ERP's for inflectional morphology: A review of single route vs dual route models of word recognition

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ERP's for inflectional morphology: A review of single route vs dual route models of word recognition

Shazia Akbar Ghilzai[1]

Abstract

A lot of research has been done so far on the processing of regular and irregular words. Psycholinguists have proposed different morphological processing models and opened a long standing debate, whether these regularly and irregularly inflected words are processed via single mechanism models of inflection or via dual mechanism models. According to single mechanism models of inflection both regular and irregular forms are processed in the same way. Both of them are stored as full forms in memory and can be derived through associative networks. However, dual mechanism models assume that regularly inflected words that can be decomposed into their 'stems and affix' are decomposed into their constituents while processing. Irregular forms are stored as whole forms in memory and can be retrieved directly from the mental lexicon. In this connection, some researchers supported the single mechanism models, while the others provided the evidence in favor of dual mechanism models. Rodriguez-Fornells et al. (2002) research supported the dual mechanism model while Justus et al. (2009) findings advocated the single mechanism model. Both of them used the priming techniques and reported the brain imaging and behavioral data in support of their arguments. The present research provides a review of Rodriguez-Fornells et al.'s (2002) and Justus et al.'s (2009) research works.

Keywords: single route models of word recognition, dual route models of word recognition

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Rodriguez-Fornells et al. Findings

According to single mechanism models of inflection both regular and irregular forms are processed in the same way. Both of them are stored as full forms in memory and can be derived through associative networks. On the other hand, dual mechanism models postulates that regularly inflected words that can be decomposed into their stems and affix are decomposed into their constituents while processing. Irregular forms are stored as whole forms in memory and can be retrieved directly from the mental lexicon. In order to test these models and the differences between the processing of regular and irregular forms Rodriguez-Fornells et al. (2002) conducted their research on English and German. To assess the cross linguistic validity of single versus dual mechanism and their findings on English and German they extended their research to Spanish. A delayed visual repetition priming paradigm was used. These stimuli were arranged into two lists in which in the primed condition first-person singular present-tense forms preceded corresponding infinitive forms (e.g. ''ando/andar,'' ''duermo/dormir'') with an inter-item lag of five to nine items. In the unprimed condition, the infinitive forms were preceded by present-tense forms of unrelated words from the same stimulus group, e.g., ''amar'' [to love] was preceded by an unrelated firstsegment present-tense form with a non alternated stem, and an infinitive such as ''empezar'' [to begin] was preceded by an unrelated first-segment present-tense form with an alternated stem, e.g., ''confieso'' (I confess). Both lists were matched for frequency, mean word length, number of word conjugation etc. Subjects were required to perform a lexical decision task (word/ non word discrimination) for each stimulus.
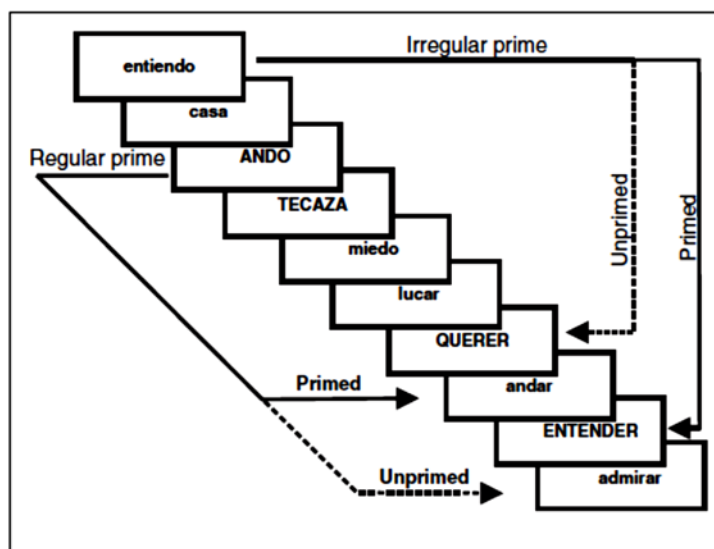
Figure1. Illustration of delayed repetition priming design/structure.

Results

Behavioral Results

Table 1 shows the mean reaction times and standard deviation for each condition. Reaction time for nonce words was slower than the existing verbs. Subjects performed fastly for nonalternated verb forms; it shows the effect of regularity. A general effect of priming was observed. Primed infinive were processed fastly then the unprimed infinitive forms. However, priming effect was only observed for existing verbs but not for nonce verbs. The priming effect for existing verbs was larger for verbs with non alternated stem forms than the nonalternated stem forms. But the difference between these two conditions was not statistically significant. The percentage error was similar for verbs and nonce verbs. While verb forms with vowel alternations produced a larger percentage of errors than non alternated forms. This effect was restricted to existing verb. The different priming conditions didn't affect the percentage errors.

Table 1. Mean Reaction Times ± *SD* for Verbs and Nonce Verbs

	Prime	Targets	
		Unprimed	Primed
Verbs with alternated stems ("irregular")	"entiendo": 700 ± 71	"querer": 672 ± 82	"entender": 650 ± 78
Verbs with nonalternated stems ("regular")	"ando": 663 ± 78	"lavar": 623 ± 68	"andar": 596 ± 63
Nonce verbs with alternated stems ("irregular")	"miero": 756 ± 99	"romar": 749 ± 119	"merer": 741 ± 105
Nonce verbs with nonalternated stems ("regular")	"poto": 743 ± 109	"vafar": 764 ± 109	"potar": 765 ± 104

Overall, Rodriguez-Fornells et al. (2002) found the ERP priming effect for inflected verb forms with non-alternated stems (ando-andar) but they didn't find the priming effect for inflected forms with alternated stem(duermo- dormer). The priming affect showed a modulation of N400 component. In addition to ERP's they reported two kind of behavioral data i.e. error scores and reaction times from a delayed visual priming repetition task. The alternated produced incorrect responses than non-alternated forms. This finding is consistent with the difference found in the ERP data for alternated and non-alternated forms.

The reaction time data showed small priming affect for both forms. Rodriguez-Fornells et al. (2002) argued that Reaction time priming effects to irregular words have been notoriously variable and difficult to replicate. They argued that this difference between N400 and response time are not necessarily sensitive to the same cognitive processes. Response time reflects the final outcome of the entire information processing sequence under study. While the N400 component indexes some intermediate stage of analysis. Regular and irregular verbs were dissociated by N400. Primed target forms of regular forms are easier to process because both contain the same stem. This easiness of processing results in reduced N400 amplitude. While, the irregular verbs the stem is altered therefore the memory trace formed

by the prime didn't activate the target sufficiently and hence it fails to produce reduced N400 priming affect.
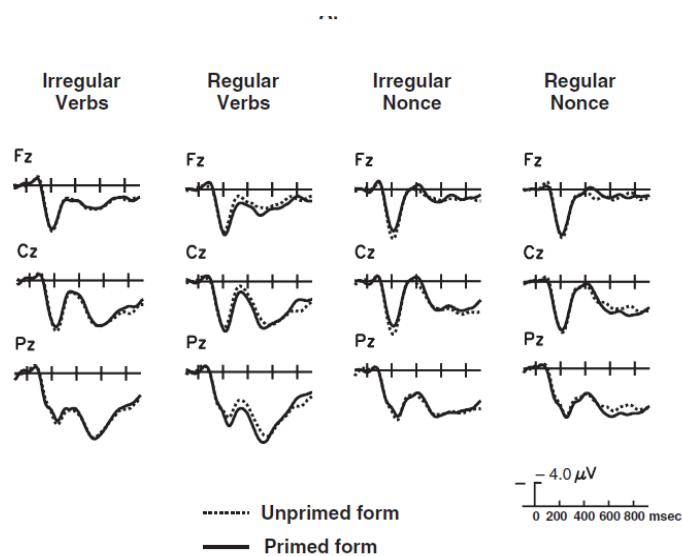

Fig. Grand average ERP's elicited by primed and unprimed words are depicted for non-alternated and alternated form of existing and nonse verbs.

Justus et al. Result

With regard to the debate concerning the single versus dual model mechanisms during the processing of regular and irregular verbs Justus et al. (2008, 2009) supported the single model mechanisms. They opposed the bipartite categorical distinction which are generated by an 'add /d/' or strip /d/ algorithm and irregular past tense which are stored form in the memory, hence processed via independent route (e.g. Pinker 1999, pinker & ullman). The dual system models predict the categorical division between regular and irregular verbs whereas, the single model systems predict the continuous division among regular, weak irregular, and strong verbs. These graded and continuous differences are predicted by the connectionist approach. In this view inflectional morphology is considered to be the convergence of form and meaning (Joanisse and Seidenberg, 1999). This approach doesn't view the division among regular, irregular and strong verbs as a tripartite categorical division rather it suggests an underlying continuum of regularity for the past tense. In which there are no discrete boundaries dividing regularity and irregularity. Figures 2 and 3 shows the illustration of both the graded & categorical division views.
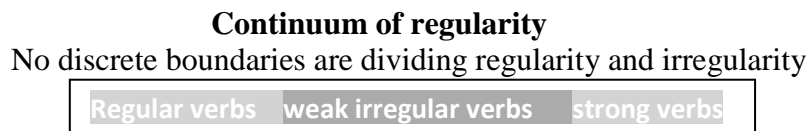
Continuum of regularity
No discrete boundaries are dividing regularity and irregularity

Regular verbs   weak irregular verbs   strong verbs

Figure 2: Graded continuous division among regular weak irregular verbs and strong verbs

Categorical division

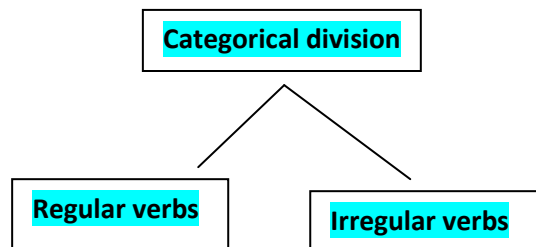Regular verbs   Irregular verbs

Figure 3: Categorical Division between regular and irregular verbs

Justus et al conducted intra model priming experiment (auditory-auditory) in support of graded continuous approach in 2008. The intra model results were thought to be the result of phonological overlap so, they replicated their experiment in 2009 with cross model experiment (auditory-visual) in support of the same graded continues approach.

Design and stimuli

1200 stimulus item were used resulting in 600 prime–target pairs with a 4 (regular, irregular, pseudopast, orthophono) by 3 (primed, unprimed, nonword) design shown in table 1. The items were matched for lemma frequency, syllabicity, word class, number of phonemes, number of letters etc. Justus et al. (2008) used a between item design.

The past tense was used as prime and the present tense used as target in two conditions made up of **regular verbs** (e.g. look, looked) and the irregular verbs. **Irregular verbs** were divided into weak irregular verbs and strong verbs. **Weak irregular verbs** (spent-spend) are similar to regulars because their past tense form end in a dental stop consonant but they do not follow a pattern similar to regular verbs. **Strong verbs (**spoke, speak) follow a pattern of vowel change and do not end in a dental stop consonant in the past tense. They included two

comparison conditions to control for phonological or orthographic the present and past tense of regular and irregular verbs.

Two control conditions i.e. pseudo past and orthophono conditions were used to control the differences in phonological and orthographical overlap between the present and past tense of regular and irregular verbs.

A pseudo past condition (e.g. bead, bee) semantically and morphologically unrelated words were selected in which the prime word differed from the target word by the addition of /t/ or /d/. They were phonologically consistent with the past tense form but not orthographically.

Orthophono condition: (barge, bar) included pair of words that were semantically unrelated such that the prime word differed from the target word by the addition of a single phoneme or one or two letters. This addition was not phonologically consistent with the regular past tense form.

Table 1.

Cross-modal immediate-priming design with lexical decision.

Word type	Priming	Prime (Aud.)	Target (Vis.)	Target Freq.[a]
Regular verbs ($n = 150$)	Primed	looked	LOOK	1.94 ± 0.4
	Unprimed	worked	SEEM	1.94 ± 0.4
	Nonword	asked	*TARB	
Irregular verbs ($n = 150$)	Primed	spoke	SPEAK	1.98 ± 0.8
	Unprimed	bound	WAKE	1.98 ± 0.8
	Nonword	took	*PLINN	
Pseudopast ($n = 150$)	Primed	bead	BEE	1.61 ± 1.1
	Unprimed	bulb	PIE	1.59 ± 1.1
	Nonword	deer	*CLEETH	
Orthophono ($n = 150$)	Primed	barge	BAR	1.29 ± 0.9
	Unprimed	bribe	TEA	1.21 ± 0.8
	Nonword	pouch	*GWAL	

[a] Log lemma frequency per million $\pm$ s.d.

Intra model morphological priming. Justus et al. (2008) reported an event related potential study of past tense priming using an auditory primes and targets. They found no significant difference between regular and irregular priming effects. They found significant response time facilitation for all four groups of stimuli and a reduction in the early portion of N400 component. Behavioral data and N400 data showed large difference for verb classes then the controlled conditions. There was significant priming effect for both the regular verbs and irregular verbs during the later portion of N400 component. They reported that the priming effect was stronger for the irregular verbs than the regular verbs with the difference being driven by the regular verbs. They reported that the dissociation between regular and irregular verbs they observed, shows that their results are consistent with the single system connectionist theory that regular and irregular words fall on a continuum of regularity (joanisse & Seidenberg, 1999). They provided an explanation for why regular verbs, along with weak irregular verbs, do not prime as strongly as do strong verbs in the intra-modal design. They attributed it to initial phonological overlap in intra model designs. They discussed the three major effects of phonological overlap that are prelexical facilitation, lexical inhibition, and strategic processes. They argued that the past tense conditions themselves contains word initial overlap. Regular verbs and weak irregular verbs contains more word initial overlap (e.g. looked,-look, spent-spend). In order to eliminate these effects Justus et al used cross model priming technique and replicated his previous experiment.
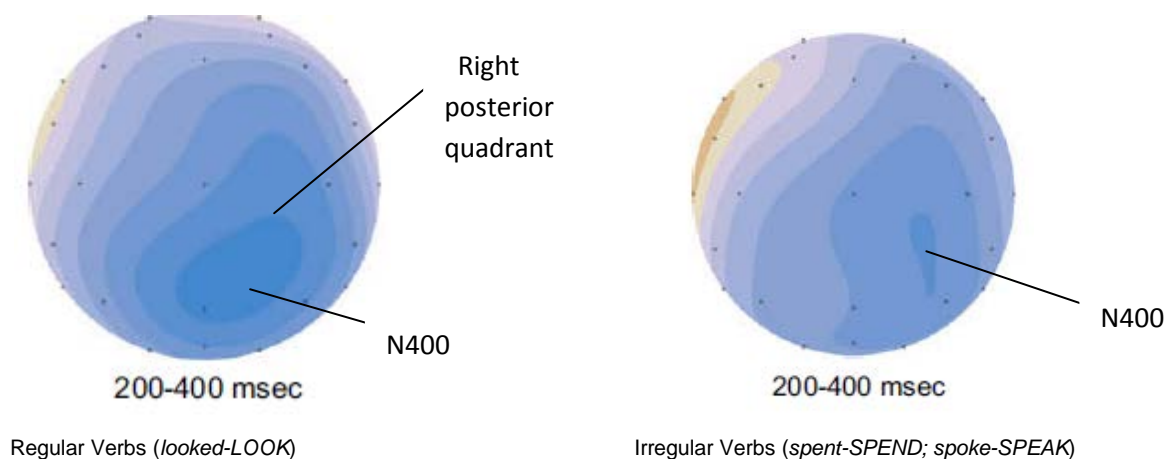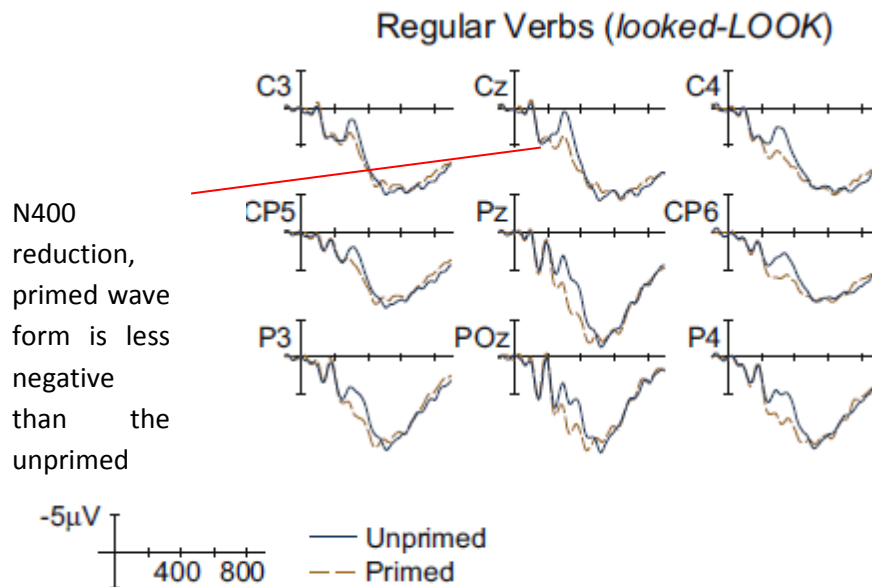
Cross model priming:

Justus et al. adopted the cross model priming design to eliminate phonological effects. They proposed that if they found continuous dissociation between regular and irregular verbs like their previous study (2008). It would suggest that the observed differences were not due to

phonological overlap. But if the dissociation disappeared due to cross model priming, it would indicate that phonological differences played the role in their intra model design.
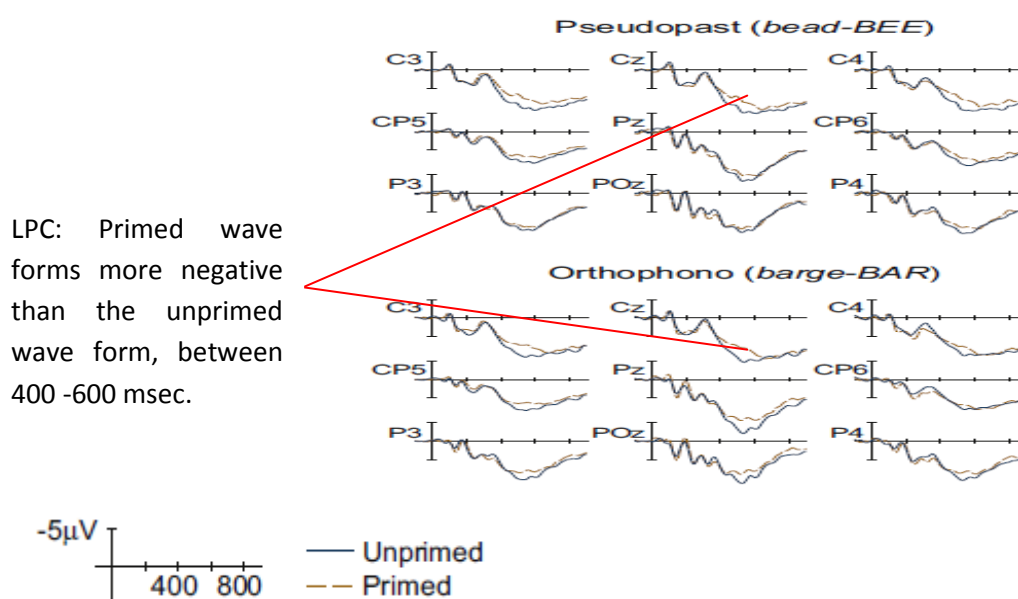
Results

Past-tense form of both regular and irregular English verbs facilitates a lexical decision to the visually presented, present-tense form (e.g., looked–LOOK or spoke–SPEAK).The behavioural facilitation results in a reduced N400 component that occurs in response to a visually presented target.N400 is a negative wave that peaks at approximately 400 ms following the presentation of a potentially meaningful stimulus, such as a word or a picture (Kutas & Hillyard, 1980; Kutas & Federmeier, 2000). The size of the N400 has been shown to reflect the ease of semantic integration into the preceding context, with an inverse relationship between the size of the N400 and the predictability of the stimulus's occurrence given the context. Thus, a word or picture that has been primed is associated with a reduced N400 component.

Right posterior quadrant

N400

200-400 msec

Regular Verbs (*looked-LOOK*)

N400

200-400 msec

Irregular Verbs (*spent-SPEND; spoke-SPEAK*)

Regular Verbs (*looked-LOOK*)

N400 reduction, primed wave form is less negative than the unprimed

-5µV

400 800

— Unprimed
-- Primed

The division of irregular verbs into strong verbs and weak verbs revealed larger behavioural effects numerically and also larger ERP priming effects for strong verbs as compared to weak verbs. The pseudo past condition resulted in a smaller but significant behavioural priming for the target word. The orthophono condition resulted in a non significant priming effect. In contrast to behavioural priming the control conditions didn't produce significant priming effects in the N400 region of interest (200-400 ms) but a reverse direction effect was observed on the late positive component (400-600 ms), such that the primed wave forms were more negative than the unprimed wave forms.

Pseudopast (*bead-BEE*)

Orthophono (*barge-BAR*)

LPC: Primed wave forms more negative than the unprimed wave form, between 400 -600 msec.

-5µV

400 800

— Unprimed
-- Primed

The time course and scalp distribution reveals that LPC shows a left ward asymmetry with a more anterior distribution. This effect can be observed in the left anterior quadrant of the regular and irregular verb conditions between 400 to 600 msec. This anterior negativity dominates the pseudo past and orthophono condition. In contrast N400 effect can be observed in the right posterior quadrant of the regular and irregular verb conditions between 200 to 400 ms window. N400 and LPC can be distinguished in both the scalp distribution and polarity. N400 is most readily observed at the central-parietal electrodes.

Pseudopast (*bead-BEE*)   **Orthophono (*barge-BAR*)**

LPC   in the left anterior quadrant region, between 400 to 600 msec. windows.

400-600 msec   400-600 msec

LPC
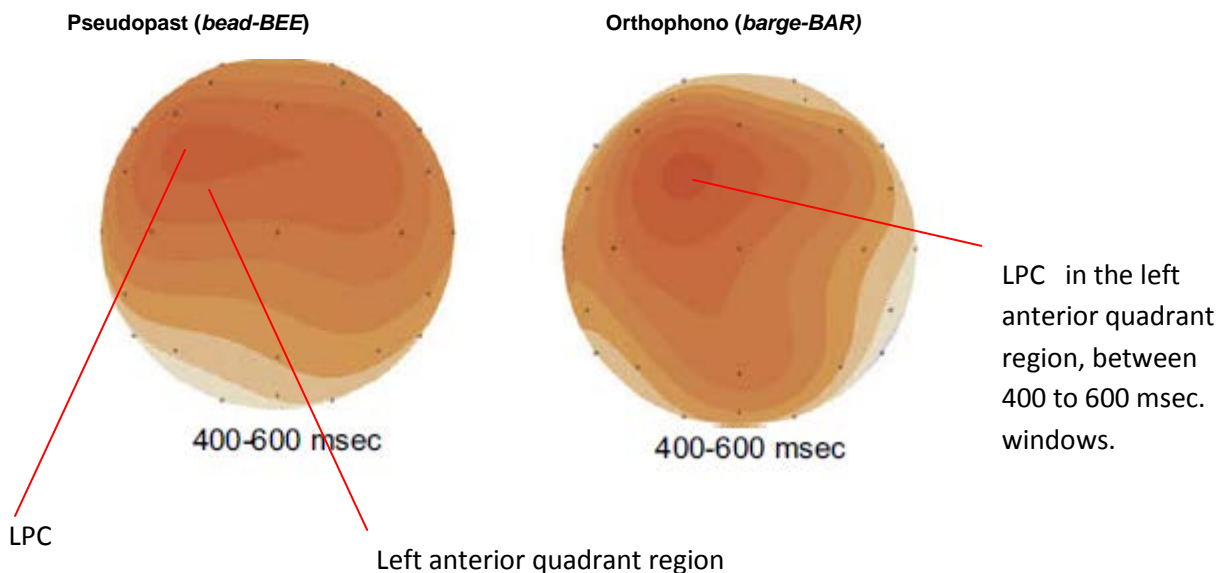
Left anterior quadrant region

Figure: LPC: late positive component

The LPC is more prominent for visually presented words. It follows the N400 and is thought to reflect the stimulus categorization and decision processes. LPC has been widely studied in explicit and implicit memory tasks (e.g., Swick & Knight, 1997). The LPC becomes greater in amplitude (more positive-going) after immediate stimulus repetition or repetition at longer lags (Karayanidis, Andrews, Ward, & McConaghy, 1991; Nagy & Rugg, 1989), but is less often influenced by semantic priming (Holcomb & Neville, 1990).

Results

Behavioural data

Response times for correct lexical decisions showed main effects of word type and priming.

Overall, faster response times were found for regular and irregular verbs as compared to the two control conditions. The participants were also faster in responding to primed words than the unprimed words. However, statistically the interaction between the word type and priming was not significant. The planned comparison revealed significant priming effect for three word types i.e. regular, irregular, and pseudopast word types but no significant priming effect was observed for orthophono word types.
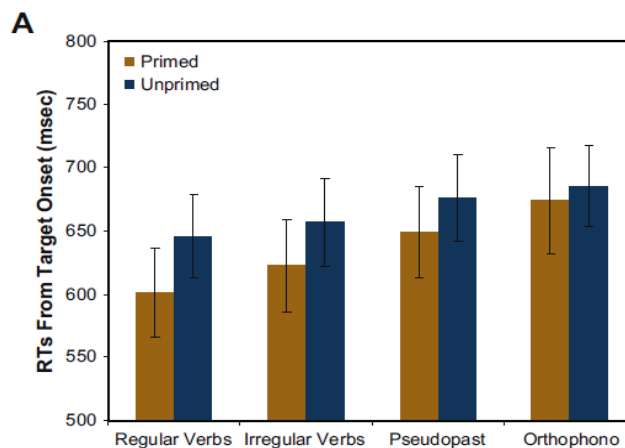
Second analysis was done to see the effect of the degree of irregularity, within the irregular word set i.e. strong verbs and weak irregular words. However no significant difference was found in the size of priming effect between the stronger verbs and the weak irregular verbs. There was no significant difference observed between each of these irregular and regular verbs.
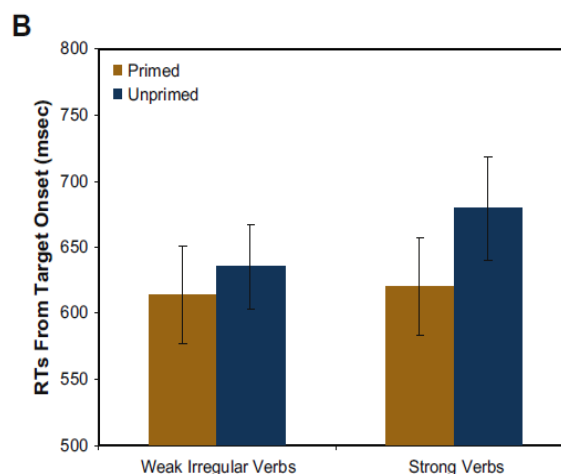
ERP-Data

N400 component was measured with a 200-400 ms window. During this window there were main effects of word type and priming. Significant N400 reductions were observed for primed regular and irregular verbs; but not for the pseudo past and orthophono conditions. Planned comparisons revealed that regular and irregular priming effects were statistically indistinguishable during this time window. However, both verbs primed more strongly than the semantically unrelated control. Priming in the pseudo past and orthophono conditions didn't differ. In an analysis that divided irregulars into strong and weak irregular verbs, a significant priming effect was found for strong verbs, but not for weak irregular verbs. These two effects were not significantly different between 200 and 400 ms window.

The late positive component (LPC) was the predominant feature during a 400-600 ms window. During this window, there was a significant effect of word type but not of priming. Significant priming affects were observed for the pseudopast and orthophono conditions but not for the regular irregular verbs. The direction of this effect is opposite than theN400 reduction. The primed pseudopast and orthophono items are more negative compared to the unprimed items. Planned comparisons revealed that the priming in the pseudopast and orthophono conditions did not differ. However, each of these semantically unrelated controls was significantly different from each word class. The nonsignificant priming effects observed in regular and irregular conditions were statistically indistinguishable from each other. When ***comparing the strong and weak irregular verbs*** during a 400 to 600 ms window significant priming was again found for strong verbs but not for weak irregular verbs. There was greater priming for strong relative to weak irregular verbs. Numerically, difference between the irregulars as a group compared with the regulars seems to be driven by the strong verbs. The priming effect for the strong verb was significantly larger than the regular verbs. But the priming effect for the weak irregular verbs was not significant.

Comparison of intra model and cross model morphological priming

Justus et al. (2008) reported that they found similar degrees of behavioural priming form both regular and irregular verbs in both the auditory intra model study and the current cross model study (Justus et al.2009). They found larger priming effects in their intra model study (73, 91) than the cross model study (45, 34). They argued that the smaller priming effects found with visual presentation of the target word is consistent with the faster response times they found in with visual presentation (651 ms) as compared to auditory presentation(860 ms).these behavioural effects were also compatible with the N400 priming effects. The auditory N400 was larger in size than visual N400.
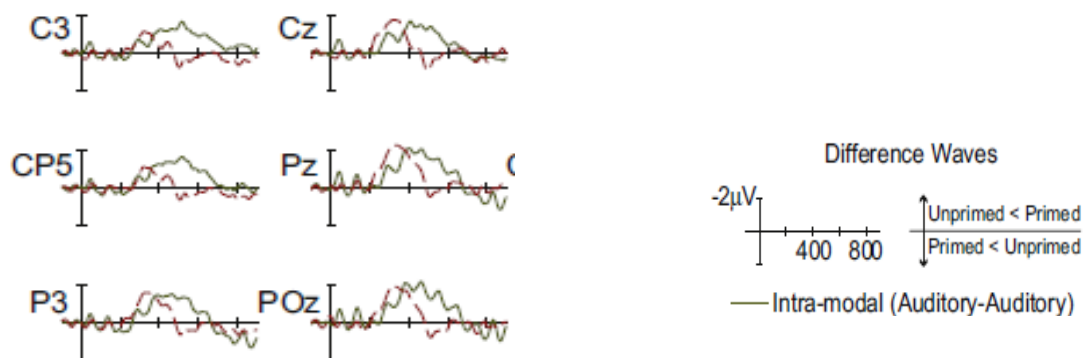
They reported that both the regular and irregular N400 priming effects were significant. However, the intra model study revealed that irregular effect was significantly larger during a later 500 -700 ms window and that this difference was driven by the strong verb. The current cross model study indicate some replication of this effect but the data is not clear at this point. The strong verbs numerically produced larger priming effects than the weak irregular verbs but the interaction was not significant like the intra model study. The ERP priming effects for strong verbs diminished by using cross model
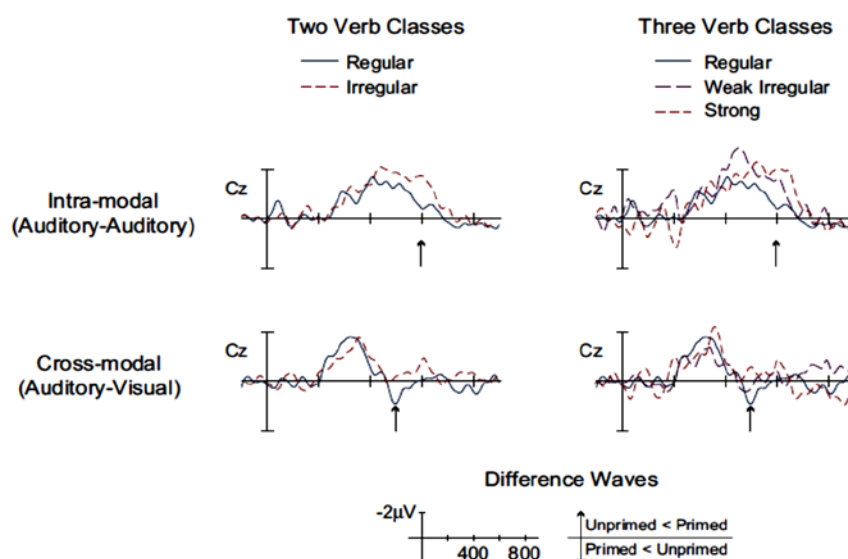
Fig. *illustration of intra model study (justus 2008) and cross model study(justus2009). Catagorical division vs graded division.*

Comparision of intra model and cross model phonological priming

The pseudopast and orthophono conditions in *intra model presentation* revealed significant behavioral priming effect as well as an N400 primng effect.whereas, in *the cross model presentation* behavioral priming was significant only for the pseudo pas condition but not for the orthophono condition. There were no significant N400 priming effects for control conditions in the cross model presentation. Instead a post lexical anterior negativity was found for conditions sharing word onset overlap. PLAN resulted in a reduction of LPC.

Justus et al. discussed the three possible effects of phonological proiming in the intra model design i.e. prelexical facilitation, lexical inhibition, and strategic processes. They argued that with cross model presentation, a smaller degree of prelexical facilitation is expected as compared to lexical inhibition and strategic effects.The prelexical facilitatory priming effects were reduced with cross model presentation.

Justus et al. proposed that the reverse direction effect on LPC-the PLAN for the control conditions represents the lexical inhibition phase of word onset phonological priming.They suggested that these effects are simplar to the effects observed by Holbcom. Holbcom et al.

found (2005) the reversal direction repetition effect with auditory primes and visual target but this reversal effect was not observed with visual primes and auditory targets.Holbcom et al. suggested that these effects seems to be related to the 'demands of visual word recognition.

Justus et al. presented many possible interpretations of PLAN, but why PLAN would occur with cross model presentation is still unclear. They suggested that the stronger modutlation of N400 in the intra model design by prelexical factors may have obscured these effects.

Discussion

There is a confounding factor in Justus et al. priming experiment. They used the between item design. They compared measures from two different items (though matched for frequency, length etc.) in the Justus et al. study.

For example

Regular verbs

Priming	Prime	Target
Primed	looked	Look
Unprimed	worked	Look

It would've been better to compare "look" preceded by "looked" to "look" preceded by an unrelated past tense form (e.g. "seemed" or "walked"). For instance

Regular verbs

Priming	prime	Target
Primed	looked	Look
Unprimed	worked	Look

Justus et al. used the intra model priming technique (auditory-auditory) in their 2008 experiment. It was thought that these results can be the effect of phonological overlap, so they used the cross model design in 2009 but the ERP priming effects for strong verbs

diminished by using cross model. It suggests that phonological effects can account for some of the graded effects of regularity observed with the intra model presentation (Justus et al. 2008). They argued that phonological factors can not completely account for these intra model effects because differences with strong verbs and weak irregular verbs still occurred with cross model presentation. But still these priming effects for strong verbs can be the result of phonological overlap because they didn't use intervening item.

References

Holcomb, P. J., Anderson, J., & Grainger, J. (2005). An electrophysiological study of cross-modal repetition priming. Psychophysiology,42, 493–507

Justus, T., et al. (2009). An event-related potential study of cross-modal morphological and phonological priming. *Journal of Neurolinguistics*, 22, 584-604.

Justus, T., Larsen, J., de Mornay Davies, P., & Swick, D. (2008). Interpreting dissociations between regular and irregular past-tense morphology: evidence from event-related potentials. Cognitive, Affective, Behavioral Neuroscience, 8, 178–194.

Joanisse, M. F., & Seidenberg, M. S. (1999). Impairments in verb morphology after brain injury: a connectionist model. Proceedings of the National Academy of Sciences, 96, 7592–7597.

Karayanidis, F., Andrews, S., Ward, P. B., & McConaghy, N. (1991). Effects of inter-item lag on word repetition: an event-related potential study. Psychophysiology, 28, 307–318.

Nagy, M. E., & Rugg, M. D. (1989). Modulation of event-related potentials by word repetition: the effects of inter-item lag. Psychophysiology, 26, 431–436

Pinker, S. (1999). Words and rules: The ingredients of language. New York: Basic.

Pinker, S., & Ullman, M. T. (2002). The past and future of the past tense. Trends in Cognitive Sciences, 6, 456–463.

Rodríguez-Fornells, Münte, Clahsen (2002). Morphological priming in Spanish verb forms: An ERP repetition priming study. *Journal of Cognitive Neuroscience*, 14, 443-454

Swick, D., & Knight, R. T. (1997). Event-related potentials differentiate the effects of aging on word and nonword repetition in explicit and implicit memory tasks. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 123–142.