Word processing through lexical decision in Brazilian Portuguese

Blends, derived, and simplex words

Gustavo Estivalet,[1,2] José Ferrari-Neto,[1,2] Rafael Minussi,[2,3] and Alina Villalva[4]

[1] Federal University of Paraiba | [2] National Council for Scientific and Technological Development | [3] Federal University of São Paulo | [4] University of Lisbon

This study investigates word processing in Brazilian Portuguese, focusing on blends, which juxtapose or overlap (W)ords and/or (C)lips (e.g. *portunhol* = *(portu)guês* 'Portuguese' + *espa(nhol)* 'Spanish'). Blends present intriguing theoretical and empirical challenges to models of morphological analysis, morphological processing, lexical access, and the mental lexicon. Most research on blends has been conducted in languages other than Portuguese. This study addresses this gap by exploring the processing of blends in Brazilian Portuguese through a behavioral lexical decision experiment. We manipulated blends in constituent structure and grammatical structure, considering (H)ead and (M)odification. Additionally, we compared blends against words with various morphological structures, such as derived complex words containing prefixes (e.g., *[des]acordo* 'disagreement') or suffixes (e.g., *cozinh[eiro]* 'cook'), and monomorphemic simplex words. We also included simplex and complex pseudowords (e.g., *[acont]arago*; *dador[eiro]*) and nonwords (e.g., *sfaricrelj*) in the experiment. Accuracy and reaction time results suggest that blends are accepted and processed differently from simplex and complex words, resembling pseudowords. This study contributes to a deeper understanding of blend description and processing, providing valuable insights into lexical access, enhancing theoretical and empirical comprehension of morphological processing.

Keywords: morphological processing, blends, lexical access, lexical decision, psycholinguistics

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Introduction

Blending is a productive word formation process that combines two or more words, by juxtaposing or overlapping word clips (any truncation of a word without morphemic status) or entire words. While this process is quite productive in many languages, the frequency of any individual blend will often be low. The rarity of these low-frequency blends makes the study of blend processing particularly valuable for understanding word processing broadly.

Neither the linguistic description, nor the study of the processing of these words is abundant, and it should be noted that the studies on blends usually come from English and French (Gries, 2012). Blends from other languages have received some attention, though less systematically, and this is also the case with Portuguese.

From a linguistic description perspective, Portuguese blends have received more attention for their phonological nature (Gonçalves, 2006) than for their morphological structure, and research on blending on morphological grounds has recently emerged (Minussi & Villalva, 2020; Villalva & Minussi, 2022). These studies have shown that Portuguese blends are not random formations but rather words with typical structures which adhere to general principles of word formation.

Although there has been extensive research across languages and experimental paradigms on the processing of simplex and complex words (Amenta & Crepaldi, 2012), blends have received less attention in morphological processing research than other types of words. Gries (2004) examined the relation of blending to other phenomena such as truncations and speech errors, as well as the recognition of blend bases. Additionally, Juhasz et al. (2017) explored blend recognition using both lexical decision and sentence reading tasks, showing that English blends are recognized more slowly than control words. This finding supports the role of morphological decomposition in word recognition and can be compared to the processing of complex words driven by their morphological structures (Colé et al., 1997), as well as the semantic composition in blend formation.

To our knowledge, no study has addressed blending in Portuguese. The present study is part of a research project on blends and compounds in Portuguese and reports a lexical decision experiment conducted to determine whether different blend structures correspond to differences in processing time, or if, on the contrary, blending structural differences are not relevant. As distractors, we used monomorphemic simplex and derived complex Portuguese words, along with a set of pseudowords and nonwords.

Methods

Within the framework of the "Blends & Compounds — Processing and Lexical Analysis" project, we developed an annotated corpus of blends from Portuguese, as no systematic source for studying these words was available. The analysis of this corpus has enabled us to identify a general structural constraint that accounts for the majority of items and allows us to distinguish between congruent and incongruent structures. This constraint posits that congruent structures are those in which the clipped constituent coincides with the head of the blend, while incongruent structures are those where no such coincidence occurs, whereas the head in composition is the base which transfers the syntactic-semantic information to the blend.

A previous Word Association Test determined whether participants could trace the base words of the blends, showing that clipped words in the head position were more frequently identified than those acting as modifiers (Villalva & Minussi, 2022). The current lexical decision test aims to assess whether reaction times can differentiate blends from derived words, simple words, pseudowords, and nonwords, as well as different blend structures.

The study was conducted in accordance with the Declaration of Helsinki, and its protocol was approved by the Human Research Ethics Committee of the Federal University of Paraíba (CAAE: 73406717.0.0000.0121).

Materials

A total of 108 words were selected, comprising 36 blends, 36 simplex, and 36 derived words. Simplex and derived words were sourced from the Brazilian Portuguese Lexicon (Estivalet & Meunier, 2015), while blends were drawn from the Portuguese Blend Corpus (Villalva & Minussi, 2022), which contains more than 450 blends collected from various sources (i.e., literature, press, television, social media, etc.). All words were controlled for low word frequency (i.e., <3 on the Zipf scale), number of letters (8–12), and number of syllables (3–5), as detailed in Table 1.

Table 1. Means and standard deviations from the controlled variables of experimental stimuli

	Frequency	Letters	Syllables
Blends	1.82 (0.56)	9.63 (0.92)	4.08 (0.28)
Derived	2.23 (0.77)	9.83 (0.89)	4.25 (0.43)
Simplex	2.28 (0.72)	9.78 (0.86)	4.11 (0.39)

Additionally, a set of 72 non-existent stimuli (i.e., 36 pseudowords and 36 nonwords) was added to the 108 experimental words, resulting in a total of 180 stimuli. Pseudowords were simplex or derived, created by manipulating existing Portuguese words into non-existent ones with the desired morphological structure. Nonwords consisted of impossible letter sequences in Portuguese (Estivalet & Meunier, 2015).

The group of 36 blends are representative of the predominant structural types. The first aspect considered was the constituent structure, where the base is either a (C)lip or a (W)ord. A clip is any truncation of a word without morphemic status which can overlap with an adjacent word. Four subtypes of constituent structure were observed.

WW: Both words forming the blend are visible with phonetic overlap at the internal peripheries of the bases (e.g., *calafriorento* 'sensitive to cold caused by a chill' = [cala[frio]]N 'chill' + [[frio]rento]ADJ 'sensitive to cold'). CC: Neither base is visible with truncation of the internal peripheries of the bases (e.g., *maravilhástico* 'wonderful and fantastic' = [maravilh[oso]]ADJ 'wonderful' + [[fant]ástico]ADJ 'fantastic'). CW: Only the second base is visible with truncation of the right periphery of the first base (e.g., *cabistonto* 'downcast and dizzy' = [cabis[baixo]]ADJ 'downcast' + [tonto]ADJ 'dizzy'). WC: Only the first base is visible with truncation of the left periphery of the second base (e.g., *sonhâmbulo* 'dream walker' = [sonho]N 'dream' + [[son]âmbulo]ADJ 'sleepwalker').

The second aspect considered was the grammatical structure, that is, the syntactic-semantic relation between the bases of the blend, classified as (H)ead-initial or head-final (M)odification structures (i.e., HM, MH), or a coordination structure (i.e., HH). Three types of syntactic-semantic structures were observed.

HH: Coordination in which both bases are heads (w.g., *fabulástico* 'fabulous and fantastic' = [fabul[oso]]ADJ 'fabulous' + [[fant]ástico]ADJ 'fantastic'). MH: The second base is the head (e.g., *sofressor* 'professor who suffers' = [sofre[dor]]ADJ 'sufferer' + [[profe]ssor]N 'professor'). HM: The first base is the head (e.g., *manifestoche* 'protester who is a puppet' = [manifest[ante]]N 'protester' + [[fant]oche]N 'puppet').

By combining constituent structure (WW, WC, CW, CC) with syntactic-semantic relation (HH, HM, MH), 12 conditions of blends were created, with three representative items per condition. For the derived words, two structures were tested: Prefix-Word (i.e., CW/MH) and Root-Suffix (i.e., WC/HM). Examples of all conditions are provided in Table 2.

Table 2. Example of stimuli in all conditions. The C in the derived words equals affix

	Blends				Derived	
Structure	WW	WC	CW	CC	WC	CW
HH	*belzeburro*	*forrogode*	*cabistonto*	*pensageiro*	–	–
HM	*baratonta*	*pãodemia*	*cartomente*	*pensatempo*	*lançamento*	–
MH	*alegrito*	*cãodidato*	*lacrimoça*	*cansástico*	–	*interface*
Simplex	*alfinete*	Nonwords	*vbestjxe*	Pseudowords	*ibalismo*	*distablo*

One list, along with its reversed order version, was constructed in a pseudo-random order to counterbalance the presentation of stimuli and conditions following the specific criteria: no consecutive stimuli with the same first letter, a maximum of three consecutive words or pseudowords, and a minimum of 10 stimuli between two stimuli of the same condition. All materials are available in Appendix A in the Supplementary Material.

Participants

Ninety native speakers of Brazilian Portuguese (mean age: 26.3 years, 45 females) participated in the study. All participants were right-handed, had normal hearing, normal or corrected-to-normal vision, and no history of cognitive disorders. They were undergraduate or graduate students at the Federal University of Paraíba, Brazil, were unaware of the research purpose, and provided written consent to participate as volunteers in the experiment.

Procedure

We used jsPsych to design and implement the experiment. Participants performed a behavioral lexical decision task, responding to visually presented items on their smartphones using a touchscreen (de Leeuw, 2015). Response buttons were assigned to both hands: a 'yes' button for existing words and a 'no' button for non-existent words. Participants were instructed to respond both promptly and accurately.

Each trial followed this sequence: a fixation point '+' appeared at the center of the screen for 500 ms, followed by the target stimulus presented in lowercase, 18pt Courier New font, with black letters on a white background. Reaction time (RT) recording began with the onset of the target stimulus, which remained on the screen for 3000 ms or until the participant responded. A blank interstimulus screen was then displayed for 500 ms before the next trial, which began with the presentation of the fixation point.

The experiment started with a consent form, followed by instructions and a practice block of ten stimuli before the main trial block. The entire session lasted approximately 18 minutes.

Results and discussion

The results of the lexical decision experiment were statistically analyzed after excluding responses faster than 300 ms or slower than 2500 ms (6.62%). We conducted mixed-effects model analyses, using the logarithm of RTs as the dependent variable in one analysis, and logical accuracy with a binomial distribution in another. Participants and items were included as random effects (Baayen et al., 2008).

Analysis on stimuli type and complexity kind

In a first analysis with all experimental items, we considered stimuli type (word, blend, pseudoword, nonword) and complexity kind (simplex, derived) as fixed-effect independent variables (Appendix B in Supplementary Material). A significant main effect was observed for stimuli type ($F(3,174)=122.16$, $p<.001$). Planned comparisons from the mixed-effect model on stimuli type revealed that blends significantly differed from words ($t(174)=-10.23$, $p<.001$) and nonwords ($t(174)=-14.87$, $p<.001$), but not from pseudowords ($t(175)=.42$, $p=.68$. Additionally, words were significantly different from pseudowords ($t(175)=8.76$, $p<.001$) and nonwords ($t(173)=-4.65$, $p<.01$), and pseudowords were significantly different from nonwords ($t(174)=-12.55$, $p<.001$). No effect for complexity kind was found ($F(1,175)=.17$, $p=.68$), nor an interaction between these variables ($F(1,175)=.15$, $p=.70$).

Regarding the accuracy results, significant effects were found for stimuli type ($\chi^2(3)=483.92$, $p<.001$). Planned comparisons on the stimuli type revealed that blends were significantly different from words ($z=16.65$, $p<.001$), pseudowords ($z=5.51$, $p<.01$), and nonwords ($z=18.16$, $p<.001$). Additionally, words were significantly different from pseudowords ($z=-9.01$, $p<.001$) and nonwords ($z=4.49$, $p<.001$), and pseudowords were significantly different from nonwords ($z=11.87$, $p<.001$). No effect was observed for complexity kind ($\chi^2(1)=1.52$, $p=.22$), but an interaction between these variables was found ($\chi^2(1)=5.98$, $p<.05$). Table 3 summarizes the RT means, standard deviations, and accuracy.

Table 3. RT means, standard deviations, and accuracy results

	Simplex and blends		Derived	
	RT (ms)	Error (%)	RT (ms)	Error (%)
Word	1166 (393)	1.26	1165 (378)	0.74
Blend	1465 (454)	11.70	–	–
Pseudoword	1463 (469)	1.40	1485 (474)	2.68
Nonword	1045 (334)	0.15	–	–

These results indicate that blends were significantly distinguished from simplex and complex words, as well as nonwords, showing a close resemblance to pseudowords. This outcome was not unexpected given that blends are words of very low frequency and native speakers have rarely or never encountered them.

The significant interaction in the accuracy results for words and pseudowords is due to the low error rate in derived words and high error rate in derived pseudowords, when compared to simplex words and pseudowords, indicating the salience of derivational affixes in morphological processing (Colé et al., 1997).

Analysis on blend constituent and grammatical structures

The second analysis focused exclusively on blending structures. We examined the effects of constituent structure (WW, WC, CW, CC) and grammatical structure (HH, HM, MH) as the fixed-effect independent variables. No significant effects were found for constituent structure ($F(3,24) = .68$, $p = .57$), grammatical structure ($F(2,24) = .05$, $p = .95$), or the interaction between these variables ($F(6,24) = 1.21$, $p = .34$).

Turning to the accuracy results, all blends were classified as existent words in the experiment, therefore, the accuracy results on blends actually reflect the participant's acceptance of the blends as a word or a pseudoword than lexical decision errors. No effect was observed for constituent structure ($\chi^2(3) = 2.35$, $p = .51$) or grammatical structure ($\chi^2(2) = 2.02$, $p = .36$). However, a significant interaction effect emerged between these variables ($\chi^2(6) = 10.43$, $p < .05$). Planned comparisons revealed that this interaction is driven by differences in WC/HH, WW/HM, and WW/MH compared to the other blend structures. Accuracy results are summarized in Figure 1. In order to focus on which blend conditions (constituent and grammatical structures) are more accepted as words or pseudowords, each graph per blend condition was standardized to 100%.

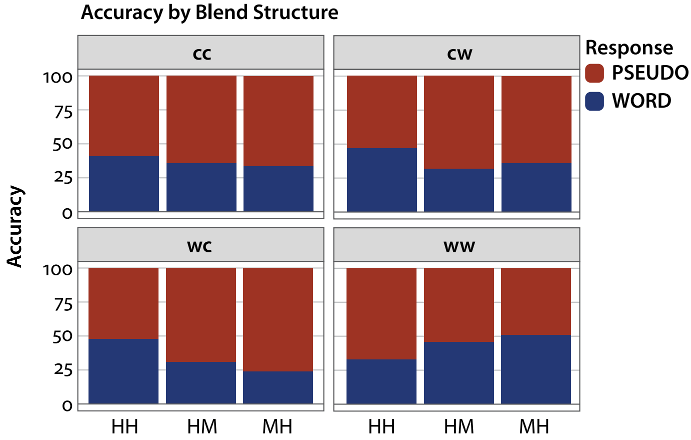

Figure 1. Blend accuracy by constituent structure and grammatical structure

Therefore, these accuracy results align with the RT results observed for stimuli type, supporting the finding that blends are frequently recognized as pseudowords (Juhasz et al., 2017). Moreover, the blend structures WC/HH, CW/HH, but also WW/MH, induced significantly more responses categorized as words, as we hypothesized regarding the congruent conditions between constituent and grammatical structures (i.e., C = H). These results suggest that the congruent structures of clip and head are the most productive and accepted for blending in Portuguese (Minussi & Villalva, 2020). Additionally, the blend cases with phonetic overlap (i.e., WW) were also largely accepted as words as they approximate the structure of composed words (Gonçalves, 2006).

Conclusion

This study was motivated by the fact that blends are complex words that speakers have rarely or never encountered and yet they often manage to understand them (Minussi & Villalva, 2020). From a linguistic point of view, they are hard to analyze because they use clips of words that have no morphological status. Therefore, the processing of blends is of tantamount importance for a better understanding of complex words processing and representation. Our main objective was to investigate the processing of words in Portuguese, focusing on blends in comparison to complex derived words, monomorphemic simplex words, pseudowords, and nonwords while exploring the role of blend constituents and grammatical structures.

Our hypothesis regarding the processing of complex words was that structural contrasts might manifest different latencies and accuracy regarding the stimuli type. Nevertheless, we expected these contrasts to be of lesser size in blends when compared to the simplex and derived words, as well as pseudowords (Colé et al., 1997).

For this purpose, we ran a behavioral lexical decision experiment with blends manipulated in constituent and grammatical structures, and other types of words and pseudowords. As the main result, blends seem to be accepted and processed differently from simplex and derived words, but are similar to pseudowords.

This study shed light on blends as a distinctive type of complex words, not only regarding their lexical specificity, but also due to their resemblance to pseudowords during processing (Juhasz et al., 2017). Thus, these findings contribute to advancing our comprehension of morphological processing from both theoretical and empirical perspectives on Portuguese blends which can be extended to other languages.

Further exploration involving lexical decision experiments coupled with priming might reveal even more interesting details to deepen our understanding of blend representation and processing as complex words in the mental lexicon.

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Appendix A. Experiment stimuli

Target	Constituent	Syntactic	Kind	Type
arfalhudo	CC	HH	BLEND	BLEND
barbalhudo	CC	HH	BLEND	BLEND
pensageiro	CC	HH	BLEND	BLEND
brasiguaio	CC	HM	BLEND	BLEND
manifestoche	CC	HM	BLEND	BLEND
pensatempo	CC	HM	BLEND	BLEND
arrumário	CC	MH	BLEND	BLEND
cansástico	CC	MH	BLEND	BLEND
gramatigalha	CC	MH	BLEND	BLEND
brutamonstro	CW	HH	BLEND	BLEND
cabistonto	CW	HH	BLEND	BLEND
traficrente	CW	HH	BLEND	BLEND
cartomente	CW	HM	BLEND	BLEND
delegato	CW	HM	BLEND	BLEND
sertanojo	CW	HM	BLEND	BLEND
ecotonto	CW	MH	BLEND	BLEND
infantasia	CW	MH	BLEND	BLEND
lacrimoça	CW	MH	BLEND	BLEND
fodástico	WC	HH	BLEND	BLEND

Appendix A. *(continued)*

Target	Constituent	Syntactic	Kind	Type
forrogode	WC	HH	BLEND	BLEND
mocolate	WC	HH	BLEND	BLEND
infernagem	WC	HM	BLEND	BLEND
pãodemia	WC	HM	BLEND	BLEND
sextaneja	WC	HM	BLEND	BLEND
baratechó	WC	MH	BLEND	BLEND
boaconha	WC	MH	BLEND	BLEND
cãodidato	WC	MH	BLEND	BLEND
belzeburro	WW	HH	BLEND	BLEND
diligentil	WW	HH	BLEND	BLEND
febrilhante	WW	HH	BLEND	BLEND
baratonta	WW	HM	BLEND	BLEND
esbocejo	WW	HM	BLEND	BLEND
herbivoraz	WW	HM	BLEND	BLEND
alegrito	WW	MH	BLEND	BLEND
caipiranha	WW	MH	BLEND	BLEND
funebrilho	WW	MH	BLEND	BLEND

Words

Target	Constituent	Syntactic	Kind	Type	Target	Kind	Type
desacordo	PW	MH	DERIVED	WORD	alfinete	SIMPLEX	WORD
desajuste	PW	MH	DERIVED	WORD	algarismo	SIMPLEX	WORD
desânimo	PW	MH	DERIVED	WORD	alicerce	SIMPLEX	WORD
extraforte	PW	MH	DERIVED	WORD	almofada	SIMPLEX	WORD
extragrande	PW	MH	DERIVED	WORD	assembléia	SIMPLEX	WORD
hiperespaço	PW	MH	DERIVED	WORD	aventura	SIMPLEX	WORD
hipertensão	PW	MH	DERIVED	WORD	borboleta	SIMPLEX	WORD
intercâmbio	PW	MH	DERIVED	WORD	caranguejo	SIMPLEX	WORD
intercurso	PW	MH	DERIVED	WORD	catarata	SIMPLEX	WORD
interface	PW	MH	DERIVED	WORD	caturrita	SIMPLEX	WORD
interfone	PW	MH	DERIVED	WORD	crocodilo	SIMPLEX	WORD
semicírculo	PW	MH	DERIVED	WORD	detergente	SIMPLEX	WORD

Appendix A. *(continued)*

Target	Constituent	Syntactic	Kind	Type	Target	Kind	Type
semideus	PW	MH	DERIVED	WORD	devaneio	SIMPLEX	WORD
supercola	PW	MH	DERIVED	WORD	dinamite	SIMPLEX	WORD
superforça	PW	MH	DERIVED	WORD	elefante	SIMPLEX	WORD
supermercado	PW	MH	DERIVED	WORD	escrúpulo	SIMPLEX	WORD
superpoder	PW	MH	DERIVED	WORD	esparadrapo	SIMPLEX	WORD
supervilão	PW	MH	DERIVED	WORD	esqueleto	SIMPLEX	WORD
abordagem	WS	HM	DERIVED	WORD	estímulo	SIMPLEX	WORD
andamento	WS	HM	DERIVED	WORD	estrogonofe	SIMPLEX	WORD
ansiedade	WS	HM	DERIVED	WORD	fenômeno	SIMPLEX	WORD
arbitragem	WS	HM	DERIVED	WORD	ginástica	SIMPLEX	WORD
borracheiro	WS	HM	DERIVED	WORD	harmonia	SIMPLEX	WORD
capacidade	WS	HM	DERIVED	WORD	lantejoula	SIMPLEX	WORD
carroceiro	WS	HM	DERIVED	WORD	objetivo	SIMPLEX	WORD
cozinheiro	WS	HM	DERIVED	WORD	orangotango	SIMPLEX	WORD
espionagem	WS	HM	DERIVED	WORD	panorama	SIMPLEX	WORD
feiticeiro	WS	HM	DERIVED	WORD	panturrilha	SIMPLEX	WORD
finalidade	WS	HM	DERIVED	WORD	papagaio	SIMPLEX	WORD
hospedagem	WS	HM	DERIVED	WORD	paralelo	SIMPLEX	WORD
jardinagem	WS	HM	DERIVED	WORD	perspectiva	SIMPLEX	WORD
lançamento	WS	HM	DERIVED	WORD	pintassilgo	SIMPLEX	WORD
mapeamento	WS	HM	DERIVED	WORD	precipícios	SIMPLEX	WORD
mensalidade	WS	HM	DERIVED	WORD	simpatia	SIMPLEX	WORD
orçamento	WS	HM	DERIVED	WORD	tartaruga	SIMPLEX	WORD
serralheiro	WS	HM	DERIVED	WORD	vestibular	SIMPLEX	WORD

Pseudowords and nonwords

Target	Constituent	Syntactic	Kind	Type	Target	Type
anterana	PP	MH	DERIVED	PSEUDO	AVNEZINX	NONWORD
distablo	PP	MH	DERIVED	PSEUDO	AVUQUSMZLEL	NONWORD
intrastifo	PP	MH	DERIVED	PSEUDO	BCISQTIBA	NONWORD
monoassino	PP	MH	DERIVED	PSEUDO	BJQUJLNJQUT	NONWORD
permiamilo	PP	MH	DERIVED	PSEUDO	BRSCAQUPJFI	NONWORD
poliginica	PP	MH	DERIVED	PSEUDO	CLFTIDADXO	NONWORD
retassimo	PP	MH	DERIVED	PSEUDO	CPIBCESR	NONWORD

Appendix A. *(continued)*

Target	Constituent	Syntactic	Kind	Type	Target	Type
semicassuvo	PP	MH	DERIVED	PSEUDO	DVANCINS	NONWORD
superasso	PP	MH	DERIVED	PSEUDO	FLSTMIXUDLNC	NONWORD
aistrativo	PS	HM	DERIVED	PSEUDO	GUVPSTOD	NONWORD
canaistrado	PS	HM	DERIVED	PSEUDO	HIULHTGAJ	NONWORD
dadoreiro	PS	HM	DERIVED	PSEUDO	IMULHPTJU	NONWORD
ibalismo	PS	HM	DERIVED	PSEUDO	IQUNHFIA	NONWORD
itaritável	PS	HM	DERIVED	PSEUDO	ITSZEBNTDIP	NONWORD
logência	PS	HM	DERIVED	PSEUDO	JNUOALZLP	NONWORD
minalista	PS	HM	DERIVED	PSEUDO	LACFONLGUG	NONWORD
rageminal	PS	HM	DERIVED	PSEUDO	MNHJLHIC	NONWORD
tramento	PS	HM	DERIVED	PSEUDO	NBUJCTQUZT	NONWORD
acontarago	P	H	SIMPLEX	PSEUDO	NHIHITVOCH	NONWORD
andistoruno	P	H	SIMPLEX	PSEUDO	OCZMILHUM	NONWORD
aprecomena	P	H	SIMPLEX	PSEUDO	OGVOLFDO	NONWORD
capregonera	P	H	SIMPLEX	PSEUDO	PERROSZKL	NONWORD
cistragefo	P	H	SIMPLEX	PSEUDO	PGEDIXGAZQ	NONWORD
estarafenvo	P	H	SIMPLEX	PSEUDO	PRUOMTIXNZ	NONWORD
estificapre	P	H	SIMPLEX	PSEUDO	PSESDCISL	NONWORD
ifidaprelone	P	H	SIMPLEX	PSEUDO	QUJCANSZOVJ	NONWORD
isticonfu	P	H	SIMPLEX	PSEUDO	QULUVRFAHZM	NONWORD
mandostara	P	H	SIMPLEX	PSEUDO	QUZOJCFUJ	NONWORD
poramenira	P	H	SIMPLEX	PSEUDO	RJIMEILEJA	NONWORD
radassimote	P	H	SIMPLEX	PSEUDO	RMFIHTFLOA	NONWORD
randistrale	P	H	SIMPLEX	PSEUDO	TRIPEXGU	NONWORD
restaramo	P	H	SIMPLEX	PSEUDO	VBESTJXE	NONWORD
saramonde	P	H	SIMPLEX	PSEUDO	VJMHEHEJVM	NONWORD
semostavo	P	H	SIMPLEX	PSEUDO	VLJCUIJS	NONWORD
tradescula	P	H	SIMPLEX	PSEUDO	ZQUMHPESIH	NONWORD
vicadostana	P	H	SIMPLEX	PSEUDO	ZVOAIHJMIJ	NONWORD

Appendix B. Mixed-effects models

All analyses were performed using mixed-effects models in R Version 4.2.1.

Mixed-effects model on all data

```
library(lme4)
library(lmerTest)
library(car)

# RT Analysis
data1$type <- relevel(data1$type, ref = “BLEND”)
lmer1A <- lmer(rtlog ~ type * kind * cs * ss + (1|subject) + (1|item), data = data1)
lmer1B <- lmer(rtlog ~ type * kind + cs + ss + (1|subject) + (1|item), data = data1)
lmer1C <- lmer(rtlog ~ type * kind + (1|subject) + (1|item), data = data1)
summary(lmer1C)
anova(lmer1C)
```

Type III Analysis of Variance Table with Satterthwaite’s method

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
type	22.6972	7.5657	3	174.24	121.8951	< 2e-16 ***
kind	0.0108	0.0108	1	174.54	0.1747	0.6764
type:kind	0.0094	0.0094	1	174.55	0.1513	0.6978

Signif. codes: 0
‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

```
# ACC Analysis
glmer1A <- glmer(acc ~ type * kind * cs * ss + (1|subject) + (1|item), family = binomial, data =
data1)
glmer1B <- glmer(acc ~ type + kind + cs + ss + (1|subject) + (1|target), family = binomial, data
= data1)
glmer1C <- glmer(acc ~ type * kind + (1|subject) + (1|target), family = binomial, data = data1)
summary(glmer1C)
Anova(glmer1C)
```

Analysis of Deviance Table (Type II Wald chisquare tests)

	Chisq	Df	Pr(>Chisq)
type	503.8476	3	< 2e-16 ***
kind	1.5193	1	0.21773
type:kind	5.9571	1	0.01466 *

Signif. codes: 0
‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Mixed-effects model on blend data

```
# RT Analysis
data2$cs <- relevel(data2$cs, ref = "WW")
data2$ss <- relevel(data2$ss, ref = "HH")

lmer2A <- lmer(rtlog ~ cs + ss + (1|subject) + (1|item), data = data2)
lmer2B <- lmer(rtlog ~ cs * ss + (1|subject) + (1|item), data = data2)
summary(lmer2B)
anova(lmer2B)
```

Type III Analysis of Variance Table with Satterthwaite's method

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
cs	0.13430	0.044766	3	23.863	0.6804	0.5727
ss	0.00629	0.003146	2	23.866	0.0478	0.9534
cs:ss	0.47670	0.079449	6	23.870	1.2076	0.3366

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```
# ACC Analysis
glmer2A <- glmer(acc ~ cs + ss + (1|subject) + (1|item), family = binomial, data = data2)
glmer2B <- glmer(acc ~ cs * ss + (1|subject) + (1|item), family = binomial, data = data2)
summary(glmer2B)
Anova(glmer2B)
```

Analysis of Deviance Table (Type II Wald chisquare tests)

	Chisq	Df	Pr(>Chisq)
cs	2.3466	3	0.5036
ss	2.0246	2	0.3634
cs:ss	10.4366	6	0.2095

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Address for correspondence

Gustavo Estivalet
Laboratory of Linguistic Processing
Federal University of Paraiba
Campus I, Cidade Universitaria, CEP: 58051-900
João Pessoa-PB
Brazil

gustavoestivalet@hotmail.com
https://orcid.org/0000-0003-3462-4156

Co-author information

José Ferrari-Neto
Laboratory of Linguistic Processing
Federal University of Paraiba
joseferrarin1974@gmail.com

Rafael Minussi
Language and Cognition Laboratory
Federal University of São Paulo
rafael.minussi@unifesp.br

Alina Villalva
Faculty of Letters
University of Lisbon
Alameda da Universidade
alinavillalva@edu.ulisboa.pt

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