EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY
0000, 00 (0), 3604

Psychology Press
Taylor & Francis Group

Are there gender differences in verbal and visuospatial working-memory resources?

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Whereas women generally outperform men in episodic-memory tasks, little is known as to how the genders compare with respect to basic working-memory operations. In reference to Baddeley's (1986) model, the present study searched for possible gender differences in terms of accuracy (but not speed) of working-memory processes. Men and women completed series of working-memory tasks respectively involving verbal and visuospatial information, as well as a double-span task involving both classes of information. Control measures included verbal fluency and mental rotation tasks in which gender differences are frequently obtained. In these tasks, the results showed several of the expected gender contrasts. However, men and women were not found to differ significantly in any type of working memory save in the double-span task where women surpassed men. The patterns of task intercorrelation were largely similar in both genders. Discussion emphasises the manifestation, based on the present exploration, of an almost identical working-memory architecture in men and women.

The comparison of men's and women's cognitive functioning in a broad spectrum of sectors has disclosed a number of similarities as well as several differences of variable magnitude (Halpern, 2000; Kimura, 1999), although these abundant data have yet to be integrated within a coherent framework. This evidence has essentially been organised in reference to the type of material, that is, verbal, numerical, or spatial, involved in the cognitive tasks used. As highlighted by Halpern (2000), the results of gender comparisons have accordingly been categorised according to cognitive abilities of either a verbal, quantitative,

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This study was supported by Grant 2602 from the Natural Sciences and Engineering Research Council of Canada to the first author. A preliminary version of this report was presented at the meeting of the Canadian Society for Brain, Behaviour, and Cognitive Science, Québec City, QC, June 2001. We are grateful to Roger Godbout for useful procedural advice, as well as pertinent comments on an earlier version of the paper. We also thank Michel Hupet and Marie-France Ehrlich for having provided us with a copy of the French version of the reading-span and verbal-span tasks, respectively. Finally, we wish to acknowledge the cooperation of Sébastien Hélie for data collection.

© 0000 Psychology Press Ltd
http://www.tandf.co.uk/journals/pp/09541446.html DOI:10.1080/09541440500234104

or visuospatial nature. However, carrying out gender comparisons that are process rather than content oriented could contribute substantially to achieving powerful and parsimonious accounts of gender similarities and differences. As a complement to the large corpus of content skills in which men and women have been found to differ or not, this strategy might lead to the identification of a few critical cognitive processes, applicable to a variety of contents, that are more or less developed or efficiently activated in each gender.

An emergent process approach may be discerned in research attempts to establish whether men and women differ in terms of memory functions. Most of these efforts have actually focused on episodic memory, that is, the remembering of personal events encoded in a specific temporal and spatial context. From their review of such findings, Herlitz, Nilsson, and Bäckman (1997) have concluded that women surpass men in recollecting diversified contents, such as words, stories, faces, and object locations. Their own data have extended the female advantage to the episodic recall of recent activities and new facts. By contrast, these authors found no significant gender differences in measurements of both priming and semantic memory. However, no research seems to have systematically compared men and women with respect to another set of memory mechanisms which are of far-reaching importance to higher level cognition since they regulate the flow of information processing during thinking, reasoning, and decision making (e.g., Eysenck, 2001). These are the working memory processes enabling the temporary storage of the outcomes of intermediate mental operations, and the execution of further operations on these outcomes as well as on incoming information.

In order to explore for possible gender differences with regard to these basic cognitive tools, the present study adopts as its general conceptual background the seminal working-memory model proposed by Baddeley (1986, 1994, 1999). The central executive, that is, the core constituent of this tripartite model, is a limited-capacity attentional control system that monitors information processing resources, coordinates the information stored in two independent subsystems, and transfers this information to long-term memory. One of these specialised subsystems is the phonological loop: It comprises a phonological store that passively holds traces of speech-based material for brief periods of time, and an articulatory control process that relies on subvocal rehearsal to enter or maintain information in the phonological store. The second subsystem consists of the visuospatial sketchpad, which retains and manipulates visuospatial images. It includes its own brief passive store, as well as control processes responsible for registering and rehearsing (e.g., through eye movements) visuospatial information. Visual and spatial components dealing respectively with patterns and their locations are incorporated.

Mixed results characterise existing comparisons of men's and women's working-memory performances in isolated tasks which, to varying extents, may be deemed to draw either on the phonological or on the visuospatial subsystem.

In a primary memory task analogous to word span tasks involving the phonological subsystem, men and women have displayed similar word recall (Herlitz et al., 1997). In another simple phonological storage task, the Digit Forward subtest of the Wechsler Intelligence Scale, some authors (Duff & Hampson, 2001; Orsini, Chiacchio, Cinque, & Cocchiaro, 1986) have reported no significant gender differences, while others have observed a female advantage (Grossi, Matarese, & Orsini, 1980). In the Digit Backward subtest, which asks for a more active involvement of the central executive, again men and women were not found to differ significantly (Duff & Hampson, 2001). The same null findings have been obtained in a task requiring the addition of each number to the one immediately preceding it in a series (Duff & Hampson, 2001). However, women were shown to be superior to men in tasks, more difficult than the preceding ones, that respectively involved a classical reading span assessment (Cochran & Davis, 1987), producing random series of digits without repeating or missing any (Duff & Hampson, 2001), and identifying whether alphanumeric signs were or were not the same as others previously presented (Speck et al., 2000).

With respect to visuospatial working memory, Corsi's test usually yields a male advantage (Capitani, Laiacona, & Ciceri, 1991; Grossi et al., 1980; Kalayc1oglu, Nalçac1, Budanur, Genç, & Çiçek, 2000; Orsini et al., 1986; but see Kessels, Postma, Kappelle, & de Haan, 2000; Postma, Jager, Kessels, Koppeschaar, & van Honk, 2004). When the locations of random cells in series of two-dimensional grids need to be stored while further grids are shown, men also outdo women (Nalçac1, Kalayc1oglou, Çiçek, M., & Budanur, 2000; but see Minor & Parks, 1999; Vecchi & Girelli, 1998). However, women's superiority has been established in locating pairs of coloured dots in a minimum of searches for individual dots concealed in an array (Duff & Hampson, 2001), whereas in more demanding tasks involving image generation, maintenance, scanning, and transformation, men proceed more rapidly than women (Loring-Meier & Halpern, 1999).

A tentative pattern seems to surface from these dispersed data on verbal and visuospatial working memory. In verbal tasks, gender differences are not systematically found but, when they occur, they indicate a female advantage; in visuospatial tasks, men generally outperform women although the reverse does occur. However, being based on an unplanned assemblage of tasks that are respectively connected to different conceptions of working memory, this portrayal is both unsystematic and fragmented. It may also be neither accurate nor reliable as it was derived from data collected across adults with different ages[1] and education levels. In addition, owing to the well-known tendency to publish

[1] As elderly participants were included in a number of cases, the outcomes of the gender comparisons may partially reflect the presence of cognitive ageing problems that differ in magnitude according to gender.

primarily statistically significant differences, the available body of information may underrepresent the number of gender comparisons having yielded null results. Finally, as independent samples were involved, intertask correlations, both within and across working-memory components, are not available to indicate whether or not both genders exploit similar architectural organisations. The latter structural aspect indeed appears to be central within a process-oriented approach. Therefore, the present study attempts to attenuate these shortcomings by submitting the same groups of men and women to a coherent assortment of tasks that are known to tap either the phonological loop or the visuospatial sketchpad and to call either for storage only or for additional concurrent processing. It also includes a double-span task that has been shown to simultaneously activate all three components of Baddeley's (1986) model (Martein, Kemps, & Vandierendonck, 1999). Whereas the remembering of object names and locations primarily depends on the phonological loop and the visuospatial sketchpad respectively, this double-span task further asks for the recollection of the exact correspondence between the name of a given object and its location. As it requires coordinating verbal and visuospatial inputs, it draws on the resources of the central executive.

As a control, the present study employs assessments of particular visuospatial or verbal skills in nonmemory tasks where achievement typically differs according to gender. Besides serving as a reference against which to judge the representativeness of our sample, the competence appraised in these tasks might be connected with working-memory functioning. On the one hand, several meta-analytic reviews of visuospatial gender comparisons (Linn & Petersen, 1985; Masters & Sanders, 1993; Voyer, Voyer, & Bryden, 1995) have revealed that men clearly outperform women in mental rotation tasks involving three-dimensional objects. Presented with two-dimensional line drawings of these objects, each in a different orientation, the participant must mentally turn the illustrated forms around their central axes and align them in order to decide whether or not they are identical. Interestingly, it has been suggested that the manipulation of mental images required in such tasks may be supported by specialised functions shared with visuospatial working memory (Baddeley, 1999; Logie, 1995; Pearson, de Beni, & Cornoldi, 2001). This appears plausible as even the easier mental rotation of two-dimensional shapes is disrupted by the simultaneous execution of a mere visuospatial tapping task (Logie & Salway, 1990).

On the other hand, no verbal task yields as robust gender differences among adults as does the mental rotation task (Kimura, 1999). However, men and women have often been reported to differ in verbal fluency tasks requiring the production, in a short time, of as many words as possible that meet certain constraints. Under phonological constraints, such as when all words must begin with a given letter, women frequently surpass men (e.g., Capitani, Laiacona, & Basso, 1998; Herlitz et al., 1997; Tombaugh, Kozak, & Rees, 1999), though not

always (e.g., Bolla, Gray, Resnick, Galante, & Kawas, 1998; Janowski, Chavez, Zamboni, & Orwoll, 1998; Lewin, Wolgers, & Herlitz, 2001). The gender contrast is less consistent under semantic constraints, such as when all words must belong to a given category. For instance, the female advantage occurs with fruit names (Bolla et al., 1998; Capitani, Laiacona, & Barbarotto, 1999; Laws, 2004), but not necessarily with animal names (Bolla et al., 1998; Janowski et al., 1998; Laws, 2004; but see Tombaugh et al., 1999), whereas with vehicle names it may even be replaced by a male advantage (Capitani et al., 1999; Laws, 2004). There is also evidence that proficiency at generating specific types of words is linked to verbal working-memory capacity, in accordance with Baddeley's (1996a) assumption of the role of executive processes in word retrieval from long-term memory. In an all-female sample, producing words belonging to various conceptual categories is indeed slowed down when performed concurrently with a verbal memory task (Baddeley, Lewis, Elridge, & Thomson, 1984). Among participants of unspecified gender, more animal names are retrieved by high than by low achievers on a verbal working-memory task combining arithmetic operations and word encoding (Rosen & Engle, 1997). Finally, fluency as assessed by speech production about a picture is positively associated with jointly recalling unrelated words and inserting each in a meaningful sentence (Daneman, 1991).

METHOD

Participants

The participants were 50 men and 50 women, each paid the equivalent of US$14. Between 19 and 25 years of age (mean age and standard deviation: 21.6 years and 1.76 in women; 21.8 years and 1.68 in men), all were students enrolled in undergraduate programmes in the social sciences at the Université de Montréal (where no subject pools are permitted). Programme of study did not significantly differ between men and women.

Tasks and scoring

Individual testing involved four verbal and four visuospatial working-memory tasks, as well as a double-span task. Control tasks included verbal fluency tasks and a mental rotation task. Unless otherwise specified, no time limit was imposed but instructions asked participants to work at a reasonably fast pace.

Verbal working memory. The selected tasks have been shown to provide fairly pure assessments of verbal working memory (Baddeley, 1996b; Daneman, 1991; Lehto, 1996; Shah & Miyake, 1996). The first one was a storage task, whereas the rest required both storage and processing. The first task consisted in the Digit Span subtest from the WAIS-R (Wechsler, 1981). The experimenter

recited series of digits which the participant had to repeat in the same order (digits forward), and then in reverse order (digits backward). Starting with two, the series progressively included up to nine digits. Each series involved a maximum of two trials. As soon as the participant was successful on one trial, the next series began. Scores (maximum: 9) were defined by the length of the longest series for which at least one trial was correct.

Another task involved the French (short) version (Desmette, Hupet, Schelstraete, & van der Linden, 1995) of the reading-span task (Daneman & Carpenter, 1980). The participant was instructed to read aloud series of unrelated sentences while memorising the last word of each sentence. Comprising 12–17 words, each sentence was printed in the centre of a sheet of paper (21.5 × 28 cm) held by the experimenter. A few practice items involved series of two sentences. Having read aloud the sentences, the participant recalled their last words, which were written down by the experimenter. The words had to be recalled in the order in which they had occurred. The task proper included three blocks. Block 1 began with a series of two sentences. If recall was correct, a three-sentence series followed. In principle, testing proceeded in the same fashion for each of the four-, five-, and six-sentence series. In fact, it was ended when the participant failed one series. The same procedure was then applied in Blocks 2 and 3. The reading span (maximum: 6) was defined as the highest number of sentences for which the participant was correct in two out of three blocks. However, this span value was raised with a .5 credit if the participant was correct in only one block of the next larger number of sentences. The total number of recalled words (maximum: 60) was also used as a less stringent measure.

The French version (Ehrlich, Brébion, & Tardieu, 1994) of the verbal-span task (Daneman & Tardif, 1986) was employed. In the central part of an index card (20 × 12.5 cm), the participant was presented with a sequence of four short words (e.g., ''pan'', ''cap'', ''talon'', ''oral'') for 10 s. He or she was asked to both create and remember a longer word that combined two of these four words without changing their order; the two words did not have to follow one another. However, the participant was not allowed to create a word with a syllable boundary corresponding to the one between two of the original words (e.g., ''pantalon''); the new word had to have a different syllable boundary (e.g., ''caporal'').[2] The experimenter wrote down the created word. A second sequence of four short words was then presented. After both sequences were completed, the participant had to orally recall the two created words (in any order). There were five series involving two sequences each. The corresponding procedure was used in five series of three and, then, four sequences. Overall,

[2] For the benefit of English-speaking readers, an example with English words would involve the presentation of the ''par'', ''don'', ''shot'', ''ate'' sequence. Whereas the participant would not be allowed to create ''pardon'', ''donate'' would be correct.

there were 45 series. The number of words (maximum: 45) correctly created and recalled was established.

In a French adaptation of the speaking-span task (Daneman & Green, 1986), the participant silently read a series of unrelated, seven-letter words, each displayed on a computer screen for 1 s at the rate of one word every 10 ms. The end of the series was indicated by a blank screen. The participant then had to orally incorporate each word in a different grammatical, meaningful sentence that was recorded on a cassette recorder. The length of the sentences was not constrained and the target words could be inserted anywhere. Overall, 70 French words were presented within five series respectively of two, three, four, and five words, in that order. These words were nouns and adjectives of average frequency of occurrence (Baudot, 1992). The span was defined by the number of target words (maximum: 70) included in correct sentences.

Visuospatial working memory. The selected tasks have been shown to provide fairly pure assessments of visuospatial working memory (Daneman & Tardif, 1986; Shah & Miyake, 1996; Vecchi, Phillips, & Cornoldi, 2001). The first two tasks were storage tasks; the remainder required both storage and processing. In Corsi's block-tapping test (Milner, 1971), series of two to nine blocks were shown. At the rate of one block per second, the experimenter started by tapping each block in the two-block series in a random order; the participant had to reproduce the sequence. Each series involved a maximum of five trials; when three trials were correct, the series with the next larger number of blocks was presented. The participant's score (maximum: 9) was given by the length of the longest series on which the success criterion was met.

In the *position-memory task* (Vecchi & Girelli, 1998), series of 3 × 3 matrices involved two, three, and four matrices, in that order, with four trials per series. On each trial, a series was shown on a single sheet of paper (21.5 × 28 cm) for 10 s; each matrix contained two differently positioned black cells. The participant was asked to remember these positions. Using blank matrices, he or she then pointed at them. The number of correctly recalled positions was added across trials (maximum: 72).

The spatial-span task A involved a two-dimensional adaptation of Daneman and Tardif's (1986) task using a three-dimensional tic-tac-toe game.[3] Each of a series of sheets of paper (21.5 × 28 cm) was divided into three panels, each showing a 3 × 3 grid. The participant was asked to imagine that, from top to bottom, the panels respectively illustrated successive moves in a standard tic-tac-toe game. Within two to four of the nine cells in each panel, red and blue circles represented the pieces of two players. Each sheet displayed a total of eight circles. The winning sequence was incorporated in this combination of

[3] Such an adaptation aimed at avoiding a floor effect since pilot testing indicated that the original, three-dimensional task was too difficult for most participants.

circles. The participant's task was to locate such a sequence, that is, the three same-colour circles that formed a straight line that was horizontal, vertical, or diagonal. Working on one sheet at a time, the participant identified the winning sequence by touching its three circles with his or her index finger. After a series of two sheets, he or she had to recall the locations of each winning sequence, in order, by pointing to the correct positions on an empty 3 × 3 grid. This was repeated in four other two-sheet series. The same procedure was used in five three-sheet series, and then in five four-sheet series. The number (maximum: 45) of correctly identified and recalled sequences was established.

In the spatial-span task B (Shah & Miyake, 1996), the participant was shown several examples of a capital letter (F, J, L, P, or R) or of its mirror image on a computer screen. The examples were presented one at a time, each rotated in a different orientation. While memorising its orientation, the participant had to decide as quickly and accurately as possible whether each letter was normal or mirror-imaged. At the end of the series, the orientations had to be recalled in correct serial order. More precisely, there were seven possible orientations (in 45° increments, excluding the upright orientation), and each of the 70 possible combinations (Letters × Orientations × Normal/mirror-image type) appeared once in the task. Only one letter was used within a series. As soon as the participant said ''normal'' or ''mirror-imaged'', the (trained) experimenter pressed a corresponding button. The letter remained on the screen for 200 ms, or for a maximum of 2200 ms if the participant did not answer. This time limit aimed at reducing the possibility that participants would intentionally delay the mental rotation requirement in order to rehearse the orientations. A 250 ms interval separated the presentation of each letter example. After presentation of the two examples included in the first series, the screen showed a diamond-shaped grid with eight squares indicating the seven possible orientations and the upright. The participant used a mouse to click in the square corresponding to the direction of the top of each letter example in its previous order of appearance. The next series followed with two examples of a different letter, and so on until two examples of all five letters had been presented. The same procedure was repeated with series of three, four, and, finally, five letter examples. Letters and orientations were presented in a random order except that opposing orientations were never presented successively and that the same orientation could appear only once in any series. At the end, the number of correctly recalled letter orientations (maximum: 70) was established.

Double-span task (Martein et al., 1999). Line drawings of 20 common objects (e.g., apple, key, flag) were used. The participant was presented with sequences of subsets of these objects, each object appearing in a particular (randomly selected) cell in a particular 4 × 4 grid (printed on a 21.5 × 28 cm sheet of paper). He or she was instructed to memorise both the name and position of each object, as well as to record its serial order of presentation. The

first sequence involved two objects; the experimenter presented the two corresponding grids at a rate of one per second. The participant was then asked to follow the correct serial order in either recalling orally the names of the objects, pointing at their positions on a blank grid, or recalling the names while pointing at the positions. The three types of recall were asked for in a random order without the participant knowing in advance which type would be involved in the coming trial. There were two trials for each recall type. The same procedure was repeated with sequences of three, four, five, and, finally, six objects. For each recall type, performance was scored as the overall number of items (maximum: 40) recalled correctly both in terms of content and serial order.

Verbal fluency. First, the participant was allowed 2 min for saying as many words as possible beginning with the letter P. Instructions specified not to include proper nouns, numbers, or different forms of the same word. This was repeated with R, and then V. Next, the participant had one min to generate as many words as possible designating fruit; this was repeated with vehicles. In all of the above cases, the experimenter wrote down the words produced. Performance was defined as the number of correct words. Finally, a French adaptation of the Making Sentences Test (Ekstrom, French, Harman, & Dermen, 1976) required the production, within 10 min, of as many meaningful sentences as possible that contained four to six words, some of which started with specified letters. Twenty items were presented on two sheets of paper (21.5 $\times$ 28 cm). Proper nouns, abbreviations, and sentences with more than one clause were not permitted. Performance corresponded to the number of correct sentences (maximum: 20).

Mental rotation. The version of the Mental Rotations Test redrawn by Peters et al. (1995) was used. The 24 items were split into two 12-item sets separated by a 4 min pause; 3 min were allowed for each set. On each item, the participant had to identify the two response choices that were the same as the target but oriented differently; a score of 1 was given if both choices were correct (maximum: 24).

Procedure

A male and a female experimenter respectively examined approximately half of the participants of each gender during two sessions lasting approximately 2 hours each. Session 1 involved the verbal fluency tasks, then the verbal working-memory tasks (in a random order that differed for each participant), and, finally, the double-span task. Session 2 involved the mental rotation task, and then the visuospatial working-memory tasks (in a random order that differed for each participant). Half of the participants started with Session 1, and the other half with Session 2. To control for possible circadian rhythm effects on working-

memory measures (Carrier & Monk, 1999), both sessions were held at the same time of day for each participant. Seventeen women were tested in the morning, 28 in the afternoon, and 5 in the evening; in men the corresponding numbers were 17, 31, and 2. For both genders, a 2- to 10-day interval (mean: 6 days) separated the two sessions.

RESULTS

The level of significance was set at .05 in all statistical analyses. For an expected medium-size gender effect, power was deemed acceptable as its level was .70.

A preliminary analysis checked whether performance differed as a function of session order and time of day for testing. An analysis of variance according to a 2 (gender) × 2 (session order) × 2 (time of day) design was conducted separately on each score measured in each task. Neither session order nor time of day exerted significant (main or interaction) effects on any score. Only the morning and afternoon participants were included in these analyses as there were too few (i.e., seven) evening participants. Based on visual inspection, the latter participants' scores did not seem to differ as a function of session order, nor from the scores of the morning and afternoon participants. Hence, although the previous analyses of variance revealed a few significant differences between men and women, gender effects were more systematically evaluated in subsequent analyses from which the session order and time of day variables were omitted.

Table 1 presents the mean scores obtained by men and women on each of the control tasks. Carried out on the verbal fluency tasks, a multivariate analysis of variance revealed a significant gender effect, Wilks' $\Lambda = .62$, $F(6, 93) = 9.57$. However, follow-up analyses of variance indicated that women only outperformed men in generating fruit names, $F(1, 98) = 14.78$, $MSE = 16.67$. In a separate analysis of variance, mental rotation performance was found to be

TABLE 1
Mean (and standard deviation) scores for men and women on the control tasks

	Verbal fluency						
Gender	*P*	*R*	*V*	*Fruit*	*Vehicles*	*Sentences*	*Mental rotation*
Men							
Mean	25.48	22.40	20.66	19.14	18.28	13.90	10.20
SD	5.16	4.51	4.95	4.11	3.99	3.18	3.43
Women							
Mean	25.94	23.18	21.70	22.28	16.86	14.40	7.28
SD	6.55	6.46	5.96	4.06	4.28	3.75	4.98

higher in men than in women, $F(1, 98) = 11.66$, i = 18.29. It is worth specifying that these two converse gender differences were the only ones detected in the above-described analyses including the session order and time of day variables.

Tables 2, 3, and 4 respectively present the mean scores obtained by men and women on each of the verbal working-memory tasks, the visuospatial working-memory tasks, and the double-span task. For men and women separately, exploratory principal-components factor analyses were respectively carried out on the scores measured in cases where more than one task was employed to assess a particular type of competence, that is, in each category of working-memory tasks, as well as in verbal fluency tasks. In all such cases, a single factor structure was extracted based on scree plot inspection. For verbal working-memory tasks, the single factor accounted for 56% of the variance in women and 50% in men. The corresponding percentages were 45 and 56 for visuospatial working-memory tasks, 72 and 70 for the double-span task, and 53 and 44 for the verbal fluency tasks. Consequently, the conceptual consistency of these task categories appeared satisfactory, as also indicated by the Cronbach's alpha coefficients. In women, these coefficients were .77 in the verbal working-memory tasks, .64 in the visuospatial working-memory tasks, .80 in the double-span task, and .82 in the verbal fluency tasks. In men, the corresponding values were .72, .72, .78, and .74.

Box's test of equality of covariance matrices (Stevens, 1996) was used to decide whether it was legitimate to merge men's and women's data into the same principal-components analyses. This test yielded nonsignificant results for each of the four previous task categories. Hence, with both genders combined, principal-components analyses were respectively performed on the scores measured in each task category. Again, a single factor structure was identified in all categories. The percentage of variance accounted for by this factor was 53 for verbal working-memory tasks, 50 for visuospatial working-memory tasks, 71 for the double-span task, and 49 for the verbal fluency tasks. The corresponding values of the Cronbach's alpha coefficients were .75, .65, .80, and .79. Table 5 presents the mean scores obtained by men and women on the single factor extracted in each task category. Applied on the factor scores, a multivariate analysis of variance revealed a globally significant gender effect, Wilks' $\Lambda = .87$, $F(4, 95) = 3.61$. However, follow-up analyses of variance showed that this effect was restricted to the double-span task where women surpassed men, $F(1, 98) = 4.54$, $MSE = 154.76$.

Finally, Table 6 reports the correlations (Pearson product–moment correlation) between factor scores in each task category, as well as scores in the mental rotation task, for men and women. In both genders, there was a relation between double-span performances and both verbal and visuospatial working-memory scores. There was also a relation between visuospatial working-memory scores and both double-span and mental rotation achievement. However, double-span and mental rotation proficiency covaried only in men. Verbal fluency was not significantly associated with any task in either men or women.

TABLE 2
Mean (and standard deviation) scores for men and women on each verbal working memory task

	Digit span		*Reading span*	*Verbal span*		*Speaking span*	
Gender	*Forward* 9[a]	*Backward* 9[a]	*Span* 6[a]	*Words recalled* 60[a]	*Words created* 45[a]	*Words recalled* 45[a]	*Words included* 70[a]
Men							
Mean	6.78	5.02	3.03	20.68	37.32	32.62	50.10
SD	1.20	1.36	0.68	8.20	5.52	6.77	6.45
Women							
Mean	6.82	5.38	3.05	20.16	38.84	34.86	42.78
SD	1.35	1.45	0.85	9.33	5.07	6.56	6.02

[a] Maximum score.

TABLE 3
Mean (and standard deviation) scores for men and women on each visuo-spatial working memory task

	Corsi	*Position memory*	*Spatial span A*		*Spatial span B*
Gender	*Series length* 9[a]	*Positions recalled* 72[a]	*Sequences identified* 45[a]	*Sequences recalled* 45[a]	*Orientations recalled* 70[a]
Men					
Mean	5.64	53.10	40.22	28.56	19.52
SD	0.99	8.80	3.16	5.47	10.45
Women					
Mean	5.58	52.10	39.02	28.54	19.46
SD	0.81	7.72	3.68	5.44	9.84

[a] Maximum score.

TABLE 4
Mean (and standard deviation) scores for men and women on the double-span task

Gender	*Object names 40*[a]	*Object positions 40*[a]	*Object names and positions 40*[a]
Men			
Mean	31.56	30.84	26.24
SD	4.82	5.50	5.50
Women			
Mean	33.36	32.36	28.22
SD	4.16	4.33	5.17

[a] Maximum score.

TABLE 5
Mean (and standard deviation) factor scores for men and women on each task category

Gender	*Verbal working memory*	*Visuospatial working memory*	*Double span*	*Verbal fluency*
Men				
Mean	145.03	155.54	88.64	119.86
SD	23.46	21.92	13.22	17.30
Women				
Mean	152.41	151.59	93.94	124.36
SD	22.67	20.78	11.61	23.15

TABLE 6
Correlations (Pearson product-moment coefficients) between scores on each task category and on the mental rotation task in men (above the diagonal) and women (below the diagonal)

	Verbal working memory	*Visuospatial working memory*	*Double span*	*Verbal fluency*	*Mental rotation*
Verbal working memory	—	.55*	.51*	.24	.22
Visuospatial working memory	.46*	—	.68*	.23	.38*
Double span	.62*	.53*	—	.26	.43*
Verbal fluency	.18	.20	.13	—	.17
Mental rotation	.19	.41*	.27	.25	—

* $p < .05$.

DISCUSSION

In spite of highly comparable working-memory scores in men and women, the present gender differences in the control tasks confirm that analysis had sufficient power to detect gender effects.[4] These differences also attest that the participants were similar to adult samples examined in typical gender comparisons involving cognitive abilities. Indeed, men were superior in the mental rotation task, as is customarily found in meta-analytic reviews (Linn & Petersen, 1985; Masters & Sanders, 1993; Voyer et al., 1995). Similarly, women excelled in the fluent production of fruit names (Bolla et al., 1998; Capitani et al., 1999; Laws, 2004). However, the male advantage in retrieving vehicle names (Capitani et al., 1999; Laws, 2004) was not significant. As to phonological fluency, there were no significant gender differences in proficiency at generating words starting with a specified letter, consistent with several studies (Bolla et al., 1998; Janowski et al., 1998; Lewin et al., 2001; but see Capitani et al., 1998; Herlitz et al., 1997; Tombaugh et al., 1999). The fact that women's verbal superiority was limited to the generation of fruit names is likely to have contributed to the absence of a significant gender difference in the verbal fluency factor which amalgamated this task and all five others on which men and women seemed equivalent.

No previous research has systematically addressed the issue of gender comparisons through the exploitation of a fairly large range of working-memory tasks selected for their association with the same conceptual framework, such as Baddeley's (1986, 1994, 1999) classical tripartite model. By and large, based on the present exploratory data, working-memory resources appear to be highly similar in men and women. Indeed, no significant gender differences were manifest in aggregated measures of either verbal or visuospatial working memory that reflect the separate operations of either the phonological or the visuospatial component under the monitoring of the central executive. Hence, over a variety of correlated tasks calling for the storage and processing of speech-based information, men and women seemed comparably accurate. Likewise, they did not significantly differ over a collection of correlated tasks involving the storage and manipulation of image-based information. These process-centred findings contrast with what could have been expected using a skill-oriented approach that rather focuses on the type of material. Such an approach would have predicted the following twofold pattern: a small female superiority in verbal working memory, in keeping with what occurs in tasks that all involve verbal material but with cognitive mechanisms that are not neces-

[4] Consistent with the present exploratory purposes, power analysis adopted a mid-range position in postulating medium-size gender effects. However, it is possible that working-memory measures display gender effects of a smaller size. Subsequent research should consider both recruiting larger samples and exploiting more sensitive assessments.

sarily related (see the meta-analysis by Hyde & Lynn, 1988), and a male superiority in visuospatial working memory, in keeping with what usually occurs in similarly diverse visuospatial tasks (see the meta-analyses by Linn & Petersen, 1985, and Voyer et al., 1995).

However, in the multisystem, double-span task that calls for the concomitant activation of each of the phonological and visuospatial components, as well as for their coordination by the central executive (Martein et al., 1999), the present data also showed that both genders do not seem to function similarly as illustrated by women's advantage on the global double-span factor. The task required the serial recollection of object names or object locations, or the joint recall of names and locations. As the participants had been instructed that on any trial they could be asked to recall either object names, object locations, or both, their best strategy was to always store both names and locations. The fact that women surpassed men at these combined operations bears a resemblance to women's superiority in episodic-memory contexts where participants are instructed to memorise the positions of various common objects within an array (Crook, Youngjohn, & Larrabee, 1990; McBurney, Gaulin, Devineni, & Adams, 1997), though this gender difference is not systematic (Janowsky et al., 1998; Postma, Izendoorn, & de Haan, 1998). However, as it occurs even more frequently in incidental encoding conditions (e.g., Barnfield, 1999; Eals & Silverman, 1994; Gaulin, Silverman, Phillips, & Reiber, 1997; James & Kimura, 1997; Montello, Lovelace, Golledge, & Self, 1999; Silverman & Eals, 1992), it may be suggested that, compared to men, women have a more generalised propensity to process verbal and spatial information in an integrated fashion. To the point, women have been shown to excel in spatial tasks where performance depends on representations that are language based, as opposed to having a strong metric component (Rybash & Hoyer, 1992).

Intertask correlations revealed nearly identical architectural organisations in both genders. First, in men and women, double-span scores were positively correlated with those in each of the verbal and the visuospatial classes of working-memory tasks. This is not surprising as the double-span task tapped the resources of both the verbal and visuospatial subsystems. Second, in men and women, performances in verbal and visuospatial working-memory tasks covaried, indicating balanced capacities across genders for maintaining and processing information in each of the two specialised subsystems. Third, in men and women, visuospatial working memory measures were associated with those in the mental rotation task, in agreement with previous suggestions of shared mechanisms for image processing in each type of task (Baddeley, 1999; Logie, 1995; Pearson et al., 2001). Fourth, in men and women, no significant correlations were found between verbal fluency and any working-memory indicator. This even held true in the case of proficiency in verbal working-memory for which a link was plausible (Baddeley et al., 1984; Daneman, 1991; Rosen & Engle, 1997). However, rather than necessarily reflect-

ing differences in terms of underlying processes, the latter result might be attributable to a basic procedural variation. Whereas accuracy indicators were collected in both verbal fluency and verbal working-memory tasks, it is only in the fluency tasks that a time limit was imposed. It may be that the central executive was thus more heavily taxed in retrieving, from long-term memory, words meeting specific phonological or conceptual requirements (Baddeley, 1996a), compared to how it operated in the verbal working-memory tasks that were free of time constraints.

Curiously, there was one correlation that emerged in men exclusively: that between the double-span and the mental rotation tasks. This was confirmed by the correlations with each segment of the double-span scores. In men, mental rotation performance was significantly related to the memory of object names (Pearson coefficient: .33) and locations (.43), as well as with the combination of both (.32), whereas in women it was to object names only (.34). As the double-span task calls for the precise sequential encoding of verbal and visuospatial details, it may have been expected that such precision would have been tied rather with women's rotation scores. Indeed, more often than men, women report applying analytic, as opposed to global strategies, while performing mental rotation operations, and their achievement is lower (Freedman & Rovegno, 1981; Peters et al., 1995). Even high female achievers seem to complement their use of efficient, global strategies with analytic ones (Pezaris & Casey, 1991). As analytic strategies involve encoding the relative positions of the key features of rotated stimuli, they are somewhat analogous to the type of processing required in the double-span task. In the present case, women did surpass men in the latter task. However, they were outperformed by men in the mental rotation task, although it was the men's rotation scores that were linked to the double-span performances. Consequently, pending replication, it is difficult to account for this odd correlation in men.

By way of conclusion, it is necessary to stress that all of the present working-memory indicators appraised the accuracy of working-memory functions, that is, the degree to which the verbal and/or visuospatial information presented had been stored and processed correctly. However, response time is generally considered to be a sensitive measurement for the purpose of comparing groups in terms of particular cognitive skills (e.g., Eysenck, 2001; Jensen, 1985; Pollatsek & Rayner, 1998). It would thus be worthwhile to subsequently investigate for possible gender differences in terms of the speed with which working-memory operations are carried out. To the point, in visuospatial working-memory tasks that required generating, maintaining, scanning, and manipulating visual images, Loring-Meier and Halpern (1999) have demonstrated that men were faster than women, yet not significantly more accurate. However, whereas in the latter sample high accuracy could have resulted in a ceiling effect, it is worth emphasising that, as shown in Tables 2–4, such an effect was clearly not involved in the present wide collection of working memory tasks. Establishing

whether the joint exploitation of accuracy and speed assessment, in both verbal and visuospatial working-memory tasks, confirms the present gender similarity will necessitate ingeniousness in adapting existing accuracy tasks, as well as in devising new ones.

Original manuscript received July 2004
Revised manuscript received January 2005
PrEview proof published online month/year

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