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FUNCTIONAL NEURORADIOLOGY

Comparison of two fMRI tasks for the evaluation of the expressive language function

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Abstract
Introduction Presurgical evaluation of language is important in patients who are candidates for neurosurgery since language decline is a frequent complication after an operation. Different functional magnetic resonance imaging (fMRI) tasks, such as the verb generation task (VGT) and the verbal fluency task (VFT) have been employed. Our objective was to compare how effective these tasks are at evaluating language functioning in controls (study 1) and patients (study 2).
Methods Eighteen controls and 58 patient candidates for neurosurgery (16 patients with temporal lobe epilepsy and 42 patients with brain lesions: 11 astrocytomas, six cavernomas, 14 gliomas, four AVM and seven meningiomas) were recruited in order to compare the activation patterns of language areas as determined by the VGT and VFT.
Results In both samples, the VGT produced a more specific activation of left Broca's area. In contrast, the VFT yielded a wider and more intense activation of the left Broca's area in controls, as well as other activations in the dorsolateral prefrontal cortex and the striatum. Additionally, both studies showed good agreement on language dominance derived from the tasks, although there was some variability in laterality index scores.
Conclusions Both language tasks are useful in evaluation of expressive language. The VGT is a more specific task, while the VFT is more unspecific but activates language-related areas that are not found with the VGT owing to its phonological component. Therefore, each task contributes to the lateralisation and localisation of expressive language areas with complementary information. The advisability of combining tasks to improve fMRI presurgical evaluation is confirmed.

Keywords fMRI · Language · Brain · Tumour · Epilepsy

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Introduction

In patients who are considered for neurosurgical resection, it is often important to assess whether the hemisphere that is going to be operated upon mediates critical language functions in order to avoid postoperative deficits. The Wada test or intracarotid amobarbital procedure (IAP) has been the "gold standard" reference procedure for identifying lateralisation of language functions, but it is invasive and therefore carries risks. Functional magnetic resonance imaging (fMRI) is a non-invasive technique that provides relevant information by mapping cognitive functions in eloquent areas. Thus, it appears as a promising alternative approach in the presurgical evaluation of patients, who are candidates for surgery [1, 2]. Previous studies have suggested good agreement between lateralisation determined by fMRI language tasks and the Wada test [1, 3–8], but now, and before fMRI can be established as a diagnostic neuroimaging modality, studies are needed to reach a consensus on standard imaging procedures, data processing and clinical interpretation of imaging findings.

Different tasks and methods for assessing language-related fMRI activations have been employed, such as the verb generation task (VGT) and the verbal fluency task (VFT). These are two of the different language paradigms that have commonly been employed worldwide, the choice of exactly which ones to use normally depending on the preference of each researcher. Some authors, however, have highlighted the importance of using different paradigms simultaneously in order to obtain a better mapping of language functions [9–11].

The VGT consists in the generation of a verb that is semantically related to a presented noun (for example, the noun "spoon", the verb "eat"; [3, 12, 13]). The VGT typically produces left-sided activations in the inferior and middle frontal gyri [3]. Some authors have suggested that this activation is related to the process of selecting the proper response from among all the possibilities and to the strength of the association between the word and the verb [14]. Previous studies have evidenced that it is one of the most reliable language tasks because of its high degree of agreement with the IAP and its good reproducibility [3, 10, 15].

In the VFT [16–18], subjects are required to silently generate different words starting with a particular letter (letters F, A, S). The VFT produces activations in the inferior, middle and superior frontal gyri, as well as the supplementary motor area (SMA) and the thalamus. Previous studies have suggested that it agrees well with the IAP [5, 19], and it is suitable for a wide range of population [18, 20]. Traditionally, it has been criticised for its high component in working memory, even though it is seems to produce a good lateralisation index.

The main objective of the current studies was to compare the effectiveness of these two classical tasks in evaluating language function in order to provide a better understanding of the fMRI technique as a clinical tool. For this purpose, we have used both language tasks in healthy controls (study 1) and patients who are candidates for surgery (study 2), in order to compare language-related fMRI activation patterns for the localisation and the lateralisation of typical language areas as determined by both tasks. Moreover, as previously studied in memory functions [21], we will also examine the advantages of using two different paradigms to map expressive language functions.

Study 1

Methods

Participants

Eighteen healthy controls (nine males and nine females) with ages ranging between 22 and 43 years (mean age = 31.5) were studied. All participants were right-handed (assessed using the Edinburgh Handedness Inventory, Oldfield [22]). Those participants with a psychiatric or neurological history were excluded. Informed consent was obtained from each subject prior to participation. The research project was approved by the ethical committee of our institution. Participants received monetary compensation for their participation.

Tasks

All the participants performed the VGT and the VFT. One of the VGT results was lost due to technical problems. Before entering the scanner, participants practised both tasks overtly but were instructed to respond silently inside the scanner in order to minimise the motion artefacts associated with speech. All the stimuli were presented aurally via earphones.

During the VGT, 12 blocks of alternating control and activation conditions were perform. After a fixation period of 6 s, participants completed the 6 min of 30-s blocks. During the activation condition, participants were asked to generate single verbs for concrete nouns presented every 3 s (ten nouns per block). During the control condition, participants were required to silently repeat letters.

The VFT consisted of 12 blocks of alternating control and activation conditions. After a period of fixation, participants completed 6 min of 30-s blocks. During the activation condition, participants were instructed to generate different words starting with a particular letter. A different letter (F, A, S, P, L or C) was displayed for each activation block, and the subject was asked to generate as many different words as possible during the 30-s period. The control condition consisted in repeating the word "casa" (Spanish for "house").

fMRI data acquisition

fMRI data were acquired on a 1.5-T Siemens Avanto, Erlangen, Germany. Participants' heads were immobilised with cushions to reduce motion artefacts. The stimuli were presented directly using earphones.

A gradient echo T2*-weighted echo-planar MR sequence was used for fMRI (repetition time/echo time (TR/TE(= 3,000/

50 ms, matrix = 64 × 64 × 29, voxel size = 3.94 × 3.94 × 6, slice thickness = 5 and 1 mm gap, flip angle=90°). We acquired 29 interleaved axial slices parallel to the anterior–posterior commissure (AC–PC) plane covering the entire brain. The first two acquisitions were discarded due to saturation effects. Prior to the functional magnetic resonance (MR) sequence, a 3D anatomical volume was acquired by using a T1-weighted gradient echo pulse sequence (TR/TE=11/4.9 ms, matrix = 256 × 224 × 176; voxel size = 1 × 1 × 1).

Imaging data analysis

fMRI data were processed using the SPM5 software (Welcome Trust Centre of Neuroimaging, London, UK). After realignment and co-registration, images were spatially normalised (2×2×2 mm; Montreal Neurology Institute, MNI co-ordinates) and smoothed with a Gaussian kernel (full width at half maximum (FWHM) 12 mm). Then, the general linear model was applied for the statistical analysis. A comparison of means was performed for the within-group analysis of each task, and an analysis of variance (ANOVA) was carried out for the group analysis of the differences between tasks. Stereotactic co-ordinates for voxels with maximal *z* values within activation clusters were reported in the Talairach and Tournaux standard space.

Region of interest (ROI) was defined for each participant separately using anatomical criteria in accordance with Rutten et al. [10]. In both the left and the right hemispheres, language regions were segmented to include the inferior frontal gyrus (BA 44 and 45) and the adjacent inferior frontal sulcus (part of BA 9 and 46). The medial activations were subtracted by a boxcar with dimensions of 20, 100, 100 and an epicentre at 0, 0, 0.

Laterality indexes (LIs) were calculated for each participant by counting the significantly activated voxels in the ROIs. LIs reflecting the hemispheric difference between voxels counts in homologous left and right ROIs were calculated using the formula: $[(L-R)/(L+R)]\times 100$, where L and R are the number of activated voxels for the left and right hemispheres. The activations were considered if ten or more adjacent voxels all passed the threshold; otherwise, they were considered to be lost values. This approach yields LIs ranging between +100 (strong left hemisphere dominance) and −100 (strong right hemisphere dominance). LIs were subsequently classified as left hemisphere language dominant (defined as $LI > +20$), symmetrical ($-20 \geq LI \leq +20$) or right hemisphere dominant ($LI < -20$).

Results

Group activation maps

Group activation patterns are shown in Table 1 ($p<0.0001$, false discovery rate (FDR)-corrected). In the VGT, we found the expected activations in the left inferior, middle and superior frontal gyri (BA 44, 45, 47, 9, 46 and 6). The effects of the VFT were observed in the left inferior, middle and superior frontal gyri (BA 44, 45, 9, 46 and 6) as well as in the striatum and right inferior frontal gyrus (BA 45, 47).

When we examined the number of voxels activated by each task, for the whole brain, the VFT value was 3,951 voxels and the VGT cluster extension was 1,514 voxels. When we restricted the voxel count to just our regions of interest, a 2×2 ANOVA including task (VFT vs. VGT) and lateralisation (left vs. right) as within-subject factors showed a significant main effect for lateralisation (F (1, 16) = 56.89, $p<0.001$) and task (F (1, 16) = 9.07, $p<0.01$). This indicates that both tasks activated more voxels in the left frontal area than the right and that VFT showed a bigger cluster extension than the VGT.

A direct comparison of VGT and VFT results for the whole brain is shown in Fig. 1 (FDR-corrected, $p<0.01$). Regions showing greater activation for the VFT than the VGT included left BA 6, 9, 44 and 45, and bilateral caudate, putamen and globus pallidus. Brain regions with more activation during the VGT than the VFT were left BA 39, 40 and 22.

Laterality indexes

In both tasks, LIs were strongly left-sided. The analysis restricted to the defined ROI ($p<0.0001$, uncorrected) showed that the two tasks yielded a left dominance for all participants but one (in which the VGT showed a bilateral distribution and VFT a right dominance). T test comparisons between both tasks revealed that LIs were significantly greater for the VGT (82.15±28.21) than for the VFT (65.81±33.18) (t (16) = 2.36, $p<0.05$). If we study the magnitude of this difference, 41% of the participants had a VGT LI that was over 30 units higher than the VFT LI. Finally, it should be noted that correlation analyses between LIs were significant (r(17) =.58, $p<0.01$).

Discussion

In this study, we evaluated the VGT and VFT modulation of the BOLD signal in expressive language areas. Although both tasks produced robust left-sided activations, the pattern of activation differed over some of the areas activated.

In the group analysis, our results showed the expected language-related activations for each task. In the VGT, we found the predicted left-sided frontal activations, which were widely related to language processing. Previous literature has found similar patterns of activation for this task including the left inferior and middle frontal gyri [3]. The activation of this region of the brain has been attributed

Table 1 Group activation patterns (FDR $p<0.0001$) (L=Left and R=Right).

	Co-ordinates	Brain region	Brodmann area	Z score	Cluster
VGT	−10, 22, 45	L, cingulate gyrus	32	6.77	357
	−2, 16, 53	L, superior frontal gyrus	6	5.57	
	−46, 28, 17	L, middle frontal gyrus	46,9	6.17	953
		L, inferior frontal gyrus	44,45		
	−34, 29, 0	L, inferior frontal gyrus	47	6.01	
	−34, 18, 6	L, insula	13	5.79	
	12, −81, −23	R, cerebellum		5.70	173
	−51, −47, −6	L, cerebellum		5.31	31
VFT	−44, 13, 23	L, inferior frontal gyrus	9, 44, 45	6.97	2,713
		L, middle frontal gyrus	46, 47, 6	6.97	
		L, putamen			
		L, caudate			
		L, lentiform nucleus	Globus pallidus		
	−36, 25, −1	L, middle frontal gyrus	47	6.28	
	−8, 20, 41	L, cingulate gyrus	32	6.38	677
		R, medial frontal gyrus	6	6.03	
	−14, 8, 49	L, medial frontal gyrus	6		
	32, 21, 1	R, insula	13	5.68	143
		R, inferior frontal gyrus	45	5.68	
	38, 17, −4	R, inferior frontal gyrus	47	5.10	
	32, −61, −20	R, cerebellum		5.40	257
	−4, −24, −9	L, midbrain	Red nucleus	5.18	77
	4, −28, −10	R, midbrain	Red nucleus	4.73	
	14, 4, −4	R, lentiform nucleus	Lateral globus pallidus	5.09	84
		R, putamen		5.09	
	14, 14, 7	R, caudate	Caudate body	4.83	
	14, 12, −1	R, caudate	Caudate body	4.96	

to the selection of information from among competing alternatives in semantic memory, as well as to the difficulty in verb retrieval related with the strength of the association between the verb and the noun [14].

On the other hand, we found more bilateral activations in language-related areas in the VFT. In addition, we also found activations that were not related with language per se, as in the basal ganglia, an area involved in the organisation and generation of information, and the BAs 6 and 9, which are areas related to working memory. Previous literature showed similar activations in healthy controls, including the left inferior and middle frontal gyri and the mesial frontal areas, including the SMA, as well as the thalamus [18].

In clinical practice, VFT is considered to be particularly sensitive to the operation of two basic factors: a verbal and an executive factor. Both factors were found in our results as well. VFT is regarded as a measure of executive dysfunction because generating words on the basis of orthographic criteria is unusual and requires the creation of non-habitual strategies based primarily on lexical representations [22]. In addition, the measure requires efficient organisation of verbal retrieval and recall as well as self-monitoring aspects of cognition (the participant must keep track of responses that have already been given), effortful self-initiation and inhibition of responses when appropriate. Empirical studies have found decreased verbal fluency following lesions in the striatum, for example in patients undergoing pallidotomy in Parkinson disease (particularly after left pallidotomy) [23], which is in keeping with the importance of the basal ganglia in this kind of task. Involvement of the striatum and the dorsolateral prefrontal cortex (DLPFC) was probably more related to the executive component of the task, whereas Broca's area reflected the verbal component.

In the direct comparison between both tasks, we found clear evidence of the differences between them. The executive component of the VFT task including BAs 6 and 9 and the striatum was not involved in the VGT. We can therefore conclude that the VGT seems to be more specific than the VFT for areas of the brain involved in expressive language. Furthermore, the VGT seemed to involve the brain areas involved in receptive language (BAs 39, 40 and 22) more than the VFT, thereby suggesting an activation of almost all the language network.

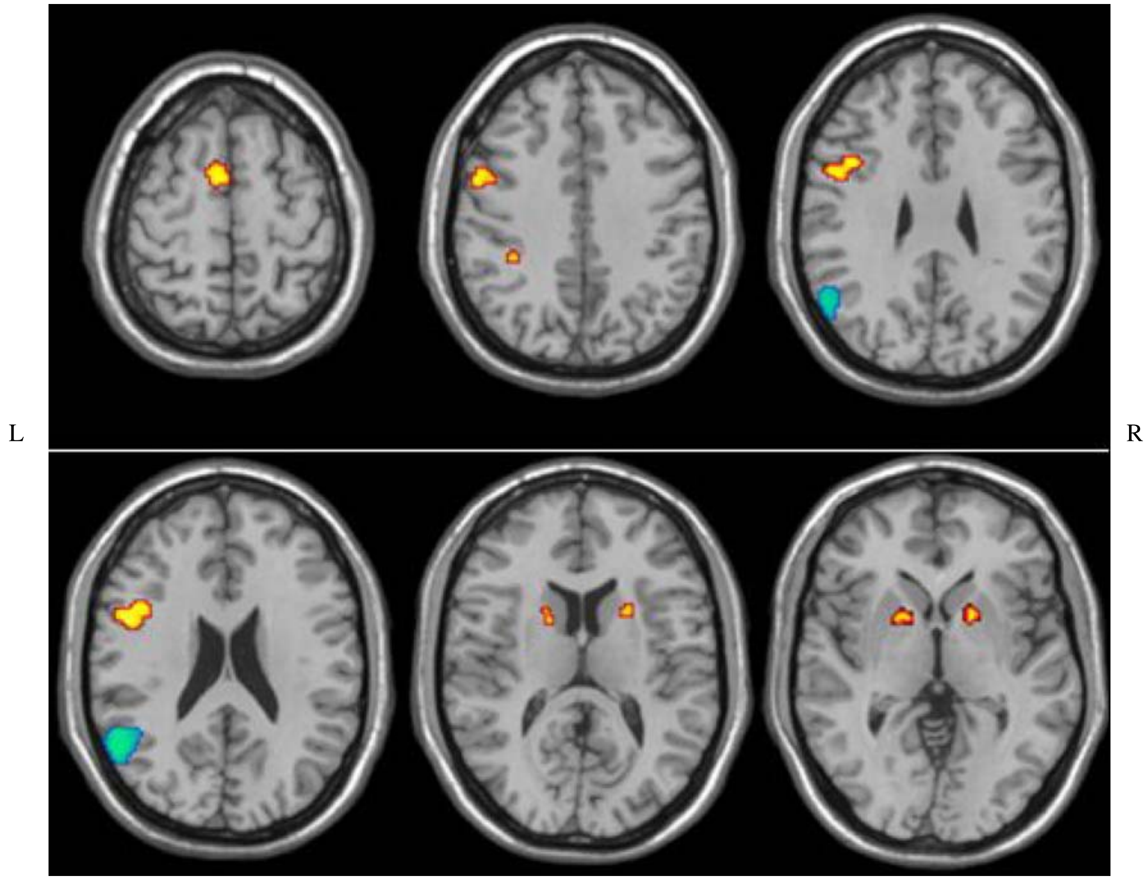

Fig. 1 A composite image of the group activation maps (FDR $p<0.01$) showing voxels with stronger VFT effects (*yellow*) and voxels with stronger VGT effects (*green*)

However, the stronger specificity of VGT as a language task also seemed to affect the activation of Broca's area. The comparison between tasks revealed that the VFT had a greater number of voxels activated within BAs 44 and 45 (Fig. 1), affecting the dorsal part of Broca's area. A recent meta-analysis of fluency tasks was consistent with the hypothesis that Broca's area has a different functional organisation, the dorsal part being more related to phonological processing and the ventral part to semantic processing [24]. Given that the VFT, when compared with the VGT, over-activated the dorsal part and there were no differences in the ventral part, we may conclude that activation of Broca's area by the VFT was better for clinically mapping the areas of the brain involved in phonological processes of expressive language. In other words, the VGT recruited semantic processing, whereas the VFT used both semantic and phonological processing. Moreover and as the comparison between the number of voxels involved in each task evidences, the VFT is more consistent than the VGT, which is a very important point in the clinical conclusions at the individual level.

Analyses of LIs also showed that both tasks produced robust left-sided activations that were correlated, as expected. However, VGT LIs were more strongly left-lateralised than VFT ones in our dominant right-handed sample. Therefore, VFT seems to be more likely to produce less lateralised distributions, again suggesting a lower specificity for mapping expressive language areas. Although agreement between the two tasks at the categorical level was strong (only one case of discordance), the analysis of individual LIs showed discrepancies of more than 30 units in 41% of cases. This fact may be important for clinical cases.

In sum, it seems difficult to decide on the best task, since both contribute to the language lateralisation and localisation with complementary information. The VGT was associated with a more specific activation of the left Broca's area that is individually reliable and produces higher LIs in accordance with the results expected in the right-dominant sample. In contrast, although the VFT yielded a more unspecific brain activation (including the DLPFC, the striatum, which also encompasses the right frontal cortex) and generated fewer left-lateralised LIs, it also produced a more intense and wider-ranging activation of dorsal Broca's area, owing to its phonological processes.

Study 2

Introduction

The functional language activations related to the VGT and the VFT were studied in healthy controls and we concluded that there is a high correlation between tasks, but there are also relevant differences. On the one hand, the VGT activated more specific language-related areas than the VFT. On the other hand, the VFT showed greater activations in working memory but also in language-related areas. Our main goal in study 2 was to investigate whether these differences are also observed in presurgical patients and the consequences of these differences in clinical practice. We were also interested in determining the advantages of using two different protocols to map the language function because previous research carried out in our lab on memory functioning showed clear discrepancies between different protocols [21]. With this purpose in mind, we compiled the data from 58 patients with brain tumours or temporal lobe epilepsy (TLE) who were candidates for surgery and who were evaluated with both language tasks as part of the presurgical protocol.

Methods

Participants

Fifty-eight consecutive patients (28 males and 30 females) were recruited. The patients' ages were between 20 and 74 (mean age $= 41.4 \pm 12.8$). All participants were right-handed (assessed using the Edinburgh Handedness Inventory, Oldfield, 1971[25]) and the expressive language function was evaluated as part of the presurgical protocol. Pathologies included 16 patients with drug-resistant TLE (five with right TLE and 11 with left TLE) and 42 patients with macroscopic brain lesions (11 astrocytomas, six cavernomas, 14 gliomas, four AVM and seven meningiomas) located in or adjacent to the left or right frontal gyrus or left temporal gyrus. Informed consent was obtained from each subject prior to participation. The research project was approved by the ethical committee of our institution.

Tasks

All the participants who were able to yield a minimum level of execution performed the VGT and VFT as explained above. Those patients showing serious difficulties during the practice session before entering the scanner were excluded from analyses. The exclusion criteria were, in accordance with the Spanish normative data, to eliminate those patients with a score under the percentile 5 for the VFT [26] and those with less than 80% of correct responses for the VGT. These criteria ruled out ten patients in the VFT (nine with tumours and one with left TLE) and two in the VGT (both with tumours). Thus, the final sample of patients consisted of 46 patients.

fMRI data acquisition

Eighteen patients were scanned on a 1.5-T Siemens Avanto, Erlangen, Germany, and a Siemens 3-T Trio, Erlangen, Germany, was used for the other 28. Participants' heads were immobilised with cushions to reduce motion artefacts. The stimuli were presented directly using earphones.

A gradient echo T2*-weighted echo-planar MR sequence was used for fMRI (TR/TE=3,000/50 ms, matrix $= 64 \times 64 \times 29$, voxelsize $= 3.94 \times 3.94 \times 6$, slice thickness=5 mm and 1 mm gap, flip angle=90°). We acquired 29 interleaved axial slices parallel to the AC–PC plane covering the entire brain. The first two acquisitions were discarded due to saturation effects. Prior to the functional MR sequence, a 3D anatomical volume was acquired by using a T1-weighted gradient echo pulse sequence (TR/TE=11/4.9 ms, matrix $= 256 \times 224 \times 176$; voxelsize $= 1 \times 1 \times 1$).

Imaging data analysis

fMRI data were processed individually using Brain Voyager QX software (Brain Innovation, Maastricht, The Netherlands). After realignment and smoothing with a Gaussian kernel (FWHM 6 mm), the fMRI data were co-registered to the anatomical T1. Then, the general linear model was applied for the statistical analysis.

ROIs were defined for each patient separately using clinical criteria according to an experienced researcher (A. S.). LIs were calculated as explained above for control participants. We adjusted the statistical criteria applied for patients to uncorrected $p<0.005$.

Results

As expected, the 3-T equipment activated a greater number of voxels than the 1.5-T scanner (M=41,584.5 for 3 T and M=24,943.2 for 1.5 T; t (90) = −4.08, $p<0.001$). Importantly, there were no significant differences between the LIs obtained for each task with the different scanners ($p>0.20$).

Regarding the cluster extension, we conducted a 2×2 ANOVA including task (VGT vs. VFT) and lateralisation (right vs. left) as within-subject factors. Results showed a significant main effect for lateralisation (F (1, 45) = 84.09, $p<0.001$), indicating that the tasks activated more voxels in the left than the right frontal area. However, this main effect was modulated by the lateralisation × task interaction

(F (1, 45) = 4.13, $p<0.05$), thus reflecting the fact that the VFT activated more voxels in the right frontal areas than VGT. No significant differences were observed in the magnitude of the activation of the left frontal area (see Fig. 2).

In the VGT, LIs were strongly left-sided (M=69.11; SD=31.86). Under the selected statistical criteria ($p<0.005$, uncorrected), 42 participants were left dominant, three patients had a bilateral representation and one patient was strongly right dominant. The VFT produced LIs that were mostly left-distributed for the defined language regions (M=54.11; SD=31.01): 40 participants were left dominant, five patients had a bilateral distribution and one patient (the same one as in the VGT) was right dominant. As a result, the discrepancy between the two tasks at the categorical level affected two patients (5%), both of whom had brain tumours and a bilateral distribution of language according to the VFT but were left dominant according the VGT.

A t test comparison between the LIs showed significant differences between the two tasks: the VGT showed a significantly stronger left dominance than the VFT ($t(45)$ = 5.27; $p<0.001$). Mean quantitative difference between both LIs was 15.0 (SD=19.28), with a range between −25 and 57. It should be remarked that 27% of the patients had a VGT LI that was over 30 units higher than the VFT LI. A Pearson correlation between both LIs was highly significant ($r(46)$ =.81, $p<0.01$).

Discussion

As expected, both tasks showed a strong tendency towards left lateralisation of language function [3, 12, 13, 16–18], thus confirming previous results with controls. As in study 1, the comparison between tasks revealed that the mean for the LIs of the VGT was significantly higher than that of the VFT. As previously obtained, this difference should be interpreted as being indicative that the VFT activated the right frontal cortex more than the VGT. In this study, however, we fail to find differences in the magnitude and extension of activation in the left frontal cortex. Then, these data indicate that the VGT is more specific in activating the expressive language areas of the brain but do not support the advantage of the VFT related to a greater cluster extension in the left frontal cortex.

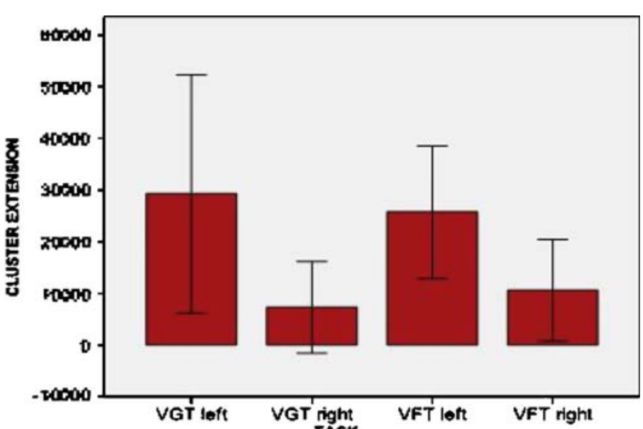

Fig. 2 Comparison of the mean cluster extension of both tasks shows significant differences in the right frontal activation

When data were analysed at the categorical level, discrepancies were found in only 5% of the patients. This percentage is low and similar to previous reports [27]. Thus, expressive language tasks showed better agreement than memory tasks [21]. At magnitude level, however, discrepancies were strong in some cases since we obtained differences that were higher than 30 units in 27% of the patients. These differences reflect an unexpected degree of variability between LIs that do not have a high impact on the clinical categorisation. Nevertheless, it does prevent us from using only one task as a diagnostic tool, especially if we bear in mind the fact that performance is not monitored online.

It is also remarkable that we found more patients with problems to perform the VFT than the VGT. These results may be due to the involvement of other cognitive processes in the VFT [22] that implies wider brain activation and could make this task more sensitive to brain diseases. From a clinical point of view, it is important to make sure that patients are able to perform the paradigms successfully in order to obtain a reliable activation and so as to be able to produce a tool that can be adapted to all kinds of subjects [28, 29]. Therefore, these results highlight the relevance of including two or more language tasks in the presurgical evaluation of the patients due to a number of advantages, such as confirming results and avoiding the need for test repetition.

As a conclusion, results of study 2 in clinical patients confirmed some of those obtained in study 1 but also yielded some discrepancies. As obtained in study 1, both tasks showed a clear left-side lateralisation of the expressive language activations, with more strongly left-sided VGT LIs. However, and in comparison to study 1, the analysis of cluster extension showed that the VFT activated more than the VGT but only in the right frontal cortex. We did not observe a greater cluster extension in language-related areas for the VFT in the left hemisphere. Another important conclusion from study 2 is that, since we were unable to perform one of the tasks in some patients, we recommend including different language paradigms in the presurgical protocol in order to ensure results and avoid lack of clinical information.

General discussion

By using fMRI tasks, studies 1 and 2 confirmed previous results showing that the VGT and VFT reliably activated left frontal areas related to the control of expressive language in healthy subjects and in clinical patients [3, 12, 13, 16–18]. The main objective of these studies was to compare these two fMRI tasks and, as expected, we found evidence that overall there is a high degree of agreement between the two tasks, but it is important to bear in mind that there are considerable differences between them.

The first difference arises from the cognitive processes involved in each task: whereas the VGT specifically involved language functions, the VFT requires the additional participation of executive functions [22]. Then, in general, both tasks showed a similar activation of the left inferior frontal gyrus (Broca's area) and the left middle and superior frontal gyri, but unsurprisingly due to the involvement of executive functions, the VFT activated the caudate bilaterally and the right medial frontal cortex. VGT therefore seemed to be more specific than VFT for lateralisation and localisation of language-related areas, while VFT showed the involvement of a more extended brain network. This difference probably also reflects the greater complexity of the VFT, which made it more sensitive to performance deficits. Then, it can explain the fact that patients in study 2 were more prone to have difficulties in completing the VFT (15.6%) than the VG task (3.1%).

Both tasks therefore replicated activations obtained in previous studies, but study 1 served to investigate more specific differences, for example, it reveals discrepancies that are also centred in language-related cognitive processes. When the brain areas involved in each task were compared directly in control participants, the results showed another remarkable discrepancy: the VFT seemed to activate the left Broca's area to a greater extent than the VGT, covering both the dorsal and ventral part of this area. Thus, the VFT would cover more language-related areas than the VGT and this is probably due to the fact that the VFT involved more phonological language-related processes than VGT. However, this pattern of differential cluster extension was not replicated in study 2 with clinical patients, since the number of voxels activated in the left frontal ROI was similar for both tasks. This aspect should be investigated in the future.

In addition to the above findings, we noted that the VFT provided LIs that were less left-lateralised than the LIs generated with the VGT in patients and healthy controls. These differences between LIs, however, did not seem to be very relevant to the knowledge of language dominance at the categorical level.

In patients, language dominance may be affected by a brain lesion. Abnormal language dominance was found in 9% of patients for the VGT and 14% of patients for the VFT. These data were similar to others previously obtained in clinical samples [4, 7]. The clinically relevant aspect is the high degree of agreement between both tasks (only 5% of discrepant results), which suggests that one task may be enough to map language dominance. Previous research, however, has reached different conclusions about the need to use different tasks to map language dominance. The validity of language lateralisation of the fMRI tasks has been evidenced through comparison with the IAP. A concordance between LIs obtained with fMRI and IAP ranging from 75% to 90% has been found depending on the tasks, methodology or kind of patients [3, 5, 6, 8, 27, 30]. Some authors have proposed that multiple tasks improved the determination of language laterality when compared with a single task [5, 6, 11] whereas others found a clear superiority of one task over the others [3, 27].

Several aspects force us to be cautious on this point. First, the correlation between fMRI tasks and IAP is good, but it only accounts for 58.4% of the variance [27]. Second, our results have detected some cases with great discrepancies in the magnitude of the LIs. Although in most of the cases the language dominance would be similar, we have found discrepancies of more than 30 units in 41% of healthy controls and 27% of patients. Then, the use of only one test may yield ambiguous results in some cases. Moreover, 17.4% of the patients were unable to perform the VFT, and 3.4% could not do VGT. In addition to being incapable of performing the task, there could be further difficulties such as motion artefacts or lack of activation that invalidate the results of the functional evaluation. Therefore, including two or more language tasks in the presurgical evaluation has the advantage of avoiding these problems and will save the need for test repetition.

One major limitation of this study is that it was not possible to compare the results with an independent methodology (intraoperative cortical mapping, Wada test or postsurgical deficits). This information could be relevant in the clinical sample since it could add further details about the sensitivity of the fMRI tasks to map language-related areas that are essential for the preservation of this cognitive function. fMRI allows us to visualise brain areas involved in the task execution but does not distinguish between areas that are critical or essential from those that are "non-critical" or expendable. Therefore, systematic comparisons of our fMRI results with a reference index would be of great value and should be the focus of follow-up studies.

Conclusion

In summary, we can conclude that both language tasks are important in the evaluation of expressive language. We have found a good correlation between them, thus suggesting shared evaluation of functions, but there are significant differences as well. VGT is a more specific task for language functions, while VFT is more unspecific but activates language-related areas not found with VGT. Therefore, they contribute to lateralisation and localisation of language function by providing complementary information. The latest studies highlight the advisability of combining tasks to improve language evaluation in the presurgical evaluation of patients who are candidates for surgery, rather than assessing functioning with just one task, and our results support this approach.

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Conflict of interest statement We declare that we have no conflict of interest.

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