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THE EFFECTS OF WORD LENGTH AND EMOTIONALITY ON HEMISPHERIC CONTRIBUTION TO LEXICAL DECISION

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Abstract—The effects of emotionality and length on lateralized lexical decision of abstract nouns were investigated in 41 normal and three commissurotomized subjects. Emotionality had the same effect in both visual fields: Emotional words were responded to more accurately than neutral words. Length had different effects in the two visual fields: The accuracy of lexical decisions in the left visual field was selectively higher for four-letter words and in the right visual field it was selectively lower for six-letter words. The latency of lexical decisions revealed equivalent length effects in both visual fields. Of the commissurotomy patients, only L.B.'s left hemisphere performed above chance and revealed a length effect. Length effects are interpreted to reflect a change from a parallel graphemic analysis to a sequential parsing strategy when resources are limited. Such a change can occur for words or nonwords in either visual hemifield.

INTRODUCTION

THE MAJORITY of studies using lateralized lexical decision tasks find an overall right visual field advantage (RVFA), which is interpreted as a sign of left hemisphere (LH) specialization for this linguistic task (see [2] for review). Performance with stimuli presented to the left visual field (LVF) has been shown to vary as a function of several psycholinguistic variables, and this has been taken to reflect right hemisphere (RH) involvement in processing at least one level of each variable. Thus, the RH may be able to process words high in imageability [13, 6], concrete nouns [1, 4, 5, 8, 20], highly frequent words [12], highly emotional words [10] and short (three- and four-letter) words [1, 4, 5].

The hypothesis that the RH is functioning as more than just a relay station for LVF stimuli is based on the interpretation of a particular statistical data pattern: an interaction between the specific stimulus characteristic (e.g. concreteness, emotionality) and visual field of presentation [15, 21, 22]. This type of pattern, termed a "processing dissociation" [20], is illustrated in Fig. 1. The interpretation rests on the reasoning that the RH must be doing something that results in a large difference between level 1 and level 2 stimuli in the LVF, when this difference does not occur in the RVF. An alternative interpretation is that stimuli on level 1 are "better" transferred across the corpus callosum, losing less time and being less degraded, resulting in better performance than level 2 stimuli.

It is possible to distinguish between these interpretations by examining the character of the independent variable that interacts with the visual field of presentation. If what is being varied is a physical characteristic of the stimuli, like size or brightness, then the callosal relay interpretation is consistent with the data (although it may be ruled out by other patterns). This is because these are characteristics which may affect the efficiency of callosal transfer. However, if what is being varied is some semantic characteristic of the stimuli, like the

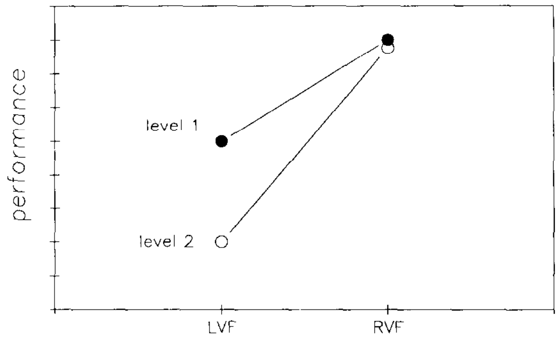

Fig. 1. Processing dissociation between visual field of presentation and a stimulus characteristic.

majority of the psycholinguistic variables listed above, then the callosal relay interpretation cannot be correct. Otherwise, the RH would have to somehow distinguish between the levels, for example, between concrete and abstract words, in order to preferentially transfer the concrete words.

Several studies have varied both types of stimulus characteristics. ELLIS *et al.* [7], BUB [4], BUB and LEWINE [5], and BRUYER and JANLIN [1] all varied both a physical (string length) and a semantic (concreteness) component of their stimuli in lexical decision and naming tasks. Ellis *et al.* found an effect of length for both concrete and abstract words in the LVF, and no effect of length in the RVF. For nonwords, they report an effect of length in both visual fields (Exp. 2). Thus, they found a laterality effect of the physical component of the stimuli, not of the semantic component. On the basis of these latency data, and earlier accuracy data from a naming task [18], they propose two modes of early visual processing of letter strings in the two hemispheres. Mode A is a parallel processing of all the items in the string. This is a fast process which is not sensitive to string length and is available only to the LH for words in a conventional format. Mode B is a sequential process involving transfer of the letters in the string into an abstract graphemic storage prior to lexical access. This mode of processing is the only one available to the RH, and is used by the LH to process nonwords. Because they did not find an interaction with the semantic variable, Ellis *et al.* lean towards an interpretation of the processing dissociation between string length and visual field that includes both direct access and callosal relay components: "In our view LVF words probably achieve lexical access via abstract graphemic storage and the left hemisphere lexicon, but if there is any form of right hemisphere lexicon our data imply that that too is only accessed via abstract graphemic storage in the mode B manner" (p. 270).

The other three studies which have used the same two variables [1, 4, 5] do not report data supporting Ellis *et al.*'s interpretation. The predictions of the interpretation are that performance on all stimuli in the LVF will show length effects, and that in the RVF, nonwords will result in length effects, but words will not. BUB [4] and BRUYER and JANLIN [1] looked at the effects of string length and concreteness on a lateralized naming task. Both studies report length effects in the LVF for abstract, but not for concrete words. BUB and LEWINE [5] used a lexical decision task and found much stronger length effects in latency scores for abstract words than for concrete words in the LVF, and no effects of length in the RVF. Thus, these studies find that the effects of word length (the physical variable) are dependent on word concreteness (the semantic variable) (see Table 4 for a summary of the findings in the various studies). The authors conclude that the RH is processing short concrete words in a manner not dependent on length (e.g. not sequentially in the mode B manner).

Additional problems for the interpretation proposed by Ellis *et al.* arise in the patterns of responses to nonwords. Bruyer and Janlin do find length effects in both visual fields for naming nonwords. However, Bub and Lewine do not. In fact, Bub and Lewine do not find a visual field advantage for latency of correctly rejecting nonwords. This processing dissociation between "wordness" and visual field has been reported previously by our group [8, 14]. Thus, in spite of the intuitive appeal and elegance of the interpretation proposed by Ellis *et al.*, the cumulative data do not support it in its present form.

These disparate results suggest that word length may interact in complex ways with word concreteness. Ellis *et al.*'s results with words are compatible with a direct access model, where the RH does at least initial processing of both concrete and abstract words presented to the LVF. In this case, the length effect is interpreted to reflect a visual parsing process (transfer into abstract graphemic storage). Bub and Lewine's findings are compatible with a model where concrete words are processed in a direct access manner, and abstract words are callosally transferred from the RH to the LH for processing. In this case, the length effect is interpreted to reflect a callosal relay process. In the present experiment we looked at the interactive effects of a different semantic component, emotionality, and stimulus length. This is interesting for two reasons. First, by controlling for concreteness (all of our stimuli are abstract words), we were able to see if emotionality as a semantic component interacts with word length and visual field of presentation in ways similar to the findings with concreteness. Second, clinical studies of brain damaged individuals have suggested that the RH is involved in the processing of emotional stimuli. With normal subjects, Graves *et al.* [10] found an effect of the emotionality of the stimulus on the accuracy of the responses to LVF stimuli (where emotional words resulted in more accurate scores than neutral words), but not to RVF stimuli. They also varied the imageability and frequency of the stimuli and found that for male subjects, emotionality was the only relevant factor in responses to LVF stimuli. All of their stimuli were four letters long. Thus, like concreteness, emotionality has been found to attentuate RH incompetence in lexical decision. In this study we tested whether high emotionality and short length improve the relative right hemisphere incompetence in making decisions about abstract words.

Another converging source of evidence for differential hemispheric capabilities is the pattern of responses elicited from commissurotomized subjects. In these cases, responses to LVF stimuli arise only from processing in the RH. Thus, if the disconnected RH of these subjects can respond to LVF stimuli, then the strong direct access interpretation of the processing dissociation with normal subjects is supported. If the disconnected RH cannot perform the task, then it may be the case that the normal RH is contributing to the decision process, but it must still rely on LH abilities (this is not possible for the split brain subjects).

We used a manual lexical decision task with normal subjects and three commisurotomized subjects, measuring the accuracy and latency of responses to both words and nonwords. As all of the stimuli are abstract words, we expect to find an effect of word length in the LVF, but not in the RVF (in a replication of the previous studies reviewed above). The effects of emotionality in conjuction with word length and visual field of presentation are of particular interest. Both Bub and Lewine [5] and Bruyer and Janlin [1] found effects of length in the LVF only for abstract words. They concluded that the RH may have the capability to process short concrete words, as the effect of concreteness was dependent on word length in the LVF. If the RH can also process emotional words, then the effects of emotionality should also be dependent on word length, and this should interact with the visual field of presentation. The responses of the disconnected RH, in turn, allow us to directly tap exclusive RH abilities for our stimuli.

METHOD

Subjects

The normal subjects were 17 male and 24 female introductory psychology students at the University of California, Los Angeles. All of the subjects were strongly right-handed (as assessed by a handedness inventory), had no left-handed relatives, and had not spoken or understood any language except English until at least the age of eight. Subjects were asked about their neurological history, and all those who had suffered from any neurological disease or ever had episodes of unconsciousness were excluded. The subjects received course credit for their participation.

Three commissurotomized subjects from the California series were also tested, R.Y., N.G. and L.B. Their case histories are summarized in Table 1.

Materials and apparatus

Emotionality ratings for 150 words were gathered from 176 undergraduates. The ratings were on a 9-point scale, with 1 being negative, 5 being neutral and 9 being positive. Words with mean and median ratings less than 3 and greater than 7 were chosen as emotional, while words with mean and median ratings between 4 and 6 were chosen as neutral.

The stimuli were 64 words and 64 pronounceable orthographically regular nonwords that were matched for length. The words were chosen such that 16 were four letters long, 24 were five letters long and 24 were six letters long. All of the words had a written frequency of more than 35 per million as nouns and less than 15 per million as verbs [9]. All of the words were abstract in the sense that none named concrete objects. The stimuli are listed in the appendix.

There were eight emotional and eight neutral four letter words, 12 emotional and 12 neutral five letter words, and 12 emotional and 12 neutral six letter words. Each stimulus string appeared only once during the experiment. Order and visual field of presentation were randomly determined for each subject. Thus, each subject participated in 128 experimental trials, and all stimuli appeared in both visual fields across subjects.

The stimuli were presented on a TSD monitor (model NDC-15) by a DEC LSI-11/23 minicomputer, which also collected the responses. The word were 1 cm in height, with the longest being 3 cm in length. The stimuli were viewed at a distance of 50 cm and offset from the fixation point by 2° of visual angle, such that they subtended from 2° to 5° of visual angle.

Procedure

The subjects were seated with their chin in a chin rest that held their eyes at a fixed distance from the center of the screen. Subjects responded by pressing one of two side-by-side buttons labelled YES and NO on a response box that was centered directly in front of them. For half the trials, the normal subjects responded with their left hand, and for half the trials with their right hand. The order of hand blocks was counterbalanced across subjects. In addition, the direction of YES and NO responses was **controlled** across hands, so that for both hands the responses required the same movement of the index finger.

The task was explained to the subjects who were told that maintaining fixation was extremely important and that it increases accuracy. The subjects were given 32 practice trials, 16 with each hand. During the practice trials the subjects were given immediate feedback as to whether their response had been correct or not. No feedback was given during the 128 experimental trials.

Presentation of each trial was as follows: a tone of 1000 Hz was heard for 100 msec and the fixation point then appeared for 500 msec. The stimulus appeared either in the right or the left visual half field for 80 msec. The subject had 3 sec in which to respond, and after an additional 2 sec interval, the next trial began.

The procedure for the split brain subjects was slightly different. The stimuli were exposed for 150 msec instead of 80. Each trial was initiated by the experimenter and the intertrial intervals were longer for the patients than for the normal subjects. In addition, each commissurotomized subject responded to stimuli in a given visual field with the homolateral hand, that is, stimuli in the RVF were responded to with the right hand and stimuli in the LVF were responded to with the left hand. These subjects saw all of the stimuli twice, once in each visual field. Half of the words in each category appeared first in the LVF and half appeared first in the RVF.

Table 1. Summary of case histories

Patient	Sex	Reason for surgery	Surgery	Age at surgery	Years postop. at testing (1983)	Age at onset of symptoms	IO History	
							preop.	postop.
N.G.	F	Intractable epilepsy	Complete cerebral commissurotomy: single-stage midline section of anterior commissure, corpus callosum (and presumably psalterium), massa intermedia and right fornix. Surgical approach by retraction of the right hemisphere	30	20	18	Wechsler–Bellevue 76 (79, 74) at age 30	WAIS 77 (83, 71) at age 35
L.B.	M	Intractable epilepsy	As above, but massa intermedia was not visualized	13	18	3:6	WISC 113 (119, 108) at age 13	WAIS 106 (110, 100) at age 16
R.Y.	M	Intractable epilepsy	As above. (Normal cerebral development until age 13)	43	17	17		WAIS 90 (99, 79) at age 45

RESULTS

Commissurotomized subjects

Table 2 presents the hit and correct rejection performance of the commissurotimized subjects. It can be seen that none of the disconnected RHs reveal effects of length or of emotionality, or for that matter, better than chance performance ($d' > 1$). The sensitivity scores show that only L.B.'s left hemisphere reveals a length effect, responding better to four than to five than to six letter stimuli. These data provide no support for the strong direct access interpretation of the processing dissociation in the results of the normal subjects. The disconnected RH cannot perform lexical decisions on these abstract words even when they are short and emotional.

Table 2. Performance of three commissurotomized subjects

	Right hemisphere			Left hemisphere		
	emotional	neutral	nonwords	emotional	neutral	nonwords
L.B.						
Four	5/8*	4/8	10/16	8/8*	7/8*	13/16*
Five	7/12	7/10	17/24*	10/11*	9/12*	17/23*
Six	8/11	5/10	13/23	7/12	8/10*	15/25
N.G.						
Four	4/8	7/8*	8/16	6/8	6/8	10/16
Five	8/12	7/12	10/24	10/11*	8/11	17/24*
Six	6/12	6/12	8/23	11/12*	8/12	16/25
R.Y.						
Four	6/8	1/8	4/16	6/8	4/8	13/16*
Five	11/12*	9/11*	9/24	5/12	4/12	17/24*
Six	9/12*	10/12*	9/23	3/12	2/12	21/25*

Sensitivity (d')	L.B.		N.G.		R.Y.	
	RH	LH	RH	LH	RH	LH
Four	0.69	2.43	0.5	1.0	−0.82	1.21
Five	0.92	1.56	0.1	1.47	0.82	0.22
Six	0.46	0.72	0.52	0.18	−0.38	1.16

*Indicates above chance performance, $P < 0.05$.

Normal subjects

Separate analyses were performed on the latency and the accuracy scores. The mean accuracies and latencies (summed over gender) are presented in Table 3.†

Latency

An analysis of variance for unequal groups was performed with gender as a between-group factor, and string type (emotional words, neutral words and nonwords), visual field and string length (four, five and six letters) as within-group factors. The analysis revealed a significant effect of gender [$F(1, 39) = 5.4, P = 0.024$], with males responding faster than females (841 vs 959 msec). Gender did not interact with any other factor, so that for

†An item analysis using valence of emotion (positive or negative) revealed no effects of this variable in either measure. Therefore, valence of emotion was ignored.

Table 3. Mean accuracies and latencies in the stimulus type by visual field by string length cells

	Latency (msec)					
	Words				Nonwords	
	Emotional		Neutral			
	LVF	RVF	LVF	RVF	LVF	RVF
Four	820	759	890	775	1031	983
Five	876	786	934	786	1056	982
Six	906	786	895	848	1061	1026
	Accuracy					
	Words				Nonwords	
	Emotional		Neutral			
	LVF	RVF	LVF	RVF	LVF	RVF
Four	88	95	77	83.5	67.8	78.5
Five	71.8	88.5	66	86.2	67.8	74
Six	72.3	82.4	67.4	78.6	67.6	76.6

subsequent analyses data from males and females were pooled. There was a main effect of string type [$F(2, 78) = 58.36$, $P < 0.001$], with words being responded to faster than nonwords, (words = 838 msec, nonwords = 1023 msec). We found a significant right visual field advantage [$F(1, 39) = 32.37$, $P < 0.001$] (LVF = 941 msec, RVF = 859 msec) and a significant main effect of string length [$F(2, 78) = 6.2$, $P = 0.004$] (four letters = 876 msec, five = 903 msec, six = 920 msec). An examination of word stimuli alone revealed a significant effect of emotionality [$F(1, 39) = 7.29$, $P = 0.01$] (emotional words = 822 msec, neutral words = 855 msec). No higher order interactions approached significance. The patterns for words (summed over emotional category) and nonwords are shown in Fig. 2.

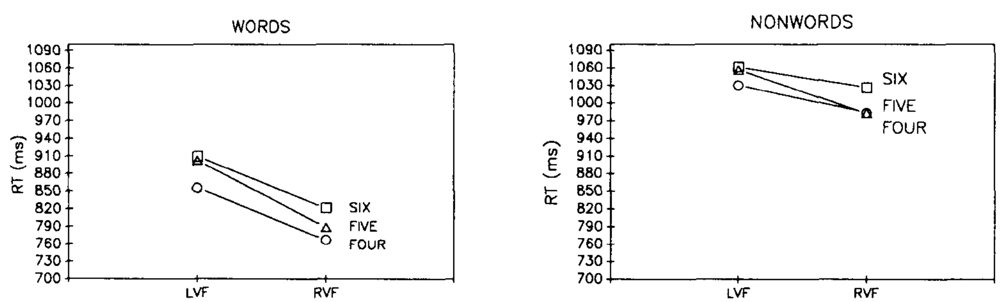

Fig. 2. The effects of string length on response latencies to words and nonwords in the left and right visual fields.

Accuracy

An analysis of variance was performed on the percentage of hits (for words) and correct rejections (for nonwords) in each condition. Gender of subject was a between-group variable and visual field (LVF, RVF), length (four, five and six letter stimuli) and word type (emotional, neutral, nonword) were within-group variables.

No main effects or interactions with gender were found, so data from males and females were pooled. The analysis revealed a significant effect of stimulus type [$F(2, 78) = 14.15$, $P < 0.001$] (emotional words = 83%, neutral words = 76.4%, nonwords = 72.1%). There was a significant effect of visual field [$F(1, 39)=76.02$, $P<0.001$] with the RVF resulting in 82.6% correct and the LVF in 71.7% correct. The main effect of length was significant [$F(2, 78)=14.21$, $P<0.001$] (four letters = 81.6%, five letters = 75.7% and six letters = 74.1%).

The interaction of interest, visual field by length by word type was not significant when emotional and neutral words were tabulated separately ($P=0.1$). However, when responses to emotional and neutral words were pooled, the interaction of visual field, length and word type (word vs nonword) was significant [$F(2, 78)=3.6$, $P=0.03$]. Figure 3 illustrates the pattern of responses in these cells.

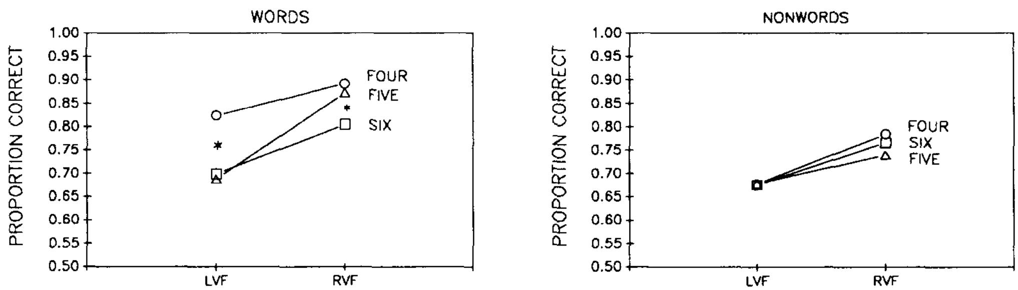

Fig. 3. The effects of string length on accuracy to words and nonwords in the left and right visual fields. * = Difference significant at the 0.001 level.

Subsequent planned comparisons revealed a significant visual field by length interaction for words [$F(2, 78)=5.128$, $P=0.008$] but not for nonwords ($P>0.5$). For words in the LVF, hit rates for four letter words were significantly higher than for five and six letter words [$F(1, 39)=18.56$, $P<0.001$]. In the RVF, hit rates for both four and five letter words were significantly better than for six letter words [$F(1, 39)=16.91$, $P<0.001$]. For nonwords there was a significant RVFA [$F(1, 39)=18.9$, $P<0.001$] and no effect of length ($P>0.5$).

DISCUSSION

We did not find a processing dissociation based on the semantic characteristic of our stimuli (the emotionality variable). Emotionality had the same effect across the visual fields, with emotional words being responded to faster and more accurately than neutral words. Emotionality did not interact with the length of the stimuli as had been reported previously about concreteness.

Our findings about the effects of stimulus string length reveal a complex pattern. The latency scores for words do not replicate previous studies. Unlike ELLIS *et al.* [7] and BUB and LEWINE [5], we do not find a processing dissociation between string length and visual field of presentation: the main effect of length occurs over both visual fields. For nonwords, our latency scores do replicate those reported by Ellis *et al.*, where there are length effects in both visual fields, but not of Bub and Lewine, who found no effects of length on the latency of correct rejection of nonwords in a lexical decision task.

Our findings with performance accuracy do reveal the expected interaction between string length and visual field for words. However, unlike previous studies, we find length effects in the RVF as well. For nonwords, our accuracy scores reveal no effects of length together with an overall RVFA.

These patterns do not conform to the predictions of the interpretation presented by Ellis *et al.* Their account predicts no effects of length for words in the RVF. In addition, we found a dissociation of patterns in latency and accuracy for nonwords, although its implications are not clear. The discrepancies between our findings and previous studies for words and nonwords are discussed separately below. The results of previous studies, together with our results are summarized in Table 4.

Table 4. Summary of results from studies manipulating semantic and physical components of the stimuli. + indicates a significant effect of stimulus length, − indicates no effect of stimulus length

Study	Concrete words LVF	Concrete words RVF	Abstract words LVF	Abstract words RVF	Nonwords LVF	Nonwords RVF	Measure
Ellis *et al.* (lexical decision)	+	−	+	−	+	+	RT
Bub and Lewine (lexical decision)	−	−	+	−	−	−	RT
Bruyer and Janlin (naming)	−	−	+	−	+	+	ACC
Young and Ellis (naming)	+	−	+	−			ACC
	Emotional words LVF	**Emotional words RVF**	**Neutral words LVF**	**Neutral words RVF**	**Nonwords LVF**	**Nonwords RVF**	
Eviatar and Zaidel	+	+	+	+	−	−	ACC
	+	+	+	+	+	+	RT

Discrepancies for words

The most interesting discrepancy between our findings and previous research is our finding of an effect of word length in the RVF, for words that were presented directly to the LH. It is interesting to note that L.B.'s sensitivity scores for the LH also suggest an effect of word length. We hypothesize that these discrepancies result from methodological differences between the studies, which have implications to how the task was performed by the subjects. We rely here on the distinction proposed by NORMAN and BOBROW [16] between resource and data limited processes. Figure 4 presents three hypothetical performance curves for four, five and six letter words in the RVF.

The amount of resources needed to perform the task is shown on the x-axis, and a measure of performance is on the y-axis. Norman and Bobrow distinguish between the part of the curve that has a measurable slope and the asymptote. The section in which performance level rises as more resources are allocated to the task is defined as "resource limited". The section in which the function is at asymptote is defined as "data limited", because the allocation of additional resources will not improve performance. Norman and Bobrow propose that speed–accuracy trade-offs will only be found where tasks are resource limited. Both Ellis *et al.* and Bub and Lewine used relatively long stimulus exposure durations (180 msec and 150 msec), and report very low error rates. This suggests that there was no speed–accuracy trade-off. In other words, the lexical decision task was data limited for the LH. The same may be true about YOUNG and ELLIS's [18] Exp. 2. There they lowered overall naming performance by using short stimulus exposure times and a *mask*, thus creating a data limited condition. It may be, as Fig. 4 illustrates, that in the absence of data limitation (i.e. when

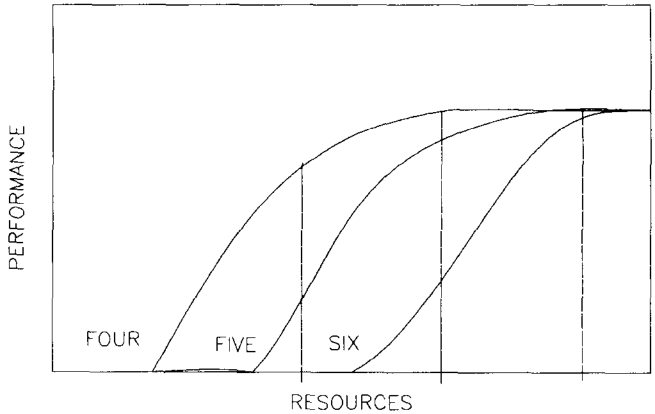

Fig. 4. Hypothetical performance curves for four, five and six letter words in the left hemisphere. Tapping performance patterns before the curves asymptote reveals length effects in the RVF. Tapping performance patterns after the curves asymptote reveals no perceptible length effects.

speed–accuracy trade-offs occur), the LH does indeed require more resources to process longer words than shorter words. By using a shorter stimulus exposure duration and abstract words, we may have limited the amount of resources available to the LH to process our stimuli, which allowed us to see differences in the time taken to process words of different lengths in the RVF.

The hypothesis that ours was a resource limited task is supported by the accuracy data of our normal subjects, where we found length effects in both visual fields. However, the strking result there is the finding of a double processing dissociation. Performance seems to break down at different points in the two visual fields: in the LVF the task becomes difficult when words are longer than four letters, and in the RVF performance falls when words are longer than five letters. A callosal relay interpretation of the pattern in the LVF could be the following: four letter words result in better performance than longer words because they are better transferred across the corpus callosum, while longer words are degraded to such an extent that subjects are performing near chance. The implication of this hypothesis is that there are floor effects for five and six letter words in the LVF. We tested this by looking at the variances of performance accuracy in these cells. If performance is truly at floor, then the variance of the distributions in those cells should be smaller than in cells where performance level is high. The variances are shown in Table 5. It can be seen that this does not occur. It therefore appears that we are not seeing a floor effect in responses.

Table 5. Variance (in percentage points) of hit rates of four, five and six letter words in the two visual fields

	LVF	RVF
Four	17	19
Five	24	11
Six	30	17

Together with the latency data, these findings suggest that we are sampling from points on the functions where processing is resource limited. This allowed us to see length effects in both visual fields, and may indicate shifts in strategies at different points in the two visual fields.

The acuity hypothesis

An alternative account of length effects has been raised by SCHWARTZ *et al.* [17], suggesting that length effects appear in the LVF more than in the RVF because the allegedly more informative initial letters of the words are closer to the fovea in RVF presentation. YOUNG and ELLIS [18, 19] have tested this hypothesis by equating the placement of initial letters in the LVF, and still found length effects. They concluded that length effects are due to characterisitics of processing, not loss of important initial letter information in the LVF.

We have tested the acuity hypothesis also, in a different way. We reasoned that informativeness of letter sequences is operationalized in how much they limit the identification of a word. In a lexical decision task, a misperceived word can result in two outcomes: it can be categorized as a nonword, or as a different word. Thus, words in which the initial letters can be misperceived to form a large number of other words would result in more correct responses with degradation than words for which this is not true. We operationalized this construct as a redundancy index, and for each of our stimuli we calculated the number of other words that can be formed when the first two or the last two letters are changed. If the acuity hypothesis is correct, the predictions are the following: When changing the first two letters of the word results in many other words, the difference between left and right visual field presentation should be small, because even though the first two letters were not well perceived in the LVF, subjects may still categorize the stimulus correctly as a word. The opposite is true if the last two letters are more redundant than the first two—misperceptions of the last letters in the RVF should also result in more word than nonword categorizations.

We divided our stimuli into three categories: words in which the first two letters are more redundant than the last two (F > L), words for which the opposite is true (F < L), and words for which these changes result in an equal number of other words (F = L). We then performed an item analysis on the accuracy for these stimuli with length, emotionality and redundancy index as between-group variables, and visual field of presentation as a within-group variables (each word appeared in both visual fields across subjects). There was no difference in the distribution of the three redundancy categories between emotional and neutral words. The lateral differences between accuracy scores (accuracy in RVF – accuracy in LVF) in each redundancy by word length category are presented in Table 6. The interaction of redundancy index and visual field was not significant ($P > 0.33$), nor was this effect significant when length was taken into account ($P > 0.5$). Thus, the informativeness of the initial and final letters in our stimuli was not the cause of the length effects in either visual field. These findings replicate those reported by BRYDEN *et al.* [3].

Discrepancies for nonwords

Across studies, nonwords resulted in every possible combination of effects. We and ELLIS *et al.* [7] found an effect of length on latency of responses in a lexical decision task in both visual fields. BRUYER and JANLIN [1] found the same pattern in accuracy scores in a naming task. BUB and LEWINE [5] did not find length effects for their nonwords in either visual field, nor did they find a visual field advantage in latency scores. We do find a right visual field

Table 6. Differences between percentage accuracy scores in the left and right visual fields for words with more redundant initial letters (F > L), last letters (F < L) and equal redundancies (F = L)

	Right–Left		
	Four	Five	Six
F > L	9.01	18.9	13.97
F = L	−8.15	15.5	4.0
F < L	10.83	10.02	15.9

advantage in accuracy measures together with no effects of length on responses to nonwords. These inconsistencies remain to be explained and suggest that models of lexical decision need to account for the processes occuring during the correct rejection of nonwords, in addition to lexical access for words. Moreover, such models should account for different findings in latency and in accuracy.

CONCLUSIONS

The test of the emotionality effect revealed that it does not affect processing in the same way as stimulus concreteness. We had expected to find a visual field by length effect only for neutral words (analogous to the previous finding of an effect only for abstract words). Instead, the effects of emotionality were equal in the two visual fields, with emotional words resulting in better performance than neutral words.

The effects of string length on response patterns are complex. We have replicated the results of previous studies in the LVF, but not in the RVF. This pattern does not conform to the predictions of the interpretation proposed by ELLIS *et al.* [7] for the characteristic modes of processing visually-presented letter strings in the two visual fields. The accuracy of performance reveals discontinuities as a function of string length, but at different points in the two visual fields. Latency of responses shows length effects in both visual fields. This difference between latency and accuracy suggests a possible shift in speed–accuracy trade-off strategy between the visual fields, and at least partial RH contribution to the processing of LVF stimuli. The processing dissociation between visual field and the variable "wordness" suggests that there may be separate RH and LH contributions to the processing of words and nonwords.

All the findings to date satisfy the following constraint: If an easier condition shows a length effect, then so does a more difficult condition. Assuming that abstract (neutral) words are more difficult than concrete (emotional) words, and that processing words in the LVF is more difficult than in the RVF, we see (Table 4) that a length effect for concrete or emotional words in a given visual field is always associated with a length effect for abstract or neutral words in the same visual field. Similarly, a length effect in the RVF for some condition is associated with a length effect in the LVF for the same condition. This pattern is consistent with the resource limitation account of the length effect proposed above.

Finally, we would like to emphasize the importance of measuring all aspects of performance, both speed and accuracy, when characterizing a behavior. On their own, the latency data could point us towards a callosal relay interpretation of length effects, because length is a physical characteristic of the stimuli, and is thus a variable that may affect callosal transfer. However, the accuracy data reveal a double processing dissociation which seems to reflect at least partial RH contribution to lexical access. Thus, speed and accuracy may be sensitive to different aspects of the task, and give us nonredundant information about the differential contributions of the hemispheres to lexical decision.

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APPENDIX

Stimuli used in the experiment:
Words:

	Emotional	Neutral
Four letters:		
	bond	case
	goal	code

life	week
loss	part
love	role
luck	side
pain	site
self	size

Five letters:

birth	agent
crime	basis
death	curve
error	dozen
guilt	front
peace	index
pride	place
prize	point
saint	pupil
skill	route
spite	staff
truth	verse

Six letters:

beauty	weight
crisis	course
danger	length
friend	notion
health	number
income	patent
murder	phrase
threat	signal
victim	source
summer	system
wisdom	volume
talent	budget

Nonwords:

Four letters	Five letters	Six letters
semp	prutt	setent
cosd	prite	nenoth
gafe	stipp	barcle
lirk	soork	imtome
beel	skack	cemuty
paze	dorth	voorse
lare	brile	mostem
lurf	phere	silger
woat	anror	fapure
cort	spize	derder
sote	irpex	pusmer
lote	sirth	punber
sode	fruve	stirce
posk	tosis	lagnal
raim	cumil	wition
	voint	ceelth
	relth	clend
	pozet	shrame
	duilk	baremt
	peams	horume
	epent	vaimis
	goink	tudgem
	cronk	nimdom
	pamer	nicrim
	braff	