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Age-related changes in hemispheric asymmetry depend on sex

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A total of 92 participants, 50 younger (mean age 26.3 years) and 42 older (mean age 63.8 years), were tested for visual-field asymmetries. On a word-matching task, a right-visual-field (RVF) advantage increased with age, consistent with the theory that right-hemispheric function shows relatively greater decline with age than left-hemispheric function. On a figural-comparison task, a left-visual-field (LVF) advantage was marginally decreased with age in the men, but significantly *increased* in the women, probably because age-related changes in hormonal levels are more pronounced in women. This increase in LVF advantage is contrary to both the HAROLD theory that hemispheric asymmetry declines with age, and the theory of relative right-hemispheric decline.

Hemispheric asymmetry is a fundamental aspect of the functional organisation of the human brain. Hemispheric asymmetries are not stable, however, but undergo dynamic changes during the life span.

It is well known that ageing affects cognitive processes and brain functions. The disuse of certain skills and abilities, increasing physical illness, and neurobiological changes are responsible for age-related cognitive deterioration (Zec, 1995). However, it is still not well established whether functional cerebral asymmetries change in a systematic way from young adulthood to older age. Two partly conflicting hypotheses have been proposed, namely the *differential-*

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ageing hypothesis (Goldstein & Shelley, 1981) and the hypothesis of *hemispheric asymmetry reduction in old adults* (*HAROLD;* Cabeza, 2001a, 2001b).

The differential-ageing hypothesis was based originally on evidence that older people show a decline in performance IQ of the Wechsler Adult Intelligence Scale (WAIS, Wechsler, 1958), while verbal IQ on this scale is affected only marginally, or not at all (Goldstein & Shelley, 1981). The decline in performance IQ but not on verbal IQ might relate to the fact that all performance IQ tests of the WAIS have a speed factor whereas this factor is absent in verbal IQ tests. This suggests that age differences might reflect a general slowing down in processing rather than specific neurofunctional changes with age. However, this differential impairment also applies to patients with right-hemisphere injuries, which are characteristically associated with more prominent nonverbal, especially visuospatial, than verbal impairments, and this leads to the conclusion that ageing involves greater loss of right- than left-hemisphere functions, or that the right hemisphere ages more rapidly than the left (e.g., Ellis & Oscar-Berman, 1989). There has been some corroboration of greater impairment of nonverbal than of verbal functions with age (Jenkins, Myerson, Joerding, & Hale, 2000; Kliszc, 1978; Lima, Hale, & Myerson, 1991; Meudell & Greenhalgh, 1987), but attempts to measure cerebral lateralisation using visual half-field techniques or dichotic listening have provided an inconsistent picture of the age-related differences in hemispheric asymmetries. A few have supported the differential-ageing hypothesis (e.g., Clark & Knowles, 1973; Gerhardstein, Peterson, & Rapcsak, 1998; Johnson et al., 1979), but many have failed to show differences in hemispheric asymmetries between younger and older participants (e.g., Cherry & Hellige, 1999; Cherry, Hellige, & McDowd, 1995; Hoyer & Rybash, 1992; Obler, Woodward, & Albert, 1984; for review see Ellis & Oscar-Berman, 1989).

The HAROLD hypothesis is based primarily on the results of neuroimaging studies of activation patterns during cognitive performance in younger and older adults. The most consistent finding of these studies (e.g., Cabeza et al., 1997; Grady, Bernstein, Beig, & Siegenthaler, 2002; Grady, McIntosh, Horwitz, & Rapoport, 2000; Madden et al., 1999; Reuter-Lorenz et al., 2000) is that brain activity tends to be less lateralised in older than in younger adults (for review, see Cabeza, 2001a). HAROLD is also supported by electrophysiological (e.g., Elmo, 1987; Nelson, Collins, & Torres, 1990) and behavioural studies (Reuter-Lorenz, Stanczak, & Miller, 1999). Unfortunately, these studies are less revealing as to which cerebral hemisphere was the more responsible for age-related differences in asymmetry patterns.

Although the two hypotheses are somewhat conflicting, they make some predictions in common. If an age-related decline is especially pronounced in the right hemisphere, as supposed by the differential-ageing hypothesis, it should be possible to observe different asymmetry patterns depending on the task that is used. In tasks that draw on right-hemispheric functions, the right-hemispheric advantage should be reduced, resulting in a reduced asymmetry in older age, as also predicted by HAROLD. In contrast, the two hypotheses make conflicting predictions in tasks drawing primarily on left-hemispheric functions. According to the differential-ageing hypothesis, a decline in performance of the right hemisphere should result in an increased left-hemispheric advantage in tasks that are specialised in the left hemisphere, whereas HAROLD predicts a general bilateral symmetry pattern in older adults that is independent of the task. According to HAROLD, the complexity of a task might be more relevant than the relative involvement of the left or right hemisphere. Reuter-Lorenz et al. (1999) presented letter-matching tasks of varying complexity, and found that younger participants showed a benefit from bihemispheric processing only during the most complex task, whereas older participants showed this benefit at lower levels of task complexity as well. The authors concluded that ''recruitment [of additional neural space within the contralateral hemisphere] may improve the brain's ability to meet processing demands and thus may compensate for neural decline that accompanies normal aging'' (p. 499).

So far, neither hypothesis postulates a mechanism that might explain the age-related differences in lateralisation, nor do they consider variables that are potentially related to ageing and that are known to affect functional cerebral asymmetries. One such variable is hormonal level.

The concentrations of gonadal sex hormones change as a function of age. Although age-related changes in sex hormone levels occur in both sexes (Gould, Petty, & Jacobs, 2000), they are especially pronounced in women following menopause (Chakravarti et al., 1976). There is evidence, not only for sex differences in hemispheric asymmetries (e.g., Hausmann & Güntürkün, 1999, 2000; McGlone, 1980; Voyer, 1996), but also for activating effects of gonadal sex hormones on cognition and hemispheric asymmetries (e.g., Bibawi, Cherry, & Hellige, 1995; Hausmann, Becker, Gather, & Güntürkün, 2002; Hausmann & Güntürkün, 2000; Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis, & Güntürkün, 2000; Janowski, Oviatt, & Orwoll, 1994; Kimura, 1996; Sanders & Wenmoth, 1998). If changes in the sex-hormonal environment, which are especially pronounced in postmenopausal women, are partly responsible for age-related differences in hemispheric asymmetries, a sex difference in the age-related differences of asymmetry patterns should be observable. Age-related changes in hemispheric asymmetries should be especially pronounced in older women, whereas the asymmetry patterns should be more stable in older males. In previous studies of age-related differences in hemispheric asymmetry, the influences of sex and changes in hormone levels were not examined, although Gerhardstein et al. (1998) noted that differential ageing between men and women could affect age-related changes in hemispheric asymmetry.

This study examines the influence of sex on age-related differences in hemispheric asymmetries. We investigated males and females in two age-groups. Women in the older group were all ''postmenopausal'' and did not take any sex-hormonal replacement. We used three visual half-field tasks to assess left-hemispheric functions (word-matching task) as well as right-hemispheric functions (figural-comparison and face-discrimination tasks). These tasks depend on different processes, which should result in task-specific outcomes. Although all tasks are likely to be affected by hormonal fluctuations, the figural-comparison task is especially known to be sensitive to both sex and changes in the level of sex hormones (Hausmann et al., 2002; Hausmann & Güntürkün, 1999, 2000).

METHOD

Participants

A total of 92 participants, 50 in a younger age group (23 males, 27 females) and 42 in an older age group (22 males, 20 females), participated in the experiment. The mean age of younger participants was 26.3 years (SD = 6.7, range: 19–46 years; females: 25.8 years, SD = 6.8, range 19–44 years, males: 26.9 years, SD = 6.6, range: 19–46) and of the older group 63.8 years (SD = 4.9, range: 55–74 years; females: 63.7, SD = 5.7, range: 55–74 years, males: 63.95, SD = 4.2, range: 55–70 years). Although the age gap between the upper limit of the younger group and the lower limit of the older group is small, the two female age groups clearly differed in their hormonal status (pre- vs postmenopausal). The women in the younger group all reported regular menstrual cycles, while the women in the older group reported having ceased menses for an average of 14.9 years (SD = 5.65, range: 7–27 years). None of the participants had used any medication that might affect nervous-system function during the previous 6 months, and none of the older participants took any hormonal replacements. All were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971), and all had normal or corrected-to-normal visual acuity and were naive to the hypothesis. They were recruited by advertisement and paid for their participation.

Procedure and materials

The visual half-field (VHF) procedure of this experiment was identical to that of previous studies (Hausmann et al., 2002; Hausmann & Güntürkün, 1999, 2000). Participants sat with their chins on a chin rest at a distance of 68 cm from a monitor. All were instructed to keep their heads and bodies still during the whole test and to fixate a cross in the centre of the screen. All stimuli were presented for 185 ms within a frame 4.8 cm wide and 4.5 cm high (4.0° and 3.8° visual angle, respectively). The distance between the fixation cross and the inner edge of the frame was 2.6 cm (2.2° visual angle), which ensured a lateralised stimulus presentation to the left or to the right of the fixation cross. All tasks required participants to respond by pressing designated keys as quickly and accurately as possible with the index finger and middle finger of one hand.

Each of the three tasks comprised 70 trials. The first 10 were treated as practice trials and disregarded. After 30 trials the responding hand was changed, in a counterbalanced order across participants. The order of tasks was also counterbalanced across participants. Frequency of correct answers and median response times (RT) for both VHFs were used as dependent variables for all tasks. To correct the age-group difference in the degree of asymmetry for differences in overall performance, we used an asymmetry ratio, defined as the ratio of the difference between the LVF and RVF to overall performance (LVF + RVF). The tasks were as follows:

Word matching. A pool of 105 German nouns was used for the word-matching task. The words consisted of at least four letters up to maximum of seven. The stimuli were selected for a high degree of abstraction (Baschek, Bredenkamp, Oehrle, & Wippich, 1977) to maximise the left-hemisphere advantage. Each trial began with presentation of a fixation cross for 2 s. Next, a word appeared in the centre of the monitor for 185 ms. Then a fixation cross was presented again for 2 s, followed by another word for 185 ms. The words were in the LVF or RVF in a pseudo-randomised order. A subsequent question mark instructed the participant to decide by key press whether the two words were the same or different. In the mismatch trials words were identical with regard to the initial letter and to the number of letters. In previous studies (Hausmann & Güntürkün, 1999, 2000) this task has typically resulted in better performance for words presented in the right visual field (RVF), corresponding to the left hemisphere.

Figural comparison. For the figural-comparison task 105 black irregular polygons with at least eight edges were constructed using Paintshop® software. The procedure and timing were identical to those of the word-comparison task. Participants had to decide by finger key press whether the two polygons were the same or different. Typically, this task shows an advantage for the LVF, corresponding to the right hemisphere (Hausmann & Güntürkün, 1999, 2000).

Face recognition. Photographs for the face-recognition task were taken from a US college album from the 1950s. The students on these pictures were all male, clean-shaven, short-haired, without glasses, and in their early 20s. To avoid further non-facial characteristics, all photographs were framed with an ovoid overlay that covered the background and the clothes, with the exception of the collar. Normal and altered ''monster'' faces were used as stimuli. For the latter stimuli some facial characteristics were translocated. For example, the position of one eye and the mouth were swapped, or everything was deleted except the nose, etc. All faces were shown in the same upright orientation and had unemotional, neutral expressions (Hausmann & Güntürkün, 1999). After presentation of a fixation cross for 2 s, the stimuli appeared, lateralised pseudorandomly either in the left or the right visual half-field, while an empty frame was presented in the other VHF. The participants were instructed to indicate by key press whether the faces they saw were unchanged, ''normal'' faces of male college students or altered, ''monster'' faces. In previous studies (Hausmann & Güntürkün, 1999, 2000) this task showed a very strong advantage for the left visual field (LVF), corresponding to the right hemisphere.

For each task, functional cerebral asymmetry in accuracy and response time (median response times of correct responses) were analysed using $2 \times 2 \times 2$ ANOVAs with repeated measures, with ''VHF'' (left, right) as a within-participant factor and ''age group'' (young, older) and ''sex'' as between-participants factors. For all tests, a significance level of 5% (two-tailed) was used. The significance of all multiple tests was adjusted using the Bonferroni correction (Holm, 1979).

RESULTS

Descriptive statistics for accuracy are shown in Table 1 and for response times in Table 2. Table 3 presents the percentage of participants showing a right or left visual field advantage in the tasks, as a function of age and sex.

Word-matching task

Accuracy. ANOVA for accuracy in the word-matching task revealed a significant main effect of VHF, $F(1, 88) = 42.24$, $p < .0001$, indicating a strong advantage for the right visual field (RVF), and a significant main effect of Age Group, $F(1, 88) = 64.33$, $p < .0001$, with higher accuracy in younger participants. There was also a significant interaction between VHF and Age Group, $F(1, 88) = 22.48$, $p < .0001$ (Figure 1).

TABLE 1
Mean accuracy [%] and standard error means across tasks, visual half-fields, gender, and age groups

	Word matching		*Figural comparison*		*Face recognition*	
Age group	*LVF*	*RVF*	*LVF*	*RVF*	*LVF*	*RVF*
Males						
Younger	94.05 (1.92)	95.22 (1.80)	87.10 (1.50)	87.24 (2.03)	85.29 (1.75)	80.28 (1.80)
Older	76.17 (1.96)	85.04 (1.84)	77.68 (1.53)	77.39 (2.07)	69.62 (1.79)	65.06 (1.84)
Females						
Younger	91.97 (1.77)	94.17 (1.66)	86.05 (1.38)	86.30 (1.87)	84.90 (1.61)	78.00 (1.66)
Older	74.99 (2.06)	87.65 (1.93)	77.31 (1.60)	78.99 (2.17)	74.84 (1.88)	68.17 (1.93)

TABLE 2
Mean response times of correct responses (ms) and standard error means across tasks, visual half-fields, gender, and age groups

	Word matching		*Figural comparison*		*Face recognition*	
Age group	*LVF*	*RVF*	*LVF*	*RVF*	*LVF*	*RVF*
Males						
Younger	920 (60.5)	921 (58.6)	813 (37.7)	836 (40.3)	869 (51.8)	935 (50.2)
Older	1125 (61.8)	1140 (59.9)	947 (38.5)	952 (41.2)	1061 (52.9)	1091 (51.3)
Females						
Younger	974 (55.8)	959 (54.1)	896 (34.8)	918 (37.2)	901 (47.8)	924 (46.3)
Older	1134 (64.8)	1117 (62.9)	1003 (40.4)	1076 (43.2)	1079 (55.5)	1130 (53.8)

TABLE 3
Hemispheric advantage as a function of age and sex

		Males		*Females*	
		Younger	*Older*	*Younger*	*Older*
Word matching					
	L+	34.9	72.7	40.7	80.0
OK	Bi	26.1	4.5	37.0	–
	R+	39.1	22.7	22.2	20.0
	L+	60.9	36.4	55.6	50.0
RT	Bi	–	–	–	–
	R+	39.1	63.6	44.4	50.0
Figural comparison					
	L+	34.9	40.9	44.4	45.0
OK	Bi	21.7	4.5	25.9	25.0
	R+	43.5	54.5	29.6	30.0
	L+	26.1	36.4	33.3	15.0
RT	Bi	–	–	3.7	–
	R+	73.9	63.6	63.0	85.0
Face recognition					
	L+	17.4	31.8	18.5	15.0
OK	Bi	17.4	9.1	11.1	10.0
	R+	65.2	59.1	70.4	75.0
	L+	13.0	36.4	25.9	40.0
RT	Bi	–	–	–	–
	R+	87.0	63.6	74.1	60.0

Percentage of participants showing a left hemispheric advantage (L+), right hemispheric advantage (R+) or no hemispheric advantage (Bi) in the tasks, as a function of age and sex. Accuracy and response times (RT).

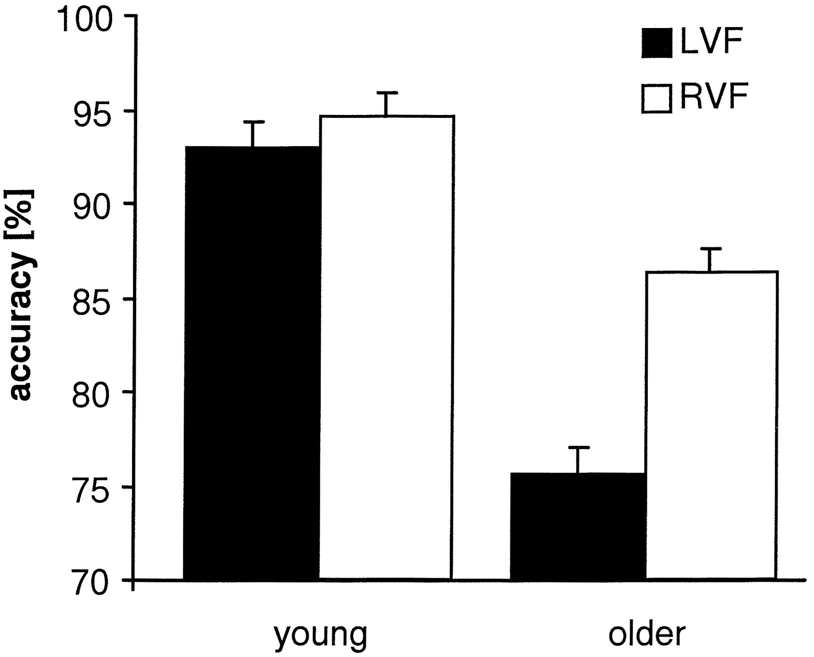

Figure 1. Significant interaction between age group and visual half-field in the accuracy [%] of the word-matching task.

Post-hoc *t*-tests showed a significant RVF advantage in the older group, $t(41) = 6.11, p < .0001$, and were significant on a directional test in the younger group, $t(49) = 1.80, p = .039$, one-tailed. No other effects approached significance (all *F*s < 1.59, n.s.). Although the performance of both hemispheres was significantly reduced in the older group, LVF: $t(90) = 9.05, p < .0001$; RVF: $t(90) = 4.66, p < .0001$, the interaction between VHF and Age Group indicates that this was significantly more pronounced in the LVF. This result strongly supports the idea that the decrease in performance with age was especially marked for the right hemisphere.

As revealed by ANOVA, the age-group difference in asymmetry ratio was still significant, $F(1, 88) = 42.77, p < .0001$, reflecting greater asymmetry in the older group. No other effects approached significance (all *F*s < 1.61, n.s.). Post-hoc one-sample *t*-tests comparing the asymmetry ratios with a symmetry score of 0, revealed a significant RVF advantage only for the older group, $t(41) = 5.96, p < .0001$, whereas it only approached significance for the younger group, $t(49) = 1.87, p = .067$.

Response times. ANOVA for the response times in the word-matching task revealed only a significant main effect of Age Group, $F(1, 88) = 10.03, p < .01$, with the older group responding more slowly. No other effects approached significance (all *F*s < 0.97, n.s.).

Figural-comparison task

Accuracy. ANOVA for accuracy on the figural-comparison task showed a significant main effect of Age Group, $F(1, 88) = 38.10$, $p < .0001$. No other effects approached significance (all *F*s < 0.32, n.s.).

Response times. ANOVA for the response times in the figural-comparison task revealed a significant overall LVF advantage, $F(1, 88) = 14.42$, $p < .001$, a significant main effect of Age Group, $F(1, 88) = 11.30$, $p < .01$, as well as a significant effect of Sex, $F(1, 88) = 5.10$, $p < .05$, with males responding faster than females. The interactions between VHF and Sex, $F(1, 88) = 4.29$, $p < .05$, and between VHF, Sex, and Age Group, $F(1, 88) = 4.28$, $p < .05$, also reached significance. Post-hoc *t*-tests to break down the two-way interaction indicate a significant LVF advantage only in females, $t(46) = 3.09$, $p < .01$, while in males it only approached significance, $t(44) = 1.82$, $p = .075$. Post-hoc *t*-tests to break down the three-way interaction showed that a clearly significant age-related increase in response times for males in the LVF, $t(43) = 2.75$, $p < .01$, although, with an adjustment for post-hoc testing, it was still significant at a 5% level in the RVF, $t(43) = 2.36$, $p = .023$. In contrast, females showed an age-related increase in response times in the RVF, $t(45) = 2.47$, $p = .017$, whereas there was only a trend towards significance in the LVF, $t(45) = 1.87$, $p = .068$. As for the degree of asymmetry, post hoc *t*-tests of the three-way interaction showed a significant LVF advantage only in older women, $t(19) = 2.81$, $p = .011$, whereas the younger men showed a LVF advantage only on a directional test, $t(22) = 2.01$, one-tailed $p = .0285$, and the difference was not significant for either of the other groups: young women: $t(26) = 1.53$, n.s., older men: $t(21) = 0.50$, n.s. Other effects did not approach significance (all *F*s < 0.99, n.s.).

For the asymmetry ratio, which corrects the degree of asymmetry for differences in overall performance, ANOVA revealed similar results. Most notably, the interaction between Age Group and Sex remained significant, $F(1, 88) = 4.11$, $p < .05$. As in the previous analyses, post-hoc one-sample *t*-tests, which compared the asymmetry ratios with a symmetry score of 0, revealed a significant asymmetry only in older women, $t(19) = 2.86$, $p = .01$. The younger men showed a significant asymmetry only on a directional test, $t(22) = 1.81$, one-tailed $p = .042$, and the asymmetry was not significant for either of the other groups: young women: $t(26) = 1.47$, n.s., older men: $t(21) = 0.53$, n.s.)

Face-recognition task

Accuracy. ANOVA for accuracy in the face-recognition task showed a significant main effect of VHF, $F(1, 88) = 27.68$, $p < .0001$, indicating a strong

LVF advantage. The main effect of Age Group was also significant, $F(1, 88) = 81.77$, $p < .001$, with the older group performing less accurately. No other main effects or interactions approached significance (all Fs < 3.84, n.s.).

Response times. ANOVA for the response times again revealed a significant LVF advantage, $F(1, 88) = 13.47$, $p < .0001$, and a significant main effect of Age Group, $F(1, 88) = 13.43$, $p < .0001$. The three-way interaction between VHF, Age, and Sex showed the same pattern as in the figural-comparison task, but did not approach significance, $F(1, 88) = 2.00$, n.s. No other effects were significant (all Fs < 0.22, n.s.).

In this task a significant LVF advantage was observed for accuracy and response times. Although in both other tasks the expected visual half-field advantage was only found in one of these dependent variables, the results were in the same direction, indicating no speed/accuracy trade-off.

DISCUSSION

The aim of this study was to compare the explanatory power of two partly conflicting hypotheses (the HAROLD and the differential-ageing hypothesis) using left- and right-hemispheric tasks and to examine the influence of sex on age-related changes in hemispheric asymmetries. Neither hypothesis was fully supported. According to the HAROLD hypothesis, hemispheric asymmetry undergoes a general decline with age. Although older men showed a tendency to be less lateralised than younger men in the figural-comparison task, in support of HAROLD, the effect was not significant, and the women showed the opposite pattern. Moreover, the larger asymmetry in older women was a result of a left-hemispheric performance decrement, which is also counter to the differential-ageing hypothesis that age affects right-hemispheric function more than it affects left-hemispheric function. On the other hand, the left-hemispheric-dominant word-matching task showed an increased left-hemispheric advantage in the older group, due to an age-related decrease of right-hemispheric performance. This is consistent with the differential-ageing hypothesis, but inconsistent with HAROLD.

The results are therefore more complex than either of the two hypotheses would predict, and show that age-related changes in hemispheric asymmetries are different for left- and right-hemispheric tasks. Although both right-hemispheric tasks (face-recognition task and figural comparison) revealed a similar relationship between hemispheric asymmetry, age, and sex, this was significant only in the figural-comparison task. Since the face-recognition task showed the greater LVF advantage overall, this suggests that the age-related differences in hemispheric asymmetries might also be influenced by the degree of asymmetry of a specific task. Studies investigating age- or hormone-related changes in hemispheric asymmetries support the idea that tasks that are strongly lateralised are less susceptible to age- or hormone-related changes (Bibawi et al., 1995; Hausmann & Güntürkün, 2000).

Our results do support the general conclusion that age-related differences in hemispheric asymmetry depend on sex. This was especially pronounced in the figural-comparison task, although a similar but less pronounced pattern was observed in the face-recognition task. It is pertinent to note that, of the three tasks used in this study, the figural-comparison task has previously shown the most robust sex differences and responsiveness to sex-hormonal changes (Hausmann et al., 2002; Hausmann & Güntürkün, 1999, 2000). In the present study, females showed a decline in performance with age that was more marked for the left hemisphere than for the right, whereas for males the decline was more marked for the right hemisphere. Hausmann and Güntürkün (2000) similarly reported an increase in hemispheric asymmetry in postmenopausal women, and suggested that massive changes in sex hormone levels after the menopause might be largely responsible. However, they did not include older men in their study. Age-related changes in sex hormone levels in males are weaker than those in females and occur more gradually (Gould et al., 2000), which would explain why hemispheric asymmetries in males were only marginally affected by age in the present study. However, older men showed a tendency to be less lateralised than younger men in the sex-sensitive figural comparison task. If future studies confirm a reduction of lateralisation, that would raise the question of whether and how changes in testosterone levels are involved. Although it is known that testosterone is an influential factor in determining neural and behavioural asymmetries, androgen receptors needed for the direct action of testosterone are not present in the cortex at points in development when cortical asymmetry is already known to exist (Wisniewski, 1998, p. 528).

The men also performed significantly better than the women on the figural-comparison task, presumably because of the visuospatial character of the task (e.g., Halpern, 2000; Voyer, Voyer, & Bryden, 1995). The women were more lateralised than the men, which is contrary to what is reported in the majority of studies investigating sex differences in functional cerebral asymmetries (McGlone, 1980; Voyer, 1996). However, this finding is largely due to a strong hemispheric asymmetry in older women, which is in agreement with a previous study (Hausmann & Güntürkün, 2000) which also found strong lateralisation patterns in postmenospausal women in the same VHF-tasks. Unfortunately this study did not include older men. This again highlights the importance of not confounding sex and age in future studies.

The influence of sex on age-related changes in hemispheric asymmetry in the figural-comparison task is the most notable result of this study and shows that the gender composition of the experimental groups might strongly affect age-related differences in lateralisation. This has often been neglected in previous research. For example, White, Green, and Steiner (1995) found no systematic age-related differences in lateralisation using a dual-task paradigm, but the three age groups they used included only males, and their results were in fact similar to those of the male participants in the present study. In another study, Gerhardstein et al. (1998) noted that an unequal number of males and females in their older group precluded an analysis of gender effects. Moreover, if hormones have a significant influence on cognition and hemispheric asymmetries, it might be important to select participants with respect to their hormonal status and to exclude older participants on hormonal replacement (assuming hormonal medication is not the focus of the study). Acceleration of age effects on some cognitive functions following menopause (e.g., Halbreich, Lumley, Palter, Manning, Gengos, & Joe, 1995) and improvements of some cognitive functions following hormonal replacement therapy (for review, see LeBlanc, Janowski, Chan, & Nelson, 2000) are well known. However, the influence of sex hormones on age-related changes in functional cerebral asymmetries and their implications are still largely unknown.

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