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Regularity and irregularity in French verbal inflection

Fanny Meunier and William Marslen-Wilson
Medical Research Council, Cognition and Brain Sciences Unit, Cambridge, UK

Can regular and irregular verb forms be accommodated by a single representational mechanism or is a dual mechanism account required? In a first experiment, we used a cross-modal repetition priming paradigm to investigate the mental representation of regular and irregular verb forms in French. Participants heard a spoken prime (such as *aimons*, 'we love') immediately followed by lexical decision to a visual probe (such as *aimer*, 'to love'). We contrasted four types of French verbs, varying in the regularity and degree of allomorphy of their verb form inflection. These were (i) fully regular verbs (*aimons/aimer*, 'we love/to love') (ii) regular verbs that undergo minor and phonologically predictable allomorphic changes (*sèment/semer*, 'they sow/to sow') (iii) irregular verbs exhibiting subregularities (*peignent/peindre*, 'they paint/to paint') and (iv) irregular verbs with idiosyncratic alternations (*vont/aller*, 'they go/to go'). The infinitive forms of these verbs were presented as targets in three prime conditions, preceded either by a regular form, an allomorphic form (except for the fuller regular verbs), or an unrelated prime. Morphologically related primes significantly facilitated lexical decision responses for all four verb classes, irrespective of regularity and allomorphy. The same pattern of results was observed in a second experiment using a masked priming paradigm. These results contrasted with English, where regularly inflected verbs prime their stems but irregular verbs do not. We argue that this reflects cross-linguistic differences in the morphophonological decomposability of French irregular forms, and that the current results enable us to deconfound regularity/irregularity distinctions from language-specific morphophonological differences.

Correspondence should be addressed to Fanny Meunier, Laboratoire Dynamique Du Langage, CNRS-UMR 5596, Institut des Sciences de l'Homme, 14 avenue Berthelot, 69363 Lyon Cedex 07, France.
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A recurrent issue in psycholinguistic research is the implications for learning and representation of the patterns of regularity and irregularity in a given language system. These link to long-standing debates about the distinction between information that can be obtained through rules and information that must be recalled from a list of stored exceptions. Distributed approaches argue for a single, subsymbolic mechanism underlying the representation and processing of both regular and irregular items (e.g., Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986), while symbolic approaches argue for a dual mechanism account, where regular forms are generated by rule but irregular forms are stored as rote-learned whole forms (e.g. Pinker, 1991). Many studies tackle this issue by trying to determine whether the co-occurrence of regular and irregular verb forms in a given language can be accommodated by a single representational mechanism or whether a dual mechanism account is required.

In English, verbs have only three types of morphological processing contexts: 3rd person singular, past tense, and progressive forms (*jumps*, *jumped*, *jumping*). This inflectional system offers a sharp contrast between a single, dominant, regular process of past-tense formation (adding the regular alveolar affix /-d/ to a phonologically unchanged stem) and a small, heterogeneous, and idiosyncratic group of irregular past-tense forms. Several sources of evidence suggest that the linguistic differences between regular and irregular forms lead to differences in the way these forms are represented in the English mental lexicon. A major source of evidence is research using repetition priming tasks, where a test word is preceded by a related prime word. The target word *walk*, for example, is preceded either by a morphologically related word (e.g., *walked*), or an unrelated word (e.g., *goal*). Previous research done in English shows diminished or absent priming between irregular tense forms and their stems (*drove/drive*) versus a strong priming effect between regular pairs such as *walked/walk* (Kempley & Morton, 1982; Napps, 1989; Stanners, Neiser, Hernon, & Hall, 1979). Pinker (1991, 1999) claimed that these results support the dual mechanism dichotomy. Convergent results have been observed using a cross-modal repetition paradigm, where the prime is presented auditorily and the target visually (Marslen-Wilson, Hare & Older, 1995). Again significant priming is only observed for regular inflected forms (such as *walked/walk*) and not for irregular ones (such as *dug/dig*).

In this framework, priming between regular forms and their stem is typically explained by assuming that inflected forms of a given verb map directly onto an abstract representation of the stem morpheme at the level of the lexical entry. The morphological priming effect results from the repeated activation of the same stem morpheme by prime and target. In contrast, an irregular form will have a separate form representation from

the stem to which it is related and this can lead to a reduction of priming between the two items, under specific testing conditions. This may be due either to competition between the two representations (stem and irregular form) or as a consequence of the blocking function assigned to the listed irregular form (the presence of a lexical entry for the irregular form will prevent the application of the default suffix). In more recent studies, taking into account neuropsychological data, we have expanded this account to cover potential differences in the neural systems underlying the representation and processing of English regular and irregular forms (Marslen-Wilson & Tyler, 1997, 1998). The implications of this alternative dual route account are explored in more detail in the final discussion of this paper.

One problem with English, however, as a basis for generalisations about regularity and irregularity, is that the English past-tense forms do not differ simply in regularity, but also along a number of other dimensions, including contrasts in basic morphological processes, and high versus low type frequency of classes of past forms. In order to disentangle potential evidence about the general properties of morphological systems from the possible idiosyncrasies of English past tense formation, it is necessary to conduct parallel experiments in other languages which exhibit comparable but cleaner contrasts between regular and irregular procedures.

One language that we have looked at already in this light is Italian. This is a much richer inflected language (with many different types of tense, aspect and person suffixes), where irregular past-tense forms occur in a morphologically more structured and phonologically more predictable linguistic environment than in English. Irregular forms occur primarily in a single class of verbs (conjugation 2), where over 80% of all verbs have irregularities in certain past tense forms, and where the majority of these irregular forms share subregularities—for example, the presence of a characteristic tense affix. Using a cross-modal priming paradigm, Orsolini and Marslen-Wilson (1997) observed the same amount of priming when the prime and target were regular (*amarono-amare*, 'they loved-to love') and when the prime was from this irregular subclass (*presero-prendere*, 'they took-to take').

Here we report an extension of this research to French, which, like Italian, has a richer inflectional system than English, and which allows us to explore a wider range of types of irregularity. In French, verbs are organised into three basic morphological classes, called conjugations (Grevisse, 1993). These distinctions use as primary criterion the infinitive form and as second the imperfect form. The major class is conjugation 1, containing verbs with infinitives ending in -er (such as *aimer*, 'to love', *voler*, 'to fly'). This is the most productive class and fully regular. Conjugation 2 is formed by verbs that have an infinitive in -ir and

imperfect in -iss- (such as *finir*, 'to finish', *salir*, 'to make dirty' …). It is a smaller class than conjugation 1 and it is no longer productive, but it is fully regular. Conjugation 3 contains verbs with infinitives ending in -ir (and that do not have an imperfect in -iss-), -oir, -re (such as *dormir*, 'to sleep', *boire*, 'to drink', *peindre*, 'to paint' …) and the verb *aller*, 'to go'. Verbs contained in this group are highly irregular.

In our experiment we used four types of verbs that contrasted in the degree of regularity/irregularity of some of their inflected forms and in the degree of associated allomorphy ('allomorphy' is defined as a phonological change in the form of a stem when it occurs in specific morphological environments). The first condition, which we will refer to as the *regular* condition, contained fully regular verbs from the first conjugation such as *aimer*, 'to love', where there are no allomorphic changes in the form of the verb stem (*aim-* in this case). The second condition was also composed of regular verbs from the first conjugation but which, under certain conditions, undergo a minor phonologically triggered change in the form of the stem, as in *amener-amène*, 'to bring-I bring'. This is a regular surface change due to the concatenation of a stem and a 'silent e'.[1] This type of phonological change (a high/low alternation) is very common in Romance languages. In French it occurs not only in verb inflection but also in gender marking alternations such as *fermier-fermière*, 'farmer-female farmer'. We will call this group the *morphophonological constraint* condition. These two conditions, *regular* and *morphophonological constraint*, use verbal forms that are obtained by regular suffixation processes and are fully predictable and transparent. We assume that in each case the inflected forms are represented as combinations of the same underlying abstract stem with different affixes, and that there should be no reduction in priming between such pairs.

These two conditions are contrasted with two more clearly irregular conditions. The third condition consisted of a group of irregular verbs from the third conjugation, such as *peindre-peignent*, 'to paint-they paint'. Here the allomorphic alternation in the form of the stem is idiosyncratic, because it is not predictable on general phonological principles, but where it is common to a subgroup of at least 10 verbs (e.g., *teindre-teignent*, 'to dye-they dye', etc). These types of irregularities represent clusters of subregularity (see Orsolini & Marslen-Wilson, 1997), because even though they differ from the regular pattern, all verbs sharing a particular ending (in this case -eindre) will follow the irregular pattern. We will refer to this group as the *subregularity* condition. Verbs in this group are closest to

[1] The phonological rule is as follows: if there is an 'e' or an 'é' (in bold in the examples) in the penultimate syllable of the infinitive form then the suffixation process that adds a 'silent e' will induce the modification of the segment 'e' or 'é' to 'è'.

those used in Italian (Orsolini & Marslen-Wilson, 1997), where we found no significant differences between this type of verb and fully regular ones. The fourth group, more similar to the type of irregularity found in English, was made up of idiosyncratic suppletive alternations such as *aller-irons*, 'to go-we will go' or *boire-buvaient*, 'to drink-they drank', which typically only apply to one or two verbs in the language. We will refer to this as the *idiosyncratic* condition. On the account given earlier, where reduced priming is attributed to the presence of a separate representation of the irregular stem, we are most likely to see effects of irregularity on priming in these two conditions, although such effects may be moderated in the subregularity condition by the consistency of the allomorphic change for each verbal subgroup.

As noted earlier, irregularity in French verbal inflectional morphology always takes place in a broader context of primarily regular inflectional paradigms. Thus we can pair each irregular and/or allomorphic prime-target pair (as in *peignent-PEINDRE*, 'they paint-to paint') with a further pair, such as *peindra-PEINDRE*, 'he will paint-to paint', where the prime is a regular inflectional form of the same verb, with no allomorphic changes in the stem. This allows us to compare directly the amount of priming elicited by the different types of irregularity and allomorphy, on a within-verb basis, relative to an appropriate unrelated prime.

If the patterns of results observed in English and in Italian are not language specific but are due to type of irregularity, then in French we should observe the same amount of priming when the prime is regular and in the morphophonological constraint and subregularity conditions. In contrast, when the prime is an idiosyncratic form, we may, as in English, observe significantly reduced priming relative to regular forms.

EXPERIMENT 1

Method

Material and design. We used a cross-modal immediate repetition paradigm. The prime was auditorily presented and immediately followed by a visual presentation of the target-item. Participants made a lexical decision response to the visual target, which was preceded by a regular or irregular related or unrelated prime.

Ninety-six verbs falling in four categories were selected, as described earlier, and examples are listed in Table 1 below. We used as the target the infinitive form of the verb. We chose for each verb of each category, three types of prime (all verb forms): A 'no change' regular form, an allomorphic form (except for the fully regular verbs), and a control (or baseline) word matched to the no-change regular form. To keep the design balanced, verb targets in the fully regular condition were preceded by two different no-

TABLE 1
Sample stimuli

Verb type	*Infinitive target*	*No change Regular prime*	*Allomorphic/ Irregular prime*
Regular	*AIMER* 'to love'	*aimerons* 'we will love' *aimons* 'we love'	*n/a*
Morphophonological constraint	*SEMER* 'to sow'	*semons* 'we sow'	*sème* 'I sow'
Subregularity	*PEINDRE* 'to paint'	*peindra* 'he will paint'	*peignent* 'they paint'
Idiosyncratic	*ALLER* 'to go'	*allons* 'we go'	*iront* 'they will go'

change regular primes (Regular 1 and Regular 2 in Table 1). Targets were between 4 and 11 letters long. On average the lengths in letters of the targets for each group were: fully regular verbs 6.37, morphophonological constraint verbs 6.96, subregularity verbs 7.66, and idiosyncratic verbs 6.12. The mean log frequencies for each verb group (calculated per million using Trésor de la Langue Française, Imbs, 1971) was 3.85 for the fully regular verbs, 3.32 for the morphophonological constraint verbs, 2.92 for the subregulars, and 3.88 for the idiosyncratic verbs.

For each of the 96 no change regular primes, we selected a control word that was matched to the regular experimental prime for surface frequency, number of syllables and tense and person of the verb form. None of the neutral condition words were morphologically, semantically, or phonologically related to the target. We also constructed filler pairs in order to reduce the proportion of related pairs within the list. We added 64 pairs in which the target was a word (such as *calculons/partir*, 'we calculate/to leave'), and 160 pairs in which the target was a non-word (such as *marchera/enteler*, 'he will walk/enteler'). Each prime list contained 96 experimental words (of which 64 were related to the target and 32 were not), 64 words with an unrelated target word, for a total of 160 word-word pairs. These were accompanied by 160 words with a nonword target (64 pairs in which prime and target shared formal features and 96 primes followed by a nonword target which was unrelated). The proportion of related prime-target pairs was 40%.

To avoid the repetition of a given target for a participant, we constructed three experimental lists of 320 items each. Each target appeared only once in each list: with a no change regular prime in one list, an irregular/ allomorphic related prime (except in the fully regular condition) in the

second list and a control prime in the third one. In each list, 2/3 of the experimental prime-target pairs were morphologically related (64 pairs). The number of pairs from each experimental condition was equal (8) in each list. Each participant heard only one list so that each saw a third of the items with a no change regular related prime, a third with an irregular/allomorphic related prime and a third with a control prime. The list of targets was the same for all participants, only the primes varied. To give a break to the participants we split up each list. Experimental pairs of each condition were equally distributed in each segment of the list. Each part of the list started with 10 dummy items. Before being exposed to the list itself, the participants were trained on 20 prime-target pairs. The experimental session lasted 25 minutes.

Procedure. A French female native speaker recorded primes on a DAT. Each prime was then digitised at a rate of 22 kHz and stored on computer hard disk. Each word was isolated in a single independent file. This allowed us to control the time between the end of the prime and the presentation of the target. The prime was binaurally presented to the participant and was immediately followed (ISI 0 ms) by the presentation of the target on a CRT screen. The target stayed on the screen until the participant made a response. The task of the participant was to push one of the two buttons on a response box (one for word, the other for non-word), as fast as he or she could. Participants were alone in the testing room.

Participants. Thirty-six students of Psychology at the University Paris V-René Descartes took part in the experiment. All were native French speakers and they were between 18 and 30 years old.

Results

Very slow responses (reaction times higher than 1500 ms) were eliminated from the statistical analysis as they were considered not to reflect task variables; less than 1% of reaction times fell into this category. There were 2% of errors on experimental words. Analyses of variance were conducted on the inverse reaction time data. This is a well-established procedure for data treatment which reduces error variance without requiring outliers to be trimmed (Ratcliff, 1993; Ulrich & Miller, 1994). As a precaution, however, we ran a second set of analyses using raw RT data, and obtained the same pattern of results (at a .05 threshold). We report only the inverse transform analyses below, which we believe provide a statistically more robust basis for interpreting the results. Two analyses were run, across participants (F_1) and items (F_2). Reaction times per condition are

presented in Table 2. This also gives the priming effects and their associated significance values.

In an overall analysis of variance with two factors—prime type (three levels) and verb type (four levels)—we observed a main effect of prime type, $F_1(2, 70) = 73.64$, $p < .000$; $F_2(2, 184) = 59.14$, $p < .000$, an effect of verb type by participants by not items, $F_1(3, 105) = 10.51$, $p < .000$; $F_2(3, 92) = 2.09$, $p < .11$, but no interaction ($F_1 < 1$; $F_2 < 1$). Looking first at the effects for the no change regular conditions, the size of the facilitatory priming effect was very similar across the four verb types (fully regular 40 ms, morphophonological constraint 57 ms, subregularity 60 ms and idiosyncratic 49 ms). Overall, for no change regular conditions vs. control, there was a significant effect of morphological priming, $F_1(1, 35) = 103.17$, $p < .000$; $F_2(1, 92) = 119.45$, $p < .000$, an effect of verb type by participants but not by items, $F_1(3, 105) = 9.19$, $p < .000$; $F_2(1, 92) = 2.05$, n.s., and no interaction between these two factors ($F_1 < 1$; $F_2 < 1$. Turning to the three irregular/allomorphic prime conditions, the facilitatory effects are very similar across the board (morphophonological constraint 51 ms, subregularity 62 ms and idiosyncratic 48 ms). Overall, comparing irregular conditions with control conditions, we observed an effect of morphological priming, $F_1(1, 35) = 80.43$, $p < .000$; $F_2(1, 92) = 142.33$, $p < .000$, and an effect of verb type, $F_1(3, 105) = 7.04$, $p < .000$; $F_2(1, 92) = 2.26$, $p < .09$, but no interaction between the two, $F_1(3,105) = 1.31$, n.s.; $F_2(3, 92) = 1.83$, n.s. Finally, comparing regular and irregular conditions directly, we observed no difference in the amount of priming, $F_1(1, 35) = 2.98$, n.s.; $F_2(1, 92) = 1.01$, n.s. Irregular/allomorphic and no

TABLE 2
Mean lexical decision times for Experiment 1

Type of verb	*Primes*	*Targets*	*RT (ms)*	*Priming effect*
Regular	*aimerons*	*AIMER*	523	44**
	aimons		530	37**
	porterons		567	
Morphophonological constraint	*semons*	*SEMER*	539	57**
	sème		545	51**
	votons		596	
Subregularity	*peindra*	*PEINDRE*	553	60**
	peignent		551	62**
	nichera		613	
Idiosyncratic	*allons*	*ALLER*	544	49**
	irons		545	48**
	tenons		593	

Note: ** $p < .05$.

change regular verb forms prime their infinitive form equally well, and these priming effects do not vary with the type of verb.

Discussion

This cross-modal priming experiment presented a clear-cut pattern of results: strong morphological priming and no interaction with type of prime (no change regular vs. irregular/allomorphic) or verb type (ranging from fully regular to idiosyncratic). For French there seems to be no difference in the amount of cross-modal priming produced by a regular verb form as opposed to an irregular form. This holds even for the subset of idiosyncratic irregular verbs, which are most similar to the English irregular verbs which did show reduced priming in the same cross-modal task.

A major concern in cross-modal experiments is to determine if the priming effects observed for morphologically related pairs are due to shared morphemes in a morphologically structured mental lexicon, or if they are due to the semantic relationships between the morphologically related pairs. Given the across-the-board priming effects in Experiment 1, and given that all the primes and targets were highly semantically as well as morphologically related, we decided to run the same materials in a second experiment using the masked priming technique (Forster & Davis, 1984). The masked priming technique has been shown to be highly sensitive to overlap at the level of form (Forster, Davis, Schoknecht, & Carter, 1987; Forster & Taft, 1994), but not of meaning. Although masked priming effects for associatively related pairs have been observed (Sereno, 1991), convincing pure semantic effects are rarely reported.

In masked priming a forward pattern mask is presented immediately before the prime and the prime is then replaced on the screen by the target item, which also functions as a backward mask. The temporal interval between the onset of the priming stimulus and the subsequent target stimulus is very brief (47 ms in our experiment). At these short prime durations, the combination of forward and the backward masking prevents the participant from consciously seeing the prime. This reduces the possibility that any priming effect is due to the fact that the participant realises that the prime and the target often share a common morpheme, or that the effects are semantic rather than morphological in nature.

EXPERIMENT 2

The second experiment uses the masked priming task to determine whether the priming effects obtained across conditions in Experiment 1 are primarily morphological in nature, or whether possible variations along

this dimension were obscured by semantic effects, especially for the more idiosyncratic irregular forms.

Method

Material and design. The second experiment used the same stimuli as the previous experiment, with the addition of two new controls: a semantic condition, where the prime and the target were semantically related, to check that the masked priming paradigm was not picking up semantic effects; and an orthographic condition where the prime and the target orthographically overlapped to the same degree as the related pairs but had no semantic or morphological relationship. We selected 24 target words. For each target word in this condition (such as *mâcher*, 'to chew'), one prime was semantically related to the target (*broyait*, 'he used to grind'), one prime was orthographically related to the target (*machine*, 'engine') and the third type of prime was an unrelated control (*progrès*, 'progress'). As a consequence of these changes we removed 24 word/word filler pairs to keep the balance between word and nonword answers. This gave us the same number of items in each list as for the previous experiment. In this experiment the relatedness proportion between primes and targets was 50%.

Procedure. The same hardware and software were used as before. Each trial consisted of three visual events. The first was a forward pattern mask consisting of a sequence of '#'. The second event was the display of the prime word for 47 ms. The third event was the presentation of a target word or nonword for 500 ms. The prime was in lower case and the target in upper case to make sure that the former was appropriately masked. The font used was Times New Roman, size 30. All stimuli were presented in white on a black background. Participants were asked to make a quick and accurate lexical decision about the target by pressing a 'word' or 'nonword' key. The experiment lasted about 30 minutes and started with 10 practice trials followed by 10 warm-up pairs and then the experimental trials. There were breaks as in the previous experiment. No participants reported any awareness of the presence of a prime.

Participants. Another 42 native French speakers of the same age and from the same population as before took part in the experiment.

Results

Reaction times higher than 1500 ms were eliminated from the statistical analyses; less than 1% of reaction times were suppressed with this criterion. There were 2% of errors on experimental words. Analyses of

variance were conducted on the inverse reaction time data both across participant (F_1) and item (F_2). The same pattern of results was observed (at a .05 threshold) with raw reaction times. Reaction times per condition are presented in Table 3. This also gives the priming effects and their associated significance values.

The results overall are very similar to those for Experiment 1. Although, as expected, the numerical size of the priming effect is reduced, it remains significant for all morphological conditions. In an overall analysis of variance with two factors—prime type (three levels) and verb type (four levels)—we observed an effect of prime type, $F_1(2, 82) = 14.34$, $p < .000$; $F_2(2, 184) = 26.72$, $p < .000$, an effect of verb type by participants but not by items, $F_1(3, 123) = 6.66$, $p < .000$; $F_2(3, 92) = 1.01$, n.s., and no interaction ($F_1 < 1$; $F_2 < 1$). Focusing first on the no change regular conditions, priming is significant for all four conditions, but slightly higher for the subregularity verbs (32 ms) and the idiosyncratic verbs (32 ms) than for the regular (18.5 ms) and the morphophonological constraint verbs (19 ms). However this variation is not statistically significant. Comparing no change regular conditions and control conditions, there is a main effect of morphological priming, $F_1(1, 41) = 36.74$, $p < .000$; $F_2(1, 92) = 59.06$, $p < .000$, an effect of verb type by participants but not by items, $F_1(3, 123) = 4.73$, $p < .004$; $F_2 < 1$, and no interaction between the two factors ($F_1 < 1$; $F_2 < 1$). Turning to the irregular prime conditions and their controls, priming is significant across the board with no statistically

TABLE 3
Results of Experiment 2

Conditions	*Primes*	*Targets*	*RT (ms)*	*Priming effect*
Regular	*aimerons*	*AIMER*	551	19**
	aimons		552	18**
	porterons		570	
Morphophonological constraint	*semons*	*SEMER*	569	19**
	sème		566	22**
	votons		588	
Subregularity	*peindra*	*PEINDRE*	564	32**
	peignent		578	18**
	nichera		596	
Idiosyncratic	*allons*	*ALLER*	560	32**
	irons		578	14**
	tenons		592	
Semantic and orthographic controls	*broyait*	*MACHER*	587	5
	machine		599	−7
	progres		592	

Note: ** $p < .05$.

significant variation in the size of the effects (morphophonological constraint verbs 22 ms, subregularity group 18 ms, and idiosyncratic verbs 14 ms). Overall, comparing irregular conditions with control conditions, there is a main effect of morphological priming, $F_1(1, 41) = 22.03$, $p < .000$; $F_2(1, 92) = 30.96$, $p < .000$, an effect of verb type by participants but not by items, $F_1(3, 123) = 7.84$, $p < .000$; $F_2(1, 92) = 1.15$, n.s., and no interaction ($F_1 < 1$; $F_2 < 1$). Comparing directly the size of the priming effects in the no change regular and irregular/allomorphy conditions, we observed no main effect of prime type, $F_1(1, 41) = 2.16$, n.s.; $F_2(1, 92) = 2.09$, n.s., an effect of verb type by participants but not by items, $F_1(3, 123) = 4.81$, $p < .003$; $F_2 < 1$, and no interaction, $F_1(3, 123) = 1.31$, n.s.; $F_2(3, 92) = 1.18$, n.s.

In the two additional conditions (semantic and orthographic controls), we found no effect of semantic priming, $F_1(1, 41) = 1.8$, n.s.; $F_2(1, 21) = 1.05$, n.s., consistent with previously reported evidence that semantic effects are generally weak or nonexistent in masked priming, and no effect of orthographic overlap ($F_1 < 1$; $F_2 < 1$), allowing us to rule out accounts of the results in terms of simple form overlap between prime and target (see also Rastle, Davis, Marslen-Wilson, & Tyler, 2000).

Despite the lack of statistical significance in the relevant contrasts, the results in Table 3 do seem to suggest a reduced effect for irregular/allomorphic primes compared with no change regular primes in the subregularity condition (32 ms vs. 18 ms) and the idiosyncratic condition (32 ms vs. 14 ms). However, in so far as there is an effect here, it seems to be an effect in the regular priming conditions and not in the irregular ones. The size of the priming effects varies relatively little over the three irregular/allomorphic morphological priming contrasts, averaging 18 ms, and is equivalent in size to the no change regular priming effects in the regular and morphophonological constraint conditions. The divergence comes in the subregularity and idiosyncratic regular prime conditions, where the priming effect is elevated to 32 ms. We do not have an explanation for this divergence but we would emphasise that there is no reduced priming associated with irregular/allomorphic primes, but rather a nonsignificant increase in priming for a subset of no change regular primes.

Overall, the results of the masked priming experiment confirmed the results observed in the cross-modal experiment and show that irregular and regular verb forms prime their infinitive form equally, and that these priming effects do not vary with the degree of irregularity and allomorphy of the verb stems involved. The fact that these effects are found in a task which is generally insensitive to semantic relations between prime and target—and where the semantic control condition showed no priming—is good evidence that these are genuinely morphological effects, reflecting repeated access to the same underlying morpheme. This morpheme seems

to be accessed equally effectively, regardless of the irregularity of the prime word. We can also reject any simple form-based account, given the consistency in priming effects for morphologically related items across wide variations in orthographic overlap between prime and target, and the absence of any effect in the orthographic control condition.

GENERAL DISCUSSION

The question asked here was whether French regular and irregular inflected forms show different priming patterns. The classic dual mechanism hypothesis (Pinker, 1991, 1999) postulates a rule-based symbolic processor that supports the representation and generation of regular forms, while an associative rote-memory system is required to account for irregular forms. Pinker (1991) claimed that the different priming effects observed in English for regular and irregular forms support the dual mechanism dichotomy. Using French we found no such difference. The priming generated by regular inflected words did no differ from the priming generated by irregular forms. The facilitatory effects of morphologically related primes are just as strong whether they involve the same or different underlying roots as their targets. Pairs like *buvons/boire* prime just as well as pairs like *aimons/aimer*. These findings seem inconsistent with the predictions of the dual mechanism hypothesis for the processing behaviour of listed forms in a repetition priming task. In the framework of the dual mechanism account, because verbal forms from our idiosyncrasy condition are irregular and unpredictable, the irregular stems will have to be learned by rote and will be stored as independent but linked forms in a pattern-associative memory. For a priming task, this predicts reduced priming between prime/target pairs involving different underlying roots, a prediction confirmed in earlier research in English. The results obtained in French contrast with those obtained in English, but they are consistent with those observed in Italian. How can we explain that English speakers produced a pattern of results that was different for regular and irregular verbal forms while French and Italian speakers do not?

One approach that does predict this difference is the dual route account proposed by Marslen-Wilson & Tyler (1998), which re-interprets the priming differences between English regular and irregular forms, and in particular the accumulating evidence for neuropsychological dissociations involving these forms (Marslen-Wilson & Tyler, 1997, 1998; Tyler, deMornay-Davies, Anokinah, Longworth, Randall, & Marslen-Wilson, 2002; Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker, 1997), in terms of different phonological access processes, rather than to regularity and irregularity per se. Marslen-Wilson and Tyler (1998)

distinguish an access system that involves processes of morphophonologically assembly and disassembly, typically involving left inferior frontal systems, from access processes based in the temporal lobes that can map phonological input onto stored whole-form representations.

In English, as in the other languages we have studied, the normal perception and production of the regular past tense is argued not to involve simply the look-up of a stored form, but rather the dynamic combination of the stem with an inflectional affix. This requires the involvement of the processes of phonological assembly and disassembly mentioned above. When the brain areas supporting these processes are damaged, then patients will show impairments in tasks—such as primed lexical decision—involving the regular past tense. However, the irregular past tense in English is not morphophonologically complex in the same way. Forms such as *gave*, *brought*, or *took*, cannot be broken down in smaller phonological units consisting of a stem and an inflectional affix. Instead, they have to be learned and stored as whole forms. This means that access to representations of these forms does not require the engagement of phonological parsing processes in the same way as the regular forms, and can apparently be handled by temporal lobe speech processing systems. This, in turn, leads to the differential sensitivity of English regular and irregular forms to brain injury in the different areas involved, as well as, we would argue, the differential priming effects observed in English cross-modal priming experiments.

One consequence of this view is that when the regular/irregular contrast does not coincide, as in English, with the distinction between stored whole forms and concatenated stems and affixes, then we will not see the same distinction between the processing routes differentially involved by regular and irregular forms. In French, as in Italian, almost all verb forms combine a stem with at least an affix marking person and number, and often with an affix marking tense or aspect as well. This applies equally to words formed with regular stems as well as with irregular stems. A verb like *boire* may have the irregular alternate stem {buv-}, but this enters into the normal concatenative paradigms (see Table 4), with the tense-appropriate suffixes attached to it. Furthermore, these suffixes are almost always the regular suffixes, as illustrated for *boire* and *devoir* in Table 4. Although the stems may alternate between regular and irregular forms, the suffixes remain constant.

This means that the recognition of the idiosyncratic irregular form *buvaient*, 'they were drinking' requires morphophonological parsing just as much as the regular form *boiront*, 'they will drink'. On this basis, there is no reason to expect differences in priming behaviour simply because a form has a regular or irregular form—or indeed one of the intermediate types of allomorphy seen in our morphophonological constraint and

TABLE 4
Verbal forms of the verb *boire* and *devoir* for the three indicative tenses and the three singular and plural persons

aller (*infinitive form*)	*Present*	*Imperfect*	*Future*
je (1 sing.)	*bois* *dois*	*buvais* *devais*	*boirai* *devrai*
tu (2 sing.)	*bois* *dois*	*buvais* *devais*	*boiras* *devras*
il/elle/on (3 sing.)	*boit* *doit*	*buvait* *devait*	*boira* *devra*
nous (1 plur.)	*buvons* *devons*	*buvions* *devions*	*boirons* *devrons*
vous (2 plur.)	*buvez* *devez*	*buviez* *deviez*	*boirez* *devrez*
ils/elles (3 plur.)	*boivent* *doivent*	*buvaient* *devaient*	*boiront* *devront*

Note: sing. = singular; plur. = plural; 1 = first person (I or we); 2 = second person (you); 3 = third person (he/she or they).

subregularity conditions. In this respect, the absence of differential effects for the Romance languages French and Italian are consistent with our diagnosis of the regular/irregular effects in English as being language specific. Interestingly, there is some evidence that German, from the same West Germanic language family as English, may show similar regular/irregular differences (Sonnenstuhl, Eisenbeiss, & Clahsen, 1999), with the available priming data patterning with English rather than French.

It is also the case, however, that the pattern of results observed in French can readily be explained in terms of single-system accounts, and in particular in terms of connectionist distributed networks (e.g., Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986; MacWhinney & Leinbach, 1991). Certainly, the parallels between the priming effects for regular and irregular forms are consistent with a single mechanism hypothesis. French in any case offers a much less clear-cut distinction between regularity and irregularity than English, which may promote the emergence of a uniform representation account. In French irregular verbs typically also participate in many fully regular inflectional paradigms, and often combine regular forms and irregular forms within the same paradigm. Table 4 presents the different forms of the irregular verbs *boire* and *devoir*, for three different tenses and all persons. Thus, for the verb *boire*, the future forms are fully regular (as in *boira*), imperfect forms all have an irregular stem (as in *buvait*), while the present forms include both

regular and irregular variants, depending on person (as in *il boit* but *nous buvons*). For the verb *devoir*, while future and imperfect forms are all regular (such as *devra* and *devait*), present forms are both regular and irregular, again depending on the person (as in *nous devons* but *il doit*). This complexity and the lack of a clear-cut distinction between the domains of application of regular and irregular procedures, may facilitate a single system representational framework. However, it should be noted that the representation of polysyllabic morphologically complex forms remains a largely unsolved problem in the distributed processing literature.

In summary, the experiments presented in this paper show that French irregular verb forms prime their infinitive forms as effectively as regular forms, irrespective of the degree of unpredictability and idiosyncrasy involved. These results can be explained by a connectionist account but also follow readily from a revised dual route account which focuses on cross-linguistic variations in the morphophonological complexity of regular and irregular forms. The results—in particular the normal priming effects for the idiosyncratic forms—present more of a problem for the classic dual mechanism hypothesis.

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APPENDIX A
Experimental materials

Regular verbs

Primes		TARGETS
Regular 1	Regular 2	
aimerons	aimons	AIMER;
arriverons	arrivait	ARRIVER;
situons	situerons	SITUER;
chantiez	chanta	CHANTER;
chercha	cherchait	CHERCHER;
donnait	donnerons	DONNER;
entrait	entriez	ENTRER;
giclerons	giclons	GICLER;
glisserons	glissons	GLISSER;
laissons	laissera	LAISSER;
monterons	montons	MONTER;
montrerons	montrons	MONTRER;
osons	osait	OSER;
parlait	parlons	PARLER;
passait	passera	PASSER;
pense	pensons	PENSER;
pousserez	poussèrent	POUSSER;
racle	raclera	RACLER;
restons	resta	RESTER;
résumons	résumais	RESUMER;
semblons	semblerons	SEMBLER;
tombons	tomberons	TOMBER;
trouvions	trouverons	TROUVER;
visitera	visitait	VISITER.

Verbs with morphophonologic constraints

Primes		TARGETS
Regular	Irregular/ allomorphic	
achetons	achèterons	ACHETER;
achevait	achèverons	ACHEVER;
appeliez	appellerons	APPELER;
cédera	cèdent	CEDER;
considérons	considère	CONSIDERER;
crevait	crève	CREVER;
différiez	diffère	DIFFERER;
espérera	espère	ESPERER;
exagérons	exagère	EXAGERER;
feuilletait	feuillette	FEUILLETER;
haletiez	halèterons	HALETER;

APPENDIX A (Continued)

jetions	jetterons	JETER;
levons	lèvent	LEVER;
libérait	libèrent	LIBERER;
menait	mènera	MENER;
opérons	opère	OPERER;
pesait	pèsera	PESER;
possédons	possèdes	POSSEDER;
préférons	préfères	PREFERER;
protégeait	protège	PROTEGER;
répétiez	répètent	REPETER;
révélait	révèle	REVELER;
ruisselons	ruissellerons	RUISSELER;
semait	sèmerons	SEMER.

Verbs with subregularities

Primes		TARGETS
Regular	Irregular/ allomorphic	
astreindra	astreignons	ASTREINDRE;
atteint	atteignent	ATTEINDRE;
conduira	conduisent	CONDUIRE;
construit	construisent	CONSTRUIRE;
contraindrons	contraignons	CONTRAINDRE;
craint	craignions	CRAINDRE;
cuit	cuisait	CUIRE;
déduit	déduisons	DEDUIRE;
détruirons	détruisons	DETRUIRE;
éteindront	éteignons	ETEINDRE;
étreindrez	étreignions	ETREINDRE;
feindras	feignions	FEINDRE;
geindrons	geignions	GEINDRE;
instruiront	instruisons	INSTRUIRE;
joindra	joignez	JOINDRE;
luira	luisez	LUIRE;
nuirai	nuisait	NUIRE;
peindrez	peignait	PEINDRE;
plaindrai	plaignit	PLAINDRE;
produirez	produisit	PRODUIRE;
réduirai	réduisions	REDUIRE;
séduirons	séduisait	SEDUIRE;
teindra	teignait	TEINDRE;
traduit	traduisit	TRADUIRE.

Idiosyncratic verbs		
Primes		TARGETS
Regular	Irregular/ allomorphic	
absoudrons	absolvons	ABSOUDRE;
acquérons	acquiert	ACQUERIR;
allons	irons	ALLER;
assoyons	asseyons	ASSEOIR;
vivons	vécus	VIVRE;
boiront	buvaient	BOIRE;
voyez	verrez	VOIR;
coudrons	cousons	COUDRE;
croîtrons	croissons	CROITRE;
devons	doivent	DEVOIR;
dirons	disons	DIRE;
écrirons	écrivons	ECRIRE;
émouvons	émeuvent	EMOUVOIR;
fleurissait	florissait	FLEURIR;
fait	feront	FAIRE;
lirons	lisons	LIRE;
moudre	moulu	MOUDRE;
mourez	meurt	MOURIR;
naîtra	naquit	NAITRE;
pouvons	peuvent	POUVOIR;
prend	prenons	PRENDRE;
savent	sauront	SAVOIR;
valent	vaudrons	VALOIR;
voulait	veuillez	VOULOIR.