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Global-Scale Location and Distance Estimates: Common Representations and Strategies in Absolute and Relative Judgments

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The authors examined whether absolute and relative judgments about global-scale locations and distances were generated from common representations. At the end of a 10-week class on the regional geography of the United States, participants estimated the latitudes of 16 North American cities and all possible pairwise distances between them. Although participants were relative experts, their latitude estimates revealed the presence of psychologically based regions with large gaps between them and a tendency to stretch North America southward toward the equator. The distance estimates revealed the same properties in the representation recovered via multidimensional scaling. Though the aggregated within- and between-regions distance estimates were fitted by Stevens's law (S. S. Stevens, 1957), this was an averaging artifact: The appropriateness of a power function to describe distance estimates depended on the regional membership of the cities. The authors conclude that plausible reasoning strategies, combined with regionalized representations and beliefs about the location of these relative to global landmarks, underlie global-scale latitude and distance judgments.

Keywords: cognitive maps, distance estimates, geography, spatial reasoning, spatial representation

The kind of representation that people acquire from their direct navigational experience is often contrasted with the kind of knowledge that can be acquired only through maps (e.g., Montello, Waller, Hegarty, & Richardson, 2004; Thorndyke & Hayes-Roth, 1982). Despite the intuitive validity of this distinction and some empirical evidence that supports it, most of the research on the representations and processes underlying estimation tasks in which the focus has been on remembered distances has examined distances that participants could have known at least partially from direct experience (e.g., inside buildings, on campuses, in neighborhoods, and between cities; Allen, Siegel, & Rosinski, 1978; Cadwallader, 1979; Golledge, Briggs, & Demko, 1969; Herman, Norton, & Roth, 1983; Lederman, Klatzky, Collins, & Wardell, 1987; Lloyd & Heivly, 1987; Maki, 1981; Sadalla, Staplin, & Burroughs, 1979; see Kitchin & Blades, 2002, and Montello, 1997, for review). Even research that compares map-acquired with directly acquired knowledge has dealt with relatively small distances (e.g., Thorndyke & Hayes-Roth, 1982; Richardson, Montello, & Hegarty, 1999). Further, the few studies that have investigated subjective distance estimates at a global scale (e.g., Beatty & Troster, 1987; Bratfisch, 1969; Ekman & Bratfisch, 1965; Lundberg, Bratfisch, & Ekman, 1972; Lundberg & Ekman, 1973) have done so with limited purpose (e.g., to compare psychophysical scaling methods). Thus, relatively little is known about the representations and processes underlying estimates of global distances.

In this article, our main goal is to provide evidence that distance estimates at a global scale are generated from category-based representations, via plausible reasoning processes (Brown & Siegler, 1993; Collins & Michalski, 1989; Friedman & Brown, 2000a, 2000b; Hirtle & Jonides, 1985; McNamara, 1986; A. Stevens & Coupe, 1978). Plausible reasoning is hypothesized to take place when people are asked to provide information that they cannot retrieve directly about a domain in which they have other knowledge that they might use to generate an answer. For example, when people are asked to generate the latitude of Tunis, having been told how latitudes work, they may reason that "Tunis is in northern Africa and so is the Saharan desert, which is hot, so Tunis must be near the equator" (Mark, 1992, discussed climate as a basis for reasoning about latitudes). Thus, even when people cannot retrieve a numeric (or other) fact directly, they may be able to generate a well-reasoned but incorrect response.

Previous evidence that people use plausible reasoning in geographical estimation tasks and that the representations of global geography are categorical in nature has been based principally on latitude estimates (Friedman & Brown, 2000a, 2000b; Friedman, Kerkman, & Brown, 2002; Friedman, Kerkman, Brown, Stea, & Cappello, in press). However, latitude estimates may seem strange or at least unfamiliar to lay people; in contrast, distance estimates are a much more familiar spatial construct. Thus, a priori, in the present experiment it was entirely possible that people would use qualitatively different representations to judge global distances than they would use to estimate latitudes.

Demonstrating that global distance and latitude estimates are based on common representations is important theoretically because it implies that biases in the estimates arise from the same sources, and such convergence is currently lacking (see New-

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combe, 1985, 1997). The data to date provide evidence that the biases exhibited in latitude estimates are attributable to the manner in which psychological regions are referenced to global landmarks such as the equator, the oceans, and the poles (Friedman, Kerkman, & Brown, 2002; Friedman et al., in press). If global distance judgments are based on these same representations, the pattern of bias observed in them should thus have a predictable form.

The comparison between latitude and distance judgments is also theoretically interesting because latitude judgments presumably reflect beliefs about absolute locations, whereas distance estimates are relative and thus do not, in principle, require knowledge of the absolute locations of the entities involved. It might be sufficient, for instance, to know that two North American cities are three time zones apart to generate an estimate of the distance between them. Thus, even on a plausible reasoning account (Brown, 2002; Collins & Michalski, 1989; Friedman & Brown, 2000a, 2000b), people might use different underlying beliefs as well as potentially different strategies to generate the different types of estimates.

To examine whether global-scale latitude and distance judgments are based on a common representation, we had the same group of participants make both kinds of estimates, in counterbalanced order, and used multidimensional scaling (MDS) to determine the structure of the representations underlying the distance estimates. We used bidimensional regression (BDR; Friedman & Kohler, 2003; Tobler, 1964)—a technique analogous to linear regression—to map each individual's MDS solution, obtained from his or her distance estimates, into the latitude–longitude domain. This additionally allowed us to accomplish a second goal: to demonstrate that BDR provides a principled means of determining the amount that a metric MDS solution should be rotated as well as a two-dimensional goodness-of-fit statistic for data whose configuration is inherently spatial. The analysis enabled us to assess the two-dimensional correlation between the recovered MDS structure and the actual latitudes and longitudes of the stimulus cities and to examine the nature of the obtained psychological regions and any biases in their placement. To preview our results, the two-dimensional structure underlying the distance estimates, when projected into the latitude and longitude domain, was completely consistent with the representation inferred from the latitude estimates. Thus, we concluded that plausible reasoning strategies, combined with regionalized representations and beliefs about the location of these relative to global landmarks, underlie global-scale latitude and distance judgments.

Our third goal is to demonstrate that fitting geographically based distance estimates with a power function camouflages the heterogeneity of the representations underlying them. Researchers have claimed for a long time (e.g., Dornic, 1968; Ekman & Bratfisch, 1965; Teghtsoonian & Teghtsoonian, 1970; see Wiest & Bell, 1985, for review) that global distance estimates follow Stevens's power law ($Y' = kX^n$; S. S. Stevens, 1957; see S. S. Stevens & Galantner, 1957, for review). However, opinions differ about the factors that determine the variation in, and specific value of, the exponent n. We demonstrate that such arguments are moot: Both the goodness-of-fit for the obtained power function and the value of its exponent change according to whether the cities within a judged pair belong to the same or different familiar or unfamiliar psychological regions. Consequently, a single function may not be a valid description of a given set of data. Rather, one must know whether and how the underlying representational structure is categorized into geographic regions, how those regions are believed to be situated with respect to each other and to global landmarks, and whether the cities within or between regions are positioned relative to each other with at least ordinal accuracy.

Background

In our previous research (Friedman & Brown, 2000a, 2000b), we demonstrated that Canadians' latitude estimates of North American and European cities had four distinctive characteristics, which, in the present study, we expect to replicate in the latitude estimates and to find evidence for in the distance estimates. First, participants divided the continents into nonoverlapping psychological regions that could be independently influenced by new information. Some regions contained only one country, some had several, and some countries contained more than one region. Second, the regions typically had large "boundary zones" (gaps) between them. Third, there was relatively little north–south discrimination among the locations of cities within most, though not all, of the regions. Finally, for both the Old and the New World, the estimates became more biased as the cities being estimated were actually located farther south.

These observations are consistent with the known influences of categorical information on location estimates (Brown, 2002; Friedman & Brown, 2000a, 2000b; Hirtle & Jonides, 1985; Huttenlocher, Hedges, & Duncan, 1991; McNamara, 1986; A. Stevens & Coupe, 1978) and with the use of an *ordinal conversion strategy* to derive numeric estimates in knowledge domains for which the relevant facts are scarce (Brown, 2002; Brown & Siegler, 1993). For latitude estimates, this strategy involves drawing on beliefs about the ordinal positions of the regions and their relation to *global reference points* (e.g., the equator) to define the response range and to partition it among the regions. Thus, when participants are told that latitudes run from 90° to −90° at the poles, with the equator at 0°, they map their beliefs about the relative north–south locations of the continents and the regions within them onto mutually exclusive portions of this range. They then generate an estimate for each city by identifying its region and selecting a value within that region's range. If a participant knows relatively little about the items within a region, his or her estimate might be the region's prototype location. In this case, the within-region response range tends to be truncated.

More recently, we found that participants who lived in vastly different parts of North America (Edmonton, Alberta, Canada [54°N, 113°W]; San Marcos, Texas, United States [30°N, 98°W]; and Ciudad del Victoria, Tamaulipas, Mexico [24°N, 97°W]) all had the same four characteristics in their data, including the same bias to estimate the latitudes of most Mexican cities to be relatively near the equator (Friedman et al., in press). Further, we determined that participants effected this southward "stretching" of North America in a manner that preserved the approximately correct proportional distances between the actual mean locations of the cities within each mental region (e.g., the U.S.–Mexico distance stretched more than the Canada–U.S. distance). From this, we concluded that all three national groups used an ordinal conversion strategy and that the bias to place both southern U.S. and Mexican cities too far south reflected a shared belief that the equator is either the lower bound for North America or, perhaps, the prototype for Mexico. Despite the inaccuracies in the absolute placement of the regions themselves, each participant group was more accurate about the relative location of cities within their home region than they were about the relative location of cities within the other regions. This indicates that they had at least some ordinal knowledge about the location of cities in their home region.

The Present Study: Overview and Predictions

The participants in the present study were from southern California (34°N, 120°W); we expected their latitude estimates to be qualitatively similar to those of the previous groups we have tested (Friedman et al., in press). In particular, the latitude "location profiles" should display the four characteristics mentioned earlier as well the approximately correct proportional distances between regional means. The theoretically new predictions involve what we expect to observe in the distance estimates if distance and latitude estimates are based on a common representation of North American geography. If this representation is stretched southward with boundary zones between its regions, then we can make three general predictions for what to observe in the distance estimates. First, the features of the representation revealed in the latitude estimates should be reflected in the structure of the MDS solution recovered from the distance estimates and in the best fit configuration that is mapped from the MDS solution into the latitude–longitude graticule via BDR. In particular, the latitude estimates, the MDS solution, and the predicted latitude–longitude configuration should each have four distinct regions, with relatively clear north–south spaces between them. In addition, the regions in which the north–south latitude estimates were truncated should appear to be truncated in this dimension in the recovered MDS solution as well as in the latitude–longitude graticule.

Second, distance estimates made between cities in two different regions should be larger, on average, than estimates between cities within the same region, even if the objective distances are equivalent. This prediction derives from the conjecture that the nature of the ordinal conversion strategy for distance estimates should be similar to that used for latitudes and should thus reflect the gaps between regions in the representation. In particular, when participants are told that the pole-to-pole distance is 12,400 miles, they have to map their beliefs about the relative north–south locations of the continents and their regions onto mutually exclusive portions of this range. Their distance estimates should then involve identifying the region that each city in a pair belongs to and computing a value that represents the distance between them. Even though this is a relative judgment, a reasonable way to approach a between-cities distance estimate in the absence of actual numeric knowledge is to estimate (implicitly) each city's location within its region, combined with the range believed to be taken up by the two regions and any regions in between. For those regions in which item knowledge is sparse, people might use the mean for the region in the computation. It is important to note that if people use the same representation to make both the distance and latitude estimates, then the gaps that exist between regions in the representation provide the basis for the prediction that the average between-regions estimates should be larger than the average within-region estimates.[1]

The third prediction is that for those regions in which the cities' relative north–south latitude estimates are reasonably accurate, even if they are inaccurate in an absolute sense, both the within- and the between-regions distance estimates should also exhibit at least ordinal accuracy. This prediction holds even though there might be some overall signed error in the absolute values of the distances, because there is an overall signed error in the placement of the regions themselves. Thus, if we observe ordinal accuracy for both latitude and distance estimates within and between the same regions, it will provide further evidence that the distance estimates are based on implicit estimates of each city's absolute location and that latitude and distance estimates are derived from the same representation.

With respect to whether distance estimates fit a power function, Wiest and Bell (1985) performed a meta-analysis of 70 studies and concluded that the average exponent of the function was 1.08, 0.91, and 0.74, respectively, for judgments made on the basis of direct observations, memory, or inferences; what they referred to as *inferences* are the type of judgments we examine in the present study (i.e., distances that cannot be experienced directly). Thus, Wiest and Bell (1985) emphasized the importance of task context in determining the value of the exponent of the power function in distance estimates and concluded that it accounted for about 40% of the variance in n. However, it is possible that any particular value of the exponent obtained for the function relating actual to estimated distance is an artifact of averaging over both within- and between-regions distance estimates. If so, the exponent obtained across all the regions might not reflect the heterogeneity among the functions that describe the estimates in the different types of regions (e.g., familiar and unfamiliar). The present study provides the opportunity to examine this hypothesis.

It is notable that the University of California, Santa Barbara, participants were tested during a final examination held at the end of a 10-week course on the regional geography of the United States. Because the class satisfied a General Education requirement, the students came from a wide spectrum of majors, including social sciences, biophysical sciences, and humanities. The course exposed them to the latitude–longitude graticule, and they saw North American maps on several occasions, although neither the latitudes of cities nor their pairwise distances were emphasized in the class. Nevertheless, the examination included multiple-choice questions about the human and physical geography of the United States and a map task in which students were given an outline of the United States and its individual states, unlabeled (although no cities were present, nor were latitudes or longitudes indicated).

Because their classroom and examination experiences provided our participants with recent and accurate input about the locations of North American cities, it might be reasonable to expect that their location estimates will be more accurate than those reported in past research (Friedman & Brown, 2000a, 2000b; Friedman et al., in press). However, if their latitude estimates reveal distortions

[1] Of course, others have found effects of borders (e.g., Maki, 1981) and barriers (e.g., Newcombe & Liben, 1982) on distance estimates that are consistent with the present prediction. For instance, Newcombe and Liben (1982) found that both children and adults (especially male participants) overestimated perceived distances of 5 ft if an opaque barrier was present; however, this task may be fundamentally different than a task in which the distances must be inferred. Maki (1981) found evidence for an influence of U.S. state borders on speeded east–west judgments between city pairs; in this instance, it is plausible that at least some of the distances were inferred. However, she trained her participants about the cities' locations prior to the judgment task. In contrast, in the present study, all of the regions we anticipate seeing in the data contain several states and provinces, and we did not pretrain participants. Thus, any regions revealed in the data necessarily existed prior to the experiment.

similar to those reported previously and if the distance estimates are consistent with this inferred representational structure, it will be strong evidence that the categorical nature of geographical representations and the ubiquity of plausible reasoning processes underlie most real-world geographical reasoning tasks at continental and global scales.

Method

Participants and Design

The participants were 147 student volunteers (78 men, 66 women, and 3 who did not indicate their gender and had ambiguous names) who received extra credit for their participation. Three experimental tests were handed out to all students who wanted to receive the extra credit and were administered directly after they completed the final examination in the course.

We scored data from only the 117 individuals who had lived in California since the age of 5. Of these, we eliminated 30 from further consideration because they had missing data of some sort (e.g., they did not indicate whether their latitude estimates were in the northern or southern hemisphere, or they omitted some latitude estimates, distance estimates, or both). We eliminated a further 8 individuals because they did not follow the instructions in some way (e.g., 2 flipped the latitude scale so that the larger latitudes were toward the equator; 2 gave ranges instead of point estimates; 2 gave ratings outside of the allowable range; and 2 wrote numbers in sequence, e.g., from 1 to 51, for some portion of their answers). This left 79 participants with usable data (35 male, 42 female, and 2 who did not indicate their gender and had ambiguous names). These 79 had a mean age of 21.6 years (range = 18–48; $SD = 3.8$). All participants first completed a knowledge rating task; 40 then made latitude estimates followed by distance estimates, and 39 had the reverse order of tasks.

Stimuli

We selected four cities from each of the four regions of North America generated by both Canadian and American participants in previous studies (Friedman & Brown, 2000a, 2000b; Friedman, Kerkman, & Brown, 2002). The regions were Canada, represented by Edmonton (54°), Winnipeg (50°), Montreal (46°), and Toronto (44°); the northern United States, represented by Seattle (48°), Minneapolis (45°), Boston (42°), and Pittsburgh (40°); the southern United States, represented by Las Vegas (36°), Los Angeles (34°), Houston (30°), and Tampa (28°); and Mexico, represented by Tijuana (33°), Ciudad Juarez (32°), Mazatlan (23°), and Mexico City (19°). We selected cities at the national borders so that the latitudes of cities in each region were intermingled (e.g., Toronto and Seattle; Tijuana and Tampa). For the "psychological" border (i.e., the northern vs. southern U.S. regions), we selected the cities to be approximately the same latitude apart between regions as they were, on average, within regions. The average actual great circle distance between the 24 within-region city pairs was 1,162 miles. For the three adjacent between-regions comparisons (Canada–northern United States, northern United States–southern United States, and southern United States–Mexico), comprising 48 city pairs, the average actual between-cities distance was 1,225 miles. Thus, the average actual difference in distance between the within- and the between-regions pair types was 63 miles. Similarly, the average actual latitude difference between all within- and between-adjacent-regions pairs was 6° and 7°, respectively.

The four regions used in the data analysis did not play a role in the lecture or reading material in the participants' class. The course was organized around a set of 15 thematic regions in the United States and Canada that is fairly standard in regional geography but only minimally reflects the pattern of the cognitive regions we have previously found.

Procedure

Each participant received a booklet with the three tasks: knowledge ratings, latitude estimates, and distance estimates. The cities for each task were randomized independently for each participant. As in our previous work (Friedman & Brown, 2000a, 2000b), the random order of cities was identical for the knowledge and latitude estimate tasks; however, 11 participants received a different order of cities for each task because of a procedural error.

The first page of the test booklets contained a brief introduction that explained that there were three tasks to complete and that there would be separate instructions for each. Below this introductory paragraph were the instructions for the knowledge rating task. Instructions for each task were on a separate page, and participants were asked not to turn the page until they understood the instructions.

For the knowledge ratings, participants were instructed to rate their knowledge of each of the 16 cities on a scale from 0 (*no knowledge*) to 9 (*a great deal of knowledge*). This task acquainted them with the set of cities for which they would be making latitude and distance estimates. Each city appeared on a separate line, together with its state or province and country, followed by a blank line for the knowledge rating.

For latitude estimates, participants were instructed that latitudes range between 90° at the north pole and −90° at the south pole, with the equator at 0°. They were asked to give their "best and most accurate estimate" of the latitudes of each of the 16 cities and to indicate their estimate with a number representing the latitude and the letter "*N*" if they thought the city was in the northern hemisphere or "*S*" if they thought it was in the southern hemisphere. They were asked to make an "educated guess" even if they were not sure of the answer. Each city and its state or province and country again appeared on a separate line, followed by a blank line for its estimated location.

For the distance estimate task, participants were asked to estimate the "crow's flight" (most direct route) distance in miles between all possible pairs of the 16 cities (for a total of 120 estimates). They were further informed that the "pole-to-pole" distance of the earth is approximately 12,400 miles. They were again asked to make their most informed guess even if they were not sure of the answer. Each pair of cities, together with their states or provinces and countries, appeared on a separate line, with a blank line centered between them that was to be filled in with the distance estimate.

Results and Discussion

We first examined the latitude estimates, to determine empirically (a) which cities were sorted into which regions, (b) whether there were discernible gaps between regions, (c) whether the range of estimates within some of the regions was truncated, (d) whether there was a bias to place southern U.S. and Mexican cities too far to the south, (e) whether there was ordinal accuracy for cities within familiar regions, and (f) whether the proportional differences between the mean estimated latitudes of the regions preserved the proportions that exist between the actual means. Thus, these analyses were primarily meant to provide a replication of previous findings and a set of benchmarks for the distance estimates.

Next, we analyzed the distance estimates. We first subjected each individual's estimates to MDS and the resulting two-dimensional structures to a BDR analysis, to obtain the initial evidence that the regional representation underlying the latitude estimates (and the observed biases therein) was the same as that underlying the distance estimates. We next analyzed the signed and absolute errors to test whether the between-regions estimated distances were larger, on average, than the within-regions estimated distances when actual distances were equated, to provide further evidence for the existence of gaps between regions in the representation. We then examined the ordinal accuracy of the within- and between-regions distance estimates via correlation to provide evidence for the prediction that these correlations should be high only when the latitude estimates for both regions involved in a particular city pair also exhibited ordinal accuracy. Finally, we examined each set of within- and between-regions estimates (e.g., for familiar and less familiar regions) more formally for its fit (or lack of fit) to both linear and power functions. In all of the analyses reported, we used $\alpha < .05$ as the criterion level for significance. Effect sizes are reported as η_p^2.

Latitude Estimates

Preliminary analyses on the latitude estimates for each region showed no effect of task order and no interaction between region (Canada, northern United States, southern United States, and Mexico) and task order, so we did not consider this variable further. Figure 1 shows the mean latitude estimates across participants for each of the 16 cities, sorted from the most northerly estimate to the most southerly. There were both similarities and differences between the profile of this group of Californians and the previous groups we have tested (Friedman & Brown, 2000a, 2000b; Friedman, Kerkman, & Brown, 2002; Friedman et al., in press).

As in all previous data, there was evidence of regionalization: There were clear gaps between Canada and the northern United States and between the northern and southern U.S. regions. It is also evident that, on average, the Californians knew that Tijuana is a relatively northern Mexican city, so the gap typically observed between the southern U.S. and Mexican regions was absent for this group of participants; it was also absent for the group of participants from Ciudad del Victoria in northern Mexico (Friedman et al., in press). Note, however, that the cross-border adjacency observed in the present data was between Tijuana and Tampa (the southernmost U.S. city in the stimulus set) rather than between Tijuana and Los Angeles, which would have been more accurate. Thus, participants' latitude estimates were consistent with the belief that all of Mexico is south of all of the United States. Note also that the largest bias displayed by the current participants and all others we have tested thus far was in the estimates for the locations of the remaining Mexican cities. In the following analyses, we always included the data for Tijuana in the averages for Mexico. We did this deliberately because it biases against finding differences between that region and the southern United States in any of the analyses.

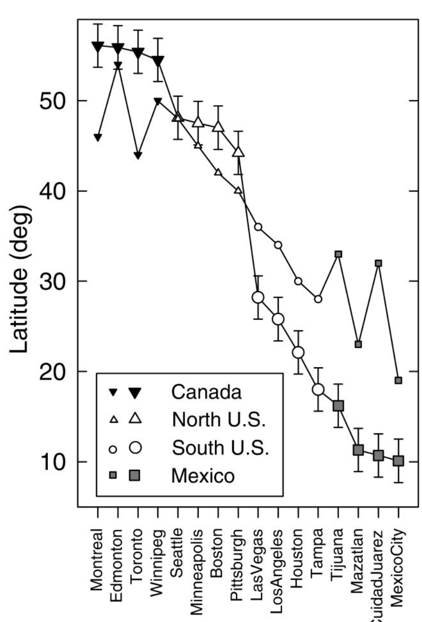

Figure 1. Mean estimated latitudes for each of the 16 stimulus cities, averaged across the 79 participants. Error bars are the 95% confidence interval for a repeated-measures design, computed from the error term in the analysis of variance with cities as the repeated measure (Loftus & Masson, 1994). The symbols without error bars are the actual latitudes for each city. deg = degree.

For each participant, we computed signed errors by subtracting the actual from the estimated latitude for each city and averaging over cities within each region. The means across participants for the Canadian, northern U.S., southern U.S., and Mexican regions were 7.0°, 2.9°, −8.5°, and −14.7°, respectively, $F(3, 234) = 50.97$, $MSE = 155.08$, $\eta_p^2 = .395$, and each of these was reliably different than zero, $t(78) = 5.46$, 2.33, −4.90, and −6.83, respectively. Further, as we have observed in all previous research, cities in both the southern United States and Mexico were biased far to the south of their actual locations. In addition, the average signed error for Mexican cities was larger than it was for cities in the southern United States, $F(1, 78) = 43.18$, $MSE = 70.19$, $\eta_p^2 = .356$.

We computed absolute errors by taking the absolute value of each signed error before averaging within regions. The means across participants for Canadian, northern U.S., southern U.S., and Mexican cities were 11.6°, 9.4°, 11.1°, and 16.9°, respectively, $F(3, 234) = 10.77$, $MSE = 76.19$, $\eta_p^2 = .121$, and all four of these were also reliably different from zero, $t(78) = 13.13$, 11.79, 6.79, and 8.57, respectively. Further, similar to what we have found previously (Friedman, Kerkman, & Brown, 2002, Friedman et al., in press), the average absolute error for Mexican cities was larger than that for Canadian cities, $F(1, 78) = 8.50$, $MSE = 260.98$, $\eta_p^2 = .098$.

We initially assigned cities to regions on the basis of the regions we had found in our previous research (Friedman & Brown, 2000a, 2000b). As a more objective means of testing whether the gap between any two cities was large enough to be an actual boundary, we submitted the 16 estimates from each participant to a one-way analysis of variance (ANOVA) and used the error term from that analysis to compute the 95% repeated-measures confidence interval around any mean entering into the main effect (Loftus & Masson, 1994; Masson & Loftus, 2003). This method does not presuppose what the regions actually are but allows the data to determine what they are. It is conservative because it does not take into account the considerable variance accounted for by the cities' belonging to regions.

The 95% confidence interval was 2.4° on each side of any given mean. By this criterion, the significant boundaries were between Canada and the northern United States (6.4°), the northern United States and the southern United States (16.0°), and Tijuana and the rest of Mexico (4.9°). None of the remaining differences between adjacent means was significant.

Despite the absence of within-region discriminability between cities, there was evidence for at least ordinal accuracy within some of the regions.[2] In particular, the Fisher-transformed Pearson correlations between actual and estimated latitudes for cities in each region yielded a main effect of region, $F(3, 234) = 27.94$, $MSE = 0.62$, $\eta_p^2 = .264$. Across participants, the average correlations (back-transformed from the ANOVAs) were .098, .445, .840, and .482, respectively, for Canada, the northern United States, the southern United States, and Mexico. As expected, the correlation for cities in the southern United States—the home region of the participants—was higher than the correlations for the other three regions. This pattern closely mimics that found with other groups of participants (Friedman, Kerkman, & Brown, 2002; Friedman et al., in press). From an inspection of Figure 1, it seems likely that the relatively high correlation for the Mexican cities was driven primarily by the estimate for Tijuana.

Finally, we examined whether the relative north–south difference between the actual regional means was preserved when the continent was “stretched.” The mean actual latitudes of the stimulus cities for the four regions were 48.5°, 43.8°, 32.0°, and 26.8° for Canada, the northern United States, the southern United States, and Mexico, respectively, which yielded differences between adjacent north–south regions of 4.7°, 11.8°, and 5.2°, respectively. Thus, in proportional terms, 21.7% of the total actual difference in mean latitudes between the Canadian and Mexican cities was represented by the difference between the means for Canada and the northern United States, 54.4% by the difference between the northern and southern United States, and 24.0% by the difference between the southern United States and Mexico.

We computed the difference in mean latitudes between regions for each participant and expressed the results as a percentage of each person’s overall Canada–Mexico difference. The mean estimated Canada–Mexico difference in latitudes across participants was twice as large as the actual one (43.4° instead of 21.7°), but the proportional differences between regions were roughly maintained: They were 22.6%, 50.3%, and 27.1%. Overall, the ratio data show that participants scaled North America to accommodate their beliefs about its range while maintaining the approximately correct relative latitude separations between the means of its regions. Thus, if participants use the regional means as the prototype location for each of the regions, then at the regional level, their beliefs have some metric validity (ignoring scale).

In summary, the location profile (see Figure 1), the presence of boundary zones, the southward stretching of the continent, and the lack of discriminability between adjacent cities within regions clearly indicate that the participants’ representations of North America were categorized, and there is also evidence that the continent itself was stretched in a manner similar to what we have previously obtained (Friedman, Kerkman, & Brown, 2002, Friedman et al., in press). Thus, the present latitude estimates were similar in most important respects to those we have previously obtained from both Albertan and Texan participants, and they share with those of the northern Mexican participants the explicit item knowledge that Tijuana abuts the southern U.S. border. The previous and present findings converge on the conclusion that where item knowledge exists, it is reflected in the relative ordinal accuracy of the estimates, whereas regional knowledge is what contributes to their absolute inaccuracy. That is, people tend to know about the relative locations of cities in familiar regions, but they may be highly inaccurate about the placement of the region as a whole.

Distance Estimates

Preliminary analyses on the between- and within-region distance estimates showed no effect of task order and no interaction between task order and region (Canada, northern United States, southern United States, and Mexico) for the within-region pairs or between task order and border (Canada–northern United States, northern United States–southern United States, and southern United States–Mexico) for the between-regions pairs. We thus did not consider this variable further.

MDS and BDR analyses. We subjected each participant’s full set of 120 distance estimates to an MDS analysis to recover a two-dimensional configuration that best fit his or her pattern of pairwise distance estimates. We then fitted both the aggregate and the individual MDS solutions to the actual latitudes and longitudes of the stimulus cities using BDR (Friedman & Kohler, 2003). This procedure allowed us to compare both the MDS and the BDR configurations with the pattern of regional organization suggested by the latitude estimates. These analyses thus provided an independent and methodologically diverse assessment of regional organization in the representations of spatial layout at the global scale.

We used a metric MDS because the data consisted of estimates of actual quantitative distances between cities rather than similarities, proximity rankings, and so forth. We assumed a euclidean metric, even though shortest distances on or parallel to the earth’s surface actually follow a spherical metric and, at global scales, spherical distances can be fairly different than euclidean distances. However, because global-scale spatial knowledge is based on exposure to various flat projections as well as other sources of knowledge besides the spherical globe, we believe that participants’ spatial knowledge is not precise enough to distinguish among these various metrics. Similarly, we assumed a two-dimensional solution because the earth’s surface is essentially two dimensional, with minor perturbations. This assumption proved reasonable because, whereas the goodness-of-fit statistic (a stress measure) improved from .61 to .56 going from one to two dimensions, adding a third dimension reduced stress by less than .005. Similarly, the correlation of input distance estimates with output distances from the MDS solution, corrected for the mean, increased from .45 to .51 going from one to two dimensions but did not increase moving to a three-dimensional solution.

Figure 2 shows the average MDS solution, computed by averaging over the *xy* MDS coordinates obtained for each city from each participant. Dimension 1 corresponds to the north–south placement of the cities and Dimension 2 to their east–west locations. It is clear that the MDS coordinates formed clusters for the Canadian and Mexican cities that were truncated in both dimensions. In addition, the two U.S. regions were apparent, and their north–south locations were truncated as they were in the latitude estimates. Further, the recovered coordinates reveal at least ordinal

[2] Because we selected the cities within the northern and southern U.S. regions to be approximately the same latitude difference apart from each other throughout the range (i.e., between about 2° and 4°), a significant correlation between estimated and actual latitude cannot distinguish between ordinal and interval accuracy in the latitude estimates. We therefore assume at least ordinal accuracy if the correlations between actual and estimated latitude are significant.

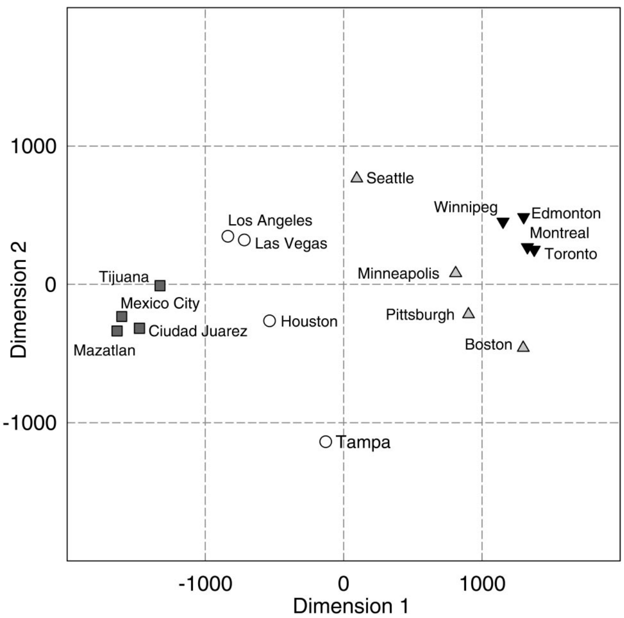

Figure 2. The two-dimensional multidimensional scaling (MDS) solution for the distance estimates between the 16 stimulus cities. Each city's point in the space is an average computed across the individual MDS solutions for each participant. Cities from Canada, the northern United States, the southern United States, and Mexico are represented by black triangles, gray triangles, circles, and squares, respectively.

accuracy for the east–west locations of the northern and southern U.S. cities.

Each city's *xy* coordinates from the aggregate MDS solution in Figure 2, as well as from the individual MDS solutions computed from each participant's distance estimates, were in arbitrary "MDS units" centered at <0,0>. To transform "MDS space" to fit into "map space," we used the aggregate MDS coordinates in Figure 2 and each individual's MDS coordinates as the independent variables and the actual latitudes and longitudes of the cities as the dependent variable in a set of BDR analyses. These analyses allowed us to find the predicted latitude and longitude values for each city, given its MDS coordinates, and thus to project each MDS solution into the actual latitude–longitude graticule using the scale, rotate, and shift parameters from the BDR analyses (see Friedman & Kohler, 2003, for details of this method). It was not necessary to rotate the MDS solutions prior to the BDR because the regression yields a parameter that does this in a nonarbitrary manner (see below). Thus, BDR provides a principled means of determining the ideal amount that a given two-dimensional metric MDS solution should be rotated, scaled, and translated to reflect the underlying structure of the domain it is supposed to represent, within the represented domain's coordinate system.

The data in Figure 3 are the coordinates obtained from the BDR analysis of the average MDS *xy* coordinates displayed in Figure 2. The points are the least squares predicted two-dimensional configuration of latitudes and longitudes for the 16 stimulus cities; the predicted configuration is thus the two-dimensional equivalent of a regression line among a set of unidimensional data points. We could not display the data points themselves on this graph, of course, because they remain in arbitrary MDS units. The important point for the present, however, is that the regions and the gaps between them are readily apparent, and the best fit configuration is properly oriented within the North American map.

The obtained BDR coefficient, *r*, estimates the goodness-of-fit between the aggregate and individual MDS solutions and the actual latitudes and longitudes. It should be noted that, just as the predicted *y* values in a linear regression are drawn toward their mean (a horizontal line) as the correlation decreases, as the bidimensional correlation decreases, each city's predicted *xy* coordinates are drawn toward the mean of the actual *xy* coordinates, which is a point. Thus, because the bidimensional correlation from the analysis of the average MDS solution was .798, all the predicted values in Figure 3 are "pulled toward" the mean of the actual latitudes and longitudes (37.8° N and 98.1° W).

Note also that Figure 3 represents an item-analysis BDR, because it was computed on the average of the 79 sets of MDS coordinates obtained for each city across participants. Therefore, similar to unidimensional regression, when we Fisher-transformed the BDR coefficients from the individual analyses before averaging and back-transformed the obtained average, the resulting regression coefficient was less than the coefficient obtained over items (.704 vs. .798, respectively). In both cases, the interpretation of the BDR coefficient is analogous to that for linear regression. Thus, on average, about 50% of the variance in the individual participants' recovered MDS coordinates can be explained by the actual latitudes and longitudes of the stimulus cities.

In addition to the bidimensional correlation, the BDR analyses on the aggregate (see Figure 2) and individual MDS coordinates each provided four parameters: (a) Φ, which is a scale parameter that reflects the amount that the MDS values had to expand or shrink to provide the latitude and longitude estimates; (b) θ, which reflects the amount that the MDS values had to be rotated into the latitude–longitude domain; (c) α_1, which is the amount of horizontal shift; and (d) α_2, which is the amount of vertical shift. In the present case, the horizontal and vertical shift parameters, α_1, and α_2, were necessarily identical across the aggregate and average of the individual analyses and equal to the mean of the actual latitudes and longitudes (98.1°W and 37.8°N), because the mean of

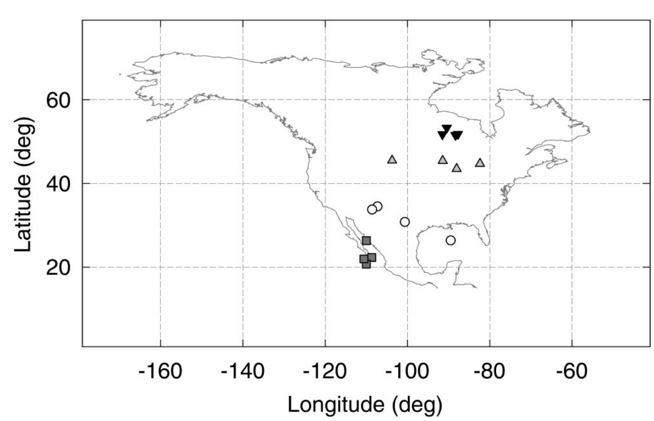

Figure 3. The best fit latitudes and longitudes for the 16 stimulus cities, computed from the bidimensional regression between the *xy* coordinates for each city in the aggregate multidimensional scaling solution displayed in Figure 2 and the actual latitudes and longitudes of each city. Cities from Canada, the northern United States, the southern United States, and Mexico are represented by black triangles, gray triangles, circles, and squares, respectively. deg = degree.

the *xy* coordinates in MDS space was <0,0>. However, because the MDS coordinates served as the independent variable in the BDR analyses, the obtained values for the remaining parameters could have, in principle, differed widely between the aggregate BDR and the average of the parameters obtained from the individual BDRs (see Friedman & Kohler, 2003, p. 483). Nevertheless, in the present case, the estimated scale and shift parameters were very similar for the item and participant analyses: The values for Φ and θ obtained from the data displayed in Figure 2 were .012 and 43.4°, respectively, and, averaged across participants, these parameters were .010 and 42.3°. Thus, on average, to convert the individual MDS solutions to predicted latitudes and longitudes for each participant required shrinking the MDS coordinates by a factor of about 100 (from coordinates in the range between 0 and +/−1500 to coordinates between about 20° and 150°), rotating them counterclockwise by 42.3°, and shifting them from the <0,0> midpoint of the two-dimensional MDS scale to the midpoint (in this instance) of −98.1°W and 37.8°N in the map domain. It is notable that when Figure 2 is rotated counterclockwise by 43.4° (the value from the item analysis) the cities retain the same relations to each other as they have in Figure 3. This is a property of the BDR analysis (Friedman & Kohler, 2003).

As final evidence that both the latitude and the distance estimates were generated from the same representations, we correlated each person's latitude estimates for the 16 stimulus cities with the latitudes projected from that individual's MDS solution via BDR. We did the same for the items: That is, we correlated the average estimated latitude for each city with that city's projected latitude, on the basis of the MDS coordinates displayed in Figure 2. The average Pearson correlation across participants was .805 (Mdn = .896), and the average over items was .996. Thus, a substantial amount of the variance in the latitudes derived from the distance estimates via the BDR analyses could be predicted from the obtained latitude estimates.

Size of within- versus between-regions estimates. To determine whether the between-regions estimates would be larger, on average, than the within-region estimates that were matched for actual distance, we averaged the distance estimates and their associated signed and absolute errors for each participant for the 24 within-region pairs and for the 48 between-regions pairs that were separated by one of the three adjacent regional boundaries (Canada and the northern United States, the northern United States and the southern United States, and the southern United States and Mexico). As we did with the latitude estimates, we counted the values for Tijuana in the Mexican averages. This is conservative because it biases against finding larger between-regions than within-region differences in either the distance estimates themselves or their signed or absolute errors.

The average within-region estimate was 1,225 miles, whereas the average between-adjacent-regions estimate was 1,579 miles, for a difference between pair types of 354 miles, $F(1, 78) = 39.17$, MSE = 126,239.00, $\eta_p^2 = .334$. Recall that the actual difference in distance between within- and between-adjacent-regions pairs was only 63 miles. Thus, the obtained difference in distance between pair types was more than five times greater than the actual difference in distance.

We do not believe that the effect of borders (national or psychological) on the distance estimates was due entirely to the overall stretching of the North American continent southward; that is, we do not believe it was due entirely to scaling. We have evidence for this position in the comparison between the within- and between-regions distance estimates for Canada and the northern United States, which are the two regions that were the least "stretched" in the location profile (see Figure 1). The mean actual distance between cities was 1,112 and 1,398 miles, respectively, for the within-Canada and within–northern U.S. pairs (7 pairs per region). For the 16 pairs that crossed the border between these two regions, the mean actual distance was 1,055 miles. Thus, the between-regions actual average distance was less than either of the actual averages within regions. Nevertheless, the average estimated distances within Canada and the northern United States and between these two regions were 801, 1,659, and 1,318 miles, respectively. Thus, in this instance, the average of the between-regions estimates was in between both of the within-region estimates. This result is inconsistent with a scaling explanation for the difference between within- and between-regions estimates.

Figure 4 shows the signed and absolute errors for the within- and between-adjacent-regions distance estimates across participants. For signed errors, participants overestimated the distances between regions, but their signed errors "averaged out" within regions (i.e., participants were just as likely to overestimate as to underestimate a given distance); the within- versus between-regions difference was significant, $F(1, 78) = 26.55$, MSE = 126,305.00, $\eta_p^2 = .254$. However, there was no evidence of a difference in the absolute magnitude of the within- and between-regions errors, $F(1, 78) = 2.32$, MSE = 97,223.00, $p = .132$. That is, when one ignores the direction of error, the overall level of accuracy in the distance estimates was equivalent within and between regions. In sum, as would be predicted by the presence of gaps between both national and psychological regions, together with the use of an ordinal conversion strategy, if a pair of cities was separated by either a national or a psychological border, the estimated distance between them

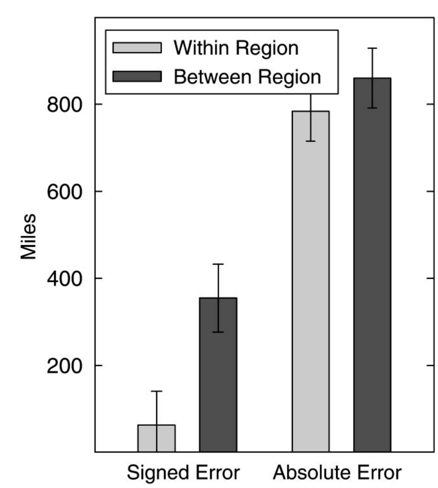

Figure 4. Signed and absolute errors in the distance estimates averaged first over each of the 24 within-region pairs and 48 between-regions pairs for each participant and then over participants. Error bars are the 95% confidence intervals for a repeated measures design, computed separately for each measure from the error term in their analyses of variance (Loftus & Masson, 1994).

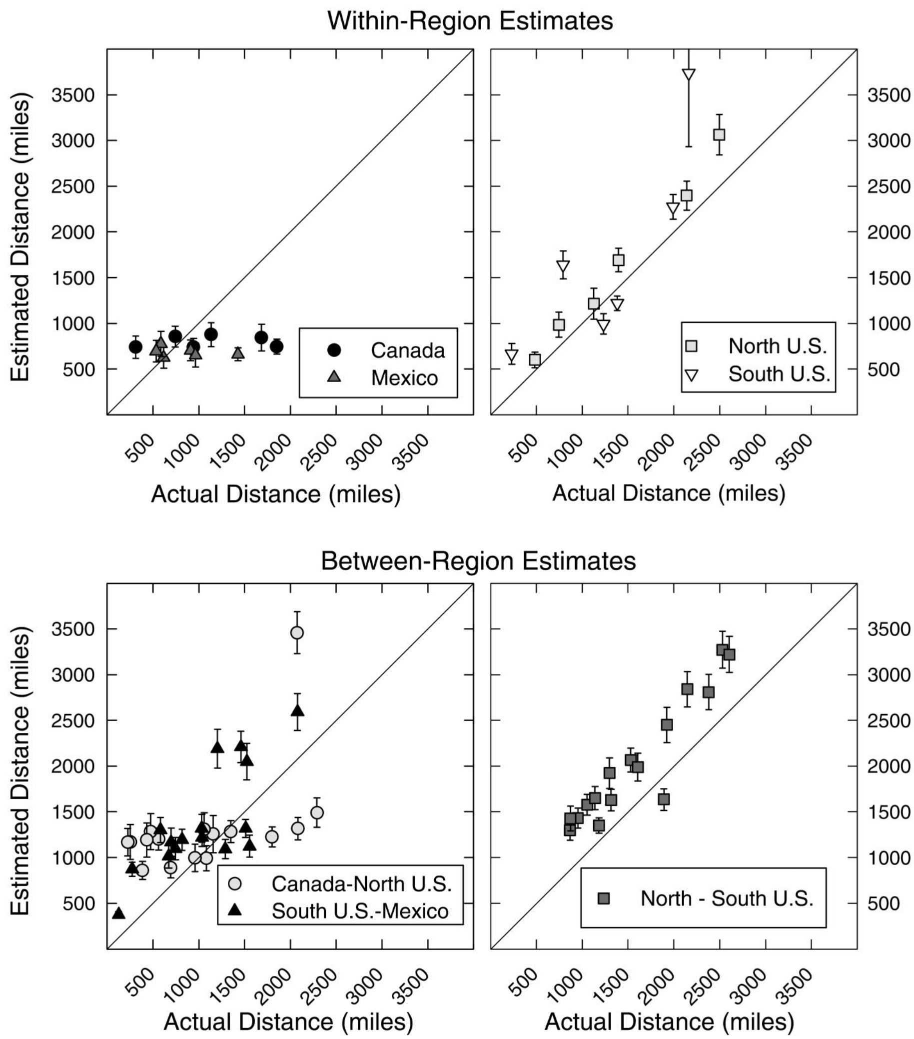

Figure 5. Mean distance estimates for 24 within-region pairs and for 48 between-adjacent-regions pairs as a function of actual distance. Means were computed for each city pair across participants. Error bars are standard errors across participants.

was larger than it would have been for pairs of equivalent distances but without such a border.

Ordinal accuracy of within- versus between-regions estimates. Figure 5 shows the average distance estimates for the 24 within-region pairs and for the 48 between-adjacent-regions pairs; the data in all four panels are plotted against the actual pairwise distances. These data are consistent in most respects with the latitude estimates. First, for the within-region pairs, distances were mostly underestimated (truncated) for Canadian and Mexican cities (the actual range of distances was 1,540 miles for the two regions, and the estimated range was 252 miles), but, with a few exceptions, the estimates were relatively accurate for city pairs within both the northern and the southern United States. The inaccuracy of the distance estimates for Canadian and Mexican pairs, and their truncation, reflects properties seen in the latitude estimates. The relative ordinal accuracy for U.S. distance estimates also mimicked that of the latitude estimates.[3] Together, the features of the within-region latitude and distance estimates across all four regions provide further evidence that both types of estimates were based on the same representation.

For the between-regions estimates, there were more overestimates of the distances between the southern U.S. and Mexican regions than there were between Canada and the northern United States. This particular asymmetry probably does reflect the differential scaling between the two sets of regions. In addition, the range of most of the distance estimates across both national borders was relatively truncated, relative to the range between the two U.S. regions. Indeed,

[3] The apparent metric accuracy of the within- and between-regions distance estimates for the northern and southern United States could be due to the relatively large longitude differences extant among the cities sampled rather than necessarily reflecting metric (as opposed to ordinal) properties of the representation in general. That is, though we cannot know from the latitude or distance estimates per se whether participants had accurate knowledge about the relative east–west position of the cities within the two U.S. regions, we may infer from prior research (Friedman & Brown, 2000a) that they did, at least at the relatively coarse level of stimulus sampling used in the present study. This knowledge, in turn, should contribute to at least ordinal accuracy in the observed distance estimates within and between these two regions.

excluding the four pairs involving Tampa, which are the four uppermost triangles in the bottom left panel of Figure 5, the actual range of distances for the southern U.S.–Mexico pairs was 1,429 miles, and the estimated range was 941 miles. The single between-regions outlier for the Canada–northern United States pairs was Seattle and Toronto. Thus, on the whole, the between-adjacent-regions estimates for pairs that included a Canadian or Mexican city were truncated relative to the actual distances.

It is also evident that the relative accuracy of the distance estimates was reasonably good between the northern and southern U.S. regions, although all but one of the distances were overestimated. Thus, the between-regions distance estimates for the northern and southern U.S. city pairs reflect both the gaps between the psychological regions (and, hence, the overestimation) and the within-region relative accuracy for items. In contrast, the between-regions estimates at each national border reflect the explicit and implicit truncated range for, respectively, the latitude and longitude dimensions for both the Canadian and the Mexican estimates.

We corroborated the generalizations above by examining the Pearson correlations between actual and estimated distances, computed separately for each participant for the four sets of within-region city pairs and the three sets of between-adjacent-regions pairs. These correlations provide a scale-free measure of the relative metric accuracy of the distance estimates.

An ANOVA that used the four Fisher-transformed correlations for each within-region distance estimate revealed a main effect of region, $F(3, 234) = 108.77$, $MSE = 0.31$, $\eta_p^2 = .582$. The back-transformed means for Canada, the northern United States, the southern United States, and Mexico were .095, .862, .785, and .027, respectively. Essentially, there was no relation between actual and estimated distances for the Canadian and Mexican city pairs but a healthy one for pairs in both of the U.S. regions.

An ANOVA that used the three Fisher-transformed correlations for the between-adjacent-regions estimates also produced a significant main effect, $F(2, 156) = 39.90$, $MSE = 0.09$, $\eta_p^2 = .338$. The back-transformed means for the Canada–northern U.S., northern U.S.–southern U.S., and southern U.S.–Mexico pairs were .389, .686, and .527, respectively. Further, all of these correlations were significantly different from each other, $t(78) = 8.72$, $SD_{\text{diff}} = 0.439$, for the difference between .389 and .686; $t(78) = 4.06$, $SD_{\text{diff}} = 0.387$, for the difference between .389 and .527; and $t(78) = 4.88$, $SD_{\text{diff}} = 0.463$, for the difference between .686 and .527. Thus, even the between-regions correlations were more accurate for the two U.S. regions than they were for comparable distances across the two national borders.

Tests of Stevens's law. We fit linear ($Y' = b_0 + b_1X$) and power ($Y' = kX^n$) functions to the mean estimated distances across all 120 pairs of cities. Figure 6, which includes all 120 stimulus pairs, shows that the obtained exponent of 0.78 for the power function is close to the average value (0.74) reported by Wiest and Bell (1985) for studies in which the estimated distances were inferred (i.e., could not be experienced directly). However, it is equally clear from a comparison of Figures 5 and 6 that the power function for the aggregate distance estimates camouflages the underlying heterogeneity of relations that exist because the cities were either within or between familiar or unfamiliar regions.

Table 1 shows the linear and power function fits for a variety of combinations of within- and between-regions city pairs. The first two rows of the table indicate the parameters and fit, respectively, for all 120 stimulus pairs, and for the 72 pairs that made up the

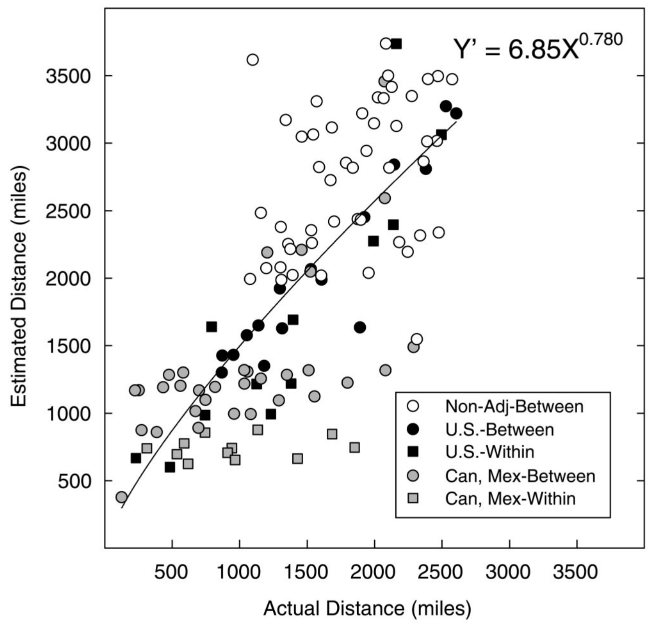

Figure 6. Mean distance estimates for all 120 stimulus pairs as a function of actual distance. Adj = adjacent; Can = Canada; Mex = Mexico.

within- and between-adjacent-regions sets that we used in the data analyses reported above. It is clear that the subset was reasonably representative of the whole.

Comparisons among the parameters and fits for the within- and between-adjacent-regions pairs provide evidence for the heterogeneity of the functions. For example, when we examine the between-adjacent-regions pairs across all four regions, the exponent for the power function (0.63) is smaller than it was over all the data, yet the exponent for the within-region pairs (1.172) is larger. The most telling comparisons are those for the within- and between-adjacent-regions estimates for U.S. pairs against the same comparisons for pairs that include Canadian and Mexican cities. If we examine just the power function fits, as Wiest and Bell (1985) did, we can see that they ranged from a low of .037 for the within-region Canadian and Mexican pairs to a high of .873 for the northern versus southern U.S. pairs. Overall, the power function fits for the more familiar northern and southern U.S. regions were better than those for the less familiar Canadian and Mexican regions, whether the estimated distances were within regions ($z = 2.23$) or between regions ($z = 2.79$).[4] Similarly, the exponents of

[4] The z values were derived as if the squared correlations were computed over independent samples, which, of course, they were not (e.g., not only were the same individuals involved in making all the estimates, but the same cities were involved in the within- and between-regions pairs). Furthermore, the models are not nested, so the fits cannot be tested with likelihood ratios or similar methods. However, if one considers the estimates as having been made over the pairs of cities, then the within- and between-adjacent-regions pairs are unique, so the independence assumption is less compromised. More important than the comparison between any two particular fits, however, is the main point: The fits of the power functions ranged widely, from virtually none to excellent, depending on the familiarity of the regions and whether the estimates were made within or between them. The same observation is true for the values of the exponents.

Table 1
Linear and Power Function Parameters and Goodness-of-Fit for Several Combinations of City Pairs

	Linear fit $Y' = b_0 + b_1X$			Power fit $Y' = kX^n$		
Pair type	b_0	b_1	r^2	k	n	r^2
All pairs (n = 120)	395	1.085	.561	6.853	0.780	.556
Analyzed pairs (n = 72)	384	0.895	.570	5.958	0.777	.540
Between adjacent regions						
Four regions (n = 48)	566	0.827	.606	18.273	0.631	.566
United States (n = 16)	359	1.061	.879	4.327	0.836	.873
Canada, Mexico (n = 32)	729	0.594	.384	80.210	0.412	.359
Within regions						
Four regions (n = 24)	55	1.007	.567	0.292	1.172	.574
United States (n = 12)	95	1.196	.779	0.915	1.042	.778
Canada, Mexico (n = 12)	708	0.036	.043	561.268	0.042	.037

the power function varied widely among the four within-region and three between-adjacent-regions pairs, from 0.042 for the within-Canada and Mexico pairs to 1.042 for the same number of pairs within both of the U.S. regions. Thus, it is not so much the task context that determines the value of the exponent in fitting global distance estimates or that determines even the degree of fit. Rather, the value of the exponent and the goodness-of-fit depend on whether the cities in a given pair belong to the same or different cognitive regions and whether those particular regions are sufficiently familiar that at least the ordinal position of the cities within them is relatively accurate.

Knowledge Ratings

The average knowledge ratings for Canadian, northern U.S., southern U.S., and Mexican cities were 2.3, 4.2, 5.9, and 2.8, respectively, $F(3, 234) = 229.86$, $MSE = 0.90$, $\eta_p^2 = .747$. Similar to Albertan, Texan, and Tamaulipan participants (Friedman et al., in press), Californians rated themselves as knowing more about cities in their home region than in any of the other three regions (the differences between all adjacent regions were reliable), $F(1, 78) = 197.98$, $MSE = 1.41$, $\eta_p^2 = .717$, for Canada vs. the northern United States; $F(1, 78) = 180.96$, $MSE = 1.31$, $\eta_p^2 = .699$, for the northern versus southern United States, and $F(1, 78) = 454.67$, $MSE = 1.69$, $\eta_p^2 = .854$, for the southern United States versus Mexico. In addition, like the Texans, the Californians rated themselves as knowing more about the Mexican cities than the Canadian cities, $F(1, 78) = 7.25$, $MSE = 2.70$, $\eta_p^2 = .085$. It should be noted that though the knowledge ratings often predict the relative accuracy of estimates within the participants' home region, the overall pattern of self-rated knowledge is not generally well reflected in the absolute accuracy of the estimates. For example, the average correlation across participants between the knowledge ratings for each of the 16 cities and the absolute error in the latitude estimates was a very modest −.17.

General Discussion

The present study provides the first evidence that a common representation underlies both absolute (latitude) and relative (distance) estimates of global locations. The location profile for the latitude estimates and the MDS solution recovered from the distance estimates both indicated that the North American cities in our sample were categorized into four distinct regions with relatively large (and, in actual terms, nonexistent) gaps between them. Both the absolute location estimates and the relative within-region distance estimates for cities in the two less familiar regions (Canada and Mexico) were truncated, reflecting the sparseness of item knowledge for these regions. In addition, there was evidence from both the latitude estimates and the recovered MDS solution that, whereas the absolute placement of the regions was inaccurate, there was reasonable relative accuracy (in both east–west and north–south dimensions) for items in the two U.S. regions as well as "local knowledge" (albeit incorrect) about the relative location of Tijuana with respect to the southern U.S. border. Thus, the distance judgments reflect the kind of metric sensitivity within familiar regions that we have previously seen using only latitude or longitude estimates (e.g., Friedman & Brown, 2000a, 2000b), and they also exhibit the same gross inaccuracies in the absolute placement of the regions themselves.

We do not believe that the convergence of the latitude and distance estimate tasks on the same regionalized representations and types of biases exhibited is limited to numerically based estimate tasks or to the particular methods we used. First, many other researchers have found evidence for the use of regionalized representations in location estimates using tasks that did not require numeric judgments (albeit primarily with relative judgments for distances that are navigable or have been learned from artificial maps or arbitrary arrays of objects; e.g., McNamara & Diwadkar, 1997; Newcombe & Liben, 1982; A. Stevens & Coupe, 1978; Thorndyke & Hayes-Roth, 1982). Second, the particular pattern of bias observed when people made nonnumeric, global-scale bearing estimates between pairs of cities (e.g., Tversky, 1981) was predictable from the same regionalized representations that were obtained from numeric latitude estimates (Friedman, Brown, & McGaffey, 2002). That is, the biases observed in bearing estimates between cities either appeared or were absent as a function of the regions to which the cities within a pair belonged. Third, we have converging evidence for the use of regionalized representations that are stretched toward the equator when people make their judgments using a "drag and drop" method that is similar to a map reconstruction task (Kerkman, Friedman, Brown, Stea, & Carmichael, 2003); indeed, the same regions, gaps, and biased estimates we had previously obtained from adults making numeric estimates (Friedman & Brown, 2000a, 2000b) were revealed with this new method in children as young as 11 years of age (Kerkman et al., 2003).

Although people certainly might use different representations to perform different kinds of spatial location tasks (Newcombe, 1985), they can clearly enlist the ordinal conversion strategy proposed here and elsewhere (Brown, 2002; Brown & Siegler, 1993; Friedman et al., in press) to make both absolute and relative numeric location estimates. Consequently, if, in fact, participants used the same strategy and representations in both tasks, it should not be surprising that we converged on similar patterns of data. Nevertheless, the overall range of numeric and nonnumeric methods used to investigate spatial knowledge at a global scale is still relatively sparse, so further research is required to strengthen and generalize the conclusions of the present study.

The present study underscores the utility of BDR in providing a principled means of determining the extent to which a metric MDS solution should be rotated. It also illustrates how BDR can be used to assess the extent to which the obtained MDS configuration accurately reflected the configuration of the stimulus cities in the latitude and longitude domain. In contrast, the stress measure reported for the MDS analysis merely reflected how well the MDS solution fit the original matrix from which it was generated; thus, it does not reflect the accuracy of the MDS solution with respect to the real-world map.

The present study also underscores the need for researchers to use caution when modeling distance estimates. Clearly, the appropriateness of using a particular function or exponent depends on factors such as whether the items being estimated lie in the same or different regions and whether the regions are familiar. Equally clearly, this is a strong conclusion to make on the basis of the necessarily small number of cities used in the present study to accommodate the number of estimates required for the MDS analysis. However, though at present we need to exercise caution in generalizing the results and the recommendations that follow from them, the overall pattern of latitude estimates obtained in the present study is similar to all others we have obtained, which includes a much wider array of cities in both the Old and the New World and participants from Canada, the United States, and Mexico (Friedman & Brown, 2000a, 2000b; Friedman, Kerkman, & Brown, 2002, Friedman, et al., in press). Thus, though the empirical work is still necessary, we believe that our conclusions about modeling inferred, global-scale distance estimates will hold more generally. Nevertheless, future research using many more stimulus cities is needed to establish when, if ever, power functions are appropriate for modeling global-scale distance estimates and, more important, whether the cautions about regional membership apply to modeling other types of distance estimates (e.g., estimates based on direct experience; perceptually based distance estimates).

It is notable that we obtained the evidence for the effect of categorical knowledge on both absolute and relative judgments despite the fact that the participants in the study were, relatively speaking, "experts" in North American regional geography and performed the estimate tasks in the context of having studied for a final exam on that topic. Indeed, they had viewed a North American map many times in the 2 months prior to data collection, and one may presume that most of them had studied such a map in preparation for their final exam. We interpret the apparent lack of influence of actual maps on the observed regionalization and inaccuracies in the latitude and distance judgments as strong support for the idea that participants were basing their judgments on long-standing representations that had the qualitative characteristics we have inferred from previous research. Even though the participants were very likely familiar with North American maps, the qualitative aspects of both their latitude and their distance estimates were not veridically "maplike" in any obvious way; a strong implication is that the participants' cognitive maps were not particularly maplike either.[5]

It is also notable that we obtained evidence for the existence and influence of cognitive regions using a task that measured distance directly and that provided a single configuration of estimates. As noted earlier, distance judgments are probably much more familiar, as a spatial construct, than are latitude judgments. Thus, distance judgments could plausibly have been based on different representations and/or processes than those used to estimate latitudes. However, all the evidence indicates that they were not. The study mentioned above that used bearing estimates, which are arguably also more familiar to lay people than latitude estimates and which do not involve numeric information at all (Friedman, Brown, & McGaffey, 2002), provided additional support for the idea that many types of geographic judgments are based on the same (categorized) representations and plausible reasoning processes. To the extent that the judgments reflect item knowledge in addition to regionalization, they may be accurate within and between regions where item knowledge is available, such as the home region.

Recently, Burris and Branscombe (2005) and Carbon and Leder (2005) found evidence that global and interurban distance estimates, respectively, were influenced by psychological borders whose existence was influenced by affective factors, which is a different sort of influence on distance estimates than those we have been discussing (e.g., global landmarks). For example, Burris and Branscombe (2005) found that university students from Memphis, Tennessee, and Lawrence, Kansas, overestimated the distances between Memphis and Toronto, Canada; Memphis and Pierre, South Dakota; and Memphis and Nuevo Laredo, Mexico but underestimated the distance between Memphis and Cape Hatteras, North Carolina (all of the objective distances were approximately equal). Because the main effect of national border (crossed or not crossed) was significant, Burris and Branscombe interpreted their data as providing evidence for a "psychological boundary" between the self and nonself.

It so happens that the four cities that were referenced to Memphis in Burris and Branscombe's (2005) study are situated in the four regions revealed in the estimates of all of our previous and

[5] Of course, if given a real map on which to place the cities, participants would undoubtedly be more accurate, if only because they would not place the cities in the oceans, and the map's boundaries would necessarily limit the range of error they could exhibit. Indeed, giving participants a real map should influence them similarly to giving them an accurate "seed fact" (Brown & Siegler, 1993; Friedman & Brown, 2000a, 2000b): Performance should become much more accurate in general. More important for the present context, it is entirely possible, and even likely within the plausible reasoning framework, that participants given a real map on which to make location judgments would evince other remnants of the influence of psychological regions. For example, we should observe clusters of cities belonging to different regions, gaps between regions, and truncated ranges within regions.

present groups of participants (Canadian, American, and Mexican; Friedman & Brown, 2000a, 2000b; Friedman, Kerkman, & Brown, 2002; Friedman et al., in press; Kerkman et al., 2003), and Burris and Branscombe's (2005) findings are consistent with this four-region, stretched representation. In particular, Memphis and Cape Hatteras are both in the southern U.S. region, and the other three comparison cities are each in a different North American cognitive region. Thus, rather than reflecting a "self versus nonself" distinction, we think it is more likely that Burris and Branscombe's data simply reflect the fact that people's global geographic representations are influenced by cognitive regions and their relation to global landmarks, such as the equator.

Carbon and Leder's (2005) data speak more clearly to the influence of affect in the creation of psychological borders that influence distance judgments, albeit between city pairs that one can travel to by car. They found that German participants overestimated the distance between cities situated in the regions that were formerly East and West Germany, compared with distances between cities within these two regions. The overestimation between regions was amplified for participants who had a negative attitude toward the reunification of Germany, and these data are striking because the reunification of Germany occurred when most of the participants were young children. Thus, this study is a more convincing demonstration of the psychosocial factors that may contribute to the mental regionalization of global geography (see also Kerkman, Stea, Norris, & Rice, 2004).

That latitude, bearing, and distance judgments are generated from a common representation should not be surprising. Nor should it be surprising that geographic judgments can be influenced by affective, psychosocial, and other "nongeographic" factors. Geographic knowledge is heterogeneous and comes from a variety of sources learned over the life span. Along with most other knowledge about complex, real-world domains, geographic knowledge is categorized, and within-category knowledge about specific items is often, though not always, sparse. Nevertheless, plausible reasoning processes and general retrieval strategies, such as ordinal conversion, can be used as general-purpose heuristics for retrieving hierarchically categorized information that will be adequate to the task under most circumstances.

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