Applied Cognitive Psychology*, *14*, 333–359.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers*, *25*, 257–271.

Collins, R. L., Taylor, S. E., & Wood, J. V. (1988). The vividness effect: Elusive or Illusory? *Journal of Experimental Social Psychology*, *24*, 1–18.

Denis, M. (1997a). The description of routes: A cognitive approach to the production of spatial discourse. *Current Psychology of Cognition*, *16*, 409–458.

Denis, M. (1997b). *Langage et Cognition Spatiale*. Paris: Masson.

Denis, M., Pazzaglia, F., Cornoldi, C., & Bertolo, L. (1999). Spatial discourse and navigation: An analysis of route directions in the city of Venice. *Applied Cognitive Psychology*, *13*, 145–174.

Fernandez, G. (1999). Aspects différentiels dans la compréhension de descriptions spatiales. In M. Huteau & J. Lautrey (Eds.), *Approches différentielles en psychologie* (pp. 155–161). Rennes: Presses Universitaires de Rennes.

Frey, K. P., & Eagly, A. H. (1993). Vividness can undermine the persuasiveness of messages. *Journal of Personality and Social Psychology*, *65*, 32–44.

Gale, N., Golledge, R. G., Pellegrino, J. W., & Doherty, S. (1990). The acquisition and integration of route knowledge in an unfamiliar neighborhood. *Journal of Environmental Psychology*, *10*, 3–25.

Halpern, D. (2000). *Sex differences in cognitive abilities*. Mahwah, NJ: Erlbaum.

Katz, A. (1995). What we need is a good theory of imagery vividness. *Journal of Mental Imagery*, *19*, 143–146.

Lee, P. U., & Tversky, B. (2005). Interplay between visual and spatial: The effect of landmark descriptions on comprehension of route/survey spatial descriptions. *Spatial Cognition and computation*, *5*, 163–185.

McKelvie, S. J. (1995). The VVIQ as a psychometric test of individual differences in visual imagery vividness: A critical quantitative review and plea for direction. *Journal of Mental Imagery*, *19*, 1–106.

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology*, *64*, 17–24.

Marks, D. (1983). Mental imagery and consciousness: A theoretical review. In A. Sheik (Ed.), *Imagery: Current theory, research, and application* (pp.96-130). New York: Wiley.

Mani, K., & Johnson-Laird, P. N. (1982). The mental representation of spatial descriptions. *Memory & Cognition*, *10*, 181–187.

Michon, P.-E., & Denis, M. (2001). When and why referring to visual landmarks in direction giving? In C. Freska & D. M. Mark (Eds.), *Spatial information theory: Cognitive and computational foundations of geographic information science* (pp. 292–305). Berlin: Springer.

Money J., Alexander D., & Walker H. T. (1965). *A standardized road map of directional sense*. Baltimore: Johns Hopkins Press.

Paivio, A. (1990). *Mental representations: A dual-coding approach*. Oxford: Oxford University Press.

Shedler, J., & Manis, M. (1986). Can the availability heuristic explain vividness effects? *Journal of Personality and Social Psychology*, *51*, 26–36.

Talmy, L. (1983). How language structures space. In H. L. Pick, Jr. & L. P. Acredolo (eds.). *Spatial orientation: Theory, research, and application*. New York: Plenum Press.

Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language*, *31*, 261–292.

Tom, A., & Denis, M. (2004). Language and spatial cognition: Comparing the roles of landmarks and street names in route instructions. *Applied Cognitive Psychology*, *18*, 1213–1230.

Tversky, B. (2005). Visuospatial reasoning. In K. Holyoak & R. Morrison (Eds.), *The Cambridge handbook of thinking and reasoning* (pp. 209–241). Cambridge: Cambridge University Press.

Tversky, B., & Lee, P. U. (1998). How space structures language. In C. Freksa, C. Habel & K. F. Wender (Eds.), *Spatial Cognition: An interdisciplinary approach to representation and processing of spatial knowledge* (pp. 157–175). Berlin: Springer-Verlag.

Tversky, B., & Lee, P. U. (1999). Pictorial and verbal tools for conveying routes. In C. Freksa, D. M. Mark (Eds.), *Spatial information theory: cognitive and computational foundations of geographic information science* (pp. 51–64). Berlin: Springer.

Vandenberg, S. J., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, *47*, 599–604.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*, 250–270.

Wolbers, T., & Hegarty, M. (2010). What determines our navigational abilities? *Trends in Cognitive Science*, *14*, 238–246.

