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Sex difference in geographical knowledge: Driving experience is not essential

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Abstract

When required to locate places on outline maps, males consistently perform more accurately than females. This sex difference in geographical knowledge has been observed in samples throughout the United States, in all age ranges examined from the second to the 9th decade of life and in samples differing in average education level from high school to postgraduate degrees. Both males and females appear to acquire geographical knowledge during surface travel through the environment. The information acquired during everyday travel is apparently integrated into topographic representations that comprise a cognitive map. This process is less efficient in females probably because they attend to and remember more about landmarks and less about distance and directional cues than do males. To examine the importance of driving experience on the ability to locate places on an outline map of the Oklahoma City metropolitan area, adolescents who were too young to drive and older persons with varying amounts of experience traveling in the metropolitan area were studied. In the present study the magnitude of the sex difference in accuracy, though not the absolute level of performance, was similar in groups of people too young to drive and in younger and older drivers. Hence, the sex difference in geographical knowledge cannot be the product of differences in driving that may exist between males and females. (*JINS*, 2002, *8*, 804–810.)

Keywords: Sex differences, Spatial cognition, Remote memory

INTRODUCTION

Sex differences favoring males have been demonstrated repeatedly on a number of tasks that require visuospatial information processing. Examples include certain visuomotor tasks that require throwing a projectile at a target, perceptual tasks that require maintaining spatial orientation and on various mental rotation tests, especially those that require mental manipulation of three-dimensional objects (see Kimura, 1999; Maccoby & Jacklin, 1974, for reviews). Males also excel at learning novel routes and mazes including a virtual version of the Morris Water Maze, a task that requires true cognitive mapping (Astur et al., 1998; Galea & Kimura, 1993; Moffat et al., 1998). Although some researchers claim that the capacity to create and use mental maps appears early in life, even in blind children, Liben and Downs (1989) reviewed the literature and concluded that cognitive mapping is not a single ability but a collection of skills that mature at different ages with different dependencies on environmental stimulation.

One method for measuring remote memory for visuospatial information is to require participants to locate cities or other geographical features on outline maps of a target region (e.g., the United States, individual states or regions, or metropolitan areas). On these tests of geographical knowledge, males consistently perform more accurately than females. Reliable sex differences have been observed in samples of college students throughout the United States (Beatty & Tröster, 1987), in residents of North Dakota ranging in age from 17 to 92 (Beatty, 1989a) and in samples that varied in average education from high school to postgraduate degrees (Beatty, 1989a; Beatty et al., 1996; Beatty & Tröster, 1987). Cross-sectional studies show that geographical knowledge is a progressively increasing function of age until the 5th or 6th decade and then is maintained at asymptote for the remainder of life (Beatty, 1989a; 2001). However, the relationship between age and geographical knowledge appears mainly to reflect the fact that as people get older they accumulate more extensive travel experiences. Multiple regression analyses have consistently shown

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that travel history (measured as the total number of places ever visited in the target area of the test map) is the best single predictor of geographical knowledge, accounting for more than 25% of the variance in performance (Beatty, 1989a; Beatty et al., 1997a). Education and gender modestly increased the accuracy of prediction.

Because of the sex differences in visuospatial perception and learning described above it might be suspected that males are simply better than females at learning and remembering the information on outline maps, but this is not the case. Using a test called New Map (Beatty & Tröster, 1987) that requires acquiring knowledge of the locations of fictitious places but is otherwise similar to tests of geographical knowledge, we have consistently found that males and females acquire information at similar rates; retention over delays ranging from 30 min to 48 hr is also similar (Beatty et al., 1996; Beatty & Bruellman, 1987; Beatty & Tröster, 1987), although in one study (Beatty et al., 1997a) females showed better retention of place location information. Available information on long term retention of geographical knowledge as measured by our methods (Beatty, 1988; Beatty & Salmon, 1991; Beatty & Spangenberger, 1988) suggests that there is little or no loss in accuracy over a period of at least 25 years.

The foregoing findings imply that the sex difference in geographical knowledge cannot arise from differences in memorial processes that occur after encoding and initial storage of place location information, and it is most unlikely that there are important differences, favoring males, in long-term storage or retrieval. It follows, therefore, that the critical difference between men and women for geographical knowledge must occur prior to the stage in visuospatial information processing in which a place location is encoded into something like a topographical map. That is, men and women must process visuospatial information differently.

One difference is that for women landmarks are the most salient features for directing navigation through space, while for men distance and direction are more important cues. This sex difference can be inferred from studies that recorded the kinds of information participants give when asked to describe how to get to a particular location (Ward et al., 1986) and the idea is also supported by recent experimental evidence. Galea and Kimura (1993) studied learning of a route through a tabletop map of a hypothetical town. Men required fewer trials and made fewer errors in learning the route; on retention tests, men recalled accurately more details about direction and distance, but women recalled more information about landmarks and street names. Other studies (Eals & Silverman, 1994; McBurney et al., 1997; McGivern et al., 1997) also indicate that females perform better on laboratory object location memory tasks. Furthermore, both males and females believe that women are better at finding lost objects in the home (Beatty & Olson, 2001). It is probably significant that the topographical maps used in our studies of geographical knowledge contain no landmarks.

A second difference is that although the number of places visited is the best predictor of geographical knowledge for both sexes, this measure of travel history is a better predictor for men than for women. Beatty (2001) studied geographical knowledge for the Oklahoma City metropolitan area. The correlation between places visited and places located was high and positive for both men ($r = 0.91$, $p < .001$), and women ($r = 0.69$, $p < .001$) and the difference in the size of the correlations was significant ($z = 2.72$, $p < .01$).

Beatty (2001) proposed a working model for the development of sex differences in geographical knowledge. First, geographical knowledge is assumed to be acquired incidentally by both men and women during the course of everyday travel through their environments. In men, visuospatial attention systems gather and record distance and direction information that is automatically encoded into the topographical brain arrays that store accurate geographical knowledge. In women, visuospatial attention systems are tuned to acquiring information about landmarks, objects and their locations. This type of information is not particularly useful for performing well on formal tests of geographical knowledge, although it can serve to direct adequate real-world navigation under many conditions (Beatty & Bernstein, 1989; Beatty & Tröster, 1987).

The validity of this account rests on the assumption that any means of surface transport that allows a person to visit a place is equally valuable for creating conditions for accurate encoding of place location. That is, it should not matter whether one plans the route and drives the automobile to the to-be-visited places or merely goes along as a passenger. Although I know of no data that bear directly on this issue, there are reasons for doubting the functional equivalence of the driver and passenger roles for the acquisition of accurate visuospatial knowledge. First, the importance of active motor responding in adaptation to distortion of visual inputs by devices such as prisms that displaced the images laterally is firmly established (Held, 1968; Held & Hein, 1963). In these experiments only participants who responded actively (e.g., throwing darts at a target) while wearing prisms adapted to the lateral distortion; passive viewing did not result in visual adaptation. Furthermore, it is known that prior to the age of 8 or 9, children do not appear to incorporate information presented during passive travel on a school bus into spatial representations of the environment (Hart & Berzok, 1982).

The second reason for suspecting that driving and being a passenger may not be equivalent for the development of accurate geographical knowledge is anecdotal and consists of the spontaneous analysis of her own poor performance on the task of locating US cities by a female participant in one of our studies. She stated: “You know, Dr. Beatty, I’ve traveled a lot in my life, but I never paid much attention to maps because my husband did all of the driving and decided where we were going” (Beatty & Tröster, 1987).

The possibility that there are sex differences in some aspect of driving which are responsible for the differences in geographical knowledge is credible because all of the participants in the studies described above were of legal driving age. We did not determine whether the participants actually had driver's licenses and whether and how much they drove. However, because most of the participants were from North Dakota or Oklahoma, two states with large intercity distances and limited public transportation systems, it seems likely that nearly all participants were drivers for whom the private automobile was the principal mode of transportation.

To determine whether any aspect of driving was critical to the sex difference in geographic knowledge we studied males and females in three different age groups; the performance of individuals who were too young to drive was compared to that of groups of younger and older drivers. Geographical knowledge was assessed using a map of the Oklahoma City area because unpublished pilot studies indicated that young teenagers have virtually no knowledge of the geography of their state of residence or of the United States.

METHODS

Research Participants

Ninety-eight (44 male and 54 female) residents of the Oklahoma City metropolitan area participated in the study. All were employees, spouses of employees, or children of employees of the University of Oklahoma Health Sciences Center. Before participating they completed a brief health survey designed to detect individuals with histories of head injury, drug and alcohol abuse, learning disabilities or psychiatric, neurological or medical conditions that could affect performance. No potential participants were rejected on health grounds. This study was a preliminary investigation to determine the suitability of materials for a larger investigation of knowledge in adolescent and adult drug abusers. The larger study was not funded. The participants were divided by age into one group ($N = 22$) that was less than 16 years of age (the minimum age to obtain a drivers license in Oklahoma) and two groups of drivers: a younger group ($N = 37$) that ranged in age from 16 to 29 years and older group ($N = 39$) that ranged in age from 30 to 60 years. All of the participants in the latter two groups confirmed that they had drivers' licenses and regularly operated motor vehicles on local roads and highways.

Participants who were 18 or older provided written informed consent after a thorough explanation of the procedures which were approved by the local Institutional Review Board. For minor children a parent provided consent and the child provided assent for participation in the study.

Procedure

Participants first provided information about their age, sex, education, and years of residence in the Oklahoma City metropolitan area. Then they attempted to locate each of 18 cities on the Oklahoma City (Metro) Map Test. The Metro Map is a square, 130 km on a side, with Oklahoma City in the center from east to west and from north to south. On the map are 25 numbered dots; the participant's task is to write the number corresponding to the location of each of the 18 named target places and indicate which places he or she has visited. In this respect the Metro Map test is like the United States and regional tests used in our earlier studies. Because this segment of the state map is featureless (it looks like a square with numbers randomly distributed upon it), two orientation cues were given: first, the position of true North was indicated by an arrow labeled in the usual way; second, solid lines representing the location of interstate highways and other major expressways were shown to depict their course through the entire 130×130 km section of the state map. The highways were not individually identified and the participant had to infer the scale of the map from the target places that were to be located.

RESULTS

Table 1 summarizes the demographic and performance data. For the demographic variables education and years of residence in the Metro area there were significant main effects of age group [$Fs(2,92) > 8.91$, $ps < .01$], but neither the main effects of sex [$Fs(1,92) < 2.07$) nor the Sex × Age Group interactions ($Fs < 1$) were significant. Older participants had visited more of the target places [$F(2,92) = 4.79$, $p < .05$], but neither the main effect of sex [$F(1,92) = 1.31$] nor the Sex × Age Group interaction ($F < 1$) was significant for this variable. Subsequent analyses showed that the older drivers had visited more places than participants in the other groups ($ps < .05$), but the difference between the young nondrivers and the younger drivers was not significant. As expected, older participants located more places accurately [$F(2,92) = 23.00$, $p < .001$] and males located more places accurately than females [$F(1,92) = 4.93$, $p < .05$], but the Sex × Age Group interaction did not approach significance ($F < 1$). Effect sizes (η^2) were age group = .333; sex = .051; Age Group × Sex = .000.

Table 2 reports t tests for between sex comparisons at each age group for all dependent variables. Young female nondrivers had resided in the Metro area longer than males of the same age and driving experience. With the small sample sizes none of the differences between males and females in locating places was significant, but if the data are collapsed across age groups, males located more places than females [$M = 10.6$ *vs.* 7.5; $t(96) = 2.45$, $p < .05$].

Table 3 summarizes product moment correlations between the number of places located accurately and potential predictors. The data are presented separately for males and females. The patterns of correlations between predictors and accuracy in locating places were similar for males and females, as were the patterns of correlations among predictors. However, the strength of the correlation between the best predictor, places visited, and the dependent variable, places located was significantly higher for males

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Table 1. Sample characteristics and performance: *M* (*sd*)*

Sample characteristics	Young nondrivers (< 16 years old) M	Young nondrivers (< 16 years old) F	Younger drivers (16–29 years old) M	Younger drivers (16–29 years old) F	Older drivers (30–60 years old) M	Older drivers (30–60 years old) F	Overall M	Overall F
N	9	13	15	22	20	19	44	54
Age	14.3 (0.7)	14.5 (0.5)	24.1 (4.2)	22.3 (5.3)	43.7 (9.4)	41.3 (7.1)	31.0	27.1
	14.4		23.0		42.5			
Education	8.0 (0.5)	8.0 (0.0)	14.9 (3.4)	14.0 (3.6)	17.0 (3.5)	17.7 (2.1)	14.5	13.9
	8.0		14.4		17.4			
Years lived in OKC metro area	9.5 (5.3)	14.5 (0.5)	7.6 (7.7)	11.0 (8.6)	18.8 (13.8)	20.4 (15.6)	13.2	15.2
	12.7		9.8		19.6			
Performance measures								
Places visited/18	7.7 (5.1)	11.8 (5.1)	11.8 (4.6)	12.3 (3.8)	14.5 (4.7)	14.4 (3.8)	12.9	13.1
	11.7		12.2		14.4			
Places located/18	4.6 (3.1)	2.4 (2.9)	9.6 (5.8)	7.2 (5.7)	14.0 (4.8)	11.4 (5.9)	10.6	7.5
	3.3		8.2		12.7			

*Overall means for males and females in the column headed "Overall" are pooled across age group. Overall means for each age group (pooled across sex) are shown below means and *SD*s for males and females in that age group for each variable.

than for females (z for the difference between rs = 2.14, $p < .05$).

Table 4 summarizes results of a hierarchical regression analysis to predict accuracy in locating places performed by first forcing the variables age, education, places visited and sex into the equation followed by the interaction terms in the order indicated in the table. Education, places visited, and sex, as main effects, accounted for significant variance. Age did not account for significant variance, presumably because, although correlated with places visited, age is a weaker predictor of accuracy.

The interaction of Education × Sex also accounted for significant variance, probably because education was a better predictor of accuracy for women than for men. Of particular importance, neither the Age × Sex nor the Places Visited × Sex interactions accounted for significant variance. Altogether, the results of these analyses are consistent with the idea that the sex difference in geographical knowledge does not depend on driving experience.

Table 2. Values of *t* for comparisons (M–F) at different age groups

Variable	Young nondrivers	Younger drivers	Older drivers
Age	−0.464	1.189	0.889
Education	0.000	0.748	−0.805
Years lived in metro area	−2.453*	−1.351	0.348
Places visited	−0.649	−0.454	−0.095
Places located	1.691	1.234	1.539

*$p < .05$.

DISCUSSION

The present study was performed to determine whether driving experience was necessary in order that the sex difference in geographical knowledge be evident. In agreement with reports from my laboratory over the past 15 years (Beatty, 1989a; Beatty et al., 1996; Beatty & Tröster, 1987) the males tested in the present study displayed superior geographical knowledge. Although accuracy of place location improved markedly with age for both males and females, replicating an earlier finding (Beatty, 1989a), the magnitude of the sex differences was comparable among young nondrivers, young drivers and older drivers. The absolute magnitude of the sex difference varied from a mean of 2.2 places located accurately for the young nondrivers to 2.6 for the older drivers. In relative terms, the percent difference was 48% for the young nondrivers compared to 25 and 19% for the young and old drivers, respectively. Variables that influence accuracy of geographical knowledge including age, education, years of residence in the relevant region and travel history (i.e., places visited) cannot be responsible for the sex difference in accuracy because at each age group there were no sex differences on these measures. In fact, among the youngest groups the females had lived in the Oklahoma City metropolitan area longer and visited somewhat more places, but the males located more places accurately. Considered together, these findings indicate that the sex difference in geographical knowledge can result when individuals gather the necessary spatial information entirely by being passively transported. Any differences that may exist between men and women in planning routes or number of miles driven are not essential to demonstrating the sex difference in the accuracy of locating places on outline maps. Nevertheless, because the sample sizes in the

Table 3. Correlations between demographic and performance measures for males ($N = 44$, italic) and females ($N = 54$, roman type)

	Age	Education	Years lived in metro	Places visited	Places located
Age		.798***	.328*	.276	.585***
Education	*.636****		.102	.157	.609***
Years lived in Metro	*.500***	*−.052*		.599***	.364**
Places visited	*.439***	*−.078*	*.704****		.619***
Places located	*.651****	*.394***	*.622****	*.822****	

**$p < .01$, ***$p < .001$.
Note: Probabilities are two-tailed, not corrected for multiple comparisons.

adolescent nondriver groups were small, the results should be interpreted cautiously.

An additional reason for caution is that the measure of geographical familiarity, namely places visited, measures only whether a place has ever been visited, but does not consider the frequency or recency of visits. It is reasonable to assume (though unproven) that both variables could affect the accuracy of geographical knowledge. Likewise, it is possible that the males in the present study had visited places on the Metro Map more frequently or more recently than the females. Future studies could profitably examine these aspects of geographical familiarity. At the same time it should be noted that in previous studies (Beatty, 1989a, 2001), as well as in the present study, the variable Places Visited has consistently accounted for at least 25% of the variance in accuracy of geographical knowledge.

In the present study, age group and driving experience were completely confounded. This was unavoidable because in the Midwest and West, virtually everyone obtains a drivers licence as soon as they are eligible. Replication of the study in a large urban area in the East could remedy this problem, but at present there is no reason to suspect that the sex difference in locating places would be much affected. In samples of undergraduates, Beatty and Tröster (1987) found that the magnitude of the sex difference in geographical knowledge was slightly larger for samples from New York City and Philadelphia than for samples from 10 other universities located in the Southeast, the Midwest and the West.

Table 4. Hierarchical regression analysis to predict places located

Predictor	Standardized Beta coefficient	t	p
Age	−.042	−0.28	.779
Education	.636	4.66	.000
Places visited	.469	6.93	.000
Sex	.504	2.49	.015
Age × Sex	.419	1.64	.106
Education × Sex	−.700	−2.22	.029
Places Visited × Sex	.088	0.37	.771

The foregoing analysis of the basis of sex differences does not imply that driving and route planning are of no importance in the development of accurate geographical knowledge by men and women. Differences in the number of places located accurately between the young nondrivers and the younger drivers were highly significant ($p < .001$) while differences between the same groups in the number of places visited were not significant. This suggests that some factor or factors combine with merely visiting places to promote the development of knowledge of their location. The identity of these experiential factors and how they combine with the age-related maturation of the nervous system is not, at present, known.

Consistent with the previous report (Beatty, 2001), in the present study the strength of the relationship between places visited and places located was significantly higher for males than for females. This finding is consistent with the working model for the acquisition of accurate geographical knowledge (Beatty, 2001). This model postulates that this learning occurs mainly incidentally and attributes the sex difference in accuracy to unknown mechanisms that predispose men to encode, relatively automatically, information about direction and distance relationships among places for wayfinding and women to focus on landmarks to locate places (Eals & Silverman, 1994; Galea & Kimura, 1993; McBurney et al., 1997; Ward et al., 1986). Although either type of information can support accurate wayfinding in the real world under many conditions, encoding distance and directional information is necessary to form cognitive maps, a capacity that favors good performance on the tests of geographical knowledge used in the present and earlier studies. Of particular importance in this regard are the findings of Astur et al. (1998). They studied the performance of college-age men and women on a virtual version of the Morris Water Maze, a task that demands cognitive mapping. They observed a robust (effect size equals about 1.0 *SD*) sex difference favoring males in learning the water maze.

The sex difference in humans described by Astur et al. (1998) is qualitatively similar to findings in rats and voles. During the reproductive season, adult male voles learn the water maze significantly more rapidly than females (Gaulin & Fitzgerald, 1986), but the sex difference is not evident before sexual maturity (Galea et al., 1994). In this species, high levels of circulating estradiol are associated with poor performance by females (Galea et al., 1995, 2000). A similar association has been reported in humans (Hampson, 1990).

Studies in laboratory rats also reveal sex differences on both the water maze and the 12-arm radial maze. Males excel on both tasks, but neonatal treatment with testosterone or estradiol improves performance of females while neonatal castration of males impairs their performance (to the level of normal females; Roof & Havens, 1992; Williams et al., 1990; Williams & Meck, 1991). Of particular interest in the present context, Williams et al. (1990) found that the radial maze performance of normal males and neonatally estrogenized females was more dependent on geometric room cues than was the performance of the neonatally castrated males or the normal females. This suggests that spatial information processing is different in male and female rats and that it is organized by the hormone environment early in life. One likely site of the hormonal organization is the hippocampus, a brain structure known to be important in spatial memory in many species. Roof and Havens (1992) described a testosterone-related sexual dimorphism in the granule cell layer of the rat hippocampus. Other work indicates that in rodents sex differences in spatial behavior and species differences in foraging patterns are related to the morphology of the hippocampus (Jacobs et al., 1990; Jacobs & Spencer, 1994).

Except as measures of orientation (Lezak, 1995), tests of geographical knowledge are rarely employed in neuropsychology. This may be unfortunate because such measures are sensitive enough to demonstrate deficits in patients with multiple sclerosis (Beatty et al., 1988a, 1989), Parkinson's disease (Beatty & Monson, 1989) or amnesia (Beatty et al., 1988b). Furthermore, studies of geographical knowledge in patients with Huntington's disease or Alzheimer's disease reveal the same patterns of differences in the temporal gradient of retrograde amnesia as those observed with more traditional tests of remote memory that require identifying famous faces and recalling past public events (Beatty, 1989b; Beatty & Salmon, 1991; Beatty et al., 1988c). Finally, preliminary evidence suggests that tests of geographical knowledge may be useful in identifying which mildly demented patients are likely to become lost while driving alone (Beatty et al., 1997b). There is a substantial literature describing the influence of dementia, particularly Alzheimer's disease, on the risk of being involved in accidents (crashes) while driving (Rizzo & Dingus, 1996), but almost nothing is known about identifying patients who are at risk of becoming lost while driving in once familiar territory. Anecdotal evidence suggests that becoming lost while driving is not uncommon in Alzheimer's disease. The consequences for the patient as we (Beatty & Bernstein, 1989) described earlier can be life threatening.

REFERENCES

Astur, R.S., Ortiz, R.J., & Sutherland, R.J. (1998). A characterization of performance by men and women in a virtual Morris Water task: A large and reliable sex difference. *Behavioral Brain Research*, *93*, 185–190.

Beatty, W.W. (2001). The acquisition and retention of geographical knowledge by men and women [Abstract]. *Journal of the International Neuropsychological Society*, *7*, 131.

Beatty, W.W. (1988). The Fargo Map Test: A standardized method for assessing remote memory for visuospatial information. *Journal of Clinical Psychology*, *44*, 61–67.

Beatty, W.W. (1989a). Geographical knowledge throughout the lifespan. *Bulletin of the Psychonomic Society*, *27*, 379–381.

Beatty, W.W. (1989b). Remote memory for visuospatial information in patients with Huntington's disease. *Psychobiology*, *7*, 431–435.

Beatty, W.W. & Bernstein, N. (1989). Geographical knowledge in Alzheimer's disease. *Journal of Geriatric Psychiatry and Neurology*, *2*, 76–82.

Beatty, W.W., Blanco, C.R., Hames, K.A., & Nixon, S.J. (1997a). Spatial cognition in alcoholics: Influence of concurrent abuse of other drugs. *Drug and Alcohol Dependence*, *44*, 167–174.

Beatty, W.W. & Bruellman, J.A. (1987). Absence of gender differences in memory for map learning. *Bulletin of the Psychonomic Society*, *25*, 238–239.

Beatty, W., English, S., Scott, J., & Winn, P. (1997b). Driving in dementia: Testing for way-finding ability [Abstract]. *Journal of the International Neuropsychological Society*, *3*, 66.

Beatty, W.W., Goodkin, D.E., Monson, N., & Beatty, P.A. (1989). Cognitive disturbances in patients with relapsing remitting multiple sclerosis. *Archives of Neurology*, *46*, 1113–1119.

Beatty, W.W., Goodkin, D.E., Monson, N., Beatty, P.A., & Hertsgaard, D. (1988a). Anterograde and retrograde amnesia in patients with chronic progressive multiple sclerosis. *Archives of Neurology*, *45*, 611–619.

Beatty, W.W., Hames, K.A., Blanco, C.R., Nixon, S.J., & Tivis, L.J. (1996). Visuospatial perception, construction and memory in alcoholism. *Journal of Studies on Alcohol*, *57*, 136–143.

Beatty, W.W., MacInnes, W.D., Porphyris, H.S., Tröster, A.I., & Cermak, L.S. (1988b). Topographical memory following right temporal lobectomy. *Brain and Cognition*, *8*, 67–76.

Beatty, W.W. & Monson, N. (1989). Geographical knowledge in patients with Parkinson's disease. *Bulletin of the Psychonomic Society*, *27*, 473–475.

Beatty, W.W. & Olson, K.A. (2001). Where the heck is it? Memory for the location of objects in the home [Abstract]. *Journal of the International Neuropsychological Society*, *7*, 131.

Beatty, W.W. & Salmon, D.P. (1991). Remote memory for visuospatial information in patients with Alzheimer's disease. *Journal of Geriatric Psychiatry and Neurology*, *4*, 14–17.

Beatty, W.W., Salmon, D.P., Butters, N., Heindel, W.C., & Granholm, E.G. (1988c). Retrograde amnesia in patients with Alzheimer's disease or Huntington's disease. *Neurobiology of Aging*, *9*, 181–186.

Beatty, W.W. & Spangenberger, M. (1988). Persistence of geographic memories in adults. *Bulletin of the Psychonomic Society*, *26*, 104–105.

Beatty, W.W. & Tröster, A.I. (1987). Gender differences in geographical knowledge. *Sex Roles*, *16*, 565–590.

Eals, M. & Silverman, I. (1994). The hunter-gatherer theory of spatial sex differences: Proximal factors mediating the female advantage in recall of object arrays. *Ethology and Sociobiology*, *15*, 95–105.

Galea, L.A.M. & Kimura, D. (1993). Sex differences in route learning. *Personality and Individual Differences*, *14*, 53–65.

Galea, L.A.M., Ormerod, B.K., Sampath, S., Kostaras, X., Wilkie, D.M., & Phelps, M.T. (2000). Spatial working memory and hippocampal size across pregnancy in rats. *Hormones and Behavior*, *37*, 86–95.

Galea, L.A.M., Ossenlcopp, K.-P., & Kavaliers, M. (1994). Developmental changes in spatial learning in the Morris watermaze in young meadow voles, *Microtus pennsylvanicus*. *Behavioural Brain Research*, *60*, 43–50.

Gaulin, S.J.C. & Fitzgerald, R.W. (1986). Sex differences in spatial ability: An evolutionary hypothesis and test. *American Naturalist*, *127*, 74–88.

Hampson, E. (1990). Variations in sex-related cognitive abilities across the menstrual cycle. *Brain and Cognition*, *14*, 26–43.

Hart, R. & Berzok, M. (1982). Children's strategies for mapping the geographic scale environment. In M. Potegal (Ed.), *Spatial abilities: Development and physiological foundations* (pp. 147–169). New York: Academic Press.

Held, R. (1968). Dissociation of visual function by deprivation and rearrangement. *Psychology Forschung*, *31*, 338–348.

Held, R. & Hein, A. (1963). Movement-produced stimulation in the development of visually guided behavior. *Journal of Comparative and Physiological Psychology*, *56*, 872–876.

Jacobs, L.F. & Spencer, W.D. (1994). Natural space-use patterns and hippocampal size in kangaroo rats. *Brain, Behavior and Evolution*, *44*, 125–132.

Jacobs, L.F., Gaulin, S.J.C., Sherry, D.F., & Hoffman, G.E. (1990). Evolution of spatial cognition: Sex-specific patterns of spatial behavior predict hippocampal size. *Proceedings of the National Academy of Science, USA*, *87*, 6349–6352.

Kimura, D. (1999). *Sex and cognition*. Cambridge, MA: The MIT Press.

Lezak, M.D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Liben, L.S. & Downs, R.M. (1989). Understanding maps as symbols: The development of map concepts in children. *Advances in Child Development and Behavior*, *22*, 145–201.

Maccoby, E.E. & Jacklin, C.N. (1974). *The psychology of sex differences*. Palo Alto, CA: Stanford University Press.

McBurney, D.H., Gaulin, S.J.C., Devineni, T., & Adams, C. (1997). Superior spatial memory of women: Stronger evidence for the gathering hypothesis. *Evolution and Human Behavior*, *18*, 165–174.

McGivern, R.F., Huston, J.P., Byrd, D., King, T., Siegle, G.J., & Reilly, J. (1997). Sex differences in visual recognition memory: Support for a sex-related difference in attention in adults and children. *Brain and Cognition*, *34*, 323–336.

Moffat, S.D., Hamson, E., & Hatzipantelis, M. (1998). Navigation in a 'virtual' maze: Sex difference and correlation with psychometric measures of ability in humans. *Evolution and Human Behavior*, *19*, 73–87.

Rizzo, M. & Dingus, T. (1996). Driving in neurological disease. *Neurologist*, *2*, 150–168.

Roof, R.L. & Havens, M.D. (1992). Testosterone improves maze performance and induces development of a male hippocampus in females. *Brain Research*, *572*, 310–313.

Ward, S.L., Newcombe, N., & Overton, W.F. (1986). Turn left at the church, or three miles north: A study of direction giving and sex differences. *Environment and Behavior*, *18*, 192–213.

Williams, C.L. & Meck, W.H. (1991). The organizational effects of gonadal steroids on sexually dimorphic spatial ability. *Psychoneuroendocrinology*, *16*, 155–176.

Williams, C.L., Barnett, A.M., & Meck, W.H. (1990). Organizational effects of early gonadal secretions on sexual differentiation in spatial memory. *Behavioral Neuroscience*, *104*, 84–97.