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Sex Differences in Functional Cerebral Asymmetries in a Repeated Measures Design

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The aim of the present study was to analyze whether task repetitions which are an inevitable part of repeated measures designs might induce performance alterations specific for gender and hemisphere. Male and female subjects conducted twice a lexical decision, a polygon recognition, and a face discrimination task as a visual half field paradigm with the two experimental sessions repeated by 2 weeks. The results show that only in female subjects can a session effect for the lexical decision and the polygon recognition task be demonstrated which is hemisphere specific. Thus, repeated measures designs seem to have a gender- and hemisphere-specific effects of their own which could confound with other variables under study. © 1999 Academic Press

Key Words: gender; lateralization; lexical decision; figural comparison; face discrimination; hemispheric asymmetries; visual half field.

INTRODUCTION

Sex differences in a number of cognitive abilities are well documented (Kimura, 1992; Maccoby & Jacklin,1974). Although performances of both genders overlap to a large degree (McKeever, 1995), women tend to outperform men in many aspects of verbal ability (Halpern, 1986; McGlone, 1980), while men tend to outperform women in spatial tasks (Halpern, 1996; Hyde, 1981; McGee, 1979; Voyer, Voyer, & Bryden, 1995; Witkin, Dyk, Faterson, Goodenough, & Karps, 1962). Additionally these abilities are lateralized, with a superiority of verbal abilities in the left hemisphere (Beaumont, 1982), opposite to a dominance for spatial functions in the right hemisphere (Kimura, 1966). It is therefore conceivable that sex differences in verbal and

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spatial abilities are related to gender-specific differences in the organization of cerebral asymmetries for speech and spatial cognitions (Voyer, 1996).

Indeed, functional brain asymmetries of speech (Bryden, 1979; Franzon & Hughdahl, 1986; Hausmann et al., 1998; Shaywitz et al., 1995), spatial orientation (Chiarello, McMahon, & Schaffer, 1989; Corballis & Sidey, 1993; Waber, 1982; Witelson, 1976), and face recognition (Borod, Koff, & White, 1983; Rizzolatti & Buchtel, 1977) are known to be sex-dependent in humans. Although contradictions exist (Ashton & McFarland, 1991; Boucher & Bryden, 1997; Kimura & Harshmann, 1984), the majority of data demonstrate that the lateralization of these processes is more pronounced in males, while the lateralization pattern tends to be more symmetrical in women (Corballis & Sidey, 1993; Halpern, 1986, 1996; Hausmann et al., 1998; Hough, Daniel, Snow, O'Brien, & Hume, 1994; Inglis & Lawson, 1981; Inglis, Ruckman, Lawson, MacLean, & Monga, 1982; Juarez & Corsi-Cabrera, 1995; McGlone, 1977, 1980; Rasmjou, Hausmann, & Güntürkün, 1999; Shaywitz et al., 1995). Clinical data also support these findings. After localized brain lesions, men tend to display verbal deficits after left hemisphere injuries and nonverbal deficits after right hemisphere damage, while the deficits are less side-specific for women (McGlone 1977; 1978; McGlone & Kertesz, 1973; Wechsler, 1955).

However, not all lateralization studies were able to show a gender effect. Reviewing an important part of the literature, Voyer (1996) concludes that even in a majority of asymmetry experiments no interaction with sex occurs. If some studies reveal a gender effect while others do not, this is mostly indicative of at least one variable which was overlooked and therefore not controlled. There is evidence that menstrual cycle could be this missing variable. Different authors reported a differential modulation of processing of the two hemispheres during the menstrual cycle (Altemus, Wexler, & Boulis, 1989; Bibawi, Cherry, & Hellige, 1995; Chiarello et al., 1989; Hampson, 1990a,b; Heister, Landis, Regard, & Schroeder-Heister, 1989; Mead & Hampson, 1996; Rode, Wagner, & Güntürkün, 1995; Sanders & Wenmoth, 1998) as a function of gonadal hormone levels.

The results of Heister et al. (1989) showed that while asymmetry in lexical decision did not change throughout the menstrual cycle, asymmetry in face perception decreased linearly from a large right hemisphere superiority during menstruation to a small left hemisphere superiority during the premenstrual phase. Also Rode et al. (1995) showed a significant cycle phase $\times$ lateralization interaction only for the right hemisphere dominant figural task. In contrast Bibawi et al. (1995) found a robust right hemisphere bias during different (menstrual) sessions for a free-vision face processing task. However, in the nonlateralized chair identification task they found a left-sided asymmetry during the midluteal phase of the menstrual cycle, indicating that the left hemisphere is more activated in this phase.

Although the consideration of hormonal fluctuation has considerably clarified data patterns, the ''empirical chaos'' as phrased by McKeever (1995) in experiments studying the interaction of lateralization, sex, and hormones partly persists. It is conceivable that a further variable constitutes an overlooked key player in the game. We herein suppose that it is the repeated measures design itself.

Functional cerebral asymmetries during different phases of the menstrual cycle are analyzed with repeated measures designs. In order to control time or session effects these studies use balanced designs and/or short practice sessions to reduce possible training effects. At present no study controlled a session effect per se. The present experiment therefore aimed to investigate session effects on cerebral asymmetries.

We selected three visual half field tasks: a lexical decision task with abstract nouns (which typically yields left hemisphere superiority) and a figural comparison task with irregular polygons (which generally gives a right hemisphere advantage) as used in the publication of Rode et al. (1995). Additionally we constructed a face discrimination task similar to the face decision task (which is generally reported to show a right hemispherical dominance too) used in the experiment of Heister et al. (1989). In order to control such effects subjects of both genders were tested twice.

METHODS

Subjects

Thirty-eight subjects (students of 19 to 45 years, 19 males, 19 females) participated in this experiment. Female subjects were not selected for the point in their menstrual cycle. Ten subjects of the female group used oral contraceptives. All this reinforced the notion of a strong heterogenity with regard to their gonadal hormone levels during both test sessions. The mean age was 24.40 years for the male and 24.72 years for the female group. Their right-handedness was determined with the Edinburgh Inventory (Oldfield, 1971). The asymmetry index (LQ) was then calculated as $(R - L / R + L) \times 100$. All values of this index range between $+100$ and -100. Positive values indicate dextrality, while sinistrality results in negative values. All subjects had a positive mean LQ of $+93.62$ (min. $+60$, max. $+100$) and were naive for the hypothesis.

Procedure and Materials

The experiment started by placing the head of a seated subject in a chin rest which allowed a fixation of the head. All subjects were instructed to keep their head and body still during the whole test. This was an important presupposition to secure that the stimulus presentation was more than 2° visual angle to the left or the right from the fixation cross. A pool of 120 German nouns was used for the lexical decision task. The words consisted of at least four to maximal seven letters. The stimuli were selected for a high degree of abstraction (Baschek, Bredenkamp, Oehrle, & Wippich, 1977) to maximize the left-hemisphere advantage. Sixty stimuli were used for the first experimental session, and the remaining 60 stimuli were used for the second: the order of these two blocks of words were balanced among subjects. For the figural comparison condition 120 (60 per session) black irregular polygons with at least eight edges were constructed with Paintshop software with the two stimulus blocks again

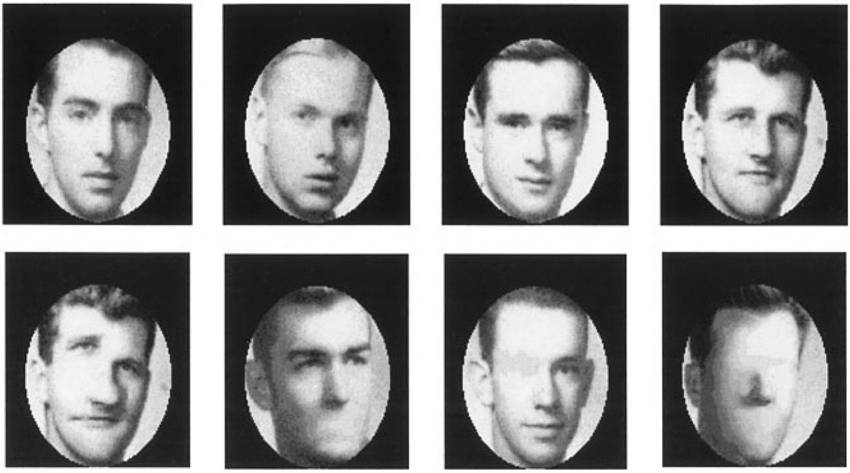

FIG. 1. Examples of the stimuli used in the face discrimination task. The upper row shows the unchanged, ‘‘normal’’ faces and the lower row shows the altered, ‘‘monster’’ faces.

being balanced. A white frame (4.8 cm wide, 4.5 cm high) was generated with the graphic program in which the stimuli were presented. The details of the lexical decision task and the figural comparison task were described by Rode et al. (1995). The only variation we used was an exposure time of 185 ms (instead of 130 ms). This was necessary due to the more difficult face discrimination. In each trial the subjects had to fixate on a cross in the center of the monitor. Then the first stimulus appeared lateralized either in the left or the right visual half field while an empty frame was presented in the other half (Rode et al., 1995). All three tasks included 70 trials. The first 10 practice trials were eliminated. Photographs for the face discrimination task were taken from a U.S. college album from the 1950s. The students on these pictures were all male, clean shaven, short haired, without glasses, and in the beginning of their 20s. To avoid further nonfacial characteristics, all photographs were framed with an ovoid overlay which covered the background and the clothes, with exception of the collar. The subjects were instructed to indicate as quickly and as correctly as possible whether the faces they saw were unchanged, ‘normal’ faces of male college students or altered, ‘‘monster’’ faces. 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. (Fig. 1). All faces had the same orientation and an unemotional, neutral expression. To control time or practice effects and to compare the results with the data of Rode et al. (1995) and other two- or three-shot measurements in menstrual cycle publications (for example: Bibawi et al., 1995; Heister et al., 1989) we tested all subjects twice with an intersession interval of 14 days. Therefore we developed a parallel version of all tasks. Although we found no differences between these parallel versions in pretests we balanced them for the subjects over the two test sessions. Additionally the tasks on their part were balanced.

RESULTS

The measurements of all 38 subjects were used in the analysis. For all three experiments the medians of the reaction times for correct responses and the frequency of correct answers were analyzed with a two-by-two (first

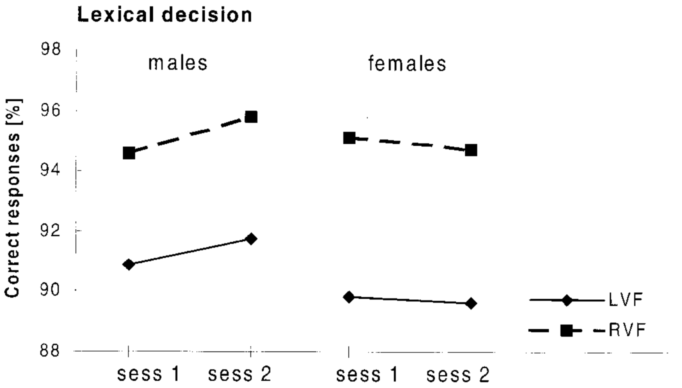

FIG. 2. Means of frequency of correct responses for the lexical stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. The RVF (left hemisphere) advantage is stable over time.

and second session; right and left visual field) analysis of variance with repeated measurement and sex as the between-subjects variable.

Lexical Decision Task

In both sexes the analysis of frequency of correct answers in the lexical decision task showed the well-known left hemisphere (right visual field) advantage for verbal stimuli ($F(1, 36) = 11.57$, $p < .01$) and no other main effect or interaction with time (first vs. second session) and/or sex (Fig. 2). For the response times the analysis yielded only a significant main effect of time ($F(1, 36) = 10.61$, $p < .01$) with shorter response times during the second session (first session, 921 ms; second session, 860 ms) and significant interactions of time with sex ($F(1, 36) = 6.81$, $p < .05$) and time with visual half field ($F(1, 36) = 5.22$, $p < .05$). Responsible for both interactions were the females, who became faster during the second session (overall response time difference: 112 ms) than males (overall response time difference: 9 ms). Moreover the females shifted in their lateralization pattern from a slight right visual field advantage to a slight left visual field superiority during the second session. The data of the males were more stable over time (Fig. 3). All other main or interaction effects, included the visual half field effect, were not significant.

The overall level of performance in the lexical decision task was high (about 92% correct responses for both sexes and both sessions.)

Figural Comparison Task

The analysis of the correct responses in the figural comparison task indicated a significant interaction of visual half field and sex ($F(1, 36) = 5.53$,

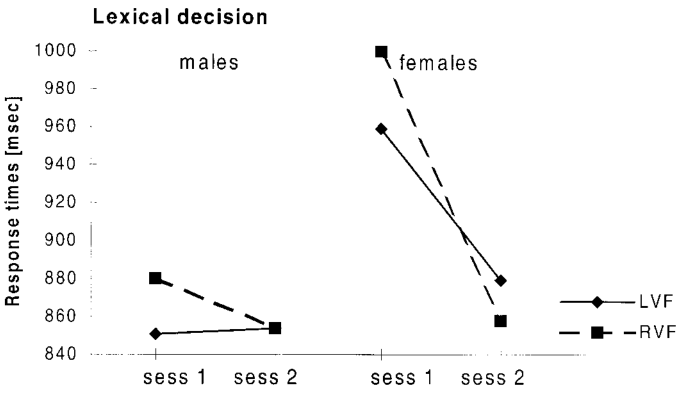

FIG. 3. Means of median response times for the lexical stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. The males were more stable over time.

$p < .05$). Females indicated a strongly reduced right hemisphere (left visual field) superiority compared to males. The male subjects showed a clear functional cerebral asymmetry in favor of the predicted right hemisphere (Fig. 4). To control the statistical extent of this observation alpha-adjusted post hoc paired *t*-tests were computed (Bonferroni–Holm test procedure). The results for the male group demonstrated a significant right-sided asymmetry ($t(1, 18) = 5.17$, $p < .001$), whereas no significant asymmetries were found in the female group ($t(1, 18) = .93$, ns), indicating a more bilateral, symmetrical performance. Nevertheless the main effect ''visual half field'' showed

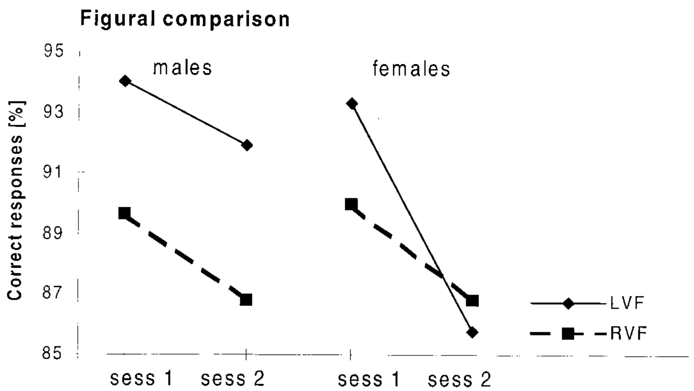

FIG. 4. Means of frequency of correct responses for the figural stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. Especially the performance of LVF (right hemisphere) in females decreases over time. Additionally a significant interaction between visual half field and sex appears.

the expected overall right hemisphere (left visual field) advantage ($F(1, 36) = 14.73$, $p < .001$). Additionally we found a significant main effect ''time'' ($F(1, 36) = 17.83$, $p < .001$). The frequency of correct responses became poorer over time (first session, 91.76%; second session, 87.86%). The interaction between time × sex × visual half field just missed significance ($F(1, 36) = 3.70$, $p = .06$). Post hoc analyses (Bonferroni–Holm test procedure) for the male group revealed significant visual half field effects in both sessions (both t's$(1, 18) > 3.00$, $p < .01$), in contrast to the female group with the only significant half-field effect in session one ($t(1, 18) = 2.52$, $p = .02$). Another post hoc test procedure (Bonferroni–Holm) was computed to observe the decrease of correct responses from session one to session two in each hemisphere for both genders. In the male group the deterioration of correct responses for both hemispheres were not significant (both t's$(1, 18) < 1.56$; ns). In contrast the correct responses of females decreased significantly from session one to session two in the right visual half field ($t(1, 18) = 2.81$; $p = .012$) as well as in the left visual half field ($t(1, 18) = 4.88$; $p < .001$). However, the decrease was more than twice as strong for the right hemisphere as for the left (differences in frequency of correct responses from session one to session two: 7.55% (LVF) vs. 3.16% (RVF)). This difference was significant ($t(1, 18) = 2.41$; $p < .05$).

The analysis of response times in the figural comparison task again showed a significant interaction between ''visual half field'' and sex ($F(1, 36) = 4.15$, $p < .05$). The main effect ''visual half field'' was not significant ($F(1, 36) = .66$, ns). Additionally only the main effect ''time'' reached significance ($F(1, 36) = 7.49$, $p < .05$). The mean response time became faster from 860 ms in session one to 811 ms in session two (Fig. 5).

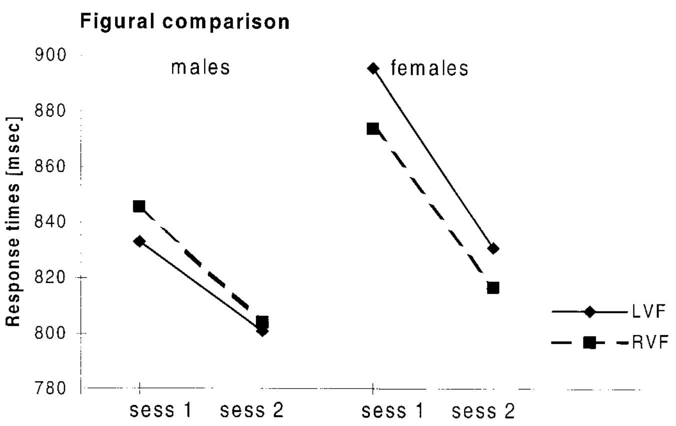

FIG. 5. Means of median response times for the figural stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. Besides a time effect, the visual half field interacts significantly with sex.

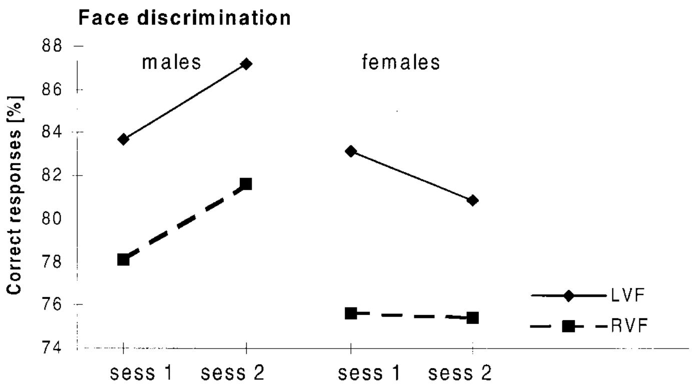

FIG. 6. Means of frequency of correct responses for the face stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. The strong superiority of the LVF (right hemisphere) does not interact with time or sex.

Face Discrimination Task

The analysis of the frequency of correct responses in the face discrimination task demonstrated a very strong superiority of the right hemisphere (left visual field advantage) ($F(1, 36) = 34.42$, $p < .001$), and this effect did not interact with ''time'' ($F(1, 36) = .22$, ns) or sex ($F(1, 36) = .18$, ns). No other main effect or interaction reached significance (Fig. 6). The overall performance in the face discrimination task (about 80% correct responses) indicated that this was the most demanding of the three tasks. The analysis of the response times demonstrated a significant practice effect ($F(1, 36) = 12.26$, $p < .001$), with a mean of 942 ms in the first and 878 ms in the second test session (Fig. 7). No other significant findings were evident.

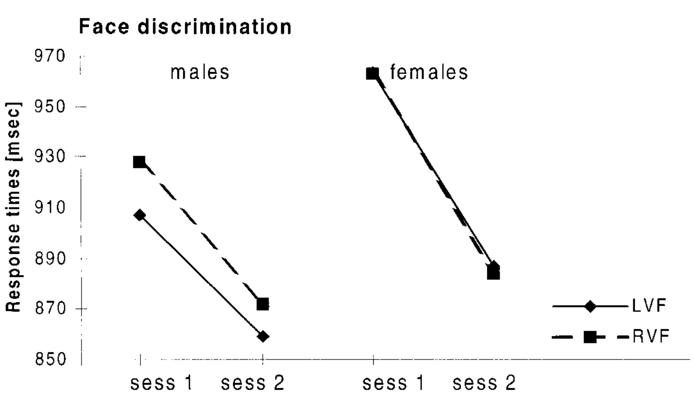

FIG. 7. Means of median response times for the face stimuli presented in the left (LVF) and right (RVF) visual half field in session one and session two for both genders. Females and males become faster in the second test session.

DISCUSSION

The most important result of the present study is the time effect and its interaction with gender and hemisphere. These interactions could be demonstrated in the lexical decision as well as the figural comparison task. The effect was especially pronounced in the accuracy data of the latter condition and resulted in a shift from a significant right hemisphere advantage in session one to a symmetrical and slightly inverted lateralization pattern in session two for the female group only. It was the decrease of accuracy in the left visual field which was mainly responsible for this result, indicating a right hemisphere specific alteration in accuracy over time. Contrarily, the asymmetries in males was stable over time. This specific time effect may thus be an important variable which has to be controlled in repeated measures designs when female subjects are included.

Overall, response times of female subjects decreased to a larger extent than those of males. In general, females also evinced a decrease of accuracy from session one to session two, indicating a gender-specific sacrifice of accuracy for speed over time. It is within this general pattern that a hemisphere-specific effect occurs for females only, which results in a decrease of asymmetry for response times or accuracy for the lexical and the figural comparison task, respectively. Since male asymmetries seem to fluctuate only minimally over this time frame, females show a more dynamic cerebral system evincing strong variations during a short time of 14 days. It is very unlikely that these fluctuations are caused by hormonal alterations since the female subjects were selected irrespective of their menstrual cycle phases and more than half of them used oral contraceptives. The results of the latter subgroup were virtually identical to the women without hormonal treatment. Thus, repeated measures designs seem to have a gender- and hemisphere-specific effect of their own.

A further essential result of the present study are sex differences in functional cerebral asymmetries. They were especially pronounced in the accuracy data where males had functional cerebral asymmetries in the expected direction while females displayed a more symmetrical or bilateral pattern (Fig. 8). This result is in agreement with the assumption of a less asymmetrical organization in females (Corballis & Sidey, 1993; Halpern, 1986, 1996; Hausmann et al., 1998; Hough et al., 1994; Inglis & Lawson, 1981; Inglis et al., 1982; Juarez & Corsi-Cabrera, 1995; McGlone, 1977; 1980; Potter & Graves, 1988; Rasmjou, Hausmann et al., 1999, Shaywitz et al., 1995). It should be noted that the figural comparison task is the same for which Rode et al. (1995) described modulations by the menstrual cycle. This finding supports the hypothesis of a coherence between sexual dimorphism and the influence of menstrual cycle. This coherence supports the notion that not sex per se, but rather the different underlying gonadal steroid hormone levels are an important factor in gender-specific tasks.

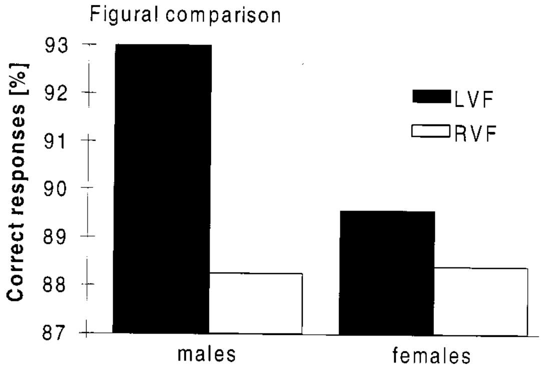

FIG. 8. Means of frequency of correct responses for the figural stimuli presented in the left (LVF) and right (RVF) visual half field pooled for both test sessions. The LVF (right hemisphere) is much more pronounced in males.

However, in the present study the time-locked fluctuations of functional cerebral asymmetries within the female group were independent of gonadal steroid levels, since our subjects were extremely heterogeneous with regard to their hormonal state. It is important to note that our conclusion is not that menstrual cycle effects in repeated measures designs are artifacts and that interactions between menstrual cycle and visual half field appear only as a function of time or session. Such a conclusion would be wrong since all lateralization studies on cycle effects had balanced the menstrual cycle and the time of testing. However, we want to indicate that repeated measures alone may have a strong influence. Perhaps the session effect in such designs is a factor responsible for the ‘empirical chaos’ in this field in which some studies detect gonadal steroid modulated lateralization patterns while others do not (McKeever, 1995). Of course the size of stability depends on typical characteristics of the measuring instrument. However, there are only few studies which have analyzed the test–retest reliabilities in visual half field research (for example, Brysbaert & D’Ydewalle, 1990; Chiarello, Dronkers, & Hardyke, 1984; Fennell, Bowers, & Satz, 1977; Hines, Fennell, Bowers, & Satz, 1980). In a critical review Voyer (1998) concludes that the reliability of laterality effects is small but satisfactory and that it varies with modality, type of task, and specific task used. Voyer (1996) reported small sex differences in laterality, but he concludes (Voyer, 1998) that this is unlikely to account for the heterogeneous reliability estimate, because the sex differences in laterality do not necessarily imply reliability differences. The low stability in lateralization patterns of some tasks in this study is not a general phenomenon. The female group especially shows the largest variability over both sessions. Future studies with repeated measures designs investigating functional cerebral asymmetries during different phases of the menstrual cycle or general steroid modulated influences of lateralization patterns in such designs have to control time or session effects more carefully.

In order to make a clear statement about the influence of gonadal steroids on cerebral asymmetries it is important to observe the pure hormone effect. One possibility is to partialize the session effect as a covariate out of the menstrual cycle effect. This should be done even if time effects are seemingly small. Most studies only used balanced designs and/or a short test session to reduce possible training effects. We think that this is not enough to control time effects. The importance of controlling time effects is evident in some repeated measures design studies, which analyze cognitive performance and cerebral asymmetries during the menstrual cycle (McKeever, 1995). Gordon, Corbin, and Lee (1986) demonstrated that women who started three testings of verbal and spatial tasks at their follicular phase outperformed women who started during menses. Mead and Hampson (1996) observed a pronounced left visual half field increase in accuracy and speed from the first to the second session, when subjects started in the midluteal phase. Hampson (1990a) reported carryover effects in which subjects who initially perform a test in a physiological state conducive to a good performance may develop better skills for doing the test a second time, even if retesting takes place under less favorable endocrine circumstances. This indicates the possibility that time or session effects may have overshadowed other interesting effects in repeated measures designs. Thus, controlling time or session effects may certainly contribute to understanding the relationship between gonadal steroids and functional cerebral asymmetries.

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