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The Effect of Instructions on Landmark, Route, and Directional Memory for Active vs. Passive Learners of a Virtual Reality Environment

by

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To my parents, for their support throughout this endeavour.

Abstract

In two experiments, subjects either freely walked around a virtual building or watched a recording made made by a matched (free walk) subject. Subjects then performed several tasks: judgment of relative direction, scene recognition and navigation back to the start. The aim was to evaluate the the relative sensitivity of these measures, and to compare learning in active and passive learners under implicit (Experiment 1) and explicit (Experiment 2) learning instructions. Results demonstrated an advantage for active learners in the navigation back to start task and no difference in the judgment of relative direction task under both implicit and explicit conditions. In the recognition task, performance was above chance levels for all factorial cells. A gender moderated trend for an advantage for active learners was found only in implicit learning.

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Learning to navigate and remember locations in a new environment of various scales is an important skill for all animals and a frequent occurrence in everyday life, whether it is learning the layout of a new office building in a new job, moving to a new city and navigating its roads, or remembering the location of a new food source. Navigating in familiar environments, but under unusual conditions like fire evacuation, when there may be less information available (e.g., due to smoke) or when normal cognitive processes are disturbed by the stress of the situation, can also be a challenge. Models and theories of spatial information acquisition might enable improvements of these processes and make them more efficient. In the two experiments reported here, we examined how different ways of presenting spatial information can affect the efficacy with which people can learn and then remember a new environment and how different testing methods may be more or less sensitive to that learning.

As it happens, most of the current literature on navigation assumes that people learn their environments while they are freely walking around them. This idea is commonly found in the very first paragraph of multiple articles. For example, "People generally acquire environmental spatial knowledge through direct experience by locomoting through an environment or by viewing a map." (Richardson, Montello, & Hegarty, 1999, p. 741), "[knowledge about their new surroundings] consists of … memory for traveled routes" (Waller, Loomis, & Steck, 2003, p. 987), and "As people act in the environment, they … acquire knowledge about it. … People use spatial knowledge of the environment to get to destinations ….” (Ishikawa & Montello, 2006, p. 94). In contrast, however, experiments in spatial cognition, including learning of novel environments, are almost exclusively conducted via showing people prerecorded movies of navigation or guiding them along particular pathways (Cornell et al., 1989; Ishikawa & Montello, 2006; Montello, Lovelace, Golledge, & Self, 1999; Richardson et al., 1999; Ruddle et al., 1997; Shelton & McNamara, 2004; Waller, Loomis, & Haun, 2004). Thus, a large gap exists between what researchers are attempting to learn about "natural" learning via navigating and the methods used to have subjects acquire the learned information.

Thus, the main goals of the project were, first, to compare the performance of subjects who were free to walk around a virtual environment with those who were passively shown the same (matched) environment. Second, we wanted to compare the efficacy of several measures of memorial accuracy. The measures we used were judgments of relative direction (JRDs), scene recognition, and finding one's way back to the start of the path. Third, we wanted to compare implicit vs. explicit learning instructions. Clearly, we expected that explicit instructions should produce better learning than implicit instructions, but the interesting question is whether an active-passive difference will be found under both or one of the learning conditions in some or all of the measures.

The rationale for the experiments reported is based on the variety of methods and designs described in previous literature. Even though active (self-directed; free – these terms refer to the same idea and will be used interchangeably, as will passive and guided) exploration may be considered to be the most common form of learning an environment, a comparison between the two modes has never been done in the same fashion as in this project. We focused first on active vs. passive learning because, as noted, studies on spatial cognition most frequently present information in a predetermined, passively viewed sequence . For example, Cornell et al. (1989) had their subjects follow the experimenter for a walk across a university campus before asking them to find the way back. Although this manner of presentation is beneficial in making sure that the entire environment is the same for all subjects, it is possible that there are differences in what is learned between this mode versus the free exploration of an environment, which is more similar to real-world situations in which people are usually free to walk where they please, and are able to stop and look around if they choose to do so.

The operational definition of active and passive exposure to an environment has differed substantially. For example, it was only very infrequently that subjects were allowed to freely walk around the environment being learned (Taylor, Naylor, & Chechile, 1999). However, in this study there was no comparison or intentional definition of passive or active learning. The focus was on identifying factors which influence representation of spatial perspective and the subjects were asked to either remember the layout of the building or the fastest routes between locations from either a map or by navigation.

In another case, subjects were following an experimenter's directions; this situation was defined as active exploration even though the path was predetermined (Wallet, Sauzéon, Rodrigues, & N'Kaoua, 2008). Passive learning has been defined (or created, when comparison of active and passive learning was not an explicit goal) by watching a movie (Shelton & McNamara, 2004); following an experimenter is also an option that has been used (Richardson et al., 1999). Christou & Bülthoff (1999) compared active learners who were controlling their movement and passive learners who watched a recording of the active learners' exploration, but movement and viewing angles were restricted in this virtual environment. Participants could only move forward and backward without turning, and their movement was constrained to one narrow walkway.

Wilson, Foreman, Gillett, & Stanton (1997) compared active and passive learning while allowing their active subjects to freely move around and found no differences. However, their subjects had an explicit goal of becoming familiar with the environment, the computer generated environment could not have had a high degree of realism due to technological limitations (the importance of this is discussed in the Method section), and in one of the experiments, a highly unnaturally structured environment was used. That environment had a single large room with several walls only wide enough to hide cube targets placed behind some of them. The experiment with the unnatural environment was also the only one of the two reported in which an actual wayfinding measure of finding previously observed objects was employed. No differences were found between active and passive learners.

Wilson (1999) also compared active and passive learning, but his participants had an explicit goal of only remembering the objects, and memory of the objects out of context was used to compare the active and passive groups, thereby creating an unnatural testing environment. In the real-world, environments and their objects do not typically get separated. Thus, this was not a test of navigation per se. One might suggest that the scene recognition task employed in our studies is a similar measure, however, in our experiments the objects were displayed as part of the scene that would be viewed in the environment. We chose implicit learning for the first experiment because it has been demonstrated that having different explicit spatial learning goals can produce different outcomes in measures used for assessing route knowledge (Taylor et al., 1999). It is thus possible that the findings in Wilson's (1999) experiment are not indicative of the differences that may be caused by an active vs. passive mode of presentation in a navigation task.

Chrastil & Warren (2012) conclude, after a literature review, that “[there is] little support for a role of decision making in spatial learning.” (p. 5), however, none of the reviewed studies compared active and passive learners in the same way as we did, with truly free and passive participants using a navigation task in a structurally realistic environment. Therefore, this project's results could either confirm or disprove this assertion.

The distinction between route and survey knowledge is frequently made in the navigation literature (Carlson, Hölscher, Shipley, & Dalton, 2010; Richardson et al., 1999; Ruddle, Payne, & Jones, 1997; Shelton & McNamara, 2004; Thorndyke & Hayes-Roth, 1982). Route (ground-level) knowledge includes sequences of walking, straight lines, turns, landmarks and specific ways to get from one point to another that is acquired from actual experience in the environment. In contrast, survey knowledge represents the environment in a top-down view fashion and includes map-like information, such as the spatial arrangement of the environment components like rooms and hallways. This knowledge can be acquired by studying a map or it can be generated from ground level experience (Thorndyke & Hayes-Roth, 1982). While movies showing top-down views and maps are used for survey perspective presentation, neither allows for a direct comparison between active and passive learning; movies allow only playback of a particular route, and it is not obvious how to create a match between active and passive learning with maps, because unlike with navigation, there is no route to record when subjects are exposed to a map. Thus, both the free exploration group and the guided-tour group learned their environments from the ground level.

Our second goal was to test the validity of several different measures of navigational learning. Testing of route (ground-level) learning in a navigational task has been done in multiple ways: estimates of route distances (Richardson et al., 1999; Taylor et al., 1999; Thorndyke & Hayes-Roth, 1982), scene recognition of images taken from a ground level perspective (Shelton & McNamara, 2004) and an actual navigation task (Cornell et al., 1989; Newman et al., 2007; Peruch, Vercher, & Gauthier, 1995). We tested the hypothesis that even with "only" ground-level presentations, some testing methods may have more ecological validity and sensitivity to learning than others.

We chose to compare tasks such as scene recognition and JRDs to the time taken to find the way back to the beginning of the route, and the distance traveled while doing so. The reasoning was that being able to find one's way back is closer to real-world behavior than other measures that have been used and may thus provide insight into the suitability of these other measures for assessing spatial knowledge. For example, with explicit scene or landmark recognition tasks, even if landmarks are used as part of navigation, testing navigation and testing landmark memory per se are still different procedures. Similarly, while JRDs may assess survey knowledge, and such knowledge may be used in navigation, remembering only the aforementioned constituents of route knowledge would be sufficient for navigation. It is thus possible not to have any survey knowledge (and, therefore, possibly not perform well in a JRD task) all the while being able to navigate perfectly well. We used two measures that are common in the literature as comparison measures. The first, scene recognition, has been used to assess both route and survey knowledge; it requires subjects to decide whether or not a static image they are viewing comes from the environment they have learned (Allen, Siegel, & Rosinski, 1978; Christou & Bülthoff, 1999; Shelton & McNamara, 2004; Shelton & Pippitt, 2007). The second task to be compared to the time and distance to find one's way back is JRDs. This measure has been used to test survey knowledge by asking subjects to determine the direction in which an unseen object is located in the environment (Jansen-Osmann, Schmid, & Heil, 2007; Luo, Luo, Wickens, & Chen, 2010; Marchette & Shelton, 2010; Richardson et al., 1999; Ruddle et al., 1997). However, we included it in the present ground-level study because previous research has shown that ground-level exposure does lead to survey knowledge formation (Christou & Bülthoff, 1999; Ruddle et al., 1997; Thorndyke & Hayes-Roth, 1982), and in fact, performance on this measure may not differ between survey and ground-level exposures when pointing is done on the same floor of a building (Richardson et al., 1999).

The third variable of interest was the degree of explicitness given in the learning instructions, which can vary greatly between designs. Subjects may be told exactly what the test task is going to be (Peruch et al., 1995; Spetch, Kelly, & Lechelt, 1998), told in general terms that their memory is going to be tested (Shelton & Pippitt, 2007; Wilson, 1999), tested to make sure that they remember a setting before proceeding with the experimental measures (Mou, McNamara, Rump, & Xiao, 2006; Shelton & Marchette, 2010; Thorndyke & Hayes-Roth, 1982), or not told at all that there will be a task to test their memory (some conditions of Cornell et al., 1989). In one of the present experiments subjects were not told that their memory would be tested, and in the other subjects were told that their memory of the building is going to be tested, and that they should try to remember as much of it as possible. Thus, we covered two options on opposite ends of the continuum: not telling subjects that they will be tested at all in the first experiment, and asking them to remember as much as they can in the second (see Method section for details)

The final variable we addressed is gender. We matched for gender across conditions because a large amount of research exists on gender differences in spatial abilities. In most cases, males perform better; in others no difference is found, and on some measures females have an advantage (Montello, Lovelace, Golledge, & Self, 1999). Montello et al. (1999), also state that "The evidence for sex-related differences is much stronger in studies that have examined environmental spatial knowledge acquired as part of the study, particularly when based on direct locomotor experience" (p. 517). Finally, these authors have found some gender differences in the guided learning task they used. To examine potential differences we recruited an equal number of males and females, and they were matched for gender in the active and passive conditions. That is, persons of the same gender either self-navigated or watched a movie of the same particular route.

In both experiments we used a desktop virtual environment. It has been shown that acquisition of survey and route knowledge from virtual environments can be similar to real-world situations (Ruddle et al., 1997), at least when the environment has one level, as opposed to a building with multiple floors (Richardson et al., 1999), and that the absence of inertial cues does not negatively affect the acquisition of spatial knowledge (Waller et al., 2003). Conversely, (Waller, Loomis, & Haun, 2004) did find some differences between subjects who were guided in a real environment and those who watched a recording, but the effect was "relatively small [in] magnitude" and did not extend to all measures used (p. 162). The difference between active and passive learning has also been found in a correlational study to load on two different factors (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). In addition, in that study, outcomes for passive learning through real-world navigation, video recordings and virtual environments were grouped into two factors, separating real-world experience from the other presentation methods. However the design was intended to support a correlational analysis and no direct comparisons were made. In addition, a different environment was used for each of the presentation methods and the measures utilized were those used for survey-testing type. Overall, it seems that virtual environments can be used to reach conclusions that would apply to real-world situations. With this in mind we used a VR system due to the greater flexibility in stimulus creation, modification, and presentation it offers.

Because our navigation task was not previously reported in the literature, our hypotheses were that an effect of type of exploration group (active vs. passive) could still be found, contrary to previous finding, with navigation task measures (time and distance traveled back to the beginning) being better in the self-guided group. Because of the differences in how active and passive learning were operationally defined, an effect could still be found for JRDs or scene recognition measures as well, even though the literature predicts no such findings. Relatively better performance for the explicit group was to be expected.

Method

Both experiments had nearly identical procedures and stimulus materials which will be described in full under Experiment 1's method section. Experiment 2 section will include only the relevant differences.

Experiment 1 – Implicit Learning

Subjects. There were 131 undergraduate volunteers from the University of Alberta's psychology subject pool who took part in the experiment in return for partial course credit. Seven females were excluded due to becoming light-headed during one of the phases. Three females and four males were excluded because they finished the free exploration task at the starting point (we had decided upon this exclusion criterion a priori). Data from three additional subjects (one male and two females) were not analyzed due to experimenter error in their collection. Two subjects (one male and one female) misunderstood the instructions and their data was excluded as well. This left 28 males and 28 females in the active condition, and 28 males and 28 females in the passive condition (mean age 19.44, SD 4.05). The group for each subject was randomly assigned, provided that there was a free exploration group subject without a matched counterpart from the guided-tour group of the same gender. Otherwise, the group assigned was free exploration (because assignment to guided-tour group required a non-matched counterpart from the free group). Thus, assignment to groups was quasi-random.

Design, stimuli and procedures. Results of previous studies of navigation may have been affected by the visual realism of the environment which can be compromised due to technological limitations (e.g., when virtual environments are used); 3D engine limitations may cause pixelization in some studies (Richardson et al., 1999), or a photorealistic display may be generated, but with a low frame rate (Farrell et al., 2003), causing a display that is somewhat choppy. Realism of structure and complexity can vary from high (Newman et al., 2007; Richardson et al., 1999) to low (Jansen-Osmann et al., 2007). Lower visual complexity and fidelity has been shown to affect the recognizability of objects (Watson, Friedman, & McGaffey, 2001). In contrast, the software we used (Half Life 2, Valve, Bellevue, WA) was capable of presenting environments at a high frame rate and with no pixelization and the simulated environment was adapted from a real building (see Figure 1).

Two groups were defined for the experiment: those who were permitted free exploration of the VR environment and those who were “given” a guided-tour. The procedure for the free exploration group was as follows: Subjects were seated in front of a PC system that was running a custom modification of the Half Life 2 video game (Valve, Bellevue, WA) simulating first-person view of custom environments. The first environment seen by this group included only two rooms connected by a corridor and was used to allow familiarization with the navigational controls on the computer’s keyboard and mouse. Translation forward and backward was controlled with the 'w' and 's' keys, respectively. Pitch rotation was controlled by moving the mouse up or down, and yaw rotation was controlled by moving the mouse left or right. Subjects learned the controls within the first environment and after demonstrating the ability to move from one room to the next and back without hesitation in a smooth fashion (judged subjectively by the experimenter), proceeded to the experimental environment. Instructions were given at this point to walk around the building simulated in the next environment and get an impression of its aesthetic properties. In particular, subjects were instructed that we were working with an architectural group to try to understand the ways that people appreciate spaces of varying size, and to "spend the next 10 minutes exploring each of these rooms and getting an aesthetic sense of how you feel about the space in general". They were told we would question them about the spatial aesthetics afterwards. This experimental map included 9 rooms (see Figure 1 for a floor plan) and was was adapted from part of the 1857 Toronto Normal and Model Schools floor plans (Archives of Ontario, n.d.). The starting point was always the same, and an internal timer indicated the end of the 10 minutes allocated for this exploratory part of the experiment. The sequence of movements throughout this phase were recorded so that they could be used for the same gender matched guided-tour subject. The free or guided exploration was followed by a recognition task. In the 9-room map, 27 unique everyday objects such as furniture and plants were placed so that from each doorway at least two different objects were visible. The Source game engine (Valve, Bellevue, WA) we used was customized to track the subjects' position as they were walking around the map which allowed for a generation of a list of doorway views to test.

For each doorway, a screen shot (see Figure 2 for a sample) was taken ahead of time in the real 9-room map, as well as in a distractor map in which the objects seen from each doorway switched places (only their arrangement was changed; the objects stayed the same). Both the “real” and “switched” scenes were used in the recognition task (see below). This type of “switch” distractor manipulation is similar to that used by Shelton and McNamara (2004) and many others (e.g., Friedman & Waller, 2008). After subjects had finished their 10 minute exploration, they were told that they would be viewing images from the building they had just seen, and the task in this phase was to decide whether the objects’ arrangement had changed. Each subject was tested only from doorways that they had actually navigated through (or watched). Response data collection and screen shot presentation from both the real and distractor maps for each tested view were conducted using E-prime (Psychology Software Tools, Pittsburgh, PA). For each trial, there was a fixation point for 500 ms, then either a stimulus or its distractor appeared, and remained on the screen until the subject responded. All subjects but one visited all 9 rooms; the range of target stimuli shown on the recognition test was between 4 and 19 (the only subject that did not visit all 9 rooms had 4 target stimuli; the next lowest number was 10). This range results from there having been some rooms with more than one entrance, and therefore a single room could have been used in more than one screen shot.

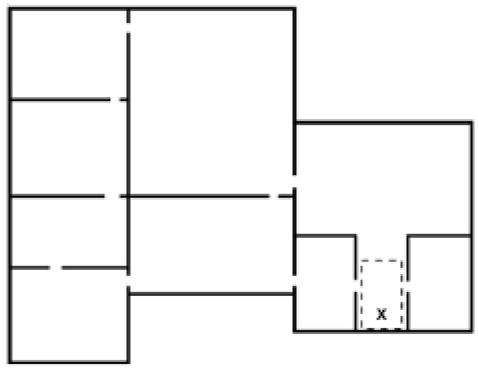

Figure 1. Floor plan of the experimental map. X marks the starting point. We do not consider the hallway were the starting point is located to be a room. Dashed rectangle marks the JRD acceptance region (see Method section).

At this point, to keep the experimental procedure as similar as possible for the two groups, subjects in the free exploration group were put back into the two-room training environment. The reason given was that this is to make sure they remember how to control movement and they were asked to demonstrate this by moving between the two rooms again. In the guided-tour group this was the phase when subjects familiarized themselves with the movement controls for the first time.

Subjects were then returned to the 9-room map to the exact position they were in when the 10 minute timer had run out. They were asked to first turn towards and then walk to where they had originally begun their exploration of this map. The first measure was their JRD, and the second was used to generate distance and time measures of the navigation task. If a mistake was made in identifying the starting location, another attempt could be made (although no feedback was given beyond informing the subject that he or she was mistaken). A limit of 5 minutes was set for this part. Note that setting this limit decreases the chances of finding differences between groups on this measure.

The procedure for guided-tour group was almost identical to that of the active exploration group, but differed in that at first, instead of going through movement control training, each subject in this group viewed the recording of the movements of the matched subject from the free exploration group. However, they were given identical instructions as to their goal. The game engine renders screen output for such recordings in exactly the same way it does during actual movements. Subjects from both groups were therefore exposed to the identical information on the screen, which is significant because view matching for active and passive learners is important when attempting to study any potential differences between these two groups (Chrastil & Warren, 2012). Exactly as in the case of free exploration, there was then the scene recognition task, followed by pointing (JRD) and navigation to the beginning from the same location where the recording had ended. This was equivalent to the matched free exploration subject's location at this experimental stage.

Figure 2. Sample screen shot used in the recognition task.

Experiment 2 – Explicit Learning

As described above, this section will only include details that differ from Experiment 1.

Subjects. There were 140 undergraduate volunteers from the same source as in Experiment 1 who took part in the experiment in return for partial course credit. Twelve females and two males were excluded due to becoming light-headed during one of the phases. Three females and three males were excluded because they finished the free exploration task at the starting point (we had decided upon this exclusion criterion a priori). Data from four additional subjects (three male and one female) were not analyzed due to experimenter error in their collection. Four subjects (one male and three females) misunderstood the instructions and their data was excluded as well. This left 28 males and 28 females in the active condition, and 28 males and 28 females (mean age 19.03, SD 1.44) in the passive condition.

Design, stimuli and procedures. Unlike in Experiment 1, both active and passive groups had keyboard and mouse controls practice in the very beginning of the experiment. Because in this experiment learning was explicit, creating suspicion about learning controls was not a concern. After controls training, subject proceeded to the experimental environment.

Instructions were given at this point to either walk around the building (free exploration group) or watch a recording (guided-tour group) and to try and remember as much as possible in anticipation of some memory tests. The instructions have thus explicitly mentioned memory tests, but did not tell the subjects what kind of memory tests to expect.

Subjects were not told what exact measures are going to be used for two main reasons. First, the main measure is time and length of navigation back to start. If subjects were told that ahead of time, they might have modified their exploration of the environment to help them perform this specific task; it might have therefore disadvantaged JRD and recognition performance. Second, if subjects were told about scene recognition and JRD tasks only, that would have given an extra advantage to these two tasks over the main task of navigation, thus making the comparison that was one of the goals of this study less meaningful.

Even if some subjects assumed that a test of their memory of the building would include having to navigate in it, this alone should not have given an advantage to any single test task of the ones we used, because they would have not known that one spot of the building was going be the target - all areas and their contents were likely to receive equal attention.

For the recognition task in this experiment, the range of target stimuli was between 11 and 19 as all subjects visited all rooms. After the recognition task, both groups went through second control training. This differs from the first experiment where for the guided-tour group, this was the phase where subjects first learned the controls.

Before proceeding to begin testing in the 9-room map, subjects went through a stage that was unique to Experiment 2. Subjects in the free exploration and guided-tour groups controlled movement in the virtual environment for different amounts of time before being tested. Both groups undergo training twice, but only subjects in the free exploration group explore the environment for ten minutes using the same manual controls. While many subjects were already familiar with the controls as evidenced by how easily they were able to move from the first moment of training, we added an extra stage to verify that any differences found between the two groups in testing could not be attributed entirely to different amounts of practice.

Such differences could have two sources – better memory of the environment and better ability to control movement. We created a simple environment which consisted of one long corridor with multiple turns. Going through this corridor required no memory at all; one simply had to keep moving forward. Subjects from both free exploration and guided-tour groups were asked to walk through this corridor before beginning the testing phase in the 9-room map. By comparing the times of the two groups, we were able to rule out that all of the difference between the two groups in the testing phase was caused by different amounts of control practice.

Results

Experiment 1 – Implicit Learning

Data analyses and scoring. We adopted a significance level of $p < .05$ for all analyses, and partial eta squared (η_p^2) or Cohen's d as the measures of effect size. Accuracy (percent correct) and d' data from the recognition task were analyzed with a 2 x 2 between subject ANOVA: group (free, guided) x gender (male, female). Additionally, we tested each level combination (e.g., free exploration females, guided-tour males) with the null hypothesis of recognition being equal to 0.5 by the means of a single mean unidirectional t-test to verify that performance was above chance.

Angular error of the pointing task (JRD) was approximated, based on the smallest error in pointing relative to a small rectangle defined around the starting point (see Figure 1), rather than using the exact starting point as a reference. In other words, a small tolerance for error was introduced and subjects could be off by a few degrees and still have their error count as 0º. This was necessary because had a single exact location been used, the resulting error could be different for two subjects pointing to the same spot but from different distances. Because the direction of error was not considered to be of significance, absolute values of pointing errors were entered into the above ANOVA design.

A time-based measure of navigation performance was computed based on the ratio between the time taken to find the starting point (or time spent looking for it, in those cases where subjects were unable to correctly identify it before time was up) by each subject in the guided-tour group relative to his or her counterpart in the free exploration group. To the extent that this ratio is more than 1.0, the free exploration group was finding the starting point faster. It was not possible to use the absolute value of each subject's actual time due to different distances from the starting point for each free exploration – guided-tour subject pair, making a direct comparison of times meaningless. The same logic applies to distance traveled while looking for the starting point, therefore a ratio was calculated for this measure as well. These distance traveled and time to find the starting point ratios were tested using a single mean unidirectional t-test, separately for each gender, with the null hypothesis that the ratio would be equal to 1.0. The experimental hypothesis was that guided-tour group subjects were expected to perform less well, and thus have higher times and travel longer distances, resulting in a greater than one ratio. A two-sample two-tailed t-test was also used to compare the two genders in time and distance ratio measures.

Findings. Time ratio analysis (testing ratios being over 1.0) revealed significant results for both males, $t(27) = 3.354$, $p = 0.001$, $d = 0.63$ and females, $t(27) = 3.041$, $p = 0.003$, $d = 0.57$ For distance ratio, similar results were found for both males, $t(27) = 3.124$, $p = 0.002$, $d = 0.59$ and females, $t(27) = 3.230$, $p =0.002$, $d = 0.61$. Since all the ratios were greater than 1.0, it means that the guided group took longer and walked larger distances to find the starting point than the free exploration group. The difference between females and males reached significance only for the distance ratio, $t(54) = -2.057$, $p = 0.045$, $d = 0.55$.

Time		Distance	
Females	Males	Females	Males
3.885	6.507	5.870	16.592

Table 1. *Means of time and distance ratios. Implicit learning.*

No significant main effects or interactions were found in the recognition accuracy analysis, however, the group by gender interaction did show a trend, $F(1, 108) = 3.2$, $p = 0.076$, $\eta_p^2 = 0.029$. Simple effects analysis revealed that the difference between free and guided males showed the same trend, $F(1, 54) = 3.221$, $p = 0.078$, $\eta_p^2 = 0.056$, whereas the difference between free and guided females did not. The t-tests confirmed that recognition was above chance for all level combinations. Free-males, $t(28) = 8.238$, $p < 0.001$, $d = 1.55$; free-females, $t(28) = 9.021$, $p < 0.001$, $d = 1.7$; guided-males, $t(28) = 7.906$, $p < 0.001$, $d = 1.49$; guided-females, $t(28) = 8.245$, $p < 0.00$, $d = 1.56$.

Males		Females	
Free	Guided	Free	Guided
0.738	0.673	0.684	0.706

Table 2. Means of recognition accuracy (percent correct). Implicit learning.

Similarly to recognition accuracy, recognition d' analysis showed no main effects, but the group by gender interaction was borderline significant, $F(1, 108) = 3.730$, $p = 0.056$, $\eta_p^2 = 0.033$. Simple effects analysis revealed that the difference between free and guided males reached significance, $F(1, 54) = 4.072$, $p = 0.049$, $\eta_p^2 = 0.070$, whereas the difference between free and guided females did not.

Males		Females	
Free	Guided	Free	Guided
1.406	0.962	1.048	1.185

Table 3. Means of recognition d' values. Implicit learning.

No pointing error analyses reached significance. This indicates that there was no difference between the groups in their JRDs.

Males		Females	
Free	Guided	Free	Guided
36.045	34.820	32.670	33.975

Table 4. Means of JRD errors. Implicit learning.

Experiment 2 – Explicit Learning

Data analyses and scoring. In addition to repeating the analyses from experiment one, the time taken by the subjects to traverse the corridor was tested using a 2 x 2 between subject ANOVA: group (free, guided) x gender (male, female).

Findings. Time ratio analysis (for ratios being over 1.0) revealed the same pattern of significant results as in the implicit experiment, for both males, $t(27) = 1.904$, $p = 0.034$, d = 0.36 and females, $t(27) = 2.536$, $p = 0.009$, $d = 0.48$. For distance ratio, similar results were found for both males, $t(27) = 1.887$, $p = 0.035$, $d = 0.36$ and females, $t(27) = 2.493$, $p = 0.01$, $d = 0.47$. No differences were found between males and females on either the time or distance measures from the navigation task. Again, however, the fact that the ratios were greater than 1.0 means that on both measures there was an advantage for free exploration.

Time		Distance	
Females	Males	Females	Males
2.068	1.844	2.649	2.518

Table 5. Means of time and distance ratios. Explicit learning.

No significant main effects or interactions were found in the percent correct recognition analysis. Also as before, t-tests confirmed that recognition was above chance for all level combinations. Free-males, $t(28) = 14.049$, $p < 0.001$, $d = 2.65$; free-females, $t(28) = 10.445$, $p < 0.001$, $d = 1.97$; guided-males, $t(28) = 10.977$, $p < 0.001$, $d = 2.08$; guided-females, $t(28) = 17.059$, $p < 0.001$, $d = 3.21$.

Unlike in Experiment 1, analysis of recognition d' showed no significant effects at all.

Males		Females	
Free	Guided	Free	Guided
0.802	0.772	0.785	0.802

Table 6. Means of recognition accuracy (percent correct). Explicit learning.

Males		Females	
Free	Guided	Free	Guided
1.838	1.669	1.785	1.823

Table 7. Means of recognition d' values. Explicit learning.

Only a main effect of gender was found to be significant in the corridor task (which was unique to Experiment 2), $F(1, 108) = 42.057$, $p < 0.001$, $\eta_p^2 = 0.28$. The active/passive main effect showed a trend toward significance, $F(1, 108) = 2.951$, $p = 0.089$, $\eta_p^2 = 0.027$. Even though this effect did not reach significance and has a very low effect size, because of its importance for the interpretation of the navigation task results, it warranted a more detailed look. The mean time to get through the corridor was 65.99 seconds for the free group, whereas for the guided group it was 73.63 seconds. These results do indicate that practice could account for some of the difference between the free and guided participants, in particular for the time ratios. It is important to emphasize, however, that all of the ratios show a difference much larger than that which was found in the corridor task. Namely, the average time ratio across gender is 5.2 under implicit instructions and 1.96 under explicit instructions. These differences are on average about 3 times larger than the approximately %12 difference found in the corridor task.

Males		Females	
Free	Guided	Free	Guided
53.360	57.407	78.619	89.859

Table 8. Means of corridor task completion times.

As in Experiment 1, no pointing error analyses reached significance. This means that there was no difference in pointing error between any groups under explicit instructions as well.

Males		Females	
Free	Guided	Free	Guided
23.285	31.989	50.373	32.945

Table 9. Means of JRD errors. Explicit learning.

Direct Comparison of Implicit and Explicit Learning

The two experiments described have some differences in design (namely, more control practice, and the inclusion of the corridor task in Experiment 2). Additionally, data were collected serially rather than in parallel, with a gap of a few months in between the two experiments. For these reasons, it is not possible to merge the data as though Experiment 1 and Experiment 2 were just two levels of a single factor. Nonetheless, a comparison between implicit and explicit instructions is of great interest. In order to confirm what appeared to be an effect of instructions on the difference between free exploration and guided-tour learners (in other words, different active/passive ratios in Experiment 1 and Experiment 2), and to check for possible gender effects, we decided to perform a 2 x 2 between subject ANOVA: instructions (implicit, explicit) x gender (male, female) on the results from the main task – navigation back to start. The caveat is that an outcome of such an analysis must be treated with caution due to the reasons stated above.

For both time ratios, $F(1, 108) = 10.574$, $p = 0.002$, $\eta_p^2 = 0.089$ and distance ratios, $F(1, 108) = 10.583$, $p = 0.002$, $\eta_p^2 = 0.089$ only the main effects of instruction reached significance indicating a larger active/passive difference under implicit instructions than under explicit instructions (see Table 5).

Time		Distance	
Implicit	Explicit	Implicit	Explicit
5.196	1.956	11.231	2.583

Table 10. *Means of time and distance ratios. Implicit and explicit learning.*

Discussion

Research in navigation most typically utilizes passive methods of information presentation. Showing prerecorded movies or guiding a subject is common. The first goal of this project was to compare performance between two groups - free exploration and guided-tour - as a means of assessing the ecological validity of passive information presentation. Assessing the proper way to accurately measure navigation performance was the second goal of this project. Spatial learning in navigation is assessed in multiple ways. Most of these measures are different - at least on the surface - from the typical use of spatial information in real-world situations, which is simply finding one's way in the environment. Finally, both of these comparisons were performed with subjects whose learning was implicit (Experiment 1) and explicit (Experiment 2).

The results were compatible with our hypotheses. For example, in the navigation task, under both implicit and explicit instructions, performance was worse in the guided-tour group than in the free exploration group – showing a difference specifically on the most direct measures of navigation and in contradiction to the conclusion in the literature about decision making playing no role in spatial learning (Chrastil & Warren, 2012). These results are also at odds with the emphasis placed by Chrastil & Warren (2012) on proprioception and vestibular information in spatial learning, as in this project a desktop virtual environment was used and thus these factors could not play a role. The corridor task results suggest that different amount of control practice could only account for a relatively small portion of the differences. These results suggest that mode of presentation (active vs. passive) has an impact on the amount of usable information for navigating that is remembered.

Measures other than time and distance traveled may very well test for some of the same knowledge that would be accessed in a normal navigational experience, however, it is not obvious that the various spatial tasks overlap to a great degree in what they test. Hegarty et al. (2006) provide a pertinent example. They found the correlations between various measures to range from .23 to .67. The second goal was thus to compare the outcome of some frequently used measures, in a navigation task in an implicitly and explicitly learned environments.

Implicit learning is important as it is closer to real-world situations: people generally learn as they navigate through their surroundings, and even though they might pay attention to some information that would allow them to find their way, they would not be actively trying to create an accurate and complete mental map as happens when subjects in an experiment are explicitly asked to do so. We are not claiming that subjects in our implicit condition could not have possibly remembered on purpose parts of the building or the path they took. Still, this would likely have been different from a purposeful attempt to create an elaborate map. Explicit learning is important because it is both frequently used in studies reported in the literature (Mou et al., 2006; Peruch et al., 1995; Shelton & Marchette, 2010; Shelton & Pippitt, 2007; Spetch et al., 1998; Thorndyke & Hayes-Roth, 1982; Wilson, 1999), and it can certainly occur in real-world situations where an individual makes an effort to remember certain routes.

Neither the JRD nor recognition accuracy produced significant results in terms of group differences under either implicit or explicit instructions, however performance was above chance level for scene recognition for both instruction conditions, and the navigation task results did come out as significant for group differences. This suggests that the navigation task is a more sensitive measure. Alternatively, if scene recognition and JRD are not less sensitive, they must test knowledge that is different than that which is used for navigation. Both options make them less than ideal, and worse than an actual navigation task for testing learning of an environment.

Another conclusion that can be reached from this project's results is that design of real-world training involving the explicit learning of the layout of environments can possibly benefit from a component where exploration of said environment is less restricted. For example, security personal are usually given a guided tour of their new work environment. Should a prompt response to an event be required, perhaps a better response time can be achieved with different training involving less restricted exploration for the learning phase, supplemented by testing.

In sum, the findings of this study have implications for both experimental design in the spatial cognition field, and real-world situations where a learning of an environment layout is beneficial. More research is needed to refine the differences between active and passive learning for the many designs and measures that exist in the spatial cognition literature.

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