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On females' lateral and males' bilateral activation during language production: A fMRI study

Anelis Kaiser [a,*], Esther Kuenzli [a], Daniela Zappatore [b], Cordula Nitsch [a]

[a] *Section of Neuroanatomy, Institute of Anatomy, University of Basel, Switzerland*
[b] *Institute of Romance Languages, University of Basel, Switzerland*

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Abstract

This study focuses on sex/gender and language in fMRI research. We explore the question of similarities and differences in 22 men and 22 women, respectively, in a fMRI language production task of fluent narration in which covert language production was contrasted with an auditory attentional task. In women, a left-lateralised activation concentrated in BA 44 while in men activation was more frontal in BA 45 and more often bilateral. This result is the opposite of those shown so far. Interestingly, the effect is only significant at the level of group analysis; it disappears when analysing activation at the level of the individual subject. We argue that sex/gender differences in the brain should be regarded much more critically, due to the numerous variables interacting and thus confounding with sex/gender. Our present study, too, cannot resolve the controversy about the existence of sex/gender similarities and differences in fMRI-language investigations.
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1. Introduction

The existence of sex/gender-differences during cognitive tasks as revealed by functional imaging is highly controversial. Gender studies indicate that there does not exist a clear-cut distinction between sex and gender (Butler, 1990). Also in the investigations described here, i.e. language representation, the biological and the sociological components for the observed activity cannot be easily differentiated. We, therefore, try to express this by using the double-term sex/gender wherever applicable.

With respect to language processing, numerous studies have been carried out in the course of the last 10 years with a variety of approaches, different techniques, and divergent results. A first investigation (Shaywitz et al., 1995) demonstrated sex/gender associated differences in lateralisation in one of several tested language tasks. With the exception of the large survey by Frost et al. (1999), which did not reveal sex/gender differences, demonstrating differences in lateralisation between women and men dominated fMRI-based language research (Kansaku et al., 2000; Kansaku and Kitazawa, 2001; Phillips et al., 2001; Baxter et al., 2003; see Table 1 listing investigations explicitly addressing the sex/gender issue by means of fMRI). More recent studies using large sample sizes (as in Frost et al., 1999) do not exhibit any sex/gender-based dissimilarities (Weiss et al., 2003; Plante et al., 2005) nor did the meta-analysis by Sommer et al. (2004). The latter study includes a number of investigations, which did not set out from the sex/gender question, but produced sex/gender related results as a by-product (e.g. Schlösser et al., 1998; Pujol et al., 1999; Pihlajamaki et al., 2000).

Conclusions about sex/gender-relevant particulars have been drawn from very different experimental approaches based on both, clinical and non-clinical research. Experimental designs considering a specific language task as only one variable among non-linguistic others may fail to assess human language in its immanent sense. For instance, Gur et al. (2000), who reported sex/gender differences in relation to task difficulty, asked subjects to answer to verbal associations in a verbal reasoning task. Linguistically, verbal associations are meant to be a part of the human language ability, but cannot be regarded as an essential feature of language processing. In fact, verbal

* Corresponding author.
E-mail address: Anelis.Kaiser@unibas.ch (A. Kaiser).

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Table 1
Sex/gender in fMRI studies on language processing

Authors	Task	Presence of differences in lateralisation	Areas exhibiting lateralisation differences	Number of subjects
Shaywitz et al. (1995)	Language perception: *orthographic, phonological, semantic*	Differences in orthographic task	F: IFG, orbital gyrus, both bilateral M: IFG, orbital gyrus, both lateral	38 (19 F, 19 M)
Frost et al. (1999)	Language perception: *auditory lexical-semantic*	No differences		100 (50 F, 50 M)
Kansaku et al. (2000)	Language perception: *listening (global structure)*	Differences in processing a narrative	F: bilateral MGT M: left STG, MGT	47 (25 F, 22 M)
Phillips et al. (2001)	Language perception: *passive listening*	Differences	F: bilateral ant., post. temporal lobe M: lateral ant., post. temporal lobe	20 (10 F, 10 M)
Baxter et al. (2003)	Language perception: *semantic language processing*	Differences	F: bilateral STG, left IFG M: left IFG, left STG, cingulate regions	19 (10 F, 9 M)
Weiss et al. (2003)	Language production: *word generation*	No differences		20 (10 F, 10 M)
Plante et al. (2005)	Language perception/production: *listening, phonology, word identification, verb generation*	Differences in sex × age		205 (101 F, 104 M)
Sommer et al. (2004)	Meta-analysis	No differences		819 (442 F, 377 M)

Investigations addressing explicitly the sex/gender question by means of fMRI language studies in healthy subjects (clinical studies not included). Difference in lateralisation means differences between bilateral versus lateral activation. When bilateralisation was found, it was in women. Abbrevations: F-female, IFG-inferior frontal gyrus, M-male, MGT-medial gyrus temporalis, STG-superior temporal gyrus.

associations may rather be considered as a judgment task, belonging to the cognitive system of decision-making rather than to the language system.

There have been many neuroimaging studies addressing the language system at a psycholinguistic level, without a defined focus on sex/gender. Most of these studies investigate sentence comprehension, testing different aspects of syntactic or/and semantic processing (Indefrey et al., 2001; Friederici et al., 2003). Sex/gender differences were detected primarily in complex comprehension tasks (Table 1). Language production – both in general studies on language processing (Franceschini et al., 2003) as well as with respect to sex/gender differences – is mostly restricted to word generation (Schlösser et al., 1998; Weiss et al., 2003), where subjects are instructed to generate words beginning with a given letter. Production of spontaneous speech (sentences or narrations), which classifies as natural language behaviour, is rarely employed. Of course language processing at sentence level has been investigated with fMRI (e.g. Haller et al., 2005). The types of sentences used (for instance 'child throws ball'), however, can hardly be compared to spontaneous and natural language production as it occurs in free narration.

Linguistic studies propose that women have advantages in language production and verbal fluency (Halpern, 1992), while men are superior in the comprehension of verbal analogy (Hyde and Linn, 1988). Therefore, the aspect of task dependency should be given serious consideration. Differences in language tasks may produce different results with respect to sex/gender (Frost et al., 1999; Phillips et al., 2001), and thus represent a confounding variable in the object of investigation, i.e. language and sex/gender.

Most fMRI studies showing sex/gender differences state that their subjects did not reveal any differences in performance at the behavioural and psycholinguistic level (Shaywitz et al., 1995; Pugh et al., 1996; Frost et al., 1999; Kansaku et al., 2000, Kansaku and Kitazawa, 2001; Baxter et al., 2003; Weiss et al., 2003). Most of them exhibited sex/gender differences in regional brain activation during language comprehension (Shaywitz et al., 1995; Pugh et al., 1996; Kansaku et al., 2000, Kansaku and Kitazawa, 2001; Phillips et al., 2001; Baxter et al., 2003). Up to now, only one fMRI study has focused explicitly on language production and sex/gender: Weiss et al. (2003) demonstrated that not sex/gender-related hemispheric organisation but task performance and therefore strategies for lexical verbal fluency are the reason for the different cortical patterns concerning the degree of lateralisation. Recently, Plante et al. (2005) also addressed the question of sex/gender based on a powerful experimental population of $N=205$ and on a broad variety of examined language tasks concerning both, language production and language perception. In their investigations, however, Plante et al. (2005) concentrated on the interaction of sex/gender with age.

In this paper, we examine the sex/gender question at the level of language production. Similar to Kansaku et al. (2000), we focus on the global structure of language, i.e. free narration as opposed to single words or isolated sentences. In line with several studies mentioned above (Shaywitz et al., 1995; Pugh et al., 1996; Schlösser et al., 1998; Baxter et al., 2003; Weiss et al., 2003), we explore the sex/gender differences and their relation to bi-/lateralisation in Broca's area and its homologue in the right hemisphere, induced by the production of narratives. In fact, most of the studies cited concentrate on one aspect of sex/gender differentiation: the bi-/lateralisation in language areas of the brain. Many of them refer, in particular, to the bi-/lateralisation in Broca's area (Shaywitz et al., 1995; Pugh et al., 1996; Schlösser et al., 1998; Baxter et al., 2003; Weiss et al., 2003). Although recent studies (Weiss et al., 2003; Sommer et al., 2004; Plante et al., 2005) did not find any difference, the notion of dissimilarities between the sexes/genders still dominates neuroscientific concepts. Therefore, it seems warranted to investigate the variable sex/gender at the level of

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