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Gender and Sexual Orientation Differences in Cognition Across Adulthood: Age is Kinder to Women Than to Men Regardless of Sexual Orientation

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RUNNING HEAD: Age, Gender, Sexual Orientation, and Cognition

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ABSTRACT

Despite some evidence of greater age-related deterioration of the brain in males than in females, gender differences in rates of cognitive aging have proved inconsistent. The present study employed web-based methodology to collect data from people aged 20-65 years (109,612 men; 88,509 women). As expected, men outperformed women on tests of mental rotation and line angle judgment, whereas women outperformed men on tests of category fluency and object location memory. Performance on all tests declined with age but significantly more so for men than for women. Heterosexuals of each gender generally outperformed bisexuals and homosexuals on tests where that gender was superior; however, there were no clear interactions between age and sexual orientation for either gender. At least for these particular tests from young adulthood to retirement, age is kinder to women than to men, but treats heterosexuals, bisexuals, and homosexuals just the same.

KEY WORDS: gender; sexual orientation; cognition; aging; Internet.

INTRODUCTION

Many aspects of cognitive function show age-related decline from young adulthood to old age (for reviews, see Birren & Schaie, 2001; Craik & Salthouse, 2000; Perfect & Maylor, 2000; Salthouse, 1991). An important focus of much research in cognitive gerontology has been on the identification of possible factors associated with slower rates of decline, with some significant results (e.g., see Hawkins, Kramer, & Capaldi, 1992, on aerobic exercise; Lövdén, Ghisletta, & Lindenberger, 2005, on social participation) but also some null effects (e.g., see Rabbitt, Chetwynd, & McInnes, 2003, on intellectual ability and socio-economic status; Salthouse, Berish, & Miles, 2002, on cognitive stimulation). One factor that has so far "received little attention" (Meinz & Salthouse, 1998) is that of gender. In this article, we present the largest-scale study to date of the association between gender and age-cognition relations from young adulthood to retirement age. To the best of our knowledge, the study also provides the first examination of the influence of sexual orientation on age-related changes in cognition.

The relative neglect of gender in the aging literature is perhaps surprising for at least two reasons. First, there are well established gender differences in cognition, with females generally outperforming males on tests of perceptual speed, verbal fluency, and memory for object locations, and males generally outperforming females on tests of visuospatial skills and mathematical reasoning (for reviews, see Kimura, 1999; Springer & Deutsch, 1998). From a process point of view, females tend to excel at tasks requiring rapid access to, and retrieval of information from, memory, whereas males excel at maintaining and manipulating mental representations (Halpern, 2000; Halpern & LaMay, 2000).

Second, there is some evidence of greater age-related deterioration of the brain in males than in females (see reviews by Coffey et al., 1998; Meinz & Salthouse, 1998). For example, using magnetic resonance imaging (MRI) scans, Gur et al. (1991) observed that brain atrophy as indicated by increased cerebrospinal fluid volume with age was greater in males than in females; Cowell et al. (1994) found greater age-related reductions in brain volume for both frontal and temporal lobes in males than in females; and Pruessner, Collins, Pruessner and Evans (2001) found a reduction in hippocampal volume across early adulthood for males but not for females. From such findings, it would be predicted that corresponding age by gender interactions would be found in behavioral data and, indeed, greater age-related cognitive decline in males than in females has been observed in both cross-sectional and longitudinal studies (e.g., Barrett-Connor & Kritz-Silverstein, 1999; Larrabee & Crook, 1993; Meyer et al., 1999; Rowe, Turcotte, & Hasher, 2004; Wiederholt et al., 1993; Zelinski & Stewart, 1998). Interestingly, similar results have been found in two studies of spatial memory in rhesus monkeys (Lacreuse et al., 2005; Lacreuse, Herndon, Killiany, Rosene, & Moss, 1999), suggesting that biological rather than sociocultural factors may underlie the gender differences in age-related decline.

A number of other studies, however, have failed to find significant gender differences in rates of cognitive aging (e.g., Aartsen, Martin, & Zimprich, 2004; Barnes et al., 2003; De Frias, Nilsson, & Herlitz, 2006; De Luca et al., 2003; Dixon et al., 2004; Herlitz, Nilsson, & Bäckman, 1997; Larrabee, Trahan, Curtiss, & Levin, 1988; 6 out of 8 tasks in Meinz & Salthouse, 1998; Rabbitt et al., 2003; Schaie, 1996; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). There have also been occasional reports of greater age-related cognitive decline in females than in males (Brayne, Gill, Paykel, Huppert, & O’Connor, 1995, in the over-75s; 2 out of 8 tasks in Meinz & Salthouse, 1998). As noted by Lacreuse et al. (2005), there may be a number of explanations for this mixed pattern of results, including population biases and the use of different tasks, age ranges, selection methods, and so on (see also Raz, 2000). For example, the greater longevity of females by approximately seven years (Hayflick, 1996) may have resulted in more positively selected males (because they are the survivors) than females, particularly in studies of very old adults (Singer et al., 2003; see also Perls, 1995; Perls, Morris, Ooi, & Lipsitz, 1993; Stewart, Zelinski, & Wallace, 2000). In addition, if gender differences in rates of cognitive aging are small, at least some of the studies showing null effects may have lacked sufficient power to detect interactions between age and gender. The present study attempted to address these issues by focusing on young and middle-aged adults (20-65 years) and by recruiting large numbers of participants using web-based methodology.

Although on average females outperform males on verbal tasks and vice versa for visuospatial tasks, there are systematic differences in cognition within each gender (but particularly in males) according to sexual orientation (LeVay, 1993). For example, homosexual men tend to perform more poorly than heterosexual men, and more like females, on some male-superior visuospatial tasks (see Collaer, Reimers, & Manning, 2007). If males do show greater age-related decline than females, and if non-heterosexuals' cognitive performance is more like that of the opposite gender, then this raises the interesting question of whether age-related decline is not only associated with gender but also with sexual orientation. This would be in line with considerable evidence that sexual orientation differences in somatic, cognitive, and behavioral traits mimic those between women and men such that these traits in male homosexuals resemble (or are shifted toward) those in female heterosexuals and traits in female homosexuals resemble those in male heterosexuals; these effects are thought to be due in part to the relative feminization and masculinization, respectively, of the brain by prenatal hormones (Ellis & Ames, 1987). Another reason to suppose that sexual orientation may play a role follows from evidence that non-heterosexuals of both genders are vulnerable populations, for example, in terms of poorer mental and physical health in comparison with heterosexuals (De Graaf, Sandfort, & ten Have, 2006; Julien & Chartrand, 2005; King et al., 2003). Aging researchers have "all but ignored gay and lesbian elders" (Allen, 2005) and as far as we are aware, there have been no previous investigations of age-related decline in cognition as a function of sexual orientation.

The Present Study

To obtain sufficient numbers of participants to allow analyses by age, gender, and sexual orientation, data were gathered via the Internet (for reviews of online experimentation, see Birnbaum, 2004; Reips, 2002). This has recently become popular because of the time, energy, and resources that can be saved by remotely testing substantial numbers of participants over a short period. Volunteers generally represent a wider demographic than those in laboratory-based studies and hence the results may be more generalizable. There may be additional advantages with respect to research on aging; for example, participants are not required to travel for testing, and older adults are probably less anxious when tested in their own familiar environment. Although home access to computers decreases with age, older adults are increasingly being encouraged to use the Internet (Cutler, Hendricks, & Guyer, 2003; Selwyn, Gorard, Furlong, & Madden, 2003). Obvious disadvantages of the methodology are more than outweighed by its considerable advantages, particularly as evidence is accumulating to suggest that web-based studies can reliably replicate laboratory findings (see Buchanan & Smith, 1999; Gosling, Vazire, Srivastava, & John, 2004; McGraw, Tew, & Williams, 2000), including recent studies of aging (e.g., Reimers & Maylor, 2005; Robins, Trzesniewski, Gosling, & Potter, 2002).

Participants completed four cognitive tasks, chosen to provide two on which men would outperform women (mental rotation and line angle judgments), and two on which women would outperform men (two versions of category fluency and object location memory). In addition, background measures known to influence cognitive performance in aging studies, namely, health and education (e.g., Adams-Price, 1992; Elias, Elias, D'Agostino, Silbershatz, & Wolf, 1997; Depp & Jeste, 2006; Diehl, Willis, & Schaie, 1995) were also collected to control for their effects in the analyses. Our main predictions were that performance would be affected by age, gender and their interaction such that men would show greater age-related decline on all tasks than women. We also predicted effects of age, sexual orientation, and their interaction for each gender such that female non-heterosexuals would show greater age-related decline than female heterosexuals but that male non-heterosexuals would show less age-related decline than male heterosexuals.

METHOD

Overview

A fuller description of the general set-up appears in Reimers (2007). Briefly, the experiment was written and hosted by the British Broadcasting Corporation (BBC) Science and Nature website, and was run in a 600 x 445 pixel pop-up window. Implementation used around 50 HTML webpages, with javascript for survey questions and embedded Adobe Flash movies for running cognitive tasks. The study comprised six blocks, each lasting between 3 and 6 minutes. Four cognitive tasks were included in the experiment, together with questions about preferences, personality and demographics. In this article, we describe the method only for the tasks and questions analysed here.

Background Measures

The following information was requested from participants (acceptable entry values appear in parentheses): age (1-99), gender (male, female), sexual orientation (heterosexual[straight], homosexual [gay/lesbian], bisexual), and education (primary or grammar school, secondary or high school, technical or vocational college, other college, university, postgraduate or professional degree [e.g., Ph.D., M.D.]). For present purposes, the first and second educational categories were combined, as were the third and fourth categories, to produce four rather than six levels of education. Participants were asked to describe their health in the last year on a 7-point scale with the ends of the scale labelled as very unhealthy (scored as 1) and very healthy (scored as 7), and to describe their intake of medicines on a 6-point scale with 1 = never, 2 = rarely, 3 = monthly, 4 = weekly, 5 = daily, and 6 = more than once per day. These last two responses provided subjective and objective estimates, respectively, of current health. On the same 6-point scale, participants were also asked about their intake of alcohol, nicotine, and drugs. Finally, participants were asked which, if any, of the following they were taking: steroids, hormone replacement therapy, the contraceptive pill, or transsexual drug therapy. Only age and gender required an acceptable response, with responses to all other questions optional.

Cognitive Measures

Mental Rotation

The mental rotation task comprised six trials taken from the redrawn Vandenberg and Kuse Mental Rotation Task (Peters et al., 1995), and was designed to follow closely the pencil-and-paper version. A fuller description of the task and discussion of gender differences in performance appear in Peters, Manning, and Reimers (2007).

The mental rotation task appeared in Block 6. After instructions, a Flash movie was initialized, controlling the task. For each trial, participants saw a reference stimulus on the left side of the screen, and four choice stimuli on the right side of the screen, two of which were rotated versions of the reference stimulus, and two of which depicted rotations of a similar, but non-matching, shape. For each trial, participants were required to identify the two matching (i.e., rotated) stimuli. They could select up to two of the choice stimuli, and could return to previously completed trials and change their selections at any point. Participants had 150 seconds to complete the six trials, indicated by a countdown timer at the bottom of the screen, after which the selections at that point were recorded. The dependent variable was the number of correct responses (maximum = 12).

Line Angle Judgment

The line angle judgment task was adapted for use over the web from Collaer (2001; which was derived from the task of Benton, Varney, & Hamsher, 1978) and is described in more detail in Collaer et al. (2007). Participants saw a sequence of 20 test items, each showing one target line at a specific angle above a matching array, and for each item had to identify the line in the matching array that was at the same angle. The matching array comprised 15 lines at different angles extending from a single point, equally spaced between the angles of 0 through 180 degrees (see Fig. 2 of Collaer et al., 2007, for a sample item). Thus, Line 1 was horizontal to the left of the center of the array, Line 2 was approximately 12.9 degrees above the horizontal, Line 8 was vertical above the center of the array, and Line 15 was horizontal to the right of the center of the array.

Line angle judgments were tested in Block 1. An HTML-coded instruction page introduced the task, and showed exemplars of target and matching array. On clicking with the mouse to start the task, an Adobe Flash movie was initialized, which controlled the task. Participants indicated their responses by clicking on the line in the matching array that they judged to be at the same angle as the target. To prevent “cheating,” participants had 10 s to respond, indicated by a countdown timer at the bottom of the screen, after which a null response was recorded and the next trial automatically started. On selection, the line number and response time (RT) were recorded (for experimental evidence that RT can be measured accurately under Flash, see Reimers & Stewart, in press). The main dependent variable of interest here was the number of correct responses (maximum = 20) although the total time taken to complete the task was also examined for evidence of any speed-accuracy trade-offs.

Category Fluency

The category fluency task comprised two 60-s trials in which participants typed as many words as possible within the time that belonged to a particular category. The two categories were “objects usually coloured GREY” (Trial 1) and “words that mean the same as

HAPPY" (Trial 2). Participants were required to separate their responses by commas. Data were saved as a single text string and the dependent variable was the total number of items produced on each trial. This task appeared immediately after the mental rotation task in Block 6.

Object Location Memory

The object location memory task was adapted from Silverman and Eals (1992), and appeared immediately after the line angle judgment task in Block 1 (see Silverman, Choi, & Peters, 2007, for full details). Briefly, participants were asked to memorize a set of line drawings of 27 items distributed over the screen (items were a combination of the quotidian and the exotic, including a paintbrush, a lamp, and an elephant). Specifically, participants were told that they had "one minute to remember the locations of the objects." After 60 s, or less if participants chose to move on by clicking with the mouse, new instructions were presented, followed by a different set comprising the same 27 items, around half of which had been swapped pair-wise in screen position. Participants indicated which items they thought were in new positions by selecting them using the mouse, with a maximum of 60 s to make their selections. The main dependent variable was the number of objects correctly selected minus the number of objects incorrectly selected (i.e., hits minus false alarms). The total time taken to complete the task was also examined for evidence of any speed-accuracy trade-offs.

Participants

For the main analyses of the data by age and gender, participants were categorized into nine 5-year intervals from young adulthood to retirement age (20-65 years). As can be seen from Table I, the age distribution was positively skewed but there were nevertheless at least 1,000 participants of each gender in all age groups. There were fewer women than men in all age groups, with the proportion of women dropping from 0.47 for the youngest group to

0.38 for the oldest group. Within each age group, the women and men were comparable in terms of their mean ages (see Table I).

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insert Table I about here

The means for self-rated health, medicine intake, and education are displayed in Figs. 1a-c, with 95% confidence intervals, as a function of age group and gender. For self-rated health (Fig. 1a), the scores of just over 5 on a 7-point scale suggest that participants considered themselves to be in reasonable health. Women (M = 5.22) produced slightly but significantly lower ratings overall than did men (M = 5.28). Health ratings varied little with age, in contrast to the striking increase with age in the intake of medicines (Fig. 1b). (Note that approximately 20,000 women who reported taking the contraceptive pill were excluded from this particular analysis.) In an analysis of variance (ANOVA) on medicine intake, there were significant effects of both age group, $F(8, 173{,}548) = 1{,}568.41$, $MSE = 1.89$, $p < .001$, $\eta^2 = .067$,[1] and gender, $F(1, 173{,}548) = 1{,}627.33$, $MSE = 1.89$, $p < .001$, $\eta^2 = .009$. There was also a significant interaction, $F(8, 173{,}548) = 2.77$, $MSE = 1.89$, $p < .01$, $\eta^2 < .001$, indicating a smaller increase in medicine intake with age for women than for men, although women's medicine intake was higher than men's in all age groups.[2]

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insert Fig. 1 about here

These results with respect to age are consistent with previous findings of minimal influence of age on self-rated health despite increases in the intake of medicines. For example, Salthouse, Kausler, and Saults (1990) observed correlations with age of .03 for self-rated health but .30 for number of prescription medicines being taken. The former is obviously more subjective than the latter and may reflect comparisons with people of one's own age or lower expectations with increasing age (see Rabbitt, 2005; Salthouse, 1991, for discussion). At any rate, the results for the more objective measure of health (medicine intake; Fig. 1b) suggest that this variable should be taken into account as a covariate when considering the cognitive data.

Similarly, for education, there were significant effects of both age group, $F(8, 196{,}509) = 525.09$, $MSE = 0.89$, $p < .001$, $\eta^2 = .021$, and gender, $F(1, 196{,}509) = 310.17$, $MSE = 0.89$, $p < .001$, $\eta^2 = .002$, and an interaction, $F(8, 196{,}509) = 25.54$, $MSE = 0.89$, $p < .001$, $\eta^2 = .001$ (see Fig. 1c). Level of education increased from the early 20s to the late 20s (presumably because a higher proportion of the youngest group had yet to complete their education) but thereafter decreased with age. Women and men in their 20s had similar levels of education but women increasingly reported lower levels of education than men in older age groups. Again, these results require the inclusion of education as a covariate in the analyses of the cognitive data.

RESULTS

Similar to the method of Collaer et al. (2007), for the line angle judgment task we excluded participants with low scores (0-3 out of 20) who may not have understood the instructions or taken the task seriously. This eliminated 0.8% of the participants for this task. For the two category fluency tasks, there were some participants with missing data but also a large number of participants with misleading scores of 1 because they failed to follow instructions by separating their responses with commas. We therefore excluded participants with scores of 1 (11.4% of participants for Trial 1; 7.4% for Trial 2), in addition to participants who achieved high scores (> 24) by not following the instructions (e.g., they typed single letters each followed by a comma), thereby excluding a further 0.05% of participants for both Trials 1 and 2.

Age and Gender

The mean scores for each of the five cognitive tasks, with 95% confidence intervals, are shown in Figs. 2a-e as a function of age group and gender. Clearly, performance on all tasks declined with increasing age and men outperformed women on the mental rotation and line angle judgment tasks whereas women outperformed men on the category fluency and object location memory tasks. In all five cases, there was evidence of differential effects of age on the performance of women and men, with age decline being less evident for women than for men.

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insert Fig. 2 about here

These observations were confirmed by 9 (age group) x 2 (gender) ANOVAs, the results of which are summarized in Table II. Thus, there were highly significant main effects of both age group and gender, together with highly significant interactions between age group and gender in all cases. Importantly, exactly the same significant results as shown in Table II were obtained after removing those taking any type of hormonal preparation (steroids, hormone replacement therapy, the contraceptive pill, or transsexual drug therapy).

The possible confounding effects of medicine intake (as a proxy for health) and education, however, need also to be considered as both varied with age group, gender, and their interaction (see Figs. 1b and 1c) and both are known to influence cognitive performance (see Introduction). On the one hand, the relatively less pronounced decline in cognition with age for women could be attributable to their relatively smaller increase with age in medicine intake, in comparison with men. On the other hand, women were at a disadvantage in terms of education with increasing age. Analyses of covariance (ANCOVAs) were therefore conducted for each of the five tasks, with medicine intake and education as covariates. (As earlier, those taking the contraceptive pill were excluded from these analyses.) For all five tasks, both medicine intake and education were significant covariates (though education was considerably stronger) but the results were qualitatively unchanged, with highly significant effects of age group, gender, and interactions between them (all *p*'s < .001).

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insert Table II about here

It can be seen from Figs. 2c-e that for category fluency and object location memory tasks (where women performed better), the Age x Gender interactions reflected increasing gender differences right across the age range from 20 to 65 years. In contrast, for mental rotation and line angle judgments (where men performed better), the interactions were less straightforward. For mental rotation (Fig. 2a), women declined more steeply at younger ages but less steeply at older ages than men. On closer inspection, it emerged that a larger percentage of men (predominantly younger men) performed at ceiling on the mental rotation task than did women (14% vs. 4%). The anomalous pattern with respect to differential age decline for women and men for mental rotation at younger age groups can therefore be explained by the artificially suppressed scores of the younger men.

For line angle judgments (Fig. 2b), the steeper decline with age for men than for women was only apparent in the younger age groups, with almost parallel functions for women and men in the older age groups. The interaction evident in the younger age groups may be slightly underestimated because, again, ceiling effects were present in a larger percentage of men (8.2%) than of women (2.4%), especially in the younger age groups. Examination of the total time to complete the line angle judgment task revealed slightly longer times for men (M = 68.9 s) than for women (M = 67.7 s) but only for the younger age groups. Crucially, over the age range where scores were dropping more rapidly for men than for women, the gender differences for time taken were approximately constant. As a formal test of a speed-accuracy trade-off explanation for the effects in Fig. 2b, an ANCOVA was conducted on correct line angle judgments with total time taken as a covariate. This revealed that time was a significant covariate but its inclusion did not alter the pattern of results, with significant effects of age group and gender, with an interaction between them (all *p*'s < .001).

For object location memory (Fig. 2e), women took slightly longer to complete the task than did men (*M* = 105.5 and 100.2 s, respectively),[3] particularly in the older age groups. Thus, to test whether a speed-accuracy trade-off could account for the observed effects, an ANCOVA was conducted on object location memory scores with time taken to complete the task as a covariate. This revealed time to be a significant covariate but the pattern of results was unaffected by its inclusion, with significant effects of age group and gender, with a significant interaction between them (all *p*'s < .001).

Following Meinz and Salthouse (1998), correlations were computed between exact ages and cognitive scores for each gender (see Table III). The correlations were very similar after medicine intake and education had been partialled out. Because of the nontrivial proportion of younger men at ceiling in the mental rotation task, correlations for mental rotation were restricted to participants aged 35-65 years. As expected from the interactions in the ANOVAs, the correlations were all significantly more negative for men than for women, with formal tests of the differences between women's and men's correlations for each of the five tasks as listed in Table III resulting in *z* scores of 3.13, 11.24, 12.75, 12.76, and 8.41 (all *p*'s < .002).

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insert Table III about here

Sexual Orientation

For the analyses of the cognitive data by age and sexual orientation (heterosexual, homosexual and bisexual) for each gender, participants were categorized into five rather than nine age groups (see Table IV). This ensured that there were at least 100 participants in each cell. There were fewer women than men in all cells with the exception of the two youngest groups of bisexuals. The percentages of heterosexuals, homosexuals, and bisexuals were relatively stable across age groups though for women there was a slight increase in heterosexuals and decrease in bisexuals with age. At least for the three youngest age groups (i.e., 20-44 years), there were more homosexuals than bisexuals for men while the reverse was the case for women, raising the possibility that men and women may use different criteria in identifying themselves as homosexual or bisexual. In comparison with previous studies (of New Zealanders by Dickson, Paul, & Herbison, 2003; of Americans and Canadians by Ellis, Robb, & Burke, 2005; of Australians by Grulich, de Visser, Smith, Rissel, & Richters, 2003; and of Dutch people by Sandfort, de Graaf, & Bijl, 2003), the present rates of homosexuality and bisexuality were either similar or slightly higher. Women and men were well matched in terms of their mean ages for each sexual orientation.

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insert Table IV about here

In terms of background measures, as expected (see Introduction), heterosexuals (*M* = 5.27, 95% confidence interval, *CI* = 5.26-5.27) reported better health than homosexuals (*M* = 5.15, *CI* = 5.11-5.20) who in turn reported better health than bisexuals (*M* = 5.04, *CI* = 5.00-5.08), regardless of age or gender. For medicines (excluding participants taking the contraceptive pill), heterosexuals (*M* = 2.96, *CI* = 2.95-2.97) reported a lower intake than either homosexuals (*M* = 3.27, *CI* = 3.22-3.31) or bisexuals (*M* = 3.19, *CI* = 3.16-3.23), regardless of age or gender. There was a more complex pattern for education such that, for women, older homosexuals and bisexuals were better educated than heterosexuals and, for men, older homosexuals were better educated than heterosexuals and bisexuals. Again, these results indicate the need to include measures of health and education as covariates in the analyses.

The mean scores for each of the five cognitive tasks, with 95% confidence intervals, are shown in Figs. 3a-e as a function of age group and sexual orientation, with women in the left panels and men in the right panels. The results of 5 (age group) x 3 (sexual orientation) ANOVAs for women and for men are summarized in Table V. There were highly significant main effects of both age group and sexual orientation but in only one case was there a significant interaction (line angle judgments for women).

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insert Fig. 3 and Table V about here

We first consider the main effects of sexual orientation, based on overall 95% confidence intervals. For mental rotation (a male-superior task) in Fig. 3a, the order was heterosexual-bisexual-homosexual for men's performance, with the order reversed for women (all groups significantly different from each other). In other words, the performance of homosexuals of each gender was closer to that of the opposite gender than was that of heterosexuals, with bisexuals in between. For line angle judgments (another male-superior task) in Fig. 3b, again the performance of non-heterosexuals was closer to that of the opposite gender than was that of heterosexuals, with no significant differences between homosexuals and bisexuals in this case. For both category fluency (female-superior) tasks in Figs. 3c and 3d, the order was homosexual-bisexual-heterosexual for men (all differences being significant). However, for women, bisexuals outperformed homosexuals and heterosexuals for gray items, and outperformed heterosexuals for happy synonyms. Finally, for object location memory, heterosexuals outperformed homosexuals and bisexuals for women, whereas heterosexuals and homosexuals outperformed bisexuals for men. In summary, for the majority of cases (i.e., 7 of the 10 patterns in Fig. 3), heterosexuals of a particular gender outperformed at least one group of non-heterosexuals on tests where that gender was better or underperformed at least one group of non-heterosexuals where that gender was poorer. The three exceptions were for women in both category fluency tasks and for men in the object location memory task.

Crucially, there were no significant interactions between age group and sexual orientation with the single exception of line angle judgments for women where bisexuals showed decline but then improvement in performance with increasing age. Almost identical patterns of results to those shown in Fig. 3 and Table V were obtained in ANCOVAs with medicine intake and education included as covariates. The only difference was the emergence of a weak though significant age group by sexual orientation interaction (p = .024) for women in the category fluency task with gray items such that age-related decline was greater for bisexuals than for the other groups. In conclusion, there was evidence of overall effects of sexual orientation, with the direction of effects quite systematically dependent on both task and gender, but no clear evidence of differential age-related decline according to sexual orientation for either women or men.

Health-Linked Behaviors

Consumption of substances known to contribute to both morbidity and mortality, namely, alcohol, nicotine and drugs, was first examined in three separate 9 (age group) x 2 (gender) ANOVAs. These revealed significantly higher consumption by men than by women for alcohol (especially at older ages), nicotine (especially at younger ages), and drugs (especially at younger ages). Alcohol intake increased across the first five age groups, nicotine intake increased from the first to the second age group and decreased thereafter, and drug intake decreased with age. Second, 5 (age group) x 3 (sexual orientation) ANOVAs were conducted on alcohol, nicotine, and drug intake, separately for women and for men. For women, alcohol intake did not vary with sexual orientation whereas for both nicotine and drugs, intake was higher for homosexuals and bisexuals than for heterosexuals, particularly at younger ages. For men, alcohol intake was lower in bisexuals than in homosexuals or heterosexuals, nicotine intake was higher for homosexuals and bisexuals than for heterosexuals, and intake of drugs was also higher for homosexuals and bisexuals than for heterosexuals but especially at older ages. Thus, in general, the consumption of substances with risks to health was more associated with men than with women, and with homosexuals and bisexuals of both genders than with heterosexuals (except for alcohol intake). Crucially, when the main analyses of cognitive performance as a function of age and gender (Table III) and age and sexual orientation (Table V) were repeated with intake of alcohol, nicotine, and drugs as covariates, the results were all unchanged.

DISCUSSION

To summarize the main findings, performance generally declined with increasing age from 20-65 years (see, e.g., Cerella & Hale, 1994; Herlitz et al., 1997; Hommel, Li, & Li, 2004, for similar declines across adulthood), and there were overall effects of gender consistent with the literature (men better for mental rotation and line angle judgments; women better for category fluency and object location memory). Importantly, men showed greater age-related decline than women, irrespective of whether the task was one on which they were better. (The line angle judgment data, however, were unusual in that the age by gender interaction was mostly confined to the younger age groups.) All the effects remained significant after covarying out measures of health and education (which also displayed differential gender relations across adulthood). The overall effects of sexual orientation were largely consistent in showing better performance by heterosexuals of each gender on tasks where that gender was better and poorer performance by heterosexuals where that gender was poorer, in comparison with non-heterosexuals. Crucially, however, there were only two weak interactions between age and sexual orientation such that age-related decline for female bisexuals was smaller in the line angle judgment task but greater in the category fluency task with gray items in comparison with female homosexuals and heterosexuals. In conclusion, female (as opposed to male) gender was clearly associated with a slower rate of cognitive decline, whereas sexual orientation was not associated with rate of cognitive decline.

The data on health-linked behaviors are largely consistent with previous literature on consumption of alcohol, nicotine, and drugs in showing greater intakes of all three substances in men than in women, and greater intakes of nicotine and drugs in non-heterosexuals than in heterosexuals (e.g., Ryan, Wortley, Easton, Pederson, & Greenwood, 2001), although we did not find higher alcohol intake in non-heterosexual women compared with heterosexual women, contrary to some studies (Cochran, Keenan, Schober, & Mays, 2000; Drabble, Midanik, & Trocki, 2005). Interestingly, if rate of cognitive decline is associated with such health-linked behaviors, then one might expect homosexual and bisexual members of both genders to show male-typical rates of cognitive decline.[4] However, this was clearly not the case (e.g., functions for homosexual and heterosexual women in Fig. 3 were approximately parallel), suggesting that at least these particular health-linked behaviors are less significant in determining rate of cognitive decline than whether a person is biologically female or male. It should additionally be emphasized that the age by gender interactions were unaltered when intake of alcohol, nicotine and drugs was covaried in ANCOVAs on each cognitive measure.

Considering further the influence of gender, it could be argued that because the proportion of female participants dropped from 0.47 in the youngest age group to 0.38 in the oldest age group, female participants were more selective than male participants at older ages. Contrary to this argument, the data suggest that men were increasingly advantaged at older ages relative to women, at least in terms of education (see Fig. 1c). Moreover, the proportion of women was stable at around 0.44 for age groups 3-7 in Table I, yet highly significant age by gender interactions (p's $<.001$) remained when the analyses were restricted to these five age groups (with the exception of mental rotation–see earlier discussion of ceiling effects for younger men in this particular task).

Our findings with respect to gender are consistent with data as reviewed earlier (see Introduction) from both neuroimaging studies, showing greater age-related deterioration of male than female brains, and a number of cognitive studies, showing greater age-related cognitive decline in males than in females. However, although highly significant, the present effects were extremely small in size. Thus, the present age by gender interactions accounted for no more than 0.1% of the variance in cognitive performance (see Table II). Note also from Table III that the age-cognition correlations differed by no more than 0.065 between women and men. To some extent, this may be attributable to the use of Internet methodology, which is subject to considerable random noise caused by the effects of different types of computers, operating systems, monitor sizes, times of day, hand positions, background sounds, lighting conditions, and so on. Thus, in general, this procedure tends to produce effects that account for only a small proportion of the variance but are highly significant. Indeed, the present effect sizes for age (see Table II) and age-cognition correlations (see Table III) were considerably smaller than from laboratory-controlled experiments (cf. Meinz & Salthouse, 1998), though one also has to bear in mind our relatively young maximum age of 65 years. Nevertheless, the present small effect sizes for the age by gender interactions perhaps suggest that one reason why so many studies in the past have failed to find significantly different rates of cognitive decline with aging in women and men may be a lack of statistical power.

The present data also offer a possible explanation for at least some of the previous observations of greater age-related decline in females than in males. One of the two tasks for which this was found in the meta-analysis of Meinz and Salthouse (1998) was speed. Meinz and Salthouse additionally noted numerically greater age-related decline in females than in males in 2 out of 10 tasks from the Woodcock-Johnson (1989) test battery, one of which was speed. Also, Der and Deary (2006) recently observed more rapid slowing of reaction times at older ages in women than in men. The time taken to perform two of the present tasks (line angle judgment and object location memory) showed similar results, namely, significantly greater age-related slowing for women than for men (though including time taken as a covariate in ANCOVAs on scores did not alter the main results). Thus, it appears that speed may be an exception to the conclusion that age is kinder to women than to men.

It has been claimed that hormone replacement therapy, which counters lower levels of endogenous estrogen after menopause, may protect women against cognitive decline but the evidence is far from strong (for a review, see Herlitz & Yonker, 2004). Moreover, where positive effects have been found, they tend to be small and restricted to female-superior tasks such as episodic memory and verbal fluency (e.g., Yonker et al., 2006). The question then arises as to whether the present pattern of slower age-related cognitive decline in women than in men can be attributable to the beneficial effects of hormone replacement therapy. This seems unlikely for at least two reasons. The first is that the age by gender interactions were apparent in both the male- and female-superior tasks. Second, and more importantly, the results were qualitatively identical with and without the inclusion of those taking hormone replacement therapy. Note also that differential rates of cognitive aging between women and men were evident both below and above the average age of menopause, which was between 49 and 50 years for the present participants.

Unfortunately, there are few theoretical models available to account for the present findings (Sinnott & Shifren, 2001). As Zelinski and Stewart (1998) commented, “it is difficult to determine what the specific sources of gender differences might be; they could conceivably include neurophysiological, hormonal, and social differences between men and women” (p. 624). The present study was not designed to distinguish among these possible sources. Nonetheless, the results do at least raise problems for the intuitively simple notion that men decline more quickly than women because they are, on average, closer to death

(Hayflick, 1996) and therefore more likely to be experiencing terminal decline (Berg, 1996). Thus, age by gender interactions were apparent even at younger ages (see Fig. 2). Also, comparison of age-cognition correlations taking into account the 7-year gender difference in longevity (i.e., women 27-65 years vs. men 20-58 years) revealed similar results to Table III, namely, significantly less negative correlations for women than for men (with the exception of mental rotation).

Finally, any explanation for gender differences in age-related cognitive decline must also incorporate the novel finding here, namely, the absence of sexual orientation-related differences in rate of decline. Regarding sexual orientation, the present study replicated previous findings of poorer health in non-heterosexuals than in heterosexuals (see Introduction) and at least partially replicated previous findings on overall effects of sexual orientation on cognition. For example, Rahman and Wilson (2003) also found better performance by heterosexual males than by homosexual males, and vice versa for females, for both mental rotation and line angle judgment tasks (although in their case, the trend for females in the latter task did not reach significance). For category and synonym fluency tasks, Rahman, Abrahams, and Wilson (2003) found better performance by homosexual males than by heterosexual males, as we did, but this was reversed for females (for whom we found no significant difference between homosexuals and heterosexuals on either fluency task). Using a spatial memory task, Rahman, Wilson, and Abrahams (2003) found better performance by homosexual males than by heterosexual males (whereas we found little difference for object location memory), with no difference between female heterosexuals and homosexuals (whereas we found better performance by heterosexuals). The present findings therefore closely resembled previous findings for male-superior tasks, while for female-superior tasks there were at least no cases where opposite results were found.

Rahman and Wilson (2003) suggested that “physically and behaviorally, homosexuals follow gender-atypical patterns and that prenatal or genetic factors are implicated in the ontogenesis of these differences” (p. 26; see also LeVay, 1993, for discussion of the biological bases for sexual orientation). The present study indicates a possible exception such that rate of cognitive decline in homosexuals (and also in bisexuals) appears to follow gender-typical rather than gender-atypical patterns. Thus, whereas overall performance was significantly influenced by both gender and sexual orientation, rate of cognitive decline with age was significantly affected by gender only. The data therefore suggest the need to focus in the future on investigating age-related changes in neurophysiological, hormonal, social, and other factors that vary between women and men, but not between heterosexuals and non-heterosexuals of the same gender. Further research is also required to both replicate these web-based findings on aging and sexual orientation in controlled laboratory settings and extend them from cross-sectional to longitudinal designs.

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Footnotes

[1]Effect sizes (partial eta squared, η^2) are reported, which indicate the proportion of variance accounted for by the independent variable or interaction between variables. Cohen (1988) suggested that η^2 values of .01, .06 and .14 can be taken to indicate small, medium and large effects, respectively.

[2]These results for medicine intake were qualitatively unaffected when those who reported being on hormone replacement therapy (around 2,000) were also excluded from the analysis.

[3]We do not know if the additional 5 s taken by women was spent in the encoding or recognition phases (or both) because only the total time taken to complete the task was recorded.

[4]We are grateful to an anonymous reviewer for this suggestion.

Table I

Numbers and Ages (Means and Standard Deviations) of Women and Men in Each of Nine Age Groups from 20 to 65 Years

			Age			
Age group	Women	Men	Women		Men	
(years)	*N*	*N*	*M*	*SD*	*M*	*SD*
20-24	24,048	26,640	22.0	1.42	22.0	1.40
25-29	20,221	23,941	26.8	1.41	26.8	1.42
30-34	14,055	18,188	31.9	1.43	31.9	1.43
35-39	9,858	13,470	36.8	1.41	36.8	1.42
40-44	7,375	9,852	41.8	1.43	41.8	1.44
45-49	5,519	7,109	46.9	1.40	46.9	1.42
50-54	4,055	5,232	51.7	1.44	51.7	1.42
55-59	2,274	3,373	56.7	1.36	56.7	1.37
60-65	1,104	1,807	61.9	1.71	61.9	1.71

Table II

Summary of Results of 9 x 2 Analyses of Variances for Each of the Five Cognitive Tasks, with Age Group and Gender as Between-Subjects Factors

	Effect		
Task	Age group	Gender	Interaction
Mental rotation	$F(8, 196{,}704) = 416.97$*	$F(1, 196{,}704) = 5{,}418.12$*	$F(8, 196{,}704) = 11.03$*
	$MSE = 5.96$, $\eta^2 = .017$	$MSE = 5.96$, $\eta^2 = .027$	$MSE = 5.96$, $\eta^2 < .001$
Line angle judgment	$F(8, 196{,}511) = 310.15$*	$F(1, 196{,}511) = 5{,}984.09$*	$F(8, 196{,}511) = 13.70$*
	$MSE = 9.26$, $\eta^2 = .012$	$MSE = 9.26$, $\eta^2 = .030$	$MSE = 9.26$, $\eta^2 = .001$
Fluency (gray items)	$F(8, 154{,}954) = 130.95$*	$F(1, 154{,}954) = 824.65$*	$F(8, 154{,}954) = 15.33$*
	$MSE = 11.18$, $\eta^2 = .007$	$MSE = 11.18$, $\eta^2 = .005$	$MSE = 11.18$, $\eta^2 = .001$
Fluency (happy synonyms)	$F(8, 176{,}643) = 61.63$*	$F(1, 176{,}643) = 746.86$*	$F(8, 176{,}643) = 20.76$*
	$MSE = 8.49$, $\eta^2 = .003$	$MSE = 8.49$, $\eta^2 = .004$	$MSE = 8.49$, $\eta^2 = .001$
Object location memory	$F(8, 198{,}062) = 67.13$*	$F(1, 198{,}062) = 3{,}027.62$*	$F(8, 198{,}062) = 9.78$*
	$MSE = 10.13$, $\eta^2 = .003$	$MSE = 10.13$, $\eta^2 = .015$	$MSE = 10.13$, $\eta^2 < .001$

*$p < .001$

Table III

Correlations Between Age in Years and Score for Each of the Five Cognitive Tests for Women and Men

	Women		Men	
Task	*r*	*N*	*r*	*N*
Mental rotation[a]	-.135*	29,979	-.159*	40,591
Line angle judgment	-.084*	87,518	-.134*	109,011
Fluency (gray items)	-.047*	70,744	-.112*	84,228
Fluency (happy synonyms)	-.013*	80,130	-.074*	96,531
Object location memory	-.032*	88,496	-.070*	109,584

*$p < .001$ (2-tailed test); [a]35-65 years only (see text for details)

Table IV

Numbers, Percentages and Ages (Means and Standard Deviations) of Women and Men in Each of Five Age Groups from 20 to 65 Years Divided by Sexual Orientation

						Age			
		Women		Men		Women		Men	
Age group (years)	Sexual Orientation[a]	N	%	N	%	*M*	*SD*	*M*	*SD*
20-24	Het	21,162	89.2	23,741	90.5	22.0	1.42	22.0	1.40
	Hom	541	2.3	1,351	5.1	22.0	1.39	22.1	1.40
	Bi	2,028	8.5	1,142	4.4	21.9	1.42	21.9	1.42
25-34	Het	30,713	90.7	37,795	90.9	28.9	2.85	29.0	2.87
	Hom	861	2.5	2,210	5.3	29.0	2.91	29.2	2.96
	Bi	2,284	6.7	1,563	3.8	28.7	2.83	29.0	2.90
35-44	Het	15,417	90.5	20,506	88.9	39.0	2.85	38.9	2.87
	Hom	680	4.0	1,505	6.5	39.1	2.87	38.9	2.77
	Bi	929	5.5	1,053	4.6	38.6	2.77	39.2	2.90
45-54	Het	8,714	92.2	11,031	90.4	48.9	2.79	48.9	2.80
	Hom	355	3.8	531	4.4	48.9	2.84	48.6	2.82
	Bi	378	4.0	639	5.2	48.8	2.85	48.9	2.72
55-65	Het	3,110	93.3	4,655	91.0	58.4	2.85	58.6	2.92
	Hom	100	3.0	196	3.8	58.4	2.83	58.2	2.83
	Bi	123	3.7	265	5.2	57.7	2.95	58.3	2.87

[a]Het = heterosexual (straight); Hom = homosexual (lesbian/gay); Bi = bisexual

Note. Percentages do not always total 100 because of rounding to one decimal place.

Table V

Summary of Results of 5 x 3 Analyses of Variances Separately for Women and Men and for Each of the Five Cognitive Tasks, with Age Group and Sexual Orientation as Between-Subjects Factors

	Effect		
Group and Task	Age group	Sexual Orientation	Interaction
Women			
Mental rotation	*F*(4, 86,740) = 51.40***	*F*(2, 86,740) = 28.61***	*F*(8, 86,740) = 0.76
	MSE = 5.35, η^2 = .002	*MSE* = 5.35, η^2 = .001	*MSE* = 5.35, η^2 < .001
Line angle judgment	*F*(4, 86,442) = 23.75***	*F*(2, 86,442) = 16.85***	*F*(8, 86,442) = 2.47*
	MSE = 9.76, η^2 = .001	*MSE* = 9.76, η^2 < .001	*MSE* = 9.76, η^2 < .001
Fluency (gray items)	*F*(4, 69,902) = 14.89***	*F*(2, 69,902) = 22.16***	*F*(8, 69,902) = 1.38
	MSE = 12.17, η^2 = .001	*MSE* = 12.17, η^2 = .001	*MSE* = 12.17, η^2 < .001
Fluency (happy synonyms)	*F*(4, 79,171) = 3.74**	*F*(2, 79,171) = 12.42***	*F*(8, 79,171) = 0.70
	MSE = 8.65, η^2 < .001	*MSE* = 8.65, η^2 < .001	*MSE* = 8.65, η^2 < .001
Object location memory	*F*(4, 87,368) = 7.16***	*F*(2, 87,368) = 25.03***	*F*(8, 87,368) = 1.02
	MSE = 9.81, η^2 < .001	*MSE* = 9.81, η^2 = .001	*MSE* = 9.81, η^2 < .001
Men			
Mental rotation	*F*(4, 107,488) = 85.06***	*F*(2, 107,488) = 74.96***	*F*(8, 107,488) = 1.49
	MSE = 6.43, η^2 = .003	*MSE* = 6.43, η^2 = .001	*MSE* = 6.43, η^2 < .001
Line angle judgment	*F*(4, 107,621) = 93.24***	*F*(2, 107,621) = 108.00***	*F*(8, 107,621) = 0.70
	MSE = 8.81, η^2 = .003	*MSE* = 8.81, η^2 = .002	*MSE* = 8.81, η^2 < .001
Fluency (gray items)	*F*(4, 83,270) = 54.80***	*F*(2, 83,270) = 42.90***	*F*(8, 83,270) = 0.46
	MSE = 10.29, η^2 = .003	*MSE* = 10.29, η^2 = .001	*MSE* = 10.29, η^2 < .001
Fluency (happy synonyms)	*F*(4, 95,434) = 36.16***	*F*(2, 95,434) = 40.83***	*F*(8, 95,434) = 1.11
	MSE = 8.32, η^2 = .002	*MSE* = 8.32, η^2 = .001	*MSE* = 8.32, η^2 < .001
Object location memory	*F*(4, 108,145) = 27.20***	*F*(2, 108,145) = 14.86***	*F*(8, 108,145) = 0.87
	MSE = 10.34, η^2 = .001	*MSE* = 10.34, η^2 < .001	*MSE* = 10.34, η^2 < .001

****p* < .001; ***p* < .01; **p* < .05

Figure Captions

Figure 1. Means with 95% confidence intervals for background measures as a function of age group for women and men for (a) self-rated health in the last year on a 7-point scale from 1 = very unhealthy to 7 = very healthy, (b) intake of medicines (excluding participants on the contraceptive pill) on a 6-point scale from 1 = never to 6 = more than once per day, and (c) education level, with 1 = primary/grammar/secondary/high school, 2 = technical/vocational/other college, 3 = university, and 4 = postgraduate or professional degree (e.g., Ph.D., M.D.).

Figure 2. Means with 95% confidence intervals as a function of age group for women and men for (a) mental rotation (number correct out of 12), (b) line angle judgment (number correct out of 20), (c) category fluency (number of gray items produced in 60 s), (d) category fluency (number of synonyms for "happy" produced in 60 s), and (e) object location memory (number of objects correctly selected minus number of incorrect selections).

Figure 3. Means with 95% confidence intervals as a function of age group and sexual orientation (heterosexual, homosexual, and bisexual) for women (left panels) and men (right panels) for (a) mental rotation (number correct out of 12), (b) line angle judgment (number correct out of 20), (c) category fluency (number of gray items produced in 60 s), (d) category fluency (number of synonyms for "happy" produced in 60 s), and (e) object location memory (number of objects correctly selected minus number of incorrect selections).

Figure 1a

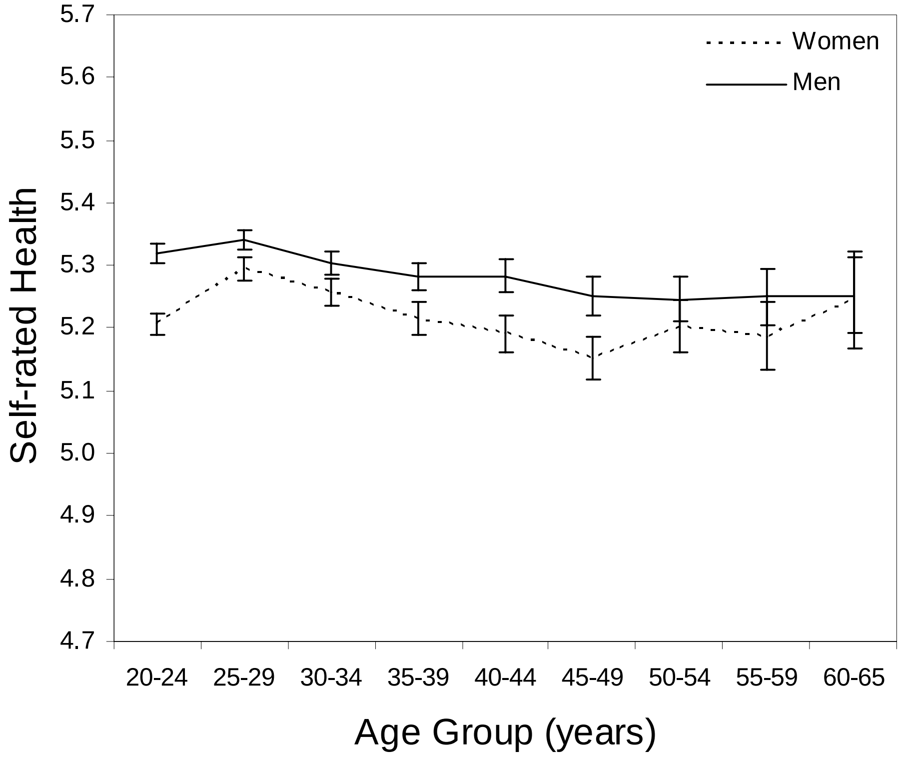


Figure 1b

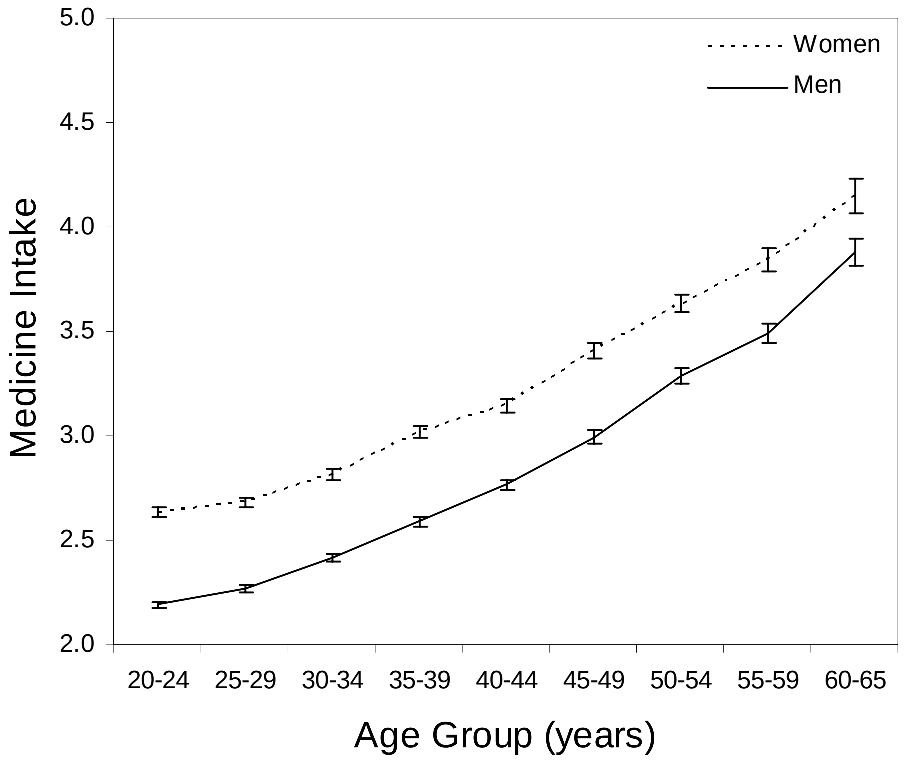


Figure 1c

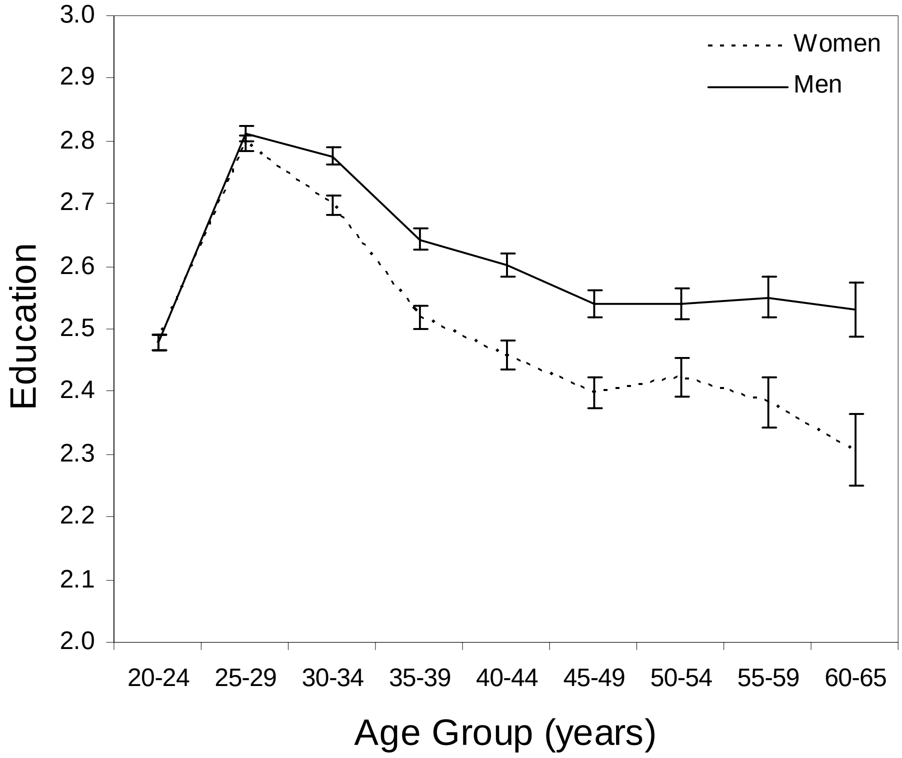

Women
Men
Education
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-65
Age Group (years)

Figure 2a

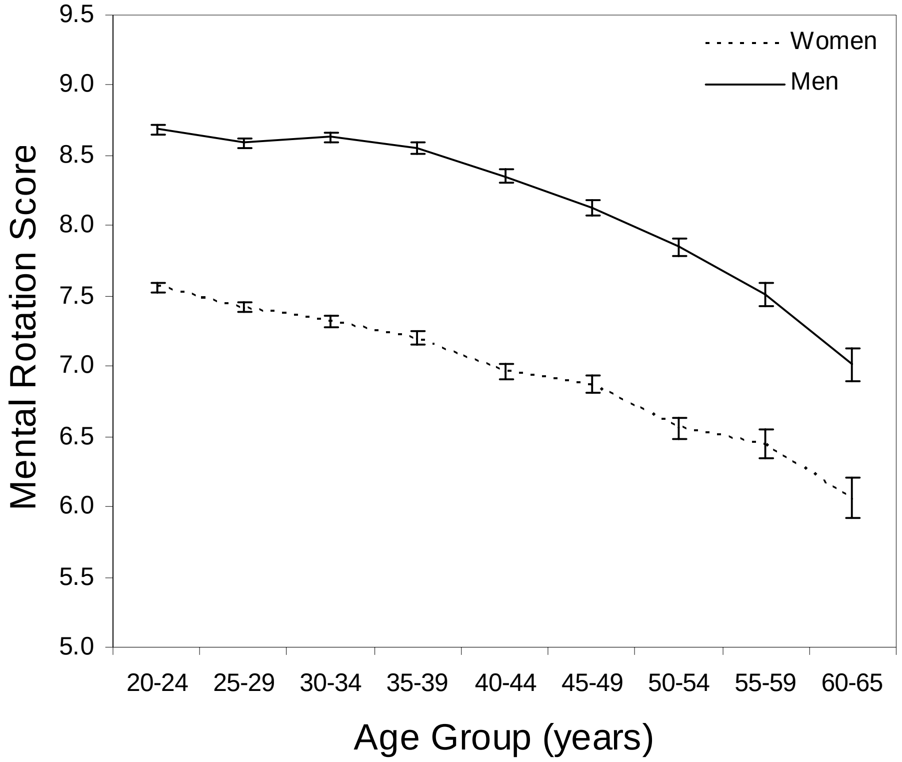


Figure 2b

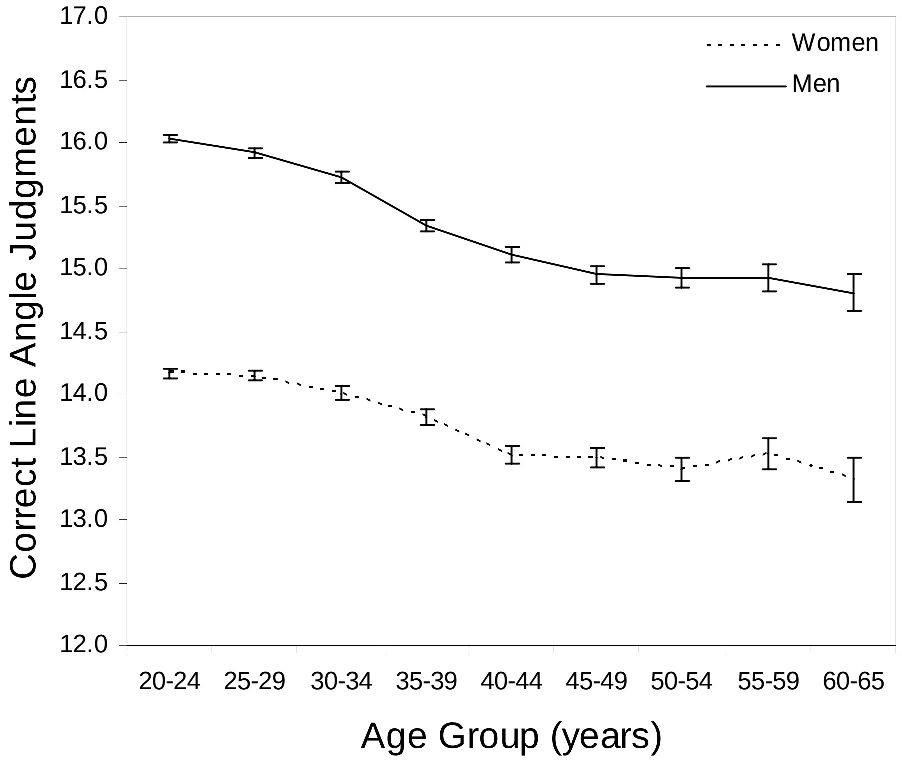


Figure 2c

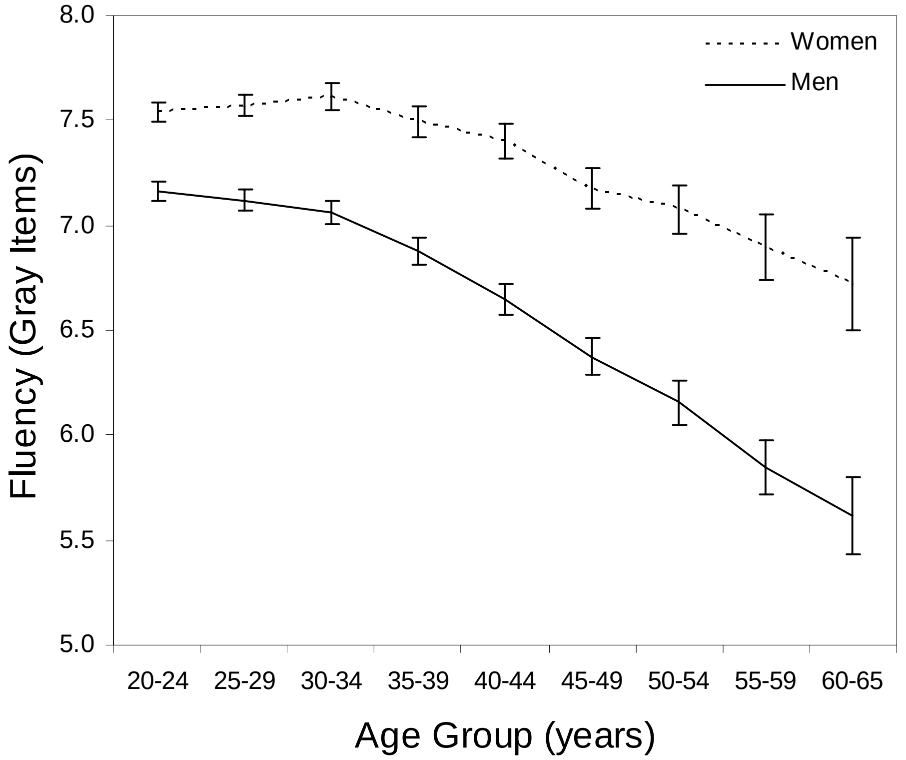


Figure 2d

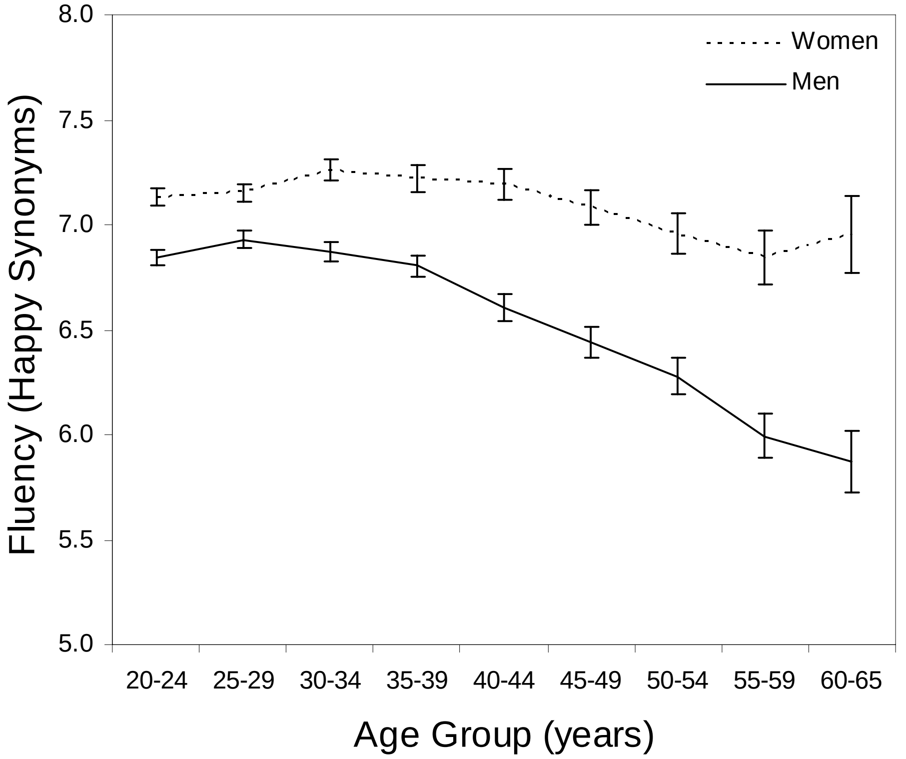
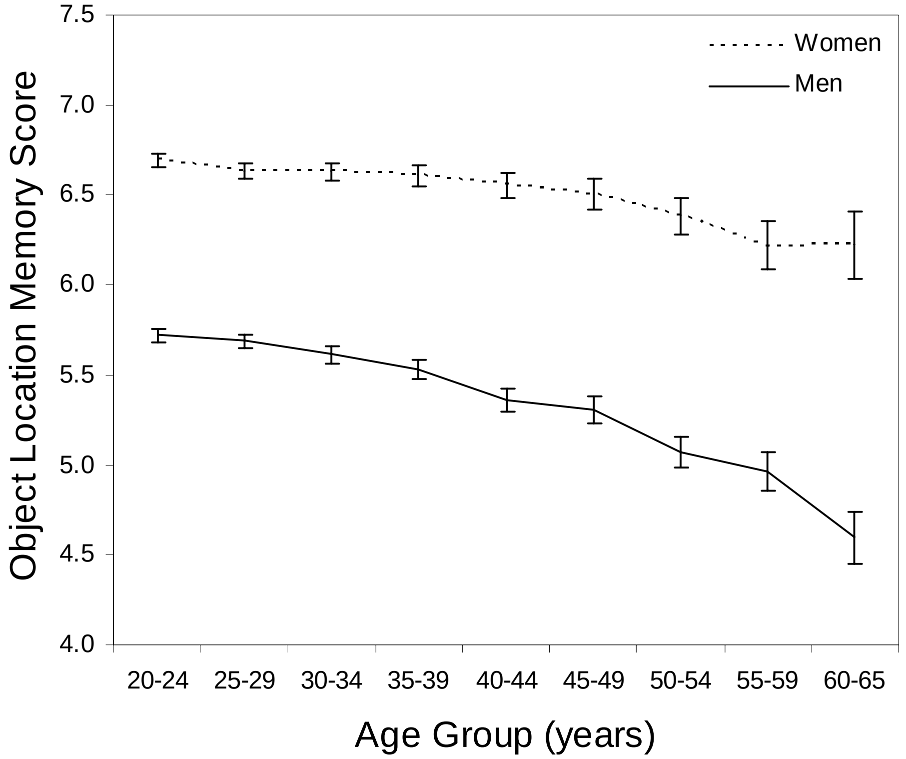
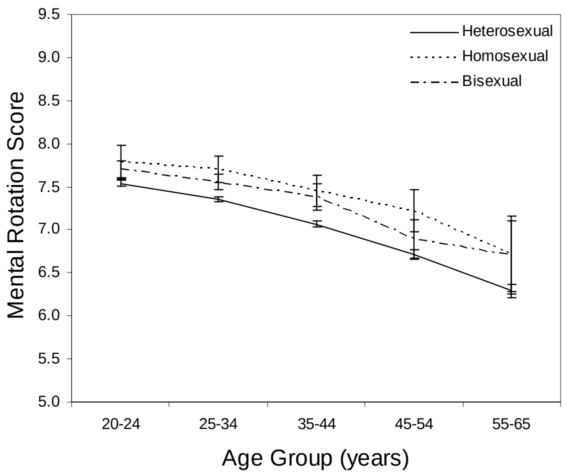


Figure 2e



Women
Men
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Object Location Memory Score
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-65
Age Group (years)

Figure 3a



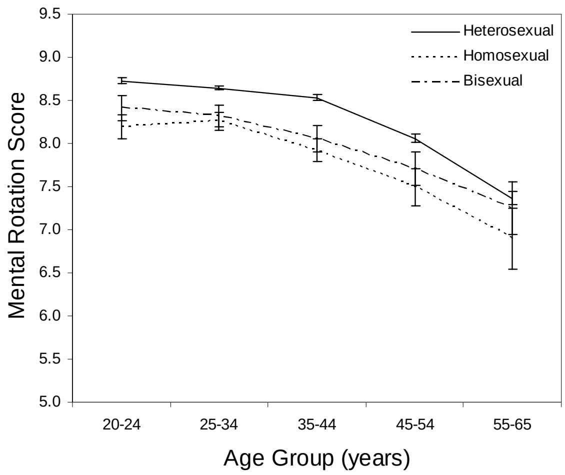
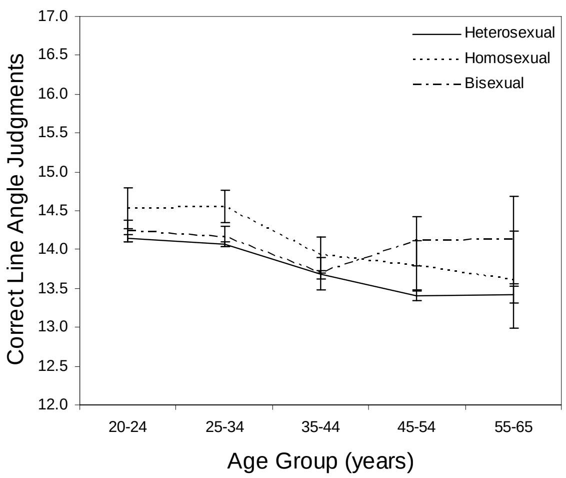


Figure 3b



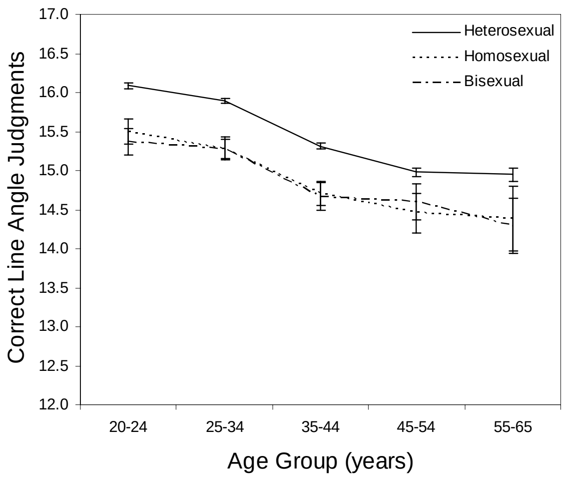
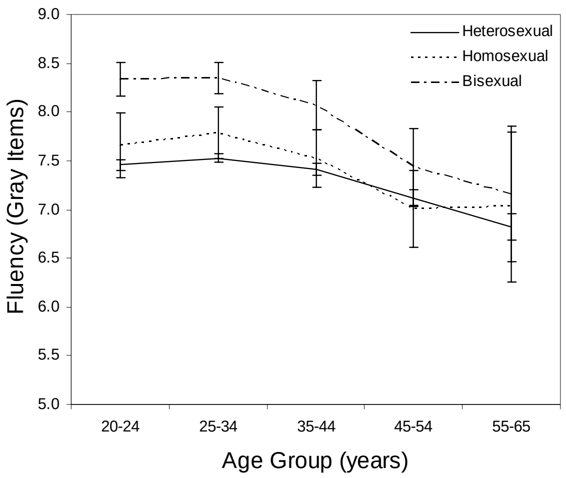


Figure 3c



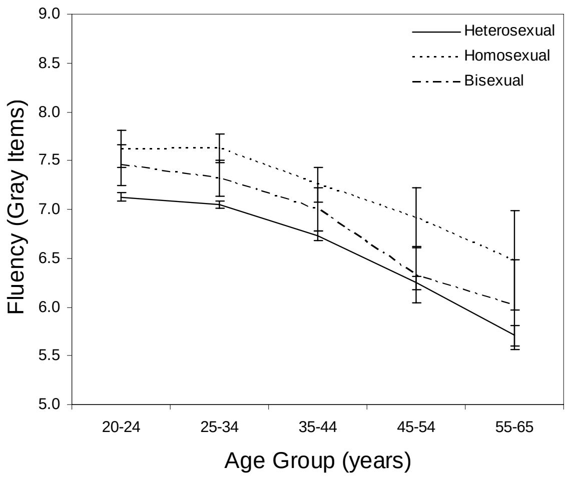
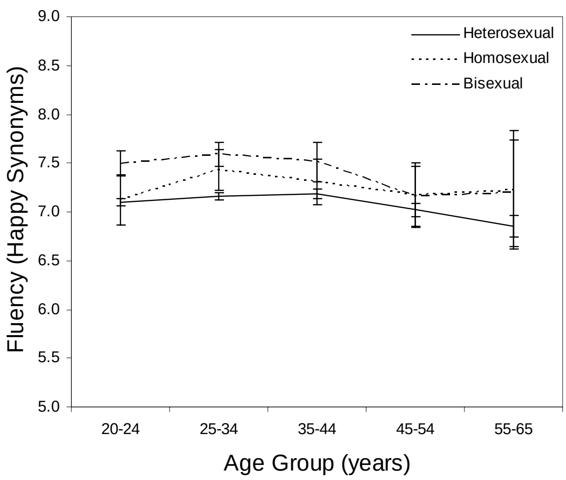


Figure 3d



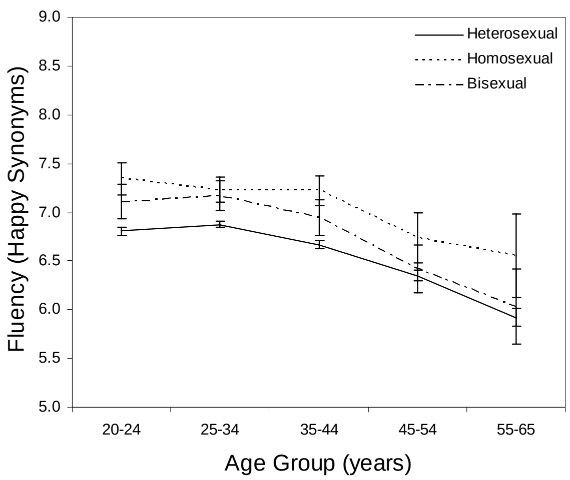
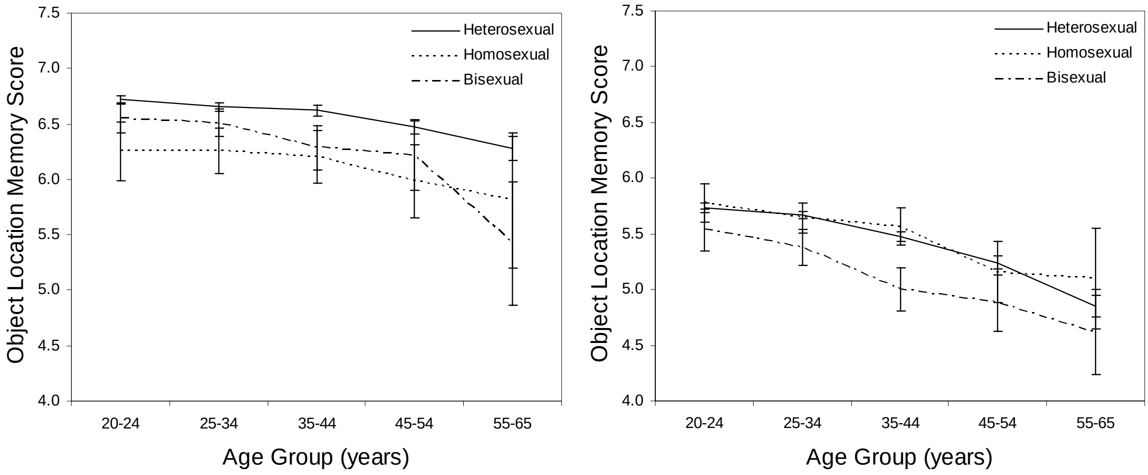


Figure 3e


Object Location Memory Score
Age Group (years)
Heterosexual
Homosexual
Bisexual
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
20-24
25-34
35-44
45-54
55-65
Object Location Memory Score
Age Group (years)
Heterosexual
Homosexual
Bisexual
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
20-24
25-34
35-44
45-54
55-65