Locating Oneself on a Map in Relation to Person Qualities and Map Characteristics

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Abstract. Adults were taken to various positions on a college campus and asked to mark their locations on a round or square map drawn from either directly overhead or from an oblique angle. In session 1, participants were also given paper and pencil spatial tests to assess their skills in mental rotation (2D figure rotation), spatial visualization (paper folding), and spatial perception (water level). In session 2, participants completed computer-based navigation and mapping tasks. Performance varied widely among participants. Regression analyses showed that spatial skills predicted performance on both campus and computer mapping tasks, but the specific spatial skills that predicted success differed. Across map types, some differences in strategies and speed were observed. Findings show the value of research with both real and simulated environments, and with maps having varying cartographic properties.

Keywords: Spatial cognition, maps, navigation, spatial skills.

1 Introduction

Spatial cognition refers to the myriad of cognitive processes involved in acquiring, storing, representing, and manipulating knowledge about space. The spaces in question may range from small spaces, visible from a single viewpoint and amenable to direct manipulation (e.g., a desk surface littered with objects), to environmental spaces that may be experienced by navigating to multiple vantage points (e.g., a campus or city environment), to geographic or celestial spaces that are rendered visible by amplifiers of human capacities (e.g., maps representing the entire surface of Earth at once, photographs of the far side of the moon) [1]. Cognitive processes concerning space may be supported by a variety of representations ranging from the interior and mental (e.g., mental images of individual objects or landmarks, a survey-like cognitive map) to the external and concrete (e.g., Global Positioning System technology, a room blueprint, a road map). The focus of the research discussed here is on human adults' ability to use external spatial representations (maps) to represent navigable environments. Specifically, we examine adults' success in connecting locations in outdoor (campus or park) environments to locations on a map.

C. Freksa et al. (Eds.): Spatial Cognition VI, LNAI 5248, pp. 171–187, 2008.

The motivation for our focus on maps is both practical and theoretical. At the practical level, maps are pervasive tools across eras and cultures, and maps are used to teach new generations about how to conceptualize and use the environments in which they live and work [2,3,4,5]. They play a central role in a wide range of disciplines as diverse as epidemiology, geology, geography, and ecology; they are used for common life tasks such as navigating to new locations, interpreting daily news reports, and making decisions about where to buy a house or locate a business [6,7]. Map use and map education may provide important pathways for enhancing users' spatial skills more generally [5,8,9,10]. Research on map use may thus help to identify what map qualities impede or enhance clarity or use, and may help to identify what qualities of people must be taken into account when designing maps or educational interventions. At the theoretical level, research on map understanding is valuable because maps challenge users' representational, logical, and – of particular relevance here – spatial concepts. Studying how adults successfully use maps (or become confused by them) may help to identify component spatial processes and strategies, in turn enhancing understanding of basic spatial cognition.

In the current research, people were asked to find correspondences between locations in environmental space and locations on a map of that space. Figuring out where one is "on a map" is an essential step for using a map to navigate from one's current location to another location. It is also an essential step for using a map to record information about spatial distributions of phenomena observed in the field, as when geologists record locations of rock outcrops, ecologists record the nesting areas of a particular species, or city planners record areas of urban blight.

There is a relatively large body of research that explores the way that people develop and use mental representations of large environments [11,12,13]. There is also a relatively large body of research that explores the way that people use maps to represent vista spaces, that is, spaces that extend beyond the tabletop, but that can still be seen from a single vantage point or with only minor amounts of locomotion [14,15]. But there has been relatively little work that combines experience in large-scale, navigable spaces with finding one's location on ecologically valid maps of those spaces. Our work falls at this intersection, and, as enumerated below, was designed to address four major topics: adults' success and strategies in identifying their current locations on a map, whether these would differ with different map characteristics, whether success would vary with participants' spatial skills and gender, and, finally, whether patterns of findings would be similar for field and computer mapping tasks.

1.1 Finding Oneself on a Map

First, we were interested in examining how well adults carry out the important step in map use of locating themselves on a map when they are in a relatively unfamiliar environmental space and are given a map of that space without verbal information. This is the condition one faces in real life when one is in a new environment with a map labeled in a completely foreign language (as, for example, when an English-literate monolingual is using a map labeled in Japanese or Arabic).

To collect relevant data, we asked college students (relatively new to campus) to show their locations on a map similar to the one routinely provided to campus visitors. Prior research [16] has shown that many adults head off in the wrong direction after consulting posted “You Are Here” maps when the map is unaligned with the referent space (i.e., when up on the map does not indicate straight ahead in the space). Would adults likewise have difficulty identifying their own location on a map even if they had the opportunity to manipulate it as they liked? Would they rotate the map as they tried to get their bearings?

1.2 Map Qualities

Second, we were interested in examining the effect of map variables on the user’s success in identifying correct locations. Within psychology, research on map use has tended to pay relatively little attention to the particular kind of map used. That is, psychological research has generally examined map performance in relation to person variables (e.g., age, sex, spatial skills) rather than in relation to cartographic variables (e.g., scale, viewing angle, color schemes). Within cartography, research has tended to examine the pragmatic effects of manipulating map variables (i.e., asking which of several maps works best), paying relatively little attention to how perceptual and cognitive theories inform or are informed by the observed effects.

One potentially fruitful way to tie these two traditions together is through the concept of *embodiment*, the notion that our bodies and bodily activities ground some aspects of meaning [17]. There has been considerable work on the importance of embodied action for encoding spatial information from the environment. For example, Hegarty and colleagues [18] reported that kinesthetic experiences associated with moving through the environment contribute to learning spatial layouts. An embodiment perspective also implies that place representations will be relatively more or less difficult to interpret to the degree that they are more or less similar to embodied experience [19]. Consistent with this argument, prior research has shown that preschool children are better able to identify locations on an oblique perspective map than on an overhead map (plan view) of their classroom, and are better able to identify referents on oblique than vertical aerial photographs [19,20,21]. In comparison to plan representations, oblique representations are more consonant with perceptual experiences as humans move through their ecological niche using the sensory and locomotor capacities of their species.

To test whether map characteristics have an effect on adult performance, we examined adults’ success in marking their locations on one of four different kinds of campus maps created by crossing two dimensions – *viewing angle* (varying whether the map was plan vs. oblique) and *map shape* (varying whether the map was round vs. square). We expected that the difference in viewing angle might show an advantage for the oblique map (following the embodiment argument above). We expected that the difference in shape might advantage the round map because unlike a rectilinear map, it does not implicitly privilege any particular orientation (thus perhaps increasing participants’ propensity to turn the map into alignment with the environment). However, because the two map variables might be expected to interact (because an oblique – but not a plan view map – specifies a particular viewing direction), we did not design this work as a test of *a priori* predictions, but instead as a means of examining adults’ success and strategies in relation to map type.

1.3 Spatial Skills and the Campus Mapping Task

A third goal of our research was to examine whether spatial skills would predict performance on the campus mapping task, and if so, which spatial tasks would have predictive value. Earlier investigators have addressed the relation between spatial abilities and success in learning large-scale spatial layouts [18,22]. Here we extended this approach to tasks that did not require integrating or remembering information gathered across time and space, but instead required participants to link information from the visible, directly perceived environment to a graphic representation of that environment. To select the candidate spatial skills, we drew from the task- and meta-analysis of Linn and Petersen [23] which identified three major kinds of spatial abilities: mental rotation (skill in imagining figures or objects moving through two- or three-dimensional space), spatial perception (skill in representing one's own or an object's orientation despite conflicting visual cues or frames of reference), and spatial visualization (skill in solving multi-step spatial tasks by a combination of verbal and visual strategies). In addition, we designed our work to examine whether participant sex would have any predictive value for performance on the mapping task, above and beyond any that might be attributed to differences in measured spatial skills. This question was of interest because of the continuing evidence of gender differences in spatial cognition [24].

1.4 Simulating Environmental Mapping

A final goal of our research was motivated by the practical challenges of studying map-related spatial cognition in the field as in the campus mapping task just described. There are surprisingly frequent changes in field sites even in environments that might be expected to be highly stable. In our work, for example, even over short time spans we have encountered the construction of new buildings, new roads, and new signage, all of which influence the test environment, require a change in routes between locations, and necessitate the preparation of new maps. Outdoor testing is open to the exigencies of weather and daylight; the use of large field sites requires energetic experimenters and participants. The layout of field sites cannot be manipulated to test theoretically interesting questions. It is difficult to identify local participants who do not yet have too much familiarity with the site and equally well it is difficult to identify and transport non-local participants to the site. These and similar concerns led us to join others who have attempted to develop simulated testing environments [19,25] to study environmental cognition.

The specific approach taken here was to derive research measures from the software included in the *Where Are We?* [*WAW?*] map-skills curriculum developed by Kastens [26]. This software links dynamic images of eye-level views of a park (videotaped as someone walked through a real park) to a plan map of that park. The software allows the user to control the walk through the park (and hence the sequence of scenes shown on the video image) by clicking on arrows beneath the videotaped inset. Arrows (straight, pointing left, pointing right) control whether the video inset shows what would be seen if walking straight ahead, turning left, or turning right. As described in more detail below, using *WAW?* exercises, we created mapping tasks in which eye-level views of the terrain had to be linked to locations and orientations on the map. Our goal was first, to explore whether the same kinds of spatial skills (if any) would predict performance on the campus mapping and computer tasks, and second, to examine whether performance on the campus and computer tasks was highly related.

1.5 Summary

In summary, this research was designed to provide descriptive data on adults' success and their strategies in marking maps to indicate their locations in a relatively new campus environment, to determine whether mapping performance or strategies would vary across maps that differed with respect to viewing angle (plan vs. oblique) and shape (square vs. round), to examine whether paper and pencil spatial tasks and participant sex would predict success on the campus mapping task, to explore whether similar person qualities would predict success on a computer mapping task, and to determine whether performance on the field and computer mapping tasks would be highly correlated.

2 Method

Students who were new to a large state university campus in the U.S. and were members of the psychology department's subject pool were recruited to participate in this study. Sixty-nine students (50 women, 19 men; *M* [*SD*] age = 18.6 [1.4] years) participated in session 1 for which they received course credit. Most participants (48) took part in this first session within 6 weeks of their arrival on campus, and the remainder did so within 10 weeks of arrival. Self-reported scores on the Scholastic Aptitude Test (SAT) were provided by 44 participants: *M*s (*SD*s) for verbal and quantitative scores, respectively, were 599 (75) and 623 (78). Participants' race/ethnicity reflected the subject pool which was almost entirely White.

Following completion of all session-1 testing, participants were invited to return for session 2 for which they received either additional course credit or $10, as preferred. Of the initial group, 43 students (31 women, 12 men) returned.

Session 1 included the outdoor campus mapping activity and paper and pencil spatial tasks; session 2 included the computer mapping tasks. All testing for session 1 was completed first to take advantage of better weather for outdoor testing, and to minimize students' familiarity with campus for the campus mapping task.

2.1 Campus Mapping Task

Participants were greeted in a small testing room in the psychology department where they completed consent forms. They were then given a map of the room and asked to place an arrow sticker on the map so that the point of the arrow would show exactly where they were sitting in the room, and the direction of the arrow would show which direction they were facing. They were told that the experimenter would be using a stopwatch to keep track of how long the activities were taking, but to place the sticker at a comfortable pace rather than attempt to rush. Participants implemented these directions indoors without difficulty. Following this introduction to the procedure, they were told that they would be doing something similar outside as they toured campus.

Participants were then led along a fixed route to five locations on campus. At each, a laminated campus map was casually handed to participants (maps were intentionally unaligned with the space), and participants were asked to place an arrow sticker on the map to show their location and direction. (Because there was some experimenter error in orienting participants at some locations, the directional data were compromised and thus only those data depending on participant location are described here.)

Each participant was randomly assigned to use one of four different campus maps described earlier. Both the oblique perspective map (the official campus map) and the plan map were created by the university cartographers except that all labels were removed. All maps were identical in size and scale: square sides and circle diameters were 205 mm, representing approximately 965 m, thus at a scale of approximately 1:4,700. An illustrative map is shown in Fig. 1.

At each location, the experimenter recorded whether the participant turned the map from its initial orientation, the time taken to place the sticker on the map (beginning from when the map was handed to the participant), and the map orientation (in relation to the participant's body) at the moment the sticker was placed. Participants did not have a map as they were led from location to location, and experimenters chatted with participants as they walked to reduce the likelihood that participants would focus on their routes. After all test locations had been visited, the participants returned to the lab where they were given the paper and pencil spatial tasks (described later). Participants were asked to provide their scores on the SAT if they could remember them and were willing to report them.

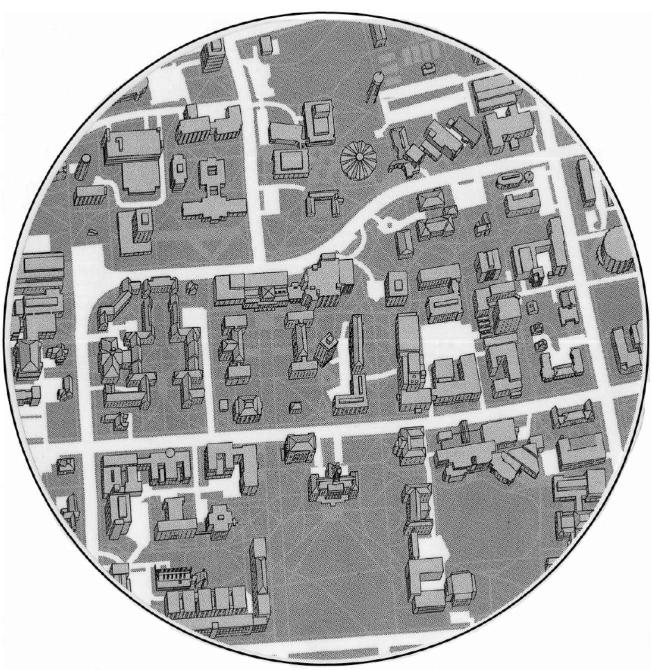

Fig. 1. Round oblique map. See text for information on map size and scale.

After the session was completed, each map with its sticker was scanned. Of the potential 345 sticker placements (5 stickers for each of 69 participants), 3 stickers from two participants' maps became dislodged before the maps were scanned and thus full data for the campus map task were available for 67 of the 69 participants. Sticker placements were scored as correct if the tip of the arrow fell within a circle centered on the correct location, with a radius of 6 mm (equivalent to approximately 28 m on the ground).

2.2 Computer Mapping Tasks

In session 2 we administered computer mapping tasks drawn from the *WAW?* curriculum described earlier. One task was drawn from the activity called *Are We There Yet?* In this activity, the participant is shown a starting position and facing direction on the map, sees on a video inset what would be visible from that position, and is asked to use the arrow keys to navigate to a target location. To ease the participant's introduction to the software, the navigation task used here was the easiest one available in *WAW?* The second activity was drawn from the *WAW?* activity called *Lost!* In this activity, participants are dropped into the park in some unknown location (i.e., it is not marked on the map), and are asked to discover where they are by traveling around the park via arrow clicks that control which video images are seen. We gave participants two *Lost!* problems, the first at the easiest level of task difficulty and the second at the most difficult. For all three tasks, we recorded whether or not the problem was solved (i.e., whether the target location was found or whether the location was correctly identified), how many seconds and how many arrow clicks the participant used within the maximum time allotted (8 minutes for each of the tasks).

2.3 Spatial Tasks

During session 1, participants were given paper and pencil tests to measure the three spatial skills identified by Linn and Petersen [23]. A paper folding test (PFT) was used to assess spatial visualization [27]. This task shows 20 sequences of between two and four drawings in which a sheet of paper is folded one or more times and then a hole is punched through the layers. Respondents are asked to select which of five drawings shows the pattern of holes that would appear if the paper were then completely unfolded. Scores are the number marked correctly minus one-fourth the number marked incorrectly within the allowed time (here 2 minutes). The test of spatial perception was the water level task (WLT) in which students are given drawings of six tipped, straight-sided bottles and asked to draw a line in each to show where the water would be if the bottle were about half full [28]. Lines drawn within 5° of horizontal were scored as correct. Finally, mental rotation (MR) was assessed by a modified version of the Spatial Relations subtest of the Primary Mental Abilities (PMA) battery [29]. Respondents are shown 21 simple line figures as models. Each model is followed by five similar figures, and respondents are asked to circle any that show the model rotated but not flipped over (i.e., not a mirror image). Scores are the number correctly circled (2 per row) minus those incorrectly circled (up to 3 per row) within the allotted time (here 2 minutes).

3 Results

The data are presented below in five sections. First, we offer descriptive data on the performance on the campus mapping task. Second, we address the question of whether performance or strategies on the campus mapping task differed as a function of map type. Third, we address whether performance on the campus mapping task is predicted by participant variables. Fourth, we address the same question for the computer mapping task. Finally, we address the relation between performance on the campus and computer mapping tasks.

3.1 Performance on the Campus Mapping Task

College students' performance on the campus mapping task covered the full range, with some placing none, and others placing all five stickers correctly, M (SD) = 2.2 (1.4). An even more telling index of performance variability is evident in Fig. 2 which shows the locations of erroneous responses for one target location. It is striking not only that many responses are distant from the correct location, but also that many responses fail to show the correct *kind* of location.

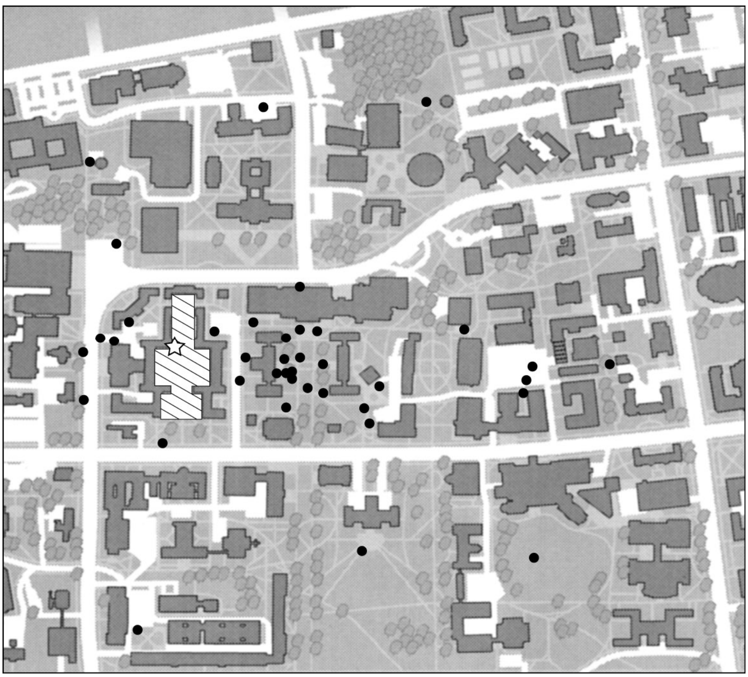

Fig. 2. Erroneous sticker placements (*40 black circle*s) for one target location (*star*). Omitted are 12 stickers placed correctly and 17 stickers falling within the area defined by adjacent buildings (*striped region*). Note that some errors were particularly egregious, as in stickers placed in open fields or parking lots.

3.2 Campus Mapping Task and Map Variables

Accuracy of Sticker Placements. As explained initially, this research was also designed to examine whether task performance would vary with map qualities of shape and viewing angle. To examine this question, the total number correct served as the dependent variable in a two-way analysis of variance (ANOVA) in which between-subjects factors were map shape and map angle. Neither main effect nor their interaction was significant. Means (*SD*s) for round versus square, respectively, were 2.2 (1.3) versus 2.3 (1.5); for plan versus oblique, 2.1 (1.4) versus 2.4 (1.4).

Speed of Sticker Placements. As a second means of examining the possible impact of map variables on performance on the campus mapping task, we analyzed the time participants took to place the arrows on the map. A two-way ANOVA showed a significant interaction between map shape and viewing angle, $F(1,65)=6.98$, $p = .010$, subsuming a main effect of viewing angle, $F(1,65)=7.52$, $p = .008$. Specifically, when the map was square, average response times were significantly longer on the plan than the oblique map, *M*s (*SD*s) in seconds, respectively: 38.7 (21.7) versus 19.1 (9.3), whereas when map shape was round, response times did not differ significantly for the plan and oblique maps, 27.7 (11.5) versus 27.74 (14.6). (If all four map types are entered as four levels of a map-type factor, the average response time was significantly longer for the square plan map than for any other map type among which there were no significant differences.) This pattern holds within individual items and irrespective of accuracy. That is, the reaction times for the square plan map are consistently longer both among individuals who responded correctly and among those who responded incorrectly on a particular item.

Map Turning. A third dependent measure examined in relation to map type was use of a map-turning strategy. For this analysis, the dependent measure was the number of locations (0-5) at which participants turned the map rather than leaving it in the orientation in which they received it from the experimenter. A few participants never turned the map or turned it only once (n=4); on average, the map was turned on 3.9 (1.3) items. An ANOVA on the number of turns revealed neither main effects nor interactions with respect to map shape or viewing angle. Means (*SD*s) for round versus square, respectively were 3.9 (1.2) versus 4.0 (1.4); for plan versus oblique, 4.1 (1.2) versus 3.8 (1.4).

Map Orientation. The final behavior examined with respect to map type was how the participant held the map (with respect to the participant's own body) while placing the sticker. Based on the sides of the square map, we defined as *canonical* the position shown in Fig. 2 or its 90°, 180°, or 270° rotation. A 2 (map shape) x 2 (map angle) ANOVA on the number of canonical orientations (0-5) revealed a significant main effect of map shape, $F(1,65)=5.35$, $p=.024$. More canonical orientations were used by participants with square than with circular maps, *M*s (*SD*s), respectively, 4.0 (1.0) versus 3.3 (1.4).

3.3 Campus Mapping Task and Participant Variables

To provide descriptive data on the association between performance on the campus mapping task and participant qualities, we first computed the correlation between the number of stickers placed correctly on the campus mapping task and scores on each of the three paper and pencil spatial tests. Correlations of sticker accuracy with mental rotation (MR), spatial visualization (PFT), and spatial perception (WLT), respectively, were $r(67) = .048$, $p = .357$; $r(67) = .321$, $p = .004$; and $r(67) = .219$, $p = .038$ (here and below, one-tailed tests were used given directional hypotheses). These correlations reflect data from all participants in session 1, irrespective of whether they were available for session 2. (An identical pattern of results holds if analyses are limited to the 43 participants who took part in both sessions.) As anticipated, performance on the three spatial measures was also correlated: MR with PFT, $r(69) = .425$, $p < .001$; MR with WLT, $r(68) = .410$, $p < .001$, and PFT with WLT, $r(68) = .253$, $p = .019$. (Again, identical patterns hold with the smaller sample as well.)

The number of correct sticker placements was then used as the criterion variable for a regression analysis of the campus mapping task. A stepwise regression was performed with the three spatial tests entered on the first step. We entered participant sex on the second step to determine if there were any effects of sex above and beyond those that could be attributed to possible spatial skill differences. Finally, on step three we entered the strategy variable of the number of locations at which the participant turned the map.

At the first level of the model, all three predictors together accounted for 15% of the variance, $R^2 = .15$, $F(3, 66) = 3.61$, $p = .018$. Within this multiple regression, however, only PFT predicted success (standardized $\beta = .34$, $p = .010$). At the second level of the model, participant sex did not significantly increase the prediction, p-change = .56, although PFT remained a significant predictor (standardized $\beta = .34$, $p = .010$) and the overall model remained significant, $R^2 = .15$, $F(4, 66) = 2.76$, $p = .035$. Finally, at the third level of the model, the map-turning strategy significantly improved the prediction, R^2-change = .108, p-change = .004 (standardized $\beta = .35$, $p = .004$), and PFT remained a significant predictor (standardized $\beta = .27$, $p = .033$). The final overall model was $R^2 = .25$, $F(5, 66) = 6.59$, $p = .002$.

3.4 Computer Mapping Task and Participant Qualities

A composite measure of participants' performance on the computer mapping tasks was created by summing the number of *WAW?* tasks that were completed correctly within the allotted amount of time. (Similar patterns of results were obtained with time or the number of arrow clicks measures instead.) As in the campus mapping task, we first computed the correlation between performance on the computer mapping task with each of the three paper and pencil spatial tests. Correlations with mental rotation (MR), spatial visualization (PFT), and spatial perception (WLT), respectively, were $r(43) = .495$, $p < .001$; $r(43) = .317$, $p = .019$; and $r(43) = -.009$, $p = .478$. These correlations necessarily reflect data from only those who participated in both session 1 and 2 (when *WAW?* data were collected).

The composite *WAW?* measure served as the outcome variable for a regression parallel to the one described above, that is, with the spatial tests entered on step 1 and participant sex on step 2 (although the map-turning strategy was not entered on step 3 because there was no corresponding opportunity for map rotation on the computer mapping task). As was true in the regression analysis of the campus mapping task, there was a significant effect of spatial measures at step 1, $R^2 = .30$, $F(3, 42) = 5.44$,

p = .003, but again, participant sex at step 2 did not add significantly to the model after spatial scores had been entered (p-change = .603). However, unlike the prior regression, in this analysis it was MR (standardized β = .52, p = .003) rather than PFT (standardized β = .12, p = .475) that predicted mapping performance on the computer task.

3.5 Relating Performance on Campus and Computer Mapping Tasks

An additional goal of this research was to explore the possibility that the computer mapping tasks drawn from *WAW?* might be a viable substitute for measuring success on mapping tasks in the real, life-size environment. To evaluate this possibility, we computed correlations between scores on the two tasks. Irrespective of which dependent measure is used for the *WAW?* tasks (number completed, time in seconds, or number of arrow clicks), there was no significant relation between scores on the campus and computer tasks. The highest correlation was between the number of correctly placed stickers on the campus mapping task and the number of correctly completed *WAW?* tasks, and it was not marginally significant even with a one-tailed test, $r(43)$ = .121, p = .22. Furthermore, what little trend toward an association there was disappears entirely by statistically controlling for scores on the spatial tasks: partial $r(39)$ = .005, p = .487.

As an additional means of examining the distinctions or comparability of the two mapping tasks, we compared the patterns of association between success on each mapping task and the success on the paper and pencil spatial tasks. As is evident from the findings described for each of the two mapping tasks taken individually, the regression analyses showed different patterns for the campus and computer mapping tasks. Particularly striking was the finding that MR score predicted performance on the computer mapping task, but not performance on the campus mapping task. To provide data bearing on the question of whether the associations differ in the two tasks, we compared the sizes of the correlations between MR score and performance on campus versus computer tasks. These correlations differed significantly, $t(40)$=1.73, p <.05. Neither of the other correlations (PFT or WLT) differed significantly between the two mapping tasks.

4 Discussion

We begin our discussion by commenting on what the empirical data suggest about how well adults can mark a map to show their location in a real, relatively newly encountered campus environment, addressing the question of whether performance differs in relation to the two manipulated map characteristics (viewing angle and map shape). In the course of doing so, we comment on the appearance and distribution of the map-related behaviors observed during the campus mapping task. We then discuss findings from the regression analyses concerning which individual difference variables predict performance on the campus mapping task and performance on the computer mapping task. Finally, we discuss implications of data concerning the relation between performance on the two mapping tasks.

4.1 Performance and Strategies on the Campus Mapping Task and Their Relation to Map Characteristics

The data from the campus mapping task offer a compelling demonstration that many adults are challenged by the request to show their location on a map. The fact that some participants were right at every one of the locations establishes that the task was a solvable one. The fact that some participants were wrong at every one of the locations establishes that the task was not a trivial one. Furthermore, egregious errors (see Fig. 2) suggest that some adults' map-interpretation skills are particularly poor. Although it is perhaps not surprising to see errors like these among preschool and elementary school children [20,30], it is surprising to see them among adults. Based on participants' comments and affective demeanor during testing, we have every reason to believe that all were engaged by the task, and all were trying their best.

In addition to providing information on absolute levels of performance, the campus mapping task was of interest as an avenue for testing the possible impact of the map characteristics of map shape and viewing angle. One reason that we thought that map characteristics might lead to different behaviors and different levels of accuracy was because the different map characteristics might be differentially conducive to participants' aligning the map with the space, and research with both adults and children had shown better performance with aligned than unaligned maps [16,31,32]. The current data, however, provided no evidence that map shape affected accuracy on the location tasks nor that it affected the number of items on which participants turned the map. This was true even if we limited the comparison to the plan maps which – unlike the oblique maps – did not imply a particular vantage point.

We had also hypothesized that oblique maps – in comparison to plan maps – might elicit better performance insofar as they were more consonant with an embodied view, that is, one more similar to that encountered by humans as they navigate through the environment [19] and given that past research had shown advantages to oblique-perspective representations for children [20,21]. Again, however, there were no significant differences in accuracy or strategies in relation to map angle, either as a main effect or in interaction with map shape.

Although there were no differences in accuracy in relation to map type, participants were significantly slower on the square plan map than on any other map type. In addition, square maps were held in canonical positions in relation to participants' bodies significantly more often, implying that these maps were less often aligned with the environmental space. Perhaps the extra time taken for the square plan maps reflects additional time needed for mental rotation with unaligned maps. That the oblique version did not require additional time suggests that participants may (like children) find it easier to work with the oblique map, despite the fact that in most orientations, its vantage point differs from the one experienced in the actual environment. The data do not yet permit definitive conclusions about process, but they do permit the conclusion that additional research on the effects of map characteristics is worthwhile.

4.2 Predictors of Success on Campus and Computer Mapping Tasks

As expected, the regression analyses showed that spatial skills significantly predicted performance on both the campus mapping task and the computer mapping task. Sex added no additional prediction in either task. Interestingly, the specific spatial skills that predicted performance differed on the two tasks. For the campus mapping task, it was the score on the paper folding task that was the significant predictor. Mental rotation scores added nothing further to the prediction. The reverse held in the computer mapping task. For this task, it was the score on the mental rotation task that predicted task success, and other spatial scores did not add significantly to the prediction.

In the taxonomy offered by Linn and Petersen [23], the paper folding task falls within the skill category labeled spatial visualization which they describe as covering tasks that involve multiple steps, using visual or verbal strategies, or both. It is possible to think of the campus mapping task as one for which varied approaches would indeed be viable. For example, someone might focus on landmark buildings, someone else might focus on the geometric qualities of the streets, someone else might try to figure out the direction walked from some earlier identified spot, some might try to align the map and the space, and so on. In other words, this outdoor task – much like normal map-based navigation – gives the map-user considerable freedom in structuring the task.

That mental rotation mattered for performance on the computer mapping task is also easily understood because in this task – unlike the campus mapping task – participants had less control over the visual array and the map. That is, although participants controlled which video clip they saw (by selecting which of three arrows they clicked at every choice point), they had no control of what was seen within the resulting video clip that was played. That is, once a video clip had been selected by an arrow click, participants saw whatever part of the park was recorded by the camera – at the camera's height, at the camera's angle, at the camera's azimuth, and at the camera's speed of rotation or translation. Furthermore, participants had no control over the orientation of the map: the map of the videotaped park was always in a fixed position, and thus, usually out of alignment with the depicted vista. It is thus not surprising that under these conditions, an ability to handle *mental* rotation was significantly associated with performance.

An additional finding from the regression analysis on the campus mapping task lends further support to the hypothesized importance of participants' own actions for success on the task. Specifically, as reported earlier, participants' use of the map-turning strategy added significant prediction to the score on the campus mapping task even after spatial skills had been entered into the regression model. Aligning a map with the referent space is an *epistemic action,* defined by Kirsch and Maglio as an action in which an agent manipulates objects in the environment with the goal of acquiring information [33]. As explicated by Kirsch and Maglio for the case of expert Tetris players, epistemic actions serve the user by revealing otherwise inaccessible information or by decreasing the cognitive load required to gain information. For example, it is more time-efficient for Tetris players to rotate a polygon on the screen and visually compare its shape with a candidate nesting place than to do the rotation and comparison mentally. In our work, we have observed epistemic actions in a task in which adults visited eight outcrops in a field site, and were asked to select which of 14 scale models best depicts the underlying geological structure [34]. As they struggled to select the correct model, some participants rotated candidate models into alignment with a map of the area, rotated candidate models into alignment with the full-scale geological structure, placed two candidate models side by side to facilitate comparison, and pushed rejected models out of the field of view. Like rotating a Tetris shape or rotating a scale model of a geological structure, rotating a map into alignment with the referent space decreases the cognitive load required to solve the task at hand by substituting direct perception for mental rotation and mental comparison. Use of epistemic actions requires that the agent foresees, before the action is taken, that the action will have epistemic value; such tactical foresight is separate from the spatial skills measured by the paper and pencil tasks, in which the actions are prescribed by the experimenter.

4.3 Computer Screens Are Not Real Environments

The regression findings just discussed provide one line of evidence that the computer mapping task cannot be used as a substitute for the campus mapping task for studying spatial cognition. That is, the finding that different spatial skills predict performance on each of the two mapping tasks implies that the two tasks differ in important ways. This conclusion is bolstered by two other findings, first, that there is a significant difference in the size of the correlation between MR and performance on the campus mapping task versus the computer mapping task, and second, that the correlation between scores on the two mapping tasks is not significant. Taken together, these data imply that it is important to continue to conduct mapping research – as well as map skill education – in real, life-size environments.

5 Conclusions

The data from the present research bear upon adults' success in using one of the most common kinds of spatial representations of large environments – maps – as they observe the environment directly in the field or via another representational medium. Our data show dramatic variability with respect to how well cognitively intact adults (all of whom met the intellectual criteria needed for university admission) succeed in indicating their locations on a map. Although some participants showed outstanding performance, others made serious errors reminiscent of those made by young children [20,32,35].

Our data also bear on questions about research in different kinds of spatial environments. The finding that different spatial skills predicted success on the campus versus computer mapping tasks coupled with the finding that participants' scores on the two mapping tasks were not significantly correlated, lead to the conclusion that it is unwise to substitute one task for the other. From the pragmatic perspective of conducting behavioral research in environmental cognition, this conclusion is perhaps disheartening. It would ease research significantly if the answer were otherwise. From the perspective of theoretical work on spatial cognition, however, the finding is more intriguing than disheartening. The current findings contribute evidence to the growing conclusion that the skills entailed in solving spatial problems in object or vista spaces do not entirely overlap with skills entailed in solving spatial problems in environmental spaces. Past researchers have shown the importance of testing in real environments even for indoor, built spaces (corridors and rooms) that are highly defined, homogeneous, and rectilinear [18]. Our findings add to the evidence for the importance of testing in larger, more varied, less clearly defined outdoor environments as well [36]. Outdoor environments provide potential clues (e.g., a nearby building, a distant skyscraper, a river, the position of the sun). But they also present potential challenges including barriers (that may obstruct otherwise useful landmarks), an absence of clear boundaries to define the borders of the space (in contrast to the walls of a room), and vistas that may appear homogenous to the untrained eye (e.g., desert vistas, dense forests, or acres of wheat fields as far as the eye can see). A full understanding of human spatial cognition will thus require studying how people identify and use information that is available within a diverse range of environments.

Likewise, the findings from the research described here bear on the role of map characteristics. Although our data do not yet permit firm conclusions about the way that map qualities interact with environmental and person qualities, they do provide strong support for the importance of systematically varying map qualities as we continue to explore the fascinating territory of spatial cognition.

Acknowledgments. Portions of this work were supported by National Science Foundation (NSF) grants to Liben (RED95-54504; ESI 01-01758) and to Kastens (ESI-96-17852; ESI 01-011086), although no endorsement by NSF is implied. We acknowledge with thanks the contributions of past and current members of the Penn State Cognitive & Social Development Lab, particularly Lisa Stevenson and Kelly Garner who contributed in so many ways to this project.

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