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Personality and Individual Differences 35 (2003) 863–875

PERSONALITY AND INDIVIDUAL DIFFERENCES

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Sex differences in cognitive functions

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Received 23 May 2002; received in revised form 29 July 2002; accepted 25 August 2002

Abstract

Gender differences in neuropsychological functioning of patients with psychiatric disorders have been studied extensively in the last years. The available studies provide conflicting results, which can be attributed to the complexity of variables influencing cognitive sex differences. In the present study, we tried to evaluate the magnitude of gender differences in verbal and visual–spatial functions and to correlate the results with a self-rating of these abilities in healthy men and women. Ninety-seven college students (51 women and 46 men) were examined with a neuropsychological battery, focusing on verbal and visual–spatial abilities. In general, we found, that women tend to perform at a higher level than men on most verbal tests and men outperfom women on visual–spatial tasks. Nevertheless, it is worth mentioning, that the effect sizes were generally small, which suggests the assumption, that the overlap in the distribution of male and female scores is much greater than the difference between them. Additionally, in a self-rating scale, men rated their spatial abilities significantly superior to those of women, while women did not rate their verbal abilities superior to those of men. In this context, the relevance of socio-cultural factors, educational factors and training on the occurrence of sex differences is highlighted, as these factors add significantly to the overall explanation of neuropsychological task-performance.

Keywords: Sex differences; Gender; Cognitive functions; Self estimation

1. Introduction

Over the past decade, the differences between males and females in terms of neuropsychological functioning have been extensively documented (Astor, Ortiz, & Sutherland, 1998; Bryden, 1979;

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PII: S0191-8869(02)00288-X

Buffery & Grey, 1972; Caplan, Crawford, Hyde, & Richardson, 1997; Collins & Kimura, 1997; Dabs, Chang, Strong, & Milun, 1998; Delgado & Prieto, 1996; Fairweather, 1976; Halpern, 1996; Harris, 1978; Harshman & Remington, 1974; Hutt, 1979; Maccoby & Jacklin, 1974; McGivern et al., 1997; McGlone, 1977) and highlighted in the media. When sex differences and similarities are considered, discussion often centres on either "nature" (most characteristics are attributed to biological differences) or "nurture" (social factors and learning which lead to the differences). This debate has been intensified after the invention of new imaging technologies like positron emission tomography and functional magnetic resonance. The last years have shown an exponential increase in investigating gender differences in neuropsychological functions, epidemiology and brain morphology of patients with psychiatric disorders such as schizophrenia, depression or Alzheimer's disease providing conflicting results due in part to methodological artifacts (Goldberg, Gold, Torrey, & Weinberger, 1995; Goldstein et al., 1998; Hoff et al., 1998). Nevertheless a thorough defining of these sex differences is important to understand the behavioural problems of these diseases and to develop a more refined approach to their treatment. However, the research into gender differences needs to be approached with caution, because many variables like culture, gender, self-perception, hormones etc. influence the results. Generally, it is assumed that the differences between the intellectual functions of the sexes seem to lie in patterns of abilities, rather than in overall intellectual functioning (Collins & Kimura, 1997; Halpern, 1992; Kolb & Wishaw, 1990). Reviews of the literature suggest that men, on average, perform better than women on certain spatial tasks, although the concept of spatial ability or spatial cognition is vague. There are several approaches as to how spatial abilities can be defined or classified. Linn and Petersen (1985) suggested a classification of spatial tests into three distinct categories, which they labelled spatial perception, mental rotation and spatial visualisation. Spatial perception was defined as the ability to determine spatial relations despite distracting information. Mental rotation was defined as the ability to rotate, quickly and accurately, two or three dimensional figures in their imagination. Finally, spatial visualisation was defined as the ability to manipulate complex spatial information, when several stages are needed to produce the correct solution. This categorization was tested by Voyer, Voyer, and Bryden (1995) in a meta-analysis of studies published between 1974 and 1993, that showed that sex differences are seen in some categories of spatial ability but not others. In fact, large sex differences in favour of males were found only on different measures of mental rotation. Smaller differences were present on measures of spatial perception (Linn & Petersen, 1985), whereas for tests in the spatial visualisation category, the differences were highly variable and frequently non-significant. Furthermore, men outperfomed women in mathematical reasoning tests and in navigating their way through a route. Men were also more accurate in tests of target-directed motor skills—that is, in guiding or intercepting projectiles.

In contrast, females exhibit greater flexibility in linguistic tasks. Women tend to be better than men in rapidly identifying matching items, a skill called perceptual speed. Common linguistic skills, in which females have been found to be superior, are verbal fluency, speech articulation, grammatical skills, and use of more complex and longer sentences. Moreover, women are faster at certain precision manual tasks, such as placing pegs in designated holes on a board and have a better perceptual speed and accuracy.

In childhood, they usually learn to speak earlier (Morley, 1957), have larger vocabularies (Nelson, 1973), are better at reading and spelling (Gates, 1961), use complex grammatical constructions sooner (Harris, 1978), and perform better on immediate and delayed memory recall tests (Kramer, Delis, Kaplan, O'Donnell, & Prifitesa, 1997). After puberty, when hormonal and psychosocial influences increase, the gap between boys and girls on verbal tasks widens (Maccoby & Jacklin, 1974).

It is important to place the sex differences on verbal tasks described above in context: some are small, some are quite large. The largest female advantage is found in certain executive speech tasks such as speed of articulation, accuracy of speech production and fluency, but this advantage in verbal expression does not extent to other aspects of the use of language such as verbal reasoning (Hutt, 1979), vocabulary and comprehension.

Also in non-verbal abilities, such as memory, some studies have shown an advantage for women (Hampson & Kimura, 1992). More specifically, it has been found that women perform at a higher level than men on episodic memory tasks such as word recall (Berenbaum, Baxter, Seidenberg, & Hermann, 1997; Hill et al., 1995; Kramer et al., 1997), word recognition (Herlitz, Nielsson, & Bäckman, 1997; Temple & Cornish, 1993; Zelinski, Gilewski, & Schaie, 1993), story recall (Hultsch, Masson, & Small, 1991; Zelinski et al., 1993), recall of words under conditions of focused and divided attention (Herlitz et al., 1997), face and name recall and recognition (Herlitz et al., 1997; Hill et al., 1995; Larrabee & Crook, 1993). Furthermore, women tend to outperform men on tests of psychomotor speed and accuracy, using verbal or visual stimuli (Hampson & Kimura, 1992; Majeres, 1988, 1990).

Several studies have shown, that at least some of the gender differences could be related to socio-cultural or educational factors (Baenninger & Newcombe, 1989; Gittler & Vitouch, 1994; Hamilton, 1995; Lawton, 1994; Sharps, Price, & Williams, 1994). When there are no explicit spatial test instructions (subjects are not told that it is a spatial task, they are just told what to do) there are no sex differences in performing mental image rotation tasks (Sharps et al., 1994). As men constantly rate their spatial abilities as superior to those of women, women are repeatedly subjected to the expectation that they cannot, or may not, excel in spatial behaviours. Thus, the negative perceptions of women toward spatial cognitive activities may be culturally mediated by traditional feminine self-concepts. Good performance on spatial tasks such as mental image rotation would be perceived as a gender inappropriate activity (Sharps et al., 1994). Consitent with these findings, Hamilton (1995) reported results, that self-perceived gender trait possessions add significantly to the overall explanation of performance in a 3D mental rotation task.

To shed more light on the possible sex differences in cognitive functions, the first purpose of the present study was to evaluate the magnitude of gender differences in verbal and visual–spatial functions and to replicate previous findings in the literature. As mentioned above, these sex differences may be due to socio-cultural factors. Therefore, the second objective was to show differences between self-ratings of spatial and verbal abilities in men and women and to correlate these findings to the objective test results.

2. Methods

2.1. Subjects

Ninty-seven university students, who studied psychology or medicine (51 women and 46 men) participated in this study. Testing was conducted in small groups of 5–10 probands in a quiet laboratory room. All subjects were examined using a battery of neuropsychological tests in a standardized fashion. In selecting the neuropsychological tests, we focused on the neuropsychological abilities that are regarded as showing gender differences, especially verbal and visual–spatial functions.

2.2. Neuropsychological tests

Verbal intelligence was measured with the Mehrfachwahl-Wortschatz-Test, Lehrl (1989), which is a multiple choice vocabulary intelligence test to assess crystallized intelligence. The Advanced Progressive Matrices Tests (Raven 1965), a nonverbal intelligence test, was used to measure mental abilities by requiring the examinee to solve problems presented in abstract figures and designs. To test verbal fluency, we used the lexical and category word generation test. In the lexical word fluency, the subject is asked to write all the words he/she can imagine that begin with a specific letter. The test is timed at 1 min per trial and there are three trials, using the letters 'B', 'A' and 'S'. In category fluency, the subject is given a category and is asked to write down all the words belonging to the category. This test is also timed at one minute per trial and the three categories are 'supermarket', 'animals' and 'vegetables'. The Digit Symbol Test, a subtest of the Wechsler Adult Intelligence Scale test, was utilized to test accelerated visual–motor processing and attention.

Verbal memory was evaluated by a modified version of the verbal subtest of the Recognition Memory Test for Words (Warrington 1984) after a delay of 20 min. Furthermore the subtest story recall from the Rivermead Behavioral Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) was used, where the subjects listen to a short passage of prose being read aloud and are required to write down as much of it as possible immediately afterwards and again after a delay.

To test visual–spatial abilities the technical subtests 7–10 of the Leistungs-Prüfsystem (LPS; Horn, 1983) were administered. LPS 7 requires the ability to rotate numbers and letters and find those elements which are mirror-images. Spatial perception is measured with LPS 8, in which participants are required to indicate what an unfolded shape would look like when folded and also in LPS 9, where subjects are shown three-dimensional figures and have to count the surfaces of the figures. LPS 10 is similar to the Embedded Figures Test, which consists of finding specific figures in larger patterns of figures and requires visual spatial ability. All tests are performed with time limits.

In addition, a version of the Shepard and Metzler Mental Rotation Test (1971) was used. Target items are two pictorial representations of mirrored three-dimensional block like figures. The participants are given a series of 20 pictures of these objects in various orientations and have to decide which of the figures match the trial figure. This test was used with a time limit of 7 min. Furthermore the three-dimensional cube test (Gittler, 1990) was administered, in which the subjects had to mentally rotate/transform seven trial cubes, which had different patterns on their faces and decide if one of them matches the target cube.

The total battery of tests took 2 h to complete; some of the measurements were used in a slightly modified form to adapt them for the group-testing situation.

Subjective estimates of the subject's verbal and visual–spatial abilities were evaluated with two questions on a five point scale. All subjects were dextral, according to the Edinburgh Handedness Inventory (Oldfield, 1971).

Table 1
Demographic data for the total sample

	Men (n=46)	Women (n=51)	P-value
Age	26.17±2.97	23.92±3.76	0.002**
Handedness[a]	30.81±4.54	29.95±4.19	0.326
Lehrl (Raw Scores)	31.59±2.57	29.82±3.22	0.004**
Lehrl IQ	116.13±12.03	110.31±12.68	0.023*
Raven[b] (Raw Scores)	33.33±6.10	31.02±6.64	0.98
Raven PR[b]	65.38±25.66	58.34±26.53	0.217
Raven IQ[b]	119.17±15.08	104.81±13.89	0.166

[a] Handedness: 100% = right handed, −100% = left handed.
[b] Raven: men n=39, women n=48.
* $P<0.05$.
** $P<0.01$.

3. Results

Demographic data (age, handedness, verbal and non-verbal Intelligence) were compared using the two-sample t-tests. Neuropsychological data and subjective estimates were compared using a nonparametric test (Mann–Whitney U-Test). In order to reduce the number of neuropsychological variables, a factor analysis was performed and subscores based on this analysis were calculated, as described below.

Table 2
Neuropsychological test results

	Women	Men	P-value (Mann–Whitney U Test)	d[a]
Warrington Test[b]	45.7±5.67	43.8±6.22	0.048*	0.30
Verbal Fluency Lexical	44.5±8.93	40.33±9.57	0.020*	0.45
Verbal Fluency Categorial	51.02±7.66	49.11±8	0.081	0.24
Digit Symbol Test	68.82±10.08	64.59±10.38	0.029*	0.41
RBMT[c] short delay	8.17±2.38	8.47±2.80	0.674	0.15
RBMT long delay	6.55±2.22	6.87±2.56	0.638	0.13
3DW[d]	6.67±3.65	8.24±4.27	0.064	0.39
Mental Rotation Test	16.49±4.64	18.46±3.67	0.027*	0.41
Rotation of numbers and letters (LPS[e] 7)	20.02±7.82	20.41±7.50	0.781	0.05
Spatial visualization of unfolded shapes (LPS 8)	29.1±9.26	29.96±8.63	0.512	0.18
Spatial visualization of figures (LPS 9)	28.31±5.70	30.3±3.76	0.070	0.42
Embedded Figures (LPS 109	25.47±7.72	21.85±9.0	0.05*	0.43

[a] d = effect size.
[b] Warrington Recognition Memory Test: women, n=50; men, n=45.
[c] RBMT = Rivermead Behavioural Memory Test (story recall).
[d] 3 DW = Three Dimensional Cube Test.
[e] LPS = Leistungsprüfsystem Horn.
* $P<0.05$.

There were no statistically significant gender differences with regard to handedness and non-verbal intelligence. The male students were significantly older and had a higher verbal IQ. Table 1 summarizes demographic data.

3.1. Verbal tasks

Table 2 gives an overview of means and standard deviations for men and women in the verbal and visual–spatial task scores as well as effect sizes. The Mann–Whitney U Test, with sex as the independent variable, showed a significant effect of sex in the Warrington Recognition Memory Test ($P=0.048$), the Lexical Verbal Fluency Task ($P=0.020$) and the Digit Symbol Test ($P=0.029$), indicating that women performed at a significantly higher level than men on these tasks. A tendency towards a better performance of women was found in the Category Verbal Fluency Test ($P=0.081$). There was no difference between men and women in the Rivermead Behavioural Memory Test (story recall) for short or long delay.

Table 3
Rotated component matrix of the three factors (visual–spatial, verbal and memory)

Tests	Factors		
	1 Visual–spatial factor	2 Memory–factor	3 Verbal–factor
LPS 8	0.736		0.266
LPS 9	0.722		
3 DW	0.720		
Mental Rotation	0.691	0.242	
LPS 7	0.646		0.344
LPS 10	0.421		0.379
RBMT (short)		0.914	
RBMT (long)		0.912	
Warrington Test		0.504	
Verbal Fluency (lexical)			0.825
Digit symbol Test			0.742
Verbal Fluency (categorical)		0.205	0.676

Factor loadings below 0.2 are not shown. Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalization.

Table 4
Comparison of mean scores of the three neuropsychological subscales (derived from the factors) for men and women

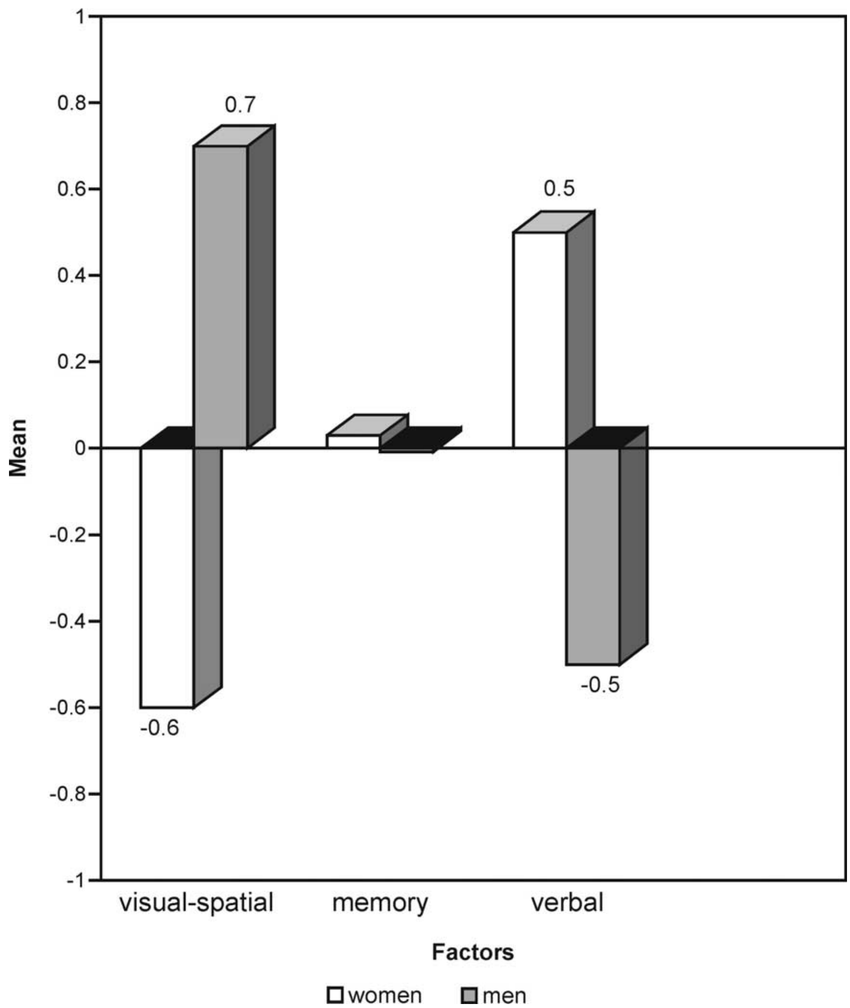
Factor (subscale)	Women	Men	P-value (t-test)
Visual–spatial factor	-0.6628 ± 3.7707	0.7349 ± 3.2791	0.056
Memory factor	0.0368 ± 2.2557	-0.0080 ± 2.6023	0.928
Verbal factor	0.5212 ± 2.0803	-0.5778 ± 2.4561	0.019*

* $P<0.05$.

Table 5
Self-rating scale of the verbal abilities and visual–spatial abilities of men and women

Self-rating	Men	Women	*P*-value Mann–Whitney *U* test
Verbal abilities	3.76±0.63	3.73±0.63	0.935
Visual–spatial abilities	3.85±0.7	3.45±0.88	0.023*

* $P<0.05$.



3.2. Visual–spatial tasks

The same statistic on the visual–spatial tests revealed that men performed at a higher level than women on the Mental Rotation Test ($P=0.027$). Subtest 10 of the LPS, a test for visual spatial ability, showed a better performance of women ($P=0.05$). A tendency for a better performance of men was found in the Three-Dimensional Cube Test ($P=0.064$) and on the subtest 9 of the LPS, which require spatial perception ($P=0.07$).

A factor analysis (principal component analysis, Varimax rotation) was performed to reduce the resulting data matrix of raw scores from neuropsychological tests. Using the scree criterion for deciding on the number of factors, a three-factor solution explaining 57.3% of the total variance was obtained, including a memory factor, a verbal factor, and a visual–spatial factor. One item (LPS 10) loaded on two factors (verbal factor = 0.379 and visual–spatial factor = 0.421) and was eliminated from the factor analysis. This resulted in the assignment of the neuropsychological tests to the three factors in the following manner: (1) visual–spatial factor: LPS subtests 7–9, Three-Dimensional Cube Test and Mental Rotation Test; (2) memory factor: Warrington Recognition Memory Test, Rivermead Behavioural Memory Test (story recall) short and long delay; (3) verbal factor: Verbal Fluency (lexical and categorical) and Digit Symbol Test. The loading matrix of the three factors is demonstrated in Table 3.

The three factors gave rise to three subscales, which were calculated as the sum of the Z-scores of the variables loading on the respective factors. The t-test was used to compare the mean scores of the three factors. As can be seen in Table 4 and Fig. 1, there was a significant difference between the groups, indicating that women performed at a higher level on the verbal factor ($P=0.019$). However, there was a tendency for men to perform at a higher level on the visual–spatial factor, but this differences missed statistical significance by a narrow margin ($P=0.056$). There was no gender effect on the memory factor.

We also performed a Mann–Whitney U-Test to compare the self-rating of the abilities and visual–spatial abilities of men and women (Table 5). Men rated their visual–spatial abilities significantly higher than women ($P=0.023$). For the self rating of verbal abilities the analysis showed no difference between the genders. A comparison of the self-ratings of verbal and visual–spatial abilities to objective test-results yielded no significant correlations.

4. Discussion

The aim of the present study was to investigate gender differences in verbal and visual–spatial abilities. In general, the results showed, that women perform at a higher level than men on most verbal tests and men tend to outperform women on visual–spatial tasks. A significant difference between men and women was found in three of the four verbal measures and one of the three visual–spatial tasks. We will discuss the results in more detail in the following discussion.

In the present study we measured verbal and nonverbal IQ and found no gender differences in the nonverbal IQ. However, IQ Tests, which are supposed to measure intellectual abilities, are constructed to eliminate sex differences in total scores. Individual test items that show large sex differences are therefore excluded entirely. This is based on the assumption that sex differences on such items may be specific to the task in question and may simply reflect differences in experience and training. Among the remaining items, those slightly favoring women are balanced against others, which favor men to an equal degree. If an IQ test shows equal total test scores for each sex, this merely reflects how well the test was constructed to rule out sex differences. In factor analyses of IQ tests, sex differences do appear, especially when analyzing the word fluency and spatial factors.

4.1. Perceptual speed and accuracy

Our study showed a better performance of women on the Digit Symbol Substitution Test. As known from the scientific literature, women tend to outperform men on tests of psychomotor speed and accuracy using visual stimuli (Majeres, 1988, 1990). This advantage has been found to be pronounced in children, but as our results demonstrate, these gender differences remain prominent in adulthood.

4.2. Verbal functions

The present study demonstrated a significant female advantage in the Lexical Verbal Fluency Task ($P=0.02$) and a tendency in the same direction for the Semantic Verbal Fluency Task ($P=0.081$). This replicates the findings of Kimura (1983) who showed a female advantage on certain executive speech-tests such as speed of articulation, accuracy of speech production and fluency. Meta-analyses of 165 studies evaluating verbal skills found significant gender differences only in one third of the studies (Hyde and Linn, 1988). While 27% of these studies showed females performing better than males, 66% of the studies produced no significant differences. Results for the memory tasks are inconsistent. Our findings resemble those of Hampson and Kimura (1992), who showed a female advantage on short-term word-recognition-memory after a delay of 20 min. Other memory tests, like story recall, produced no gender differences in our study.

4.3. Visual–spatial tests

Men tend to fare better on many visual–spatial tests, particularly on tests of spatial orientation, mechanical abilities and mathematics. This difference is not prominent until puberty, when girls' performances become poorer (Karnovsky, 1974). The Mental Rotation Test appears to produce the most robust sex difference among all neuropsychological tests, a finding, we were able to replicate. It is worth mentioning, that the Mental Rotation Test was performed with a time limit of 7 min in our study, which may be relevant for the outcome of the task. Indeed Goldstein, Haldane, and Mitchell (1990) reported that the male advantage on this test was only found, when the test was given with strict time limits. Sex differences in spatial abilities appear to be due, at least in part, to performance or situational factors. Analogous findings from research on age differences in cognitive abilities may be instructive. In this context Monge and Hultsch (1971), for example, have shown, that the difference between college students and elderly subjects on verbal learning tasks can be eliminated when the elderly subjects are allowed either more time to study the material or more time to respond, or both. A similar influence could be applied to the apparent sex differences in spatial and verbal task abilities. Males, who may have more exposure to spatial tasks, and on the other hand, women who may have more encouragement in the verbal domain, work more quickly and perhaps more confidently than the respective other sex. However, this advantage disappears when the premium for rapid performance is taken away. Other tests measuring visual–spatial performance in our study like the Three Dimensional Cube Test showed a tendency toward a better performance in males ($P=0.064$). Results of the Leistungsprüfsystem showed varying results for the subtests emphasizing the observation made by Linn and Petersen (1985) and Voyer et al. (1995) that sex differences are apparent in some types of spatial ability but not others.

Next to many other confounding variables, several researchers (Chance and Goldstein, 1971; Connor, Serbin, & Schakman, 1977; Goldstein & Chance, 1965) have found an interaction between training and gender on spatial ability tasks. Extended practice, benefited women more than men and, consequently, reduced or eliminated the original sex differences in performance. One reason, why training may help women more, is that they have had less opportunity than men to practice spatial tasks (Sherman, 1967). Another hypothesis is that women generally feel less confident or able to achieve on visual–spatial tasks than men (Goldstein & Chance, 1965). Females may feel uncomfortable with visual–spatial tasks and perceive themselves at a disadvantage and respond with more caution and therefore perform at a slower rate than men (Goldstein & Chance, 1965). This concurs with our finding that women rate their spatial abilities inferior to those of men. Beyer (1999) and Beloff (1992) reported sex differences in the self-estimation of intelligence. They found that men estimates their scores significantly higher than females and argued that the modesty training girls receive in socialisation accounts for this data. Several studies have looked at sex differences in estimates of multiple intelligences. According to Gardner (1999) intelligence was divided into seven subtypes). Furnham, Dixon, Harrison, Rasmussen, and O'Connor (2000) found consistent sex differences in self-estimates in only two types of multiple intelligence: in mathematical and spatial abilities. In particular, female self-estimates of spatial intelligence were typically 6–10 points lower than male's self-estimates. There were no sex differences on the verbal score. These results are consistent with our findings that men rate their visual–spatial abilities significantly higher than women, but there is no sex difference in the self-estimation of the verbal abilities. Presumably, if the confidence of female probands could be elevated through experimental or other means, their performance on a timed test might be equivalent to that of males.

When taking gender into account in evaluating neuropsychological test performances, it is perhaps most important to keep in mind that group differences rarely amount to as much as one-half of a standard deviation, which infers that men and women overlap enormously on many cognitive tests that show mean sex differences (McKeever, 1995). Based on our data, there was no task with an effect-size larger than 0.5. This small effect size indicates that the variation of scores within a group is much larger than the variance between the sexes, but because of the large number of participants we were able to detect significant differences with resepect to verbal and visual–spatial tasks.

Over the past 10 years, there has been an exponential increase in investigating gender differences in neuropsychological functions of patients with psychiatric disorders such as schizophrenia, providing conflicting results (Goldberg et al., 1995; Goldstein et al., 1998; Hoff et al., 1998; Lewine, Walker, Shurett, Caudle, & Haden, 1996). Facing the complex issue of variables influencing cognitive sex differences, such as sex role identification (Signorella & Jamison, 1986), environmental models (Petersen & Licata, 1979), cerebral lateralization (Bryden, 1979) and sex hormones (Collaer & Hynes, 1995), cognitive differences between the sexes must be interpreted with caution. Combining neuropsychological tests with new neuroimaging methods like positron emission tomography or functional magnetic resonance imaging could shed additional light on some of the potential underlying reasons for sex differences such as hemispheric lateralization or specialization.

Acknowledgements

E.M. Weiss was supported by the Austrian Fonds zur Förderung wissenschaftlicher Forschung (FWF: J2009).

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