Are form priming and morphological priming different for Hebrew words than for words of Indo-European languages? Not if you look at all the evidence

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Abstract

Frost, Kugler, Deutsch, and Forster (2005) claimed that the lexical representations of Hebrew are organized in a radically different manner to those of English and other Indo-European languages. Representations in the Indo-European languages are organized on the basis of orthographic similarity. Representations in Hebrew, by contrast, are organized on the basis of morphological similarity. This claim is based on two arguments: form-related priming effects are absent in Hebrew, whereas morphology-related priming effects are strong. Frost et al. suggest that this pattern is not observed in the Indo-European languages. However, on the basis of an exhaustive, meta-analytic review, we show that this is exactly the pattern observed in these languages as well, when the evidence is based on lexical decision tasks. Therefore, we see no evidence to support the view that the structure of lexical knowledge differs across users of Hebrew and Indo-European languages.

One of the questions in reading research is to what extent word processing is constrained by the orthography of a language. To what extent does visual word recognition differ in alphabetic languages (e.g., English) and in logographic languages (e.g., Chinese)? To what extent is visual word processing different in alphabetic languages that have a clear correspondence between the letters and the sounds (e.g., Serbo-Croatian, Spanish) than in languages with an opaque correspondence (e.g., English, Hebrew)? Can the differences in orthographic codes between various languages be captured by a single computation model of visual word recognition in which the parameters are varied, or do they require qualitatively different models?

A case for the latter has recently been made by Frost, Kugler, Deutsch, and Forster (2005). They claimed that the lexical representations of Hebrew are organized in a radically different manner to those of English and other Indo-European languages. Representations in the Indo-European languages, they argued, are organized on the basis of orthographic similarity (i.e., the words in these languages are represented in terms of their letters and the relative or absolute positions of those letters). Representations in Hebrew, by contrast, are organized on the basis of morphological similarity (i.e., the words in this language are represented in terms of their morphological roots). This difference in representation follows from the fact that in Indo-European languages morphologically complex words are formed by a linear concatenation of morphemic units (e.g., care, careful, carefulness), whereas in Hebrew and other Semitic languages words are formed by a three-consonant root and a word pattern that is interwoven (e.g. TI***ZM***O***R***ET [orchestra], ***Z***A***M***A***R*** [singer] are both morphological instantiations of the root ZMR). Because of this orthographic difference, word representations in Indo-European languages are stored as orthographic or phonological *word forms*, whereas in Hebrew they are stored as root morphemes plus word patterns.

Frost et al. (2005) based their claim on differences in orthographic form priming and morphological priming between the Indo-European languages and Hebrew. The first part of their argument was that masked orthographic priming is robust in the Indo-European languages and absent in Hebrew. Their strongest evidence for this position comes from two masked priming experiments using English-Hebrew and Hebrew-English bilinguals (Experiments 3A and 3B), in which they demonstrated a strong and significant masked orthographic priming effect in an English lexical decision task that was not also observed in a Hebrew lexical decision task. Bilingual English-Hebrew participants decided 26 ms faster that the target 'river' was a word when it was preceded by the orthographically-related prime 'rider' than when it was preceded by the unrelated prime 'knock', but revealed an effect of only 8 ms for an equivalent comparison in Hebrew (e.g., 'kwpth' [dumpling] preceded by the orthographically-related prime 'kwmth' [beret] or the unrelated prime 'nxswN' [brave]). Similar findings were obtained for Hebrew-English bilinguals. These experiments were accompanied by seven further monolingual experiments yielding an average Hebrew masked orthographic form priming effect of only 6 ms.

The second part of Frost et al.'s (2005) argument was that while orthographic form priming in Hebrew is weak and unreliable, masked morphological priming in Hebrew (e.g., ('mxlbh' [dairy] preceded by 'xlbwn' [protein] or by 'tcpyt' [observation]) is strong and significant. Two studies investigating these effects on Hebrew word recognition yielded an average morphological priming effect of 27 ms. No complementary data concerning English masked morphological priming were presented, although there was a strong implication by Frost et al. (2005) that similarly robust effects would not be observed.

We do not contest the Hebrew data on which Frost et al.'s (2005) claims were based. We accept that masked priming in Hebrew is strong when morphological similarity is examined and weak when orthographic similarity is examined. However, we do take issue with the supposedly deviating patterns that Frost et al. (2005) discerned for the Indo-European languages. In the following, we will demonstrate (a) that there is very little evidence for facilitatory masked orthographic priming effects in the Indo-European languages when the experimental conditions used are similar to the ones used in Frost et al. (2005); and (b) that there is a masked morphological priming effect in the Indo-European languages that is at least as strong as the effect shown in Hebrew. Overall, we argue that Frost et al.'s (2005) claim that lexical representations in Hebrew are organized differently to those in the Indo-European languages cannot be sustained. Rather, the evidence as a whole suggests that both types of language yield strong masked morphological priming effects and weak masked orthographic form priming effects.

Masked Orthographic Form Priming in the Indo-European Languages

Frost et al. (2005) stated that strong masked orthographic form priming effects have been demonstrated across many of the Indo-European languages (p. 1294). Unfortunately, they did not provide sufficient empirical evidence for this claim. Further, the references that they did cite include studies that involved different tasks (perceptual identification instead of lexical decision) and different types of prime (nonword primes instead of word primes) to those used in their own experiments. These differences are important, as previous research has shown that orthographic priming effects are larger in the perceptual identification task than in the lexical decision task (Davis & Frost, 1994) and that masked orthographic priming effects are larger with nonword primes than with word primes (Ferrand & Grainger, 1996; Drieghe & Brysbaert, 2002). If we want to know whether there is a difference in masked orthographic priming between Hebrew and other languages, we must make use of the same experimental conditions across languages. It is for this reason that Frost et al. (2005) compared the lexical decision performance of bilinguals on English and Hebrew target words preceded by word primes of matched frequency. As reported above, these experiments yielded a significant 26 ms form-related priming effect for English, against a non-significant 8 ms form-related priming effect for Hebrew.

Unfortunately, the 26 ms English form-related priming effect reported by Frost et al. is rather exceptional. Table 1 summarises all of the experiments that we could find describing masked orthographic priming effects on lexical decision in the Indo-European languages. This table separates experiments into three groups on the basis of prime type: (1) nonword primes; (2) word primes with frequencies lower than or equal to the targets; and (3) word primes with frequencies higher than the targets. The reason for this distinction is that the interactive-activation model from which current computational theories of English word recognition have been derived predicts inhibitory form-priming effects when primes are words but not when primes are nonwords (Davis, 2003), with these inhibitory effects being particularly strong when primes are of higher frequency than targets (Segui & Grainger, 1990). Inhibitory effects yielded by (high frequency) word primes are predicted on the interactive-activation model because orthographically-similar word forms compete with one another as part of the word recognition process (e.g., Davis & Lupker, 2006).

Insert Table 1 about here

Three aspects of the data presented in Table 1 are particularly noteworthy. First, it is immediately apparent that the predictions of the interactive-activation model are supported by the averaged data in Table 1. The masked orthographic priming effect is larger for nonword primes (14 ms) than for low frequency primes (3 ms) and for high frequency primes (-17 ms). Crucially for the present discussion, the condition most similar to Frost et al.'s (2005) Hebrew experiments (word primes with frequencies equal to or lower than the target) yields an overall priming effect of 3 ms, an effect of similar magnitude to the 6 ms effect that Frost et al. (2005) reported for their series of 9 masked orthographic form priming experiments in Hebrew. Indeed, looking at the literature as a whole, there is very little evidence to support Frost et al.'s (2005) claims concerning the robustness of masked orthographic form priming effects in the Indo-European languages.

Second, though the averaged data in Table 1 reveal a masked orthographic priming effect in the Indo-European languages that is weak and unreliable, it is apparent that there is considerable variability in the magnitude of the individual effects reported, with some effects being strongly facilitatory and other effects being strongly inhibitory. This pattern is in line with the interactive-activation account of orthographic priming as a balance between facilitation and inhibition (Davis, 2003;

Segui & Grainger, 1990). On the one hand, there is facilitation due to the shared orthography of the prime and the target. On the other hand, there is inhibition because form-related representations compete with one another in the process of word recognition. Which effect dominates depends not only on the type of prime (nonword, low-frequency word, high-frequency word), but also on the experimental circumstances. For example, Forster and Veres (1998) demonstrated that the type of nonwords used in the lexical decision task can modulate the magnitude of the form priming effect. In their experiments, when nonwords differed from existing words by a single letter (making the decision difficult), a masked orthographic priming effect of only 8 ms was observed. However, when nonwords differed from existing words by two letters (making the decision less difficult), the masked orthographic priming effect shot up to 32 ms. Task instructions can also turn a null or inhibitory masked orthographic priming effect into a strongly positive effect. De Moor et al. (2005) demonstrated that when accuracy was stressed in performing the lexical decision task, an orthographic inhibition effect of 45 ms was observed with high-frequency primes. However, when participants were urged to respond very quickly (thus decreasing their RTs and increasing their error rates), the inhibitory effect turned into a facilitatory effect of 28 ms. This modulation was explained in terms of differential use of local and global decision criteria postulated in the interactive-activation model of visual word recognition developed by Grainger and Jacobs (1996).

Because of the variability in the orthographic priming effects in the Indo-European languages, it is difficult to draw firm conclusions from Frost et al.'s (2005) findings with English-Hebrew bilinguals and English stimulus words. If the Hebrew and the English experiments were completely comparable in terms of task instructions and characteristics of the words and the nonwords, then the difference between form priming in English (26 ms) and form priming in Hebrew (8 ms) might be taken as evidence for a stronger orthographic priming effect in English than in Hebrew. On the other hand, given that the 26 ms orthographic priming effect reported by Frost et al. (2006) is so much at odds with the rest of the data for the same task, we feel that some scepticism is warranted about its generality.

The final finding of interest in Table 1 concerns the fact that overall RTs to word targets are shorter when these words are preceded by nonword primes (related or unrelated; 580-590 ms) than when they are preceded by low-frequency word primes (610-620 ms) or high-frequency word primes (640-660 ms). Indeed, in many experiments there seems to be an extra cost when a word prime precedes a target word, even when the prime is totally unrelated to the target. This finding throws new light on the strongly facilitatory orthographic form priming effects reported by Forster, Davis, Schoknecht, and Carter (1987; English) and Perea and Rosa (2000; Spanish). In these experiments, the unrelated conditions consisted of a target word preceded by an unrelated word prime (dinner-ANSWER) whereas the related conditions consisted of a target word preceded by an orthographically related nonword prime (antwer-ANSWER). For this reason, these two studies were not included in Table 1.

In summary, Frost et al. (2005) were wrong when they claimed that masked orthographic form priming effects are robust in English (and presumably other Indo-European languages) and absent in Hebrew. Looking at the Indo-European studies that had experimental conditions comparable to Frost et al. (2005), we see an overall masked orthographic form priming effect of 3 ms. This effect can be turned into a facilitatory effect by using nonword foils that deviate strongly from word targets stimuli and/or by stressing the speed of the response at the expense of accuracy. It is not clear whether any of these factors played a role in the 26 ms effect reported by Frost et al. (2005), but a look at Table 1 certainly suggests that this figure should be regarded as an outlier when compared against the whole of the literature relevant to masked orthographic priming effect in the Indo-European languages.

Masked Morphological Priming in the Indo-European Languages

Frost et al.'s (2005) second argument was that the Hebrew masked morphological priming effect is much stronger than the corresponding masked orthographic priming effect, leading them to claim that lexical representations in Hebrew are organized morphologically. Having found in Table 1 that the orthographic priming effect in the Indo-European languages is of a magnitude similar to that observed in Hebrew, we sought to discover the magnitude of the masked morphological priming effect in these languages. Table 2 summarizes all of the experiments that we could find investigating masked morphological priming effects on lexical decision in the Indo-European languages. Following standard practice in this literature, this table distinguishes between trials in which there was a transparent morphological relationship between prime and target (dreamer – dream) and trials in which there was no clear semantic relationship between prime and target (corner – corn). In addition, we separated the one study in which morphologically related nonwords were used (habiter-habit; Longtin & Meunier, 2005).

Insert Table 2 about here

Table 2 reveals that the average masked morphological priming effect in the Indo-European languages is 31 ms for transparent trials, 23 ms for opaque trials, and 38 ms for trials with pseudoword primes. The slightly smaller effect for the opaque trials is due to a single study (Diependaele et al., 2005) and is, therefore, unlikely to be reliably different from the effects in the other two conditions. Most importantly, the data in Table 2 demonstrate that the masked morphological priming effect in the Indo-European languages is at least as large as that reported by Frost et al. (2005) for Hebrew (27 ms). Further, unlike the variable effects seen in Table 1 for masked orthographic priming, masked morphological priming effects in the Indo-European languages are strongly and consistently positive.

Conclusion

Frost et al. (2005) claimed that lexical representations in the Indo-European languages are organized orthographically while lexical representations in Hebrew are organized morphologically. These differences in the internal structure of lexical knowledge, they argued, are a consequence of linguistic differences across these languages, with Hebrew being characterized by a particularly rich non-concatenative morphological system. Frost et al.'s (2005) case rested on two arguments: (a) masked orthographic form priming is absent in Hebrew and robust in English; and (b) masked morphological priming is robust in Hebrew (with the strong implication that it is not robust in English). However, as we have seen, neither of these arguments stands up to the test of the empirical literature. Our conclusion, therefore, must be that Frost et al. (2005) have overstated their case.

To be clear, we are not saying that the linguistic difference between Indo-European and Semitic languages in word representations is without processing consequences. The fact that the word pattern letters are interwoven in the root letters in Semitic languages must lead to differences in the connections between letter representations and word representations. However, we do take issue with the fact that ‘fundamentally different principles must be involved in the organization of the Hebrew and English mental lexicons’ (Frost et al., 2005, p. 1308). It looks very much that both in Semitic and Indo-European languages morphology plays a very strong role in the way word representations are stored and accessed. Therefore, on the basis of the available evidence it looks more likely to us that any difference in processing between Semitic and Indo-European languages will be captured by a quantitative difference (a difference in parameter values) rather than by a qualitative difference (a difference in the structure of the model).

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Table 1 : Orthographic priming effects in Indo-European languages (masked priming with prime durations from 15 ms to 67 ms). When an article contained multiple similar experiments, the data were averaged over these experiments.

Study	language	P duration	RT unrel	RT rel	RT effect	PE unrel	PE rel	PE effect
non-word primes								
Davis & Lupker (2006)	English	57	660	634	26	4.6	5.6	-1.0
Davis & Lupker (2006)	English	57	582	571	11	0.9	1.8	-0.9
Holyk & Pexman (2004)	English	15	620	580	40	15.5	14.8	0.7
Janack et al. (2004)	English	48	644	640	4	3.2	4	-0.8
van Heuven et al. (2001)	Dutch	30	545	525	20	4.3	2.9	1.4
van Heuven et al. (2001)	Dutch	60	559	537	22	3	2.1	0.9
Davis et al. (1998)	English	57	545	546	-1	3.8	8.8	-5.0
Berent (1997)	English	43	664	678	-14	4.9	5.2	-0.3
Drews & Zwitserlood (1995)	Dutch	66	583	580	3	9.3	8.7	0.6
Ferrand & Grainger (1994)	French	29	467	438	29	7.4	7.1	0.3
Ferrand & Grainger (1992)	French	33	606	583	23	11.3	10.6	0.7
Ferrand & Grainger (1992)	French	67	624	621	3	8.9	6.8	2.1
Forster & Taft (1994)	English	50	633	615	18	11.2	10.8	0.4
			594.8	**580.6**	**14.2**	**6.8**	**6.9**	**-0.1**

freq prime <= freq target								
Davis & Lupker (2006)	English	57	571	586	-15	1.9	2.4	-0.5
Frost et al. (2005)	English	43	580	554	26	6.6	6.8	-0.2
Janack et al. (2004)	English	48	656	672	-16	2.7	4	-1.3
Château & Jared (2000)	English	30	609	616	-7	13.5	8.5	5.0
Château & Jared (2000)	English	60	632	679	-47	4.7	12.2	-7.5
Feldman (2000)	English	66	613	595	18	13	20	-7.0
Feldman (2000)	English	32	662	652	10	11	16	-5.0
Forster & Veres (1998)	English	50	709	701	8	7.8	6.2	1.6
Forster & Veres (1998)	English	50	655	623	32	7.8	7.6	0.2
Drews & Zwitserlood (1995)	Dutch	66	676	673	3	7.1	7.7	-0.6
Drews & Zwitserlood (1995)	Dutch	66	580	594	-14	7.5	13.9	-6.4
Segui & Grainger (1990)	French	60	619	620	-1	4.8	5.1	-0.3
Forster (1987)	English	60	496	458	38	11	4.7	6.3
			619.8	**617.2**	**2.7**	**7.6**	**8.9**	**-1.2**
freq prime > freq target								
Davis & Lupker (2006)	English	57	634	679	-45	5.6	8.7	-3.1

De Moor et al. (2005)	Dutch	57	662	675	-13	14	15	-1.0
De Moor et al. (2005)	Dutch	57	641	686	-45	7	13	-6.0
De Moor et al. (2005)	Dutch	57	526	498	28	35	30	5.0
Brysbaert et al. (2000)	Dutch	57	616	641	-25	6	8	-2.0
Château & Jared (2000)	English	30	678	632	46	12.5	17.4	-4.9
Château & Jared (2000)	English	60	666	691	-25	9.5	14.4	-4.9
De Moor & Brysbaert (2000)	Dutch	57	668	686	-18	8.6	9.8	-1.2
Bijeljac-Babic et al. (1997)	English	57	704	732	-28	15	25.8	-10.8
Graiger & Ferrand (1994)	English	57	647	670	-23	8.3	12.8	-4.5
Segui & Grainger (1990)	French	60	641	685	-44	10	8	2.0
			643.9	**661.4**	**-17.5**	**12.0**	**14.8**	**-2.9**

Table 2 : Morphological priming effects in Indo-European languages (masked priming with prime durations from 32 to 67 ms). When an article contained multiple similar experiments, the data were averaged over these experiments.

study	language	example	Pduration	RT unrel	RT rel	RT effect	PE unrel	PE rel	PE effect
transparent									
Diependaele et al. (2005)	Dutch	teller-tel	67	628	602	26	3	1	2
	French	gaufrette-gaufre	40 & 67	584	552	32	2	1.5	0.5
Longtin & Meunier (2005)	French	adaptation-adapter	47	700	657	43	5.3	3.2	2.1
		canaliser-canal	47	629	588	41	3.9	1	3.8
Devlin et al. (2004)	English	hunter-hunt	33	631	605	26			
Feldman et al. (2004)	English	accordingly-accordance	48	747	733	14			
Pastizzo & Feldman (2004)	English	deform-conform	66	760	736	24	2.2	2.7	-0.5
		revive-survive	66	760	738	22	4.6	4.8	-0.2
Rastle et al. (2004)	English	dreamer-dream	42	597	570	27	4.5	2.7	2.8
Longtin et al. (2003)	French	gaufrette-gaufre	46	650	612	38	3.5	1.5	
Rastle & Davis (2003)	English	dreamer-dream	52	603	568	35	3.8	2.4	1.4
Badecker & Allen (2002)	Spanish	cerrar-cerro	67	700	651	49	8	6	2
		cierra-cerro	67	696	705	-9	7	6	1
		cierra-cerrar	67	691	623	68	6	3	3
		cerro-cierra	67	720	696	24	4.1	3.7	0.4

Pastizzo & Feldman (2002)	English	hatched-hatch	48	670	632	38	6	7	-1
Giraudo & Grainger (2001)	French	balai-balayage	43& 57	666	649	17	10.9	9.2	1.7
		balayeur-balayage	43&57	666	639	27	10.9	10.2	0.7
		balayage-balai	43&57	637	607	30	7.2	4.7	2.5
		laitage-laitier	57	747	667	80	12.7	9	3.7
Feldman (2000)	English	vowed-vow	32 & 66	634	604	30			
Forster & Azuma (2000)	English	survive-revive	50	601	569	32	9.5	6.3	3.2
		happy-unhappy	50	611	572	39	9.3	4	5.3
Giraudo & Grainger (2000)	French	amitié-ami	57	655	622	33	3.8	1.3	2.5
		amiable-ami	57	645	640	5	4	3.5	0.5
		ourson-ours	57	691	953	38	5.6	4.4	1.2
		cireur-cire	57	698	652	46	3.6	3.1	0.5
Rastle et al. (2000)	English	dreamer-dream	43	607	561	46	2.6	3.3	-0.7
		adaptable-adapter	43	695	651	48	6.5	6.8	-0.3
Feldman & Soltano (1999)	English	casually-casualness	48 & 66	?	?	24			
Drews & Zwitserlood (1995)	Dutch	kersen-kers	66	589	570	19	7.4	7.1	0.3
Grainger et al (1991)	French	prenom-surnom	64	655	619	36	1.3	1.1	0.2
		mural-muret	64	635	626	9	1.3	1.4	-0.1
		non-surnom	64	674	634	40	1.6	1.1	0.5
		mur-muret	64	664	664	0	1.6	2	-0.4
						31.3			**1.3**

opaque

Diependaele et al. (2005)	Dutch	koppel-kop	67	623	625	-2	3	4	-1
	French	baguette-bague	40 & 67	575	569	6	4	2	2
Devin et al. (2004)	English	passive-pass	33	631	606	25			
Feldman et al. (2004)	English	accordion-accordance	48	747	727	20			
Rastle et al. (2004)	English	gingerly-ginger	42	620	598	22	10.6	8.6	2
Longtin et al. (2003)	French	vignette-vigne	46	653	610	43	2	1.7	0.3
		baguette-bague	46	639	913	26	4	3.8	0.2
Rastle & Davis (2003)	English	gingerly-ginger	52	603	572	31	3.8	2.6	1.2
Rastle et al. (2000, Exp 1)	English	gingerly-ginger	43	617	582	35	4.1	3.7	0.4
Feldman & Soltano (1999)	English	casualty-casualness	48	?	?	23			
						22.9			**0.7**
pseudoword									
Longtin & Meunier (2005)	French	adaptiste-adapter	47	700	659	41	5.3	2.5	2.8
		canalitude-canal	47	629	593	36	3.9	3.1	0.8
						38.5			**1.8**