A selective effect of parietal damage on letter identification in mixed case words.

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Running title: parietal damage and letter identification

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Abstract

We investigated the reading of cAsE mIxInG and contrast reduction on word reading in patients with unilateral parietal lesions and attentional deficits. We show that, compared with control participants, the patients produce selective increases in lateralised errors when reading mixed case relative to same case words. However, there were not reliable increases in lateralised errors when words were degraded by low contrast. The patients also showed some increases in contralesional errors at a task aimed at feature processing in words (a gap detection task), but these effects were not increased for mixed case stimuli and errors were reduced relative to the word reading task. The results are consistent with mixed case words stressing attention-demanding letter identification, drawing-out an impairment in the patients in attending to contralesional stimuli. On the other hand, effects of contrast reduction are accommodated without necessarily recruiting attentional processes mediated by the posterior parietal lobe.

Keywords: attention, reading, parietal lesions

Introduction

There is now considerable evidence from functional brain imaging that the parietal lobe is critical for controlling visual attention (e.g, Corbetta & Shulman, 2002; Kanwisher & Wojciulik, 2000). Converging neuropsychological evidence comes from the disorders of unilateral neglect and extinction. Patients with unilateral neglect frequently fail to attend to stimuli presented on the side of space contralateral to their lesion (Heilman & Valenstein, 2003), though this problem can be reduced by cueing attention to the affected side (Riddoch & Humphreys, 1983). Patients with extinction have a less dramatic spatial deficit. These patients can identify a single stimulus present on the contralesional side but they fail to detect the same item if it appears simultaneously with another stimulus on the ipsilesional side (Karnath, 1988). As with patients showing neglect, extinction can also be reduced by having patients attend to the contralesional side (Posner, Walker, Friedrich & Rafal, 1984). Both neglect and extinction can be conceptualised in terms of there being biased competition in visual selection, with more 'weight' being attached to ipsi- than to contralesional stimuli (cf. Duncan, Humphreys & Ward, 1997; Heinke & Humphreys, 2003). As a consequence, items on the contralesional side may go undetected, especially when stimuli are presented briefly. Even with unlimited presentations, however, such patients may have difficulty in perceptual report due to problems in attentional scanning on the contralesional side (cf.. Eglin, Robertson & Knight, 1989; Riddoch & Humphreys, 1987).

Disorders of visual attention after parietal damage can also impact on reading tasks. Neglect dyslexia, for instance, is characterised by patients making lateralised (contralesional) errors in single word reading, as well as poor scanning across texts

(Caramazza & Hillis, 1990; Young, Newcombe & Ellis, 1991). As with other aspects of neglect, the contralesional errors reduce when patients are cued to attend to that side (Humphreys & Riddoch, 1983). The magnitude of the lateralised problems in reading, found after parietal damage, is affected by the familiarity of the stimuli. For example, patients typically make fewer errors with words than with nonwords, even when performance is corrected for guessing (Riddoch, Humphreys, Cleton & Fery, 1990). Familiarity effects are not only based on the lexical content of the stimuli, but also on their visual appearance. This is perhaps seen most dramatically in the syndrome of attentional dyslexia, associated with bilateral parietal damage (e.g., Baylis, Driver, Baylis & Rafal, 1994). Patients with attentional dyslexia show better reading of words than their component letters, reflecting poor attention to individual letters. However, this word advantage is reduced when the words appear in less familiar formats – for example, when words are shown in upper rather than lower case (Hall, Humphreys & Cooper, 2001). This is not just a problem in reading particular letter forms (e.g., upper case letters). Hall et al. (2001) reported better reading of familiar upper acronyms (e.g., BBC, IBM) compared with their lower case counter-parts (bbc, ibm). To account for such results, Hall et al. (2001) proposed that word recognition is sensitive to the familiarity of the visual format of words and acronyms, so that there are reduced attentional demands on the reading of visually familiar forms.

In the present study, we examined the effects of the familiarity of the visual format on the reading of patients with unilateral parietal lesions. Visual familiarity was manipulated by presenting words in single or in mIxEd-cAsE. Mixed case stimuli are less visually familiar than words presented in single case, and they are typically more difficult to read (e.g, Adams, 1979; Mayall, Humphreys, Mechelli, Olson &

Price, 2001; McClelland, 1977). One reason for this might be because the upper case letters mask the lower case forms so that, for example, the visibility/contrast of the lower case forms is reduced (Besner & Johnston, 1989). However, this seems unlikely to account for the full effect. For example, Braet and Humphreys (2006) report a double dissociation between the effects of case mixing and contrast reduction on reading following rTMS applied to occipital and parietal cortices. rTMS to the occipital cortex exacerbated the effects of contrast reduction but had no influence on the effects of case mixing. In contrast, rTMS applied to the right parietal lobe selectively disrupted the reading of mixed case words, but it did not enhance the effects of contrast reduction. These selective effects of rTMS to the occipital and parietal lobes suggest that case mixing is affected by factors additional to pure visual degradation (as manipulated through contrast reduction). As an alternative, we proposed that the unfamiliar format of mixed case stimuli increases the attentional demands during reading, with these increased demands normally being modulated by the right parietal lobe. Here we test whether a similar pattern can be observed in patients with chronic unilateral lesions of the parietal lobe. We examine any effects of case mixing in relation to general effects of degradation brought about by contrast reduction, to assess if case mixing produces particular demands on attention over and above general effects of degradation.

This was investigated using three tasks: reading (mixed case vs. single case), gap detection (mixed case vs. single case), and word reading (low contrast vs. high contrast). The reading tasks required explicit reading of the words (reading the words aloud). The gap detection task provided a baseline measure of basic feature processing. In this feature-processing task participants were asked to detect a gap in the contour of one of the letters, which was present on half the trials. With the controls we demonstrate that the gap detection task was not intrinsically easier than the word reading task. If the patients are simply worse at visual processing on the contralesional side, then a lateralised deficit should occur in gap detection, equal to that found for word reading. On the other hand, if there is a selective demand for attention in reading beyond the level of feature encoding, and if this problem is increased for mixed case stimuli, then lateralised errors should be more pronounced in word reading than in gap detection, and they should be more pronounced for mixed case than for single case items. Furthermore, there should not be an increase in lateralised errors from general effects of degradation, produced by contrast reduction.

General Method

Participants

There were 8 patients, 5 with unilateral right hemisphere lesions and 3 with unilateral left hemisphere lesions. All the patients had damage affecting the posterior parietal lobe, though in some cases the lesion extended to adjacent regions (e.g., MP who had damage to superior temporal and inferior frontal damage in addition his parietal lesion). Seven had lesions to the inferior parietal lobe, and one (MH) with damage to the superior parietal lobe, along with a widening of sulci through posterior parietal cortex. Clinical details about the patients are presented in Table 1. All the patients presented with evidence of limitations in visual attention, manifesting visual extinction under brief presentation conditions[1]. Transcriptions of their MRI scans are

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[1] In a task requiring the report of two briefly presented letters, each centred 2 deg either left or right of fixation, all of the patients showed a selective reduction of at least 20% in reporting the contralesional letter when it was presented with an ipsilesional letter relative to when the contralesional stimuli was presented alone.

depicted in Figure 1. The study was carried out in accordance with the Declaration of Helsinki (1964), and all participants gave their informed consent to participate.

Table 1

The performance of the patients was compared to a group of ten controls (of whom 6 were male), with a mean age of 64.1 years (SD=5.2), for the two tasks (reading and gap detection) with mixed case words. For the contrast task, performance was compared to a group of eight controls (3 male), with a mean age of 66.3 years (SD=10.7).

Figure 1

Stimulus presentation

For the three tasks, stimuli were presented on a 17” monitor, at an approximate viewing distance of 70 cm, using E-Prime software (Psychology Software Tools, Pittsburg) ran on a Pentium 4 (1.8 GHz). The stimuli for all three tasks were generated using the same software used in Mayall et al. (2001), and were white on a dark-gray background (or light-gray on a dark-gray background for the low contrast stimuli). Luminance values were 27 cd/m² for low contrast stimuli, and 120 cd/m² for high contrast stimulus words, and 20 cd/m² for the background. All stimuli were presented in the centre of the screen, until the participant made a response, and were 3.1° visual angle wide. See Figure 2 for examples of the stimuli.

Figure 2

Stimuli

Each tasks using mixed case words used four lists of 50 six-letter words, with a mean frequency of occurrences per million (Kucera & Francis, 1967) of respectively 158, 154, 144, and 147. Two of these lists were assigned to each of the different conditions within a task (for a total of 100 words per condition), which were counterbalanced over participants, so that a participant would see each word once in the reading task, and once in the gap detection task. For the contrast reading task two lists of 50 letter words were used, with a mean frequency of 47 and 52 occurrences per million.

Procedure

Both the reading and the feature detection tasks using mixed case words consisted of 200 trials, the order of which was counterbalanced across participants. Half of the trials contained words in single case, and the other half of the words were presented in mIxEd-cAsE. For the gap-detection task, half of the stimulus words had a gap, which could occur in any of the six letters of the word (for a given stimulus word the letter that contained the gap was identical for all participants). The reading task using low contrast words consisted of 100 trials, of which half were high contrast, and half were low contrast words. The stimuli were generated using the software employed by Mayall et al. (2001). Low contrast stimuli were light gray on a dark grey background; high contrast stimuli were white on the same background. The trials were presented in a random order for the gap-detection experiment and in a semirandom order (randomised prior to the experiment to facilitate scoring for accuracy) for the reading tasks.

Every trial started with a 1s fixation cross in the centre of the screen, which was then replaced by the stimulus word. In the reading tasks, participants were asked to name the stimulus word as quickly and accurately as possible. In the gap detection task, the participant said yes or no, according to whether a gap was present or absent. Due to variability in the responses of some patients when a voice key was used, and due to the long RTs recorded in some cases, the response was registered by the experimenter using the mouse to record RTs and go on to the next trial (this procedure was used both in the reading tasks and in the gap detection task). The experimenter was blind to the trial type. For the reading tasks, the verbal response of the participant was noted manually. Though reaction times (RTs) were of interest, it should be noted that the main analysis focused on response accuracy and the presence of lateralised errors as an indicator of reduced attention on the contralesional side of space.

Scoring

Performance was scored on the basis of the position in the word where errors occurred. Each word was divided into 3 possible locations: for contralesional letters (the two leftmost letters for patients with a right hemisphere lesion, or the two rightmost letters for left hemisphere patients), for central letters (the two middle letters), and for ipsilesional letters (the two rightmost letters for right hemisphere patients and the two leftmost letters for left hemisphere patients). For normal controls, either the left or right was coded as contralesional on a random basis (this allows for a consistent terminology in the analyses). For the gap detection task, accuracy was based on the proportion of words where the gap was detected correctly, as a function of where the gap fell (trials with stimulus words that contained no gap were discarded for this analysis, and the gap appeared in either of the first two letters, the middle two letters, or the final two letters with equal probability). Accuracy in the reading tasks was coded using a similar system to Caramazza and Hillis (1990). For each letter of the word, an omission or substitution was scored as 1 error. Transposed letters were scored as 0.5 errors in each position. Since we amalgamated the scores for pairs of letters, we took for each position the average of the letter scores for the given location.

Results

Data for the three tasks (word reading (mixed case), gap detection, and word reading (low contrast)) were analyzed separately for both error- and RT-analyses. The error data for each task were subject to a three-way repeated measures ANOVA, with the following within-subjects factors: case/contrast (single or mixed case; high or low contrast), and position (contralesional, centre or ipsilesional). Participant group (patients or controls) was included as an additional between-subjects factor. The reaction time (RT) data were analysed using a two-way repeated measures ANOVA, with case/contrast as a within-subjects factor, and participant group as a between subjects factor. Position in the word was not used in this analysis as participants had a single RT-score for the word reading task.

Word reading (lower case versus mixed case)

Accuracy

The main effects of case (F(1,16)=27.76, p<.001), position (F(2,32)=3.76, p=.034), and group(F(1,16)=6.95, p=.018) were all significant. There were also significant interactions between case and group (F(1,16)=14.59, p=.002), case and position (F(2.32)=7.12, p=.003), and group and position (F(2.32)=3.89, p=.031). The three way-interaction between case, position and group was also significant (F(2,32)=6.53, p=.004). The reading task was then analysed for the two groups to assess this three-way interaction.

Control participants

For the control participants, there was a significant main effect of case (F(1,9)=6.7, p=.029), but not position (F<1). The interaction between case and position was also not significant (F<1). Control participants made more errors in reading mixed case words (see Figure 3).

Parietal patients

For the word reading task, there was a significant main effect of case (F(1,7)=18.05, p=.004), as well as a trend for an effect of position (F(2,14)=3.06, p=.079). The interaction between case and position was also significant (F(2,14)=5.54, p=.017). The patients made more errors when reading words presented in mixed case relative to single case. Furthermore, the tendency to make more errors in the contralesional field increased significantly with mixed case items (see Figure 3). For mixed case items there was a reliable effect of position (F(2,14)=4.15, p=.038). The effect of position was not reliable with single case words (F(2,14)=1.73, p=.212).

RTs

There was a main effect of group (F(1,16)=17.41, p<.001), as well as a trend for the main effect of case (F(1,16)=3.81, p=.069). The interaction between group and case was not significant (F(1,16)=2.45, p=.137). Control participants were on average 101 ms slower to read mixed case words (an increase of 9%), while parietal patients were on average 893 ms slower (an increase of 30%).

Figure 3

Gap detection

Accuracy

There was a main effect of group (F(1,16)=6.94, p=.018), as well as a trend for a main effect of case (F(1,16)=3.94, p=.065). There were no other significant effects. When looking at the two groups separately, the case effect (lower accuracy for mixed case words) was significant for the control participants (a difference of 1.5% in accuracy, F(1,9)=9.15, p=.014), but not for the patients (a difference of 2% but with high variance, F<1).

RTs

There were significant main effects for group (F(1,16)=53.96, p<.001), as well as case (F(1,16)=16.15, p=.001). The interaction between group and case was also significant. Both the control participants and the patients were slower to detect a gap in mixed case words (F(1,9)=30.47,p<.001), and F(1,7)=9.12, p=.019, respectively). The interaction shows that the size of the case effect was larger for the patients (an increase of 574 ms (or 22%), compared to 110 ms (or 6%) for the controls) (see Figure 4).

Figure 4

Word reading (high versus low contrast words)

Accuracy

There was a significant main effect of position (F(2,28)=3.69, p=.038), as well as a trend for a main effect of contrast (F(1,14)=3.37, p=.088). The main effect of group was not significant (F(1,14)=2.12, p=.168). There was also a trend for an interaction between group and position (F(2,28)=.052), which was further investigated by analysing the data for the controls and patients separately.

Control participants

There were no significant main effects, for either contrast (F(1,7)=1.27, p=.296) or position (F<1). The interaction was also not significant (F(2, 14)=1.96, p=.178).

Parietal patients

In the contrast reading task, the patients showed a trend for a main effect of position (F(1,7)=3.54, p=.057), with a tendency to make more errors on the contralesional side of words (see Figure 6). The main effect of contrast was not significant (F(2,14)=2.63, p=.149) and, crucially, neither was the interaction between position and contrast (F<1). The tendency to make more contralesional than ipsilesional errors was not affected by the manipulation of contrast.

RTs

There were main effects of contrast (F(1,14)=9.23, p=0.009) and group (F(1,14)=6.12, p=.027). The interaction between them was also significant (F(1,14)=7.92, p=.014), with the patients showing larger effects of contrast reduction (2s slower, or an increase of 78%, compared to only 79ms or 5% for control participants) (see Figure 5). The effect of contrast was significant for both patients (F(1,7)=8.57, p=.022) and controls (F(1,7)=15.98, p=.005).

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Figure 5
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Discussion

The main result is that the patients showed a lateralised deficit in errors when reading mixed case words, whilst showing no lateralisation (and fewer errors) when reading words in single case. A similar pattern was not found for the reading of low contrast words, where the tendency to make lateralised errors did not increase relative to when high contrast words were read. In addition, there was a reliable but relatively small effect of position on errors in a gap detection task performed on high contrast mixed and same-case stimuli, and accuracy on gap detection was not affected by the cases of the letters. For both the patients and the controls, RTs were slowed by case mixing, with the patients showing the bigger effect. However, for RTs, neither the effect of case mixing nor that of subject group varied across the two tasks.

The general patterns of the results, with neglect expressed in reading mixed case words but not words in single case, and with neglect being less affected by case in the gap detection task, or by contrast in the reading task, held for both the right and left hemisphere lesioned patients, and there was no evidence for different patterns of performance in these two groups. However only three patients with left sided lesions were compared to five patients with a right sided lesion, and it cannot be ruled out that such differences could have been detected with a larger sample size.

The fact that case mixing slowed RTs for both gap detection and reading may reflect some effect of case mixing on early visual processing – for example, due to masking of the features in lower case letters by their upper case neighbours (Besner & Johnston, 1989). The patients, however, differed qualitatively from the controls in showing greater numbers of errors in the mixed case reading task, and these errors were more lateralised than in the gap detection task. The controls performed similarly in the reading and gap detection tasks, so it cannot be argued that the gap detection task was simply easier or less affected by any masking that took place. Rather we suggest that there was greater lateralisation of errors because of the special attentional demands of reading, requiring high resolution processing of all the letters at a level beyond that of coding their feature (a level tapped by the gap detection task). The deficit the parietal patients have in attending to stimuli in contralesional space is exacerbated under conditions that demand greater levels of attention. However, it was not simply the case that there was greater lateralisation in word reading simply when the stimuli were degraded, since there was no increase in the lateralisation of errors when the words were degraded by contrast reduction. Instead we suggest that errors are particularly lateralised for mixed case items because case mixing uniquely demands attentional resources. One reason for this is that attention is recruited in order to compensate for the lack of holistic codes for familiar word shapes when words are in mixed case (in contrast to when the words are shown in both high and low contrast single case). Due to the lateralised lesion to attentional processes modulated by posterior cortex, the patients then make more reading errors on the contralesional side. However, the ability to detect basic visual cues, such as the presence of a gap in a contour, remains relatively preserved in terms of accuracy of performance, and unaffected by the lesion or by case mixing. It is unlikely that this effect is because of differences in the nature of the task (i.e. reading vs. gap detection), as errors to the contralesional side of space also did not increase when the patients were asked to read low contrast words.

We should be wary in concluding from these results that there is no relationship between attention and low-level feature processing. For example, a study by Huang and Dobkins (2005) showed reduced contrast sensitivity when participants were asked to engage in contrast discrimination under dual task conditions. These attentional effects were most pronounced close to the contrast threshold for successful detection of the visual stimuli, and the authors found the effects to primarily affect early areas in the visual system. Studies such as this indicate that attention can influence low-level feature processing, but they do not indicate that attention is necessarily recruited when low level feature processing demands increase, under conditions of contrast reduction. At least in the present study, where the stimuli remained well above visibility threshold, the contrast reduction did not strain the attentional resources of the parietal patients to the extent that case mixing did (generating lateralized identification errors). This was not because the contrast reduction manipulation was ineffective, and reading RTs for controls were slowed to a similar degree by case mixing (101ms) and contrast reduction (79ms, F<1). We suggest, instead, that case mixing produces a demand on attentional processing beyond the general effects of reduced visibility and task difficulty. Our neuropsychological results here concur with data from PET, TMS and case studies of patients with bilateral parietal damage, where there is no evidence for increased involvement of the parietal lobe (and by implication, visual attention) in the reading of low contrast words (Braet & Humphreys, 2006; Mayall et al., 2001).

The findings on the selective effects of parietal damage on reading mixed case words support prior evidence from rTMS (Braet & Humphreys, 2006) and from functional brain imaging (Mayall et al., 2001). These studies have shown that there is increased activation of parietal cortex when mixed case words are read, whilst altering parietal activity, through rTMS, selectively disrupts mixed case stimuli. Interestingly, in one PET study of case mixing effects, Mayall et al. reported increased parietal activation with mixed case stimuli in a gap detection task as well as in word reading. This might be because there is some implicit processing of the words by young skilled readers, even when the task only required gap detection. However, we found that there was no increase in the errors made by parietal patients in gap detection when words were presented in mixed case. Given that lateralised errors emerged when mixed case words were identified, we conclude that the patients did not identify the letters in the gap detection task here.

Though we have demonstrated a specific effect of parietal damage on reading mixed case items, the precise mechanisms involved remain unclear. For example, it could be that mixed case stimuli tend to induce a serial reading strategy, and the patients are impaired at scanning attentional serially across the items. Alternatively, case mixing may place more demands on the parallel application of spatial attention across the words, and the patients may be impaired at attending in parallel across space. These questions require further research to be resolved.

In sum, the present data indicate that parietal damage exerts a selective, lateralised impairment on the identification of mixed case words, and, while the basic processing of lateralised features is also affected (e.g., in the gap detection task), the effects are reliably less pronounced than when identification is required. In addition, the reading of low contrast words did not reveal a similar increase in lateralised errors. The evidence is consistent with mixed case stimuli increasing the demands on spatial attention for letter identification, and with parietal damage disrupting attention to the contralesional side of space.

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Table 1:Age, sex, aetiology, location of the lesion, and neurological sings of the 8 patients who served as participants.

Figure 1: Lesion reconstructions of the patients

Figure 2: Examples of the stimulus words

Figure 3: Word reading task: single case versus mixed case

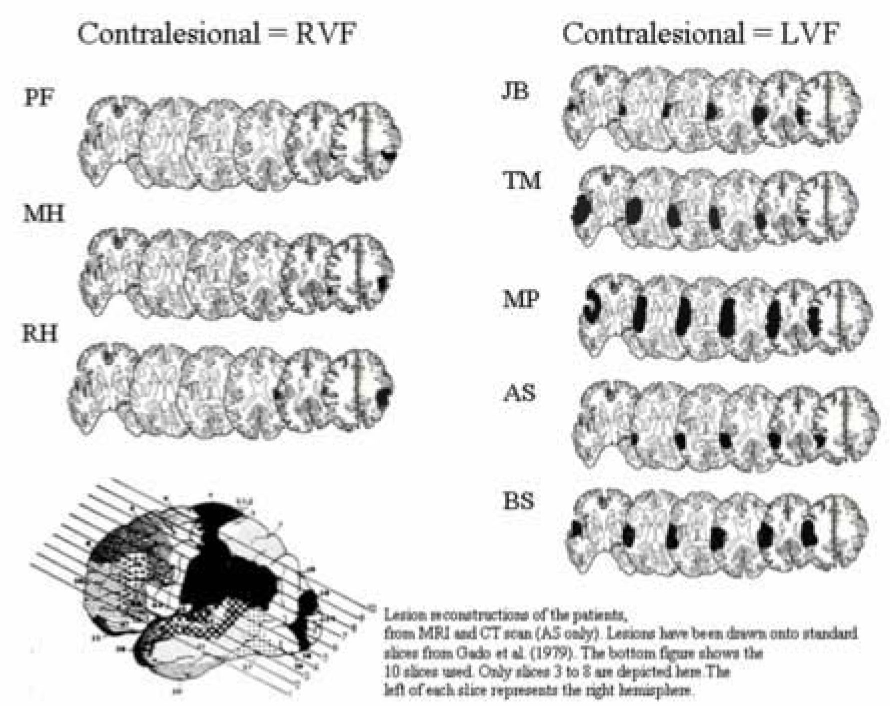
Figure 4: Gap detection task: single case versus mixed case

Figure 5: Word reading task: high versus low contrast

Table

Patient	Age/Sex	Aetiology	Location	Neurological signs
JB	63/F	Stroke	Right parietal (angular gyrus, supramarginal gyrus), superior temporal gyrus	Extinction, left neglect dyslexia
PF	57/F	Stroke	Left inferior parietal (angular gyrus, supramarginal gyrus), superior temporal gyrus	Extinction, dysgraphia
MH	48/M	Anoxia	Left inferior parietal, angular gyrus	Extinction, mislocalisation
RH	70/M	Stroke	Left parietal (angular and supramarginal gyri), superior temporal gyrus	Anomia, extinction
MP	54/M	Aneurysm	Right parietal (angular gyrus, supramarginal gyrus), inferior frontal and superior temporal gyrus	Left neglect and extinction, hemiplegia
TM	69/M	Stroke	Right temporal lobe, anterior parietal lobe including the angular gyrus	Left hemiplegia, neglect and extinction
AS	70/M	Stroke	Right inferior parietal	Mild left hemiplegia, extinction
BS	63/M	Stroke	Right parietal (angular and supramarginal gyrus), superior temporal gyrus	Left hemiplegia, neglect

Figure One



Lesion reconstructions of the patients, from MRI and CT scan (AS only). Lesions have been drawn onto standard slices from Gado et al. (1979). The bottom figure shows the 10 slices used. Only slices 3 to 8 are depicted here. The left of each slice represents the right hemisphere.

Figure Two

Figure Three

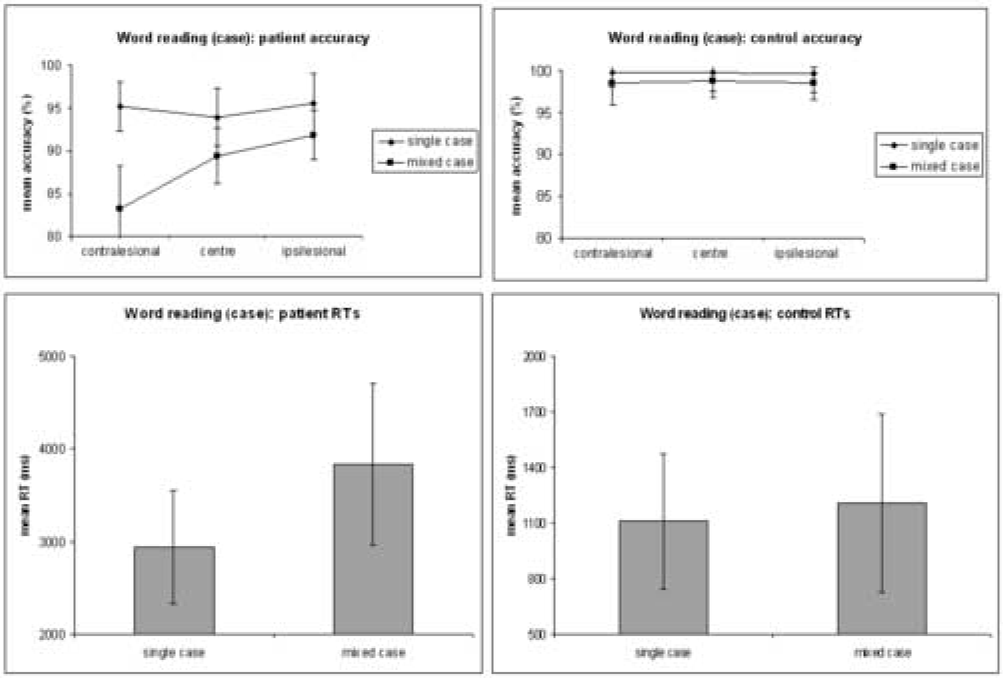


Figure Four

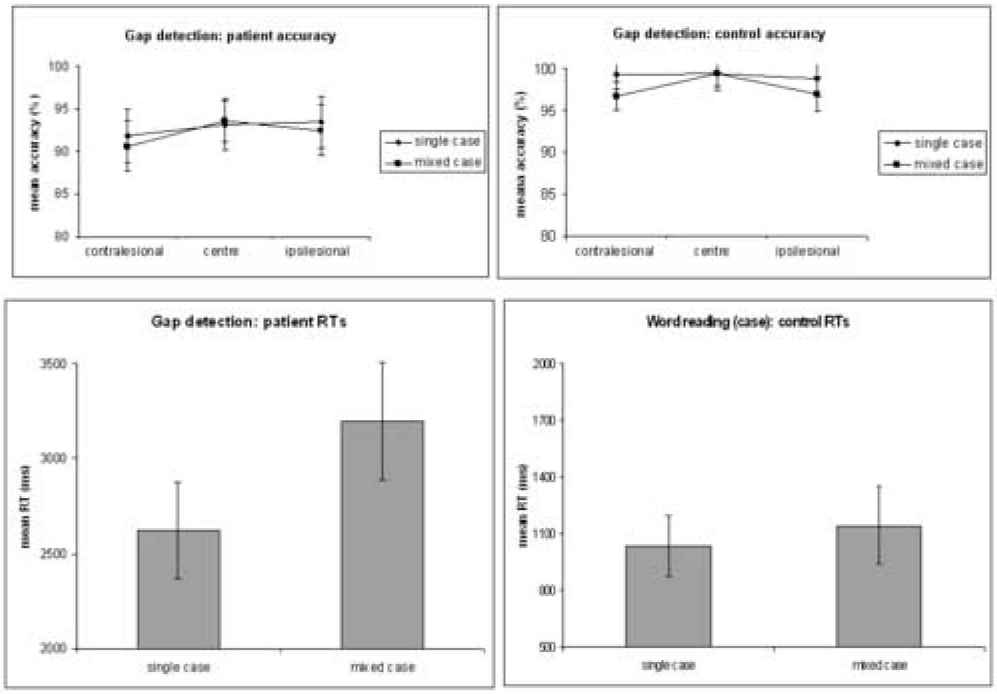
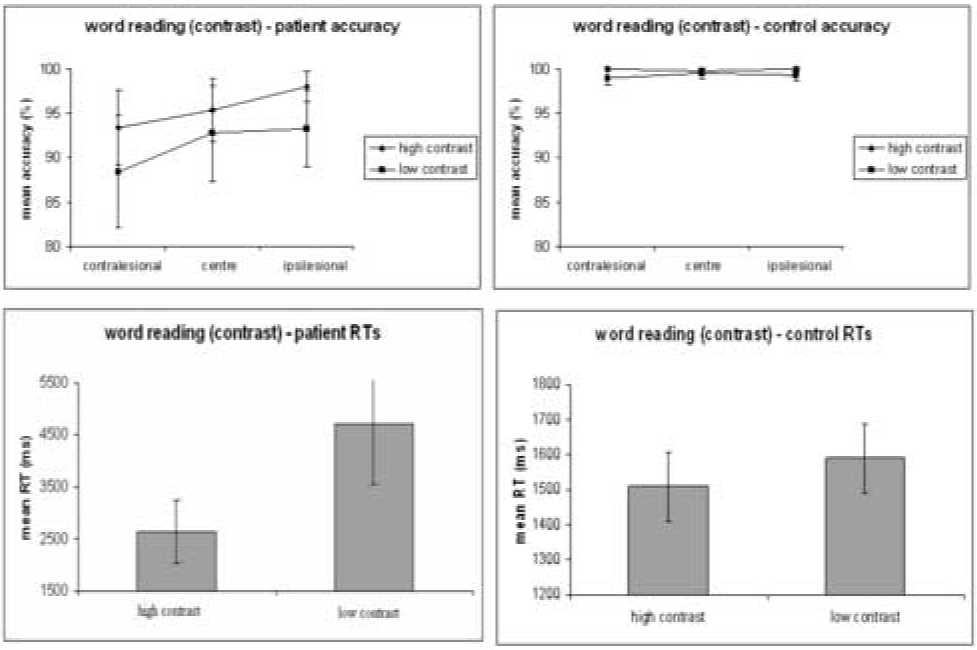

Gap detection: patient accuracy
mean accuracy (%)
100
95
90
85
80
contralesional
centre
ipsilesional
single case
mixed case
Gap detection: control accuracy
mean accuracy (%)
100
95
90
85
80
contralesional
centre
ipsilesional
single case
mixed case
Gap detection: patient RTs
mean RT (ms)
3500
3000
2500
2000
single case
mixed case
Word reading (case): control RTs
mean RT (ms)
2000
1700
1400
1100
800
500
single case
mixed case

Figure Five



word reading (contrast) - patient accuracy
mean accuracy (%)
100
95
90
85
80
contralesional
centre
ipsilesional
high contrast
low contrast
word reading (contrast) - control accuracy
mean accuracy (%)
100
95
90
85
80
contralesional
centre
ipsilesional
high contrast
low contrast
word reading (contrast) - patient RTs
mean RT (ms)
5500
4500
3500
2500
1500
high contrast
low contrast
word reading (contrast) - control RTs
mean RT (ms)
1800
1700
1600
1500
1400
1300
1200
high contrast
low contrast