

Through *dick* and *dünn*: Cognates and the legacy of diachronic change in synchronic language processing

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ABSTRACT

COGNATE FACILITATION EFFECTS have consistently been reported for words sharing (visual) form–meaning overlap across languages. We present the results of a cross-modal EEG study investigating whether historically-related L1 COGNATES’ phonological representations (activated by *auditory* primes, e.g. [maʊ] from [maʊs]) hinder or facilitate recognition of visually-presented L2 English words (e.g. mouse) for German–English bilinguals. Priming effects in lexical decision were significantly greater for noncognates than cognates with identical onsets, and EEG results indicate L1 cognate COACTIVATION depends on the (mis)matching of underlying phonological features. Fragment primes only induced significant attenuation of the N400 ERP component (relative to controls) for phonologically MISMATCHING cognates and noncognates, and no N400 effect was found for cognates with IDENTICAL or NON-MISMATCHING onsets. This suggests auditory fragments coactivate both languages’ representations (according to degree of phonological overlap), causing competition for selection and inhibition. Despite form differences, historical cognates maintain a *systematic phonological relationship* relevant for current speakers.

Keywords: German–English Cognates, EEG, Underspecification, Phonological Features

1. Introduction

This study focuses on the phonological representations of COGNATES and the influence of L1 phonology on L2 perception. A COGNATE FACILITATION EFFECT is well-accepted in the literature on L2 comprehension, such that the existence of an L1 “translation equivalent” with form overlap (e.g. English *lamp* [læmp] – Dutch *lamp* [lamp] or English *bus* [bʌs] – Welsh *bws* [bʊs])¹ is assumed to provide a processing advantage and facilitate L2 lexical access. Studies have variously compared identical to non-identical (but similar) cognates, cognates to noncognates or considered three degrees of similarity: identical, similar and non-overlapping (for a comprehensive review of the literature, see Roembke et al., 2024). This facilitation has been found most robustly in the visual modality, often reflected in decreased reaction times in lexical decision tasks (for overviews, see Dijkstra et al., 2010; Kroll et al., 2016 and references therein). The prevalence of visual studies has resulted in a focus on orthographic form and studies involving the auditory modality are much less common (although see, for example, Marian & Spivey, 2003; Blumenfeld & Marian, 2007; Cornut et al., 2021; Fritz et al., 2023; Frances et al., 2023; Fritz & Lahiri 2025; see also Roembke et al., 2024, which provides a summary of recent papers, indicating modality).

The question of the precise nature of the cognate effect in *auditory* processing therefore remains. Whilst a number of visual studies have considered phonological structure (e.g. Dijkstra et al., 1999; Comesaña et al., 2015; Tiffin-Richards, 2024), particularly in the context of different-script languages (e.g. Voga & Grainger, 2007; Hoshino & Kroll, 2008; see §1.1), the focus has often been on phonemic overlap, with phonological activation mediated by orthography. There is accumulating evidence, however, that cognate effects tend rather in the opposite direction when stimuli are presented in the auditory modality, with results from lexical decision tasks demonstrating reduced cognate effects, null effects and

even inhibition relative to noncognates (reflected in increased reaction times; see, for example, Fritz et al., 2023; Fritz & Lahiri, 2025). In a recent study by Cornut and colleagues (2021), for instance, cognate effects in both directions were reported (i.e. facilitation as well as inhibition), modulated by modality (auditory vs. visual). In lexical decision, it was found that identical orthography resulted in faster reaction times in the visual modality (responding to written words) but that this was reversed in the auditory modality, where responses were slower (i.e. total overlap impeded the recognition of spoken words).²

It is possible that phonological interactions contribute to this complexity. However, such interactions have proved difficult to capture with current approaches and have yet to be fully teased apart in models of bilingual speech perception. The present study therefore looks below the level of phonemic oppositions and considers the role of phonological feature specifications in lexical access, seeking to explore (i) whether L1 cognates facilitate or inhibit L2 perception when there is direct phonological activation (via auditory primes) and (ii) whether the asymmetric processing of certain featural contrasts (see §1.2) can reveal anything about L2 lexical activation and access.

Historical linguistics provides an alternative perspective on cognates, with a pair of words across two languages considered to be cognate if they originate from a shared proto-language (or common ancestor; see Millar & Trask, 2023). For instance, English (E) and German (G) share many cognates (e.g. E *brother* [bɪˈðə] – G *Bruder* [ˈbrʊːdɐ], inherited from West Germanic). Such cognates thus stand in opposition to loanwords, e.g. E *reptile* [ˈrɛptɪl] – G *Reptil* [ˈʁɛptiːl] (independently borrowed from French) or Mandarin 巧克力 [tʰɛ˥˥jaŋ˥˥kʰɿ˥˥li˥˥] (borrowed from E *chocolate* [tʃɒklət]; Li & Gollan, 2018). The question here is whether this conception of cognates has any relevance for psycholinguistics and bilingualism studies, where the focus is on the processing of modern languages. Is the notion of historical cognates in fact relevant for contemporary speakers, when it would be absurd to suggest that

explicit etymological knowledge is acquired as part of their language endowment? Our suggestion is that historical developments are relevant insofar as they have had consequences for the *structure* of the modern language. Drawing on insights from historical linguistics allows us to exploit the structural patterns resulting from historical change in our experimental design. This potentially enables us to tease apart questions of mental representations in a way which is not possible focusing only on cognates which overlap very closely (or totally) in terms of their phonological structure.

Our interest is in the types of similarities and differences which may exist between cognate words across two languages; as we saw above, cognates can be almost identical phonemically (e.g. E *house* [haʊs] – G *Haus* [haʊs]) or they can vary in the onset (e.g. E *thing* [θɪŋ] – G *Ding* [dɪŋ]) or the rhyme (e.g. E *leek* [li:k] – G *Lauch* [laʊx]). Although speakers have no explicit historical linguistic knowledge, they acquire and process a language system which is full of patterns resulting from past sound change. When they acquire a related language as an L2, classes of historically related words from both languages will share some sounds but differ in others. Crucially, this variation is not random; taking the linguistic system as a whole, patterns emerge, with entire classes of words differing in the same (often predictable) way, as illustrated by Table 1. Whilst these differences are in one sense phonemic, the two sounds in most cases differ only in a single phonological feature, such as [CONTINUANT] vs. [PLOSIVE] in fricative–stop pairs.

/s/–/z/ [OBS], [CONT], [COR], [STRID]		/w/–/v/ [CONT], [LAB], [VOICE]		/θ/–/ð/ [OBS], [COR]	
<i>sand</i> /sænd/	<i>Sand</i> /zand/	<i>wind</i> /wɪnd/	<i>Wind</i> /vɪnd/	<i>thick</i> /θɪk/	<i>dick</i> /dɪk/
<i>sea</i> /si:/	<i>See</i> /ze:/	<i>wax</i> /wæks/	<i>Wachs</i> /vaks/	<i>thing</i> /θɪŋ/	<i>Ding</i> /dɪŋ/
<i>sow</i> /saʊ/	<i>Sau</i> /zay/	<i>wolf</i> /wɒlf/	<i>Wolf</i> /vɔlf/	<i>thorn</i> /θɔ:n/	<i>Dorn</i> /dɔɐn/
/s/ has no voice feature /z/ = [VOICE]		/w/ = [SONORANT] /v/ = [OBSTRUENT]		/θ/ = [CONTINUANT] /ð/ = [PLOSIVE] (underspecified)	

Table 1: Classes of corresponding initial consonants in English–German cognates, with the relevant differentiating phonological feature provided below. Shared features are provided in the first row of the table (OBS = OBSTRUENT, CONT = CONTINUANT, LAB = LABIAL, COR = CORONAL, STRID = STRIDENT).

When bilingual speakers' L1 and L2 have such *systematic phonological correspondences*, we hypothesise that this should have consequences for processing. What role do differences in underlying feature specifications across two closely-related languages play, and does the existence of an L1 cognate *hinder* or *facilitate* L2 word recognition? Ultimately, it is the structure of the system which matters: cognates need not always share exactly the same phonological representation or orthography, but differences are systematic.

1.1 *Mixed results in L2 perception across modalities*

Previous literature suggests that, for both auditory and visual perception, bilingual speakers activate both languages in parallel, and this has been taken as evidence for (i) non-selectivity in lexical access with respect to language and (ii) cross-language integration in the lexicon (cf. Beauvillain & Grainger 1987; de Groot et al. 1991; Sánchez-Casas et al. 1992; Dijkstra et al. 1998a,b; Weber & Cutler 2004; Zhou et al. 2010). Consequently, linguistic input may not only activate corresponding words in the relevant language, but also coactivate related words in speakers' other languages. According to the cohort model of speech perception (e.g. Taft & Hambly, 1986; Marslen-Wilson, 1987; Lahiri & Marslen-Wilson, 1991), auditory perception proceeds in a linear manner, with the speech signal activating all words matching the input at the relevant point (the cohort). As the signal unfolds and more information becomes available, word candidates are further evaluated against this input and the cohort is reduced. Word-initial sounds are therefore crucial in word recognition, and a larger cohort may result in greater competition for lexical selection. Given the parallel activation of multiple languages by multilingual speakers, a given word onset would be predicted to activate a cohort comprising matching words from all relevant languages, which may lead to increased competition between word candidates.

Models of bilingual lexical access commonly focus on visual word recognition, as with the Bilingual Interactive Activation (+) model (e.g. Dijkstra et al. 1998; Dijkstra & Van Heuven 2002; and its latest iteration, Multilink: Dijkstra et al. 2019), which considers lexical access during written word recognition (see also Sánchez-Casas & García-Albea, 2005), although an alternative approach is offered by the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS: Shook & Marian 2012), which assumes auditory input. Cognates have consequently often been defined in terms of degree of *orthographic* overlap between translation equivalents, relying on algorithms of orthographic similarity (e.g. normalised Levenshtein Distance: Schepens et al., 2013). However, it appears that many cognate effects are orthographically driven (see Elias et al., 2025). For instance, in a visual lexical decision task involving identical and non-identical cognates, as well as noncognates, Comesaña and colleagues (2015) found that facilitation over noncognates (in terms of faster reaction times) switches to inhibition (slower reaction times) as soon as orthographically identical cognates are excluded from the experiment (e.g. Spanish *plata* – Catalan *plata* vs. Spanish *brazo* – Catalan *braç*). Interestingly, reaction times were significantly slower when the cognates’ orthography did not match but phoneme overlap was high (compared to overlap in both dimensions or neither).

As a result, there have been more recent attempts to develop algorithms which, while still providing a single numerical output similarity score, aim to take *phonological* differences into account (e.g. ALINE: Kondrak, 2003; PHOR-in-One: Costa et al., 2023). The phonological Levenshtein distance is limited in referring only to phonemes and considering all changes (such as phoneme deletions, insertions and substitutions, e.g. E [dɪɔp] – G [tʁɔp̃f] ‘drop’) to be equal. This obstacle is overcome by Costa et al.’s (2023) modified approach, in which these changes are weighted differently but calculated based on Euclidean distances between the location of phonemes on the idealised (and to a certain degree arbitrary) IPA

chart, not taking account of underlying phonological features (e.g. English *sponge* ['spʌndʒ] – Spanish *esponja* [es'poŋxa] = 0.55).

In the ALINE algorithm, Kondrak (2003) incorporates weighted sub-phonemic characteristics (e.g. 'bilabial', 'approximant', 'high vowel', 'high', 'back'), with phonemes represented as vectors of phonetic values. These properties are detailed sub-divisions based on articulatory descriptors found in Ladefoged (1975), relating to the posture of articulators rather than any abstract phonological representation. For instance, there are a great many more place features than phonological feature systems would recognise (e.g. *bilabial*, *labiodental*, *dental*, *alveolar*, *retroflex*, *palato-alveolar*, *palatal*, *velar*, *uvular*, *pharyngeal* and *glottal*) and *high* vs. *low* are specified in addition to *high vowel* vs. *low vowel*. It is not necessarily the case that the distance between all of these is equally meaningful perceptually (cf. bilabial–labiodental vs. palatal–velar), nor that any relationships should necessarily be linear or constant across languages. It is also unclear how the relative weightings should be decided and, like other approaches, collapses various dimensions of phonological differences into a single score (e.g. English *sponge* ['spʌndʒ] – Spanish *esponja* [es'poŋxa] = 0.712).

These approaches acknowledge the importance of considering the phonological representations of cognate words in the bilingual speaker's lexicon and aim to move towards more phonological measures of similarity (beyond orthographic overlap). However, these measures are unable to capture non-phonemic phonological differences, such as vowel length, syllable structure or stress. For instance, even orthographically identical words often differ substantially across languages, as in the English–German pairs *system*–*System* and *atom*–*Atom*: /'sɪstəm/–/zɪ'ste:m/, /'ætəm/–/a'to:m/, where stress placement, vowel length and phonemes all differ (note that German nouns are always spelt with a capital letter).³ One particular strength of the BLINCS model is that it retains information about syllable structure, as well as sub-phonemic detail (in the form of a three-way vector of place, manner and

voice), although this is again in phonetic terms and assumes all differences to be equal (e.g. /p/ vs. /b/ and /p/ vs. /f/).

If features are extracted from the acoustic signal and mapped onto underlying abstract mental representations, as the FUL model proposes (Lahiri & Reetz, 2002, 2010; Lahiri, 2018), models of bilingual lexical access would benefit from taking phonological features into account, particularly given the importance of phonology in L2 perception, as past studies have repeatedly demonstrated. For instance, in progressive demasking and visual lexical decision experiments, Dijkstra and colleagues (1999), explored the interaction of semantic, orthographic and phonological overlap across languages (e.g. English–Dutch “translation equivalents” *film* [film] – *film* [film], *pure* [pjʊə] – *pure* [py:rə] and *news* [nju:z] – *nieuws* [ni:ws], as well as “false friends”, e.g. *pink* [piŋk] – *pink* [piŋk] “little finger” and *cow* [kaʊ] – *kou* [kaʊ] “cold”; Dijkstra et al., 1999: 514ff.) and found that orthographic similarity led to decreased reaction times relative to matched controls (interpreted as facilitation) but *phonological* similarity actually worked in the opposite direction, resulting in increased reaction times (interpreted as inhibition).

Furthermore, there is a large amount of evidence for phonologically-driven coactivation from studies exploring languages with different scripts, particularly where those scripts are non-alphabetic, e.g. English *guitar* and Japanese ギター [gita:]. Whilst Hoshino and Kroll (2008) found reduced reaction times for cognates than noncognates in a visual English–Japanese picture naming task and Voga and Grainger (2007) found similar effects in a Greek–French masked priming study (i.e. facilitation over noncognates, but only measured against the unrelated baseline, not against the phonologically-related prime condition), cross-modal studies involving spoken language input have reported contrasting effects. For instance, in an English–Russian eyetracking study (employing a visual world paradigm), Spivey and Marian (1999) found that, when instructed to move a target object in one

language (L1 or L2), significantly more early eye movements were made towards distractor objects with initial phonetic overlap in the task-irrelevant language (e.g. Russian *marka* “stamp” – English *marker*) than to control distractors. This was interpreted as reflecting interference from the irrelevant language due to the parallel activation of both mental lexicons in spoken word recognition. In a recent cross-modal English–Bengali fragment priming study (where primes were auditory and targets visual), Fritz and Lahiri (2025) found that reaction times in lexical decision were unaffected by cognate status but that, for words with matching metrical structure, different ERP results were modulated by loan type. Where no cognate existed, the N400 component was attenuated following a matching prime (indicating ease of integration), whereas no N400 effect was found when a matching item existed in the L1. Instead the P350 was modulated (suggesting interference from the activation of the Bengali cohort where there was a greater phonological match).

These studies are relatively unusual in using auditory stimuli. For instance, in Rombke and colleagues’ (2024) overview of the literature, 23 visual studies are identified, compared to only 6 in the auditory modality (and this number includes production studies involving picture naming tasks). It is only comparatively recently that auditory presentation of stimuli has become more common in cognate processing studies (e.g. Mutman et al., 2022). This is important, as, in studies involving the auditory modality, cognate effects seem to differ from those found in visual-only studies, instead suggesting cognate inhibition, generally interpreted as being due to the language non-selective nature of lexical activation resulting in competition for lexical selection. For example, numerous studies employing lexical decision tasks have found that greater phonological overlap results in increased reaction times relative to noncognates, reflecting increased L1 activation and competition for lexical access (e.g. Guediche et al., 2020; Fritz et al., 2023; see also Declerck & Philipp,

2015, where semantically unrelated words with initial phonological overlap are compared to non-overlapping words).

Similarly, in an auditory eye-tracking study, where participants identified targets in picture displays in response to spoken stimuli, Blumenfeld and Marian (2007) found that cognates (i.e. phonologically similar items, such as English *hen* [hɛn] – German *Henne* [hɛnə] “hen”) resulted in stronger competition for selection relative to noncognates (e.g. English *dress* [dʒɹɛs] – German *Kleid* [klaɪt] “dress”), with coactivation indexed by eye movements to similar-sounding German distractors in the picture display (e.g. *Hemd* [hɛmt] “shirt”). This result is similar to that found in Fritz and colleagues (2023, see §1.3). Ultimately, the emerging picture appears to be that cognate facilitation effects are associated most strongly with the visual modality when orthographic overlap is high. With increasing phonological overlap, however, it is much more likely that such facilitation disappears and that results will tend rather towards inhibition.

English and German form the focus of this study. These two West Germanic languages are closely related and therefore share many cognates. The question we ask is whether cognates *hinder* or *facilitate* L2 word recognition. How do systematic sound relations affect processing, and do the phonological feature specifications of cognates matter? For example, does the phonological representation of *Pfanne* affect the access of *pan* for fluent L2 English speakers? The auditory domain must play a role, as we are interested in the phonological representation of words in the mental lexicon (which includes details of phonological features). This naturally has implications for theories of bilingual processing and lexical access, which will be addressed in §6. Since the phonology of cognate pairs may differ in many ways, it is important briefly to discuss the precise nature of the phonological correspondences across classes of cognates which we have chosen, before turning to our experimental details.

1.2 The phonological and historical facts

The effects of the “Second Sound Shift” (a classic example of regular sound change) differentiate Modern Standard German from Low German languages, such as English. The details are complex (see Wright, 1907), but what is relevant for our purposes is the fact that word-initial voiceless plosives became affricates (i.e. /p/ > /pf̥/ and /t/ > /ts̺/). German also subsequently shifted the dental fricative /θ/ (which English retains) to the plosive /d/. In contrast, other sounds have survived broadly unchanged from Proto-Indo-European, e.g. /f/ and the nasals /m, n/ (which do not differ in English–German cognates). These changes have resulted in *completely systematic* correspondences in the *initial* consonant of certain classes of English–German cognates (which might be a stop, fricative or affricate). That is to say, *all* German words beginning with /pf̥/ or /ts̺/ correspond to /p/ or /t/ in English (where cognates survive) and *all* English words with inherited /θ/ correspond to /d/ in German cognates: *path–Pfad*, *tin–Zinn*, *thing–Ding* etc. (see Table 2). Importantly, these changes go in different directions, with the plosives weakened to affricates in the first instance (e.g. /t/ > /ts̺/) and a fricative strengthened to a plosive in the second (/θ/ > /d/).

	West Germanic		English			German	
/p/ > /pf̥/	*p	p	<i>path</i> /pa:θ/	<i>plant</i> /pla:nt/	pf̥	<i>Pfad</i> /pfa:d/	<i>Pflanze</i> /pflantsə/
/t/ > /ts̺/	*t	t	<i>tin</i> /tɪn/	<i>tongue</i> /tʌŋ/	ts̺	<i>Zinn</i> /tsɪn/	<i>Zunge</i> /tsʊŋə/
/θ/ > /d/	*θ	θ	<i>thick</i> /θɪk/	<i>thin</i> /θɪn/	d	<i>dick</i> /dɪk/	<i>dünn</i> /dyŋ/
	*f	f	<i>fish</i> /fɪʃ/	<i>finger</i> /fɪŋgə/	f	<i>Fisch</i> /fɪʃ/	<i>Finger</i> /fɪŋgə/
no change	*m	m	<i>mouse</i> /maʊs/	<i>mast</i> /ma:st/	m	<i>Maus</i> /maʊs/	<i>Mast</i> /mast/
	*n	n	<i>nest</i> /nest/	<i>net</i> /net/	n	<i>Nest</i> /nest/	<i>Netz</i> /nets/

Table 2: Systematic phonological correspondences of initial consonants between English and German due to the Second Sound Shift and subsequent loss of /θ/.

It is important to remember that not all sound changes are equal, and this depends on the underlying abstract phonological representation. Standard phonological theory assumes that individual speech sounds (i.e. phonemes), e.g. /t/, /p/, /m/, comprise a collection of hierarchically organised phonological features, determining aspects such as voicing or place and manner of articulation (amongst other things), e.g. [VOICE], [LABIAL], [PLOSIVE] etc. Features allow us to group similar sounds into “natural classes”, such as nasals ([NASAL]), sonorants ([SONORANT]) or voiced obstruents ([OBSTRUENT, VOICE]). In perception, it is these features which speakers extract from the acoustic signal, mapping them onto the abstract phonological representation in their mental lexicon. As an example, the feature specifications of several English consonants are provided in Table 3.

		/p/	/f/	/d/	/θ/	/t/	/s/
Major class	[CONSONANTAL]	✓	✓	✓	✓	✓	✓
	[OBSTRUENT]	✓	✓	✓	✓	✓	✓
Place	[CORONAL]			(✓)	(✓)	(✓)	(✓)
	[LABIAL]	✓	✓				
Manner	[PLOSIVE]	(✓)		(✓)		(✓)	
	[CONTINUANT]		✓		✓		✓
	[STRIDENT]						✓
Laryngeal	[VOICE]			✓			

Table 3: The underlying feature representation of the English phonemes /p/, /f/, /d/, /θ/ and /s/. Features in brackets are taken to be underspecified in the mental representation (see below).

However, it is not necessarily the case that all features are specified at every level of representation; certain features may be considered to be “underspecified”, filled in at a later stage of production. This paper follows the Featurally Underspecified Lexicon (FUL) feature system (see Lahiri & Reetz, 2002, 2010; Lahiri, 2018), which accounts for production and perception by assuming the universal underspecification of the features [CORONAL] and [PLOSIVE] in mental representations (in contrast to [CONTINUANT], which defines fricatives, and is overtly specified in underlying representations). In other words, certain features, such as [CORONAL] and [PLOSIVE] are assumed to be absent from the phonemic representation of

lexical items in a speaker’s mental lexicon. However, they are existing features which are filled in during articulation and are present in the signal. Such features are then extracted from the acoustic signal during perception, where they are mapped onto phonological representations in the mind of the listener.

Underspecification is justified by the asymmetric processing of certain features in speech perception. In other words, the feature-mapping process may result in one of three possibilities: (i) a MATCH (e.g. if [CONTINUANT] is present in both the signal and the underlying representation), (ii) a MISMATCH (e.g. [PLOSIVE] is present in the signal but clashes with [CONTINUANT] in the underlying representation) or (iii) NO-MISMATCH (e.g. [CONTINUANT] is present in the signal and does not clash with the underlying representation of a plosive phoneme, which has no underlying specification for manner of articulation, due to the underspecification of the feature [PLOS]). This is illustrated in Figure 1. For experimental neurophysiological evidence for underspecification and asymmetric perception, see, for example, Lahiri & Marslen-Wilson (1992), Friedrich and colleagues (2008), Cornell and colleagues (2013) and Althaus and colleagues (2024).

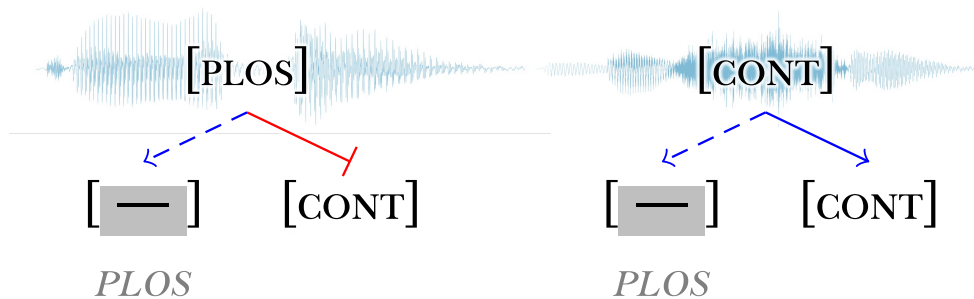


Figure 1: Illustration of the possible mapping of the features [PLOSIVE] and [CONTINUANT] onto the underlying representation of fricative and (underspecified) plosive sounds: MATCH (solid blue), MISMATCH (solid red) and NO-MISMATCH (dashed blue).

Two points arise. Firstly, it is insufficient simply to equate phonemes with orthographic characters; for instance, the same sound might have many different orthographic representations (e.g. /i:/: **piece**, **peas**, **peel**, **pique**) and vice-versa (e.g. <ch>: **chorus** /k/, **chick** /tʃ/, **chic** /ʃ/). Secondly, it is equally invalid to assume in an algorithm that all synchronic

correspondences are equal, as *direction matters*. As Cornell and colleagues (2013) demonstrate, certain manner features are contrastive in both directions (e.g. [NASAL]–[STRIDENT]), whereas others depend on the direction of featural change (e.g. [NASAL]–[PLOSIVE] or [CORONAL]–[DORSAL]). In other words, as well as constraining the direction of historical change, differences in underlying representations may have much more dramatic consequences for perception in some circumstances than in others. For example, plosives are very unlikely to lead to the activation of fricatives, but the reverse is not necessarily true.

Asymmetric correspondences were exploited in the present experiment, as described in §1.3, as the loss of the dental fricative in German has led to a correspondence in English–German cognates between the opposing features [CONTINUANT] and [PLOSIVE] (i.e. a previously specified fricative has lost the feature [CONTINUANT] and become an underspecified plosive). In contrast, the change from /p/ > /pʰ/ has resulted (in initial position) in the addition of the feature [STRIDENT] to what remains simply [PLOSIVE] in English.

1.3 *The present study*

We focus on cognates as a means of exploring systematic differences in a small number of phonological features (which happen to have arisen as a result of regular sound change). Although etymological knowledge is not part of a speaker’s grammar, historical change leaves its mark on synchronic languages in coherent and systematic ways and this may play a role in the synchronic phonology (even where there is no segmental or semantic *identity*). What consequences do these systematic sound correspondences have for auditory processing? According to the cohort model (e.g. Marslen-Wilson, 1987), initial sequences of segments will activate all items in the lexicon sharing the same sequence. Entertaining the hypothesis that lexical access is non-selective regarding language (Dijkstra et al., 1998a,b), L1 and L2

items with shared form will thus be expected to be coactivated and compete for selection. Previous cross-modal studies suggest that this coactivation leads to inhibition. Will this be true of cognates following auditory activation by spoken word fragments, or will a facilitation effect be found, as in the visual modality?

A recent cross-modal (auditory–visual) fragment-priming study by Fritz and colleagues (2023) has shown that both (i) the native phonology (in this case prosodic structure) and (ii) whether or not a loanword exists only in the L2 (English) or in both the L1 (German) and L2 affect behavioural and ERP results. It was found that, for loans only existing in English (e.g. *pigeon*), the N400 component was reduced and reaction times were fastest, but only where the metrical structure did not conflict with that of German. This indicates interference from the L1, with shared loans (e.g. E *reptile* – G *Reptil*) competing for selection. In other words, instead of cognate facilitation, the reverse (inhibition) was found, with the ease of lexical access negatively affected by the existence of a corresponding L1 competitor word. Thus, lack of competition, e.g. *pigeon*, facilitated word recognition.

On the basis of that study, fragment priming was also used in our ERP study, which involved a cross-modal lexical decision task conducted in English by native German speakers with high L2 English proficiency. The present study involved the presentation of an auditory CV fragment prime, followed by the presentation of a visual whole-word target for lexical decision. A number of other past studies have also exploited fragment priming to investigate questions of phonological representation, drawing on various experimental methodologies across a range of languages, e.g. lexical decision and ERP in German (Friedrich et al., 2008), forced choice in Swedish (Felder et al., 2009) and lexical decision and eyetracking in Bengali (Althaus et al., 2025). In cross-modal fragment priming paradigms, participants hear a matching or unrelated fragment prime (in our case CV, e.g. [maʊ]) before being presented with a visual target (e.g. *mouse*). Various priming paradigms are possible, e.g. delayed vs.

immediate or whole-word vs. fragment. However, what is common to all such paradigms is the assumption that a “prime” will pre-activate a given cohort of items, leading either to facilitation or inhibition in the perception of a target word which is semantically or phonologically related to said prime (relative to an unrelated prime–target sequence, see Bölte & Coenen, 2002; Zwitserlood, 1996). For instance, the assumption is that English [θaʊ] would prime *thousand* and result in a faster response (i.e. reduced reaction time) than the same target word preceded by an unrelated prime, such as [mʌɪ] (cf. Marslen-Wilson, 1990; Schutz et al., 2007; Friedrich et al., 2008; Scharinger & Felder, 2011; Fritz et al., 2023; Fritz & Lahiri, 2025).

As the CV fragment prime is auditorily presented, we can be sure that any activation is driven by the phonology. This contrasts with visual prime presentation, where activation is mediated by orthography and the phonology is activated more indirectly. Word-initial sounds are critical in word recognition and fragments allow us to control the degree of phonological overlap much more carefully (as additional differences may occur later in the word). Furthermore, as Marslen-Wilson and colleagues (1994: 4) note, “an auditory prime followed by an auditory probe may very well cause priming effects that are due to low-level overlap in the shared processing pathways”, particularly when priming is immediate. However, this is avoided when presentation is cross-modal, as any priming effects are mediated via the (modality-independent) lexical entry (see also Lüttman et al., 2011).

In line with previous studies, we therefore entertained the hypothesis that lexical access is not language-selective (see §1.1) and that fragments may thus *not only* activate the relevant English word, *but also* its German cognate, based on the features extracted from the initial consonant of the fragment (recall that word-initial sounds are critical in word recognition and that even a “slight mismatch” in form will still allow the activation of competitors from another language in the cohort, cf. Dijkstra & van Heuven, 2002: 94).

As illustrated in Table 4, we expected near-identical German cognates to be coactivated (see Marslen-Wilson, 1990; Lahiri & Marslen-Wilson, 1992) and compete with the target item, thus *hindering* the activation of the English word (cf. Fritz et al., 2023). In contrast, words for which no cognate exists would not be expected to result in increased competition. Therefore, depending on whether the feature specification of the initial consonant of the corresponding cognate **MATCHES**, **MISMATCHES** or is tolerated (**NO-MISMATCH**), lexical activation of the target might be inhibited or facilitated. The initial consonant of the pairs differ in *one* feature only and the place of articulation is held constant.

	English	Extracted feature (E)	German	Underlying feature (G)	Prediction
IDENTITY	[m] <i>mouse</i>	[NASAL]	/m/ <i>Maus</i>	[NASAL]	Activated: competition
	[n] <i>nest</i>	[NASAL]	→ /n/ <i>Nest</i>	[NASAL]	
	[f] <i>fish</i>	[CONTINUANT]	/f/ <i>Fisch</i>	[CONTINUANT]	
NO-MISMATCH	[θ] <i>thorn</i>	[CONTINUANT]	→→ /d/ <i>Dorn</i>	UNDERSPECIFIED [PLOSIVE]	Activated: competition
	[θ] <i>thing</i>	[CONTINUANT]	/d/ <i>Ding</i>	UNDERSPECIFIED [PLOSIVE]	
MISMATCH	[t] <i>tongue</i>	[PLOSIVE]	↯ /ts/ <i>Zunge</i>	[STRIDENT]	Not activated: no competition
	[p] <i>path</i>	[PLOSIVE]	/pf/ <i>Pfad</i>	[STRIDENT]	
NON-EXISTENT	[p] <i>pig</i>	[PLOSIVE]			Not activated: no competition
	[t] <i>take</i>	[PLOSIVE]			
	[θ] <i>thug</i>	[CONTINUANT]			
	[m] <i>meat</i>	[NASAL]			
	[n] <i>noon</i>	[NASAL]			
	[f] <i>fog</i>	[CONTINUANT]			

Table 4: Predicted activation effect of the German cognate, depending on whether the feature specification of its initial consonant is a MATCH, MISMATCH or NO-MISMATCH for the relevant feature extracted from the English signal. The feature [PLOSIVE] is assumed to be underspecified and thus not stored in the underlying lexical representation (but present in the acoustic signal, see §1.2). All examples given are translation equivalents.

The experiment comprised four experimental conditions, with the initial syllable of the English target word systematically manipulated according to the corresponding onset consonant of the word’s German cognate. The four conditions were thus IDENTITY (ID), NO-MISMATCH (NM), MISMATCH (MM) and NON-EXISTENT (NE), referring to the relationship of the features of the initial consonant between the English word and its German counterpart. Our basic assumption is that a phonological MISMATCH between the German native word and the English counterpart (or the lack of a cognate altogether) would lead to facilitation, whereas

NO-MISMATCH and MATCH would result in competition and inhibition. Example words for each condition are given in Table 4.

ERP-related studies into online word recognition which have exploited cross-modal fragment priming have typically found evidence for the P350, an ERP component with a left-anterior distribution which appears 300–450ms post-target onset and is taken to represent phonological mapping of primes to target words (e.g. Friedrich et al., 2004; 2009).

Incongruent prime–target sequences have been found to result in more positive deflections in this time window when compared to congruent sequences, although recent studies, such as Kobor and colleagues (2018), Fritz and colleagues (2023) and Fritz and Lahiri (2025), have identified more prolonged P350 effects, extending as far as 700ms post-target onset.

Other relevant ERP components found in previous studies include the phonological N400 (Friedrich et al., 2004) and the P600 (Fritz et al., 2023). The former component involves negative deflections in the 300–600ms time-window, broadly distributed across the centro-parietal region. The N400 is understood to reflect ease of lexical access (being more attenuated with greater facilitation, Scharinger & Felder, 2011). In other words, when prime and target match, target access is easier, eliciting a less negative deflection than when prime and target do not match. In line with previous studies, we understand the P350 and N400 to reflect different mechanisms, with the former reflecting early, purely phonological mapping, whereas the latter reflects lexical access and integration. A further late-stage positivity coinciding roughly with participants' response to the stimulus, again broadly distributed in the centro-parietal region, has also been found in past studies (e.g. Peeters and colleagues, 2013; Fritz and colleagues, 2023), interpreted as a P600 and reflecting resolution of a conflict induced by similarity between the presented target and an L1 word. There seems to be a strong orthographic aspect to this effect, as no comparable P600 was found by Fritz and Lahiri (2025), who carried out a similar fragment-priming study with native speakers of

Bengali (a language with a markedly different abugida writing system). However, the precise interpretation of this component remains an open question.

All conditions are expected to prime relative to a control. In the IDENTITY condition, however, we predict lexical coactivation of both the English target words and their German cognates (which MATCH in terms of features), resulting in competition for lexical access between the two languages and thus inhibition. This would be reflected in a reduced priming effect compared to the NON-EXISTENT condition (which should not be affected by competing L1 items). In terms of ERP data, we would thus expect to find no significant N400 effect for IDENTITY, but potentially a P350, as this reflects shallower mapping processes, prior to lexical access or integration. If our predictions are correct, we would expect the NO-MISMATCH condition to pattern with IDENTITY, such that no N400 effect should be present and the priming effect may again be smaller than for the NON-EXISTENT condition (albeit possibly to a lesser degree). This is because we predict the lack of a mismatch between the English and German cognates' onsets to lead to the activation of both items, resulting in increased competition for selection and thus inhibition of target selection.

The NON-EXISTENT condition would not be predicted to exhibit any competition from L1 cognates, resulting in facilitation. We therefore expect it to produce the largest priming effect and differ substantially from the IDENTITY and NO-MISMATCH conditions. This would be reflected in a significantly attenuated N400 (as has been found in earlier work on loans, e.g. Fritz et al., 2023). If the MISMATCH condition does indeed result in a mismatch and fail to activate the L1 cognate as a competitor, then we predict this condition to pattern with NON-EXISTENT and again result in facilitation. This would therefore be reflected in a large priming effect which should not differ from that of the NON-EXISTENT condition (or at least only be slightly reduced in comparison). If our assumptions about the NO-MISMATCH condition are incorrect (and the L1 cognate is *not* activated by the English fragment), then this condition

would be expected to pattern with NON-EXISTENT and MISMATCH and not differ in comparison to the former. If the results are reversed and IDENTITY in fact shows the greatest priming effect, this would indicate phonological cognate facilitation, rather than inhibition.

2. Materials and methods

2.1 Participants

36 native German speakers participated in the study (mean age 22.39, SD 2.56; 25 female, 9 male, 2 N/A), compensated at the rate of €15 per hour. Participants were all raised monolingually in Germany and were recruited and tested at Ludwig Maximilian University of Munich, where they studied English at degree level. All participants had normal or corrected-to-normal vision and did not report any neurological or psychiatric conditions, nor any reading, hearing or language impairments, further confirming that they were taking no medication which affects attention. To obtain a more representative sample of the population, left-handed participants ($n = 3$) were not excluded from recruitment (cf. Willems et al., 2014), although one left-handed participant was later excluded from the EEG analysis, due to excessive artefacts. Prior to the experiment, participants provided language background information via an abridged version of the Language Experience and Proficiency Questionnaire (Marian et al., 2007). The results are summarised in Appendix A. Participants also completed the English version of LexTale (Lemhöfer & Broersma, 2012), a lexical decision test which is taken to be a reliable indicator of language proficiency. Participants' mean score was 86.97% (SD = 8.83), corresponding to a C1/C2 level (advanced/mastery) in the Common European Framework of Reference for Languages.⁴

2.2 *Stimulus design*

The experimental stimuli comprised 96 English target words, split across the four main conditions (24 items per condition), according to the phonological representation of their corresponding German cognate (see §1.3). In the IDENTITY condition, the English and German words began with the same onset consonant, so the features therefore MATCH (i.e. they share the same abstract, underlying feature specification, even if details of their phonetic implementation subtly differ). These words begin with one of three consonants inherited intact from West Germanic: /f/ ([LABIAL, CONTINUANT], e.g. /fɪʃ/~fɪʃ/), /m/ ([LAB, NASAL], e.g. /maʊs/~maʊs/) and /n/ ([CORONAL, NASAL], e.g. /nɛst/~nɛst/), with eight items each.

The NO-MISMATCH and MISMATCH conditions comprise words for which a cognate also exists in German but—due to historical sound changes which affected German—the initial consonant differs. In the case of NO-MISMATCH, the English and German onsets agree for all features except the manner feature [CONTINUANT]/[PLOSIVE]. As the English consonant is a fricative (and therefore specified with the feature [CONTINUANT]), whereas the German consonant is a plosive (an underspecified feature), this would result in a NO-MISMATCH (i.e. the phonemes differ but would not result in a featural mismatch with the *underlying* German representation). Due to the phonological structure and phonemic inventories of the languages, the only available consonant for this condition was /θ/ ([CORONAL, CONTINUANT]), preserved in English but strengthened to /d/ ([CORONAL, PLOSIVE]) in early German (cf. E /θɪŋ/ ~ G /dɪŋ/).⁵

In contrast, MISMATCH comprised English words which *do* mismatch with the features of the German cognates' onset consonants. Initial /p/ and /t/ in English correspond to /p̂f/ and /t̂s/ in German cognates (e.g. /pɑ:θ/~p̂fa:d/⁶ and /tɪn/~t̂sɪn/). Under our feature representation hypothesis, German consonants are specified for the additional feature, [STRIDENT]. As the feature [STRIDENT] is underlyingly specified in the lexicon, the feature

specification for the English [PLOSIVE] consonant results in a MISMATCH with that of the German affricate. The final condition, NON-EXISTENT, essentially functioned as a control. These words all lack a German cognate, either because (i) the word has not been retained in German (e.g. *noon*) or (ii) the word has been borrowed into English from a third language, but has not been borrowed into German (e.g., *fog*). This condition draws on the same onsets appearing in the other three conditions (four items each).

Across conditions, the majority of target words were monosyllabic (due to their Germanic origin) but each condition additionally contained four to six disyllables (e.g. *thistle*, *fever*, *penny*, *maple*). Word class in English is not straight-forward, since zero derivation is rampant (most nouns can become verbs and vice-versa, e.g. *fish*, *throb*). Although most target words were nouns (IDENTITY = 20, NO-MISMATCH = 14, MISMATCH = 19, NON-EXISTENT = 19), a small number of verbs (NO-MISMATCH = 6, MISMATCH = 2, NON-EXISTENT = 4) and other word classes (adjectives, numbers and prepositions; IDENTITY = 4, NO-MISMATCH = 4, MISMATCH = 3, NON-EXISTENT = 1) had to be included to obtain full sets of 24 items each. This was balanced across conditions as far as the phonological requirements for each condition would allow (only so many qualifying words exist in the lexicon, given other norming requirements). A full list of stimuli is provided in Appendix B, but example stimuli are provided in Table 5, with the feature specifications of the initial phoneme of the English target and its German cognate (where one exists).

	English features	English phonemes	Example target	German features	German phonemes	German cognate
Existing cognates	NASAL	/m/	m ouse	NASAL	/m/	M aus
	NASAL	/n/	n est	NASAL	/n/	N est
	CONTINUANT	/f/	f ish	CONTINUANT	/f/	F isch
	CONTINUANT	/θ/	th ing	PLOSIVE	/d/	D ing
	PLOSIVE	/p/	p ath	STRIDENT	/pf/	P fad
	PLOSIVE	/t/	t ongue	STRIDENT	/ts/	Z unge
	English features	English phonemes	Example target	German features	German phonemes	German equivalent
No existing cognates	NASAL	/m/	m eat			<i>Fleisch</i>
	NASAL	/n/	n oon		–	<i>Mittag</i>
	CONTINUANT	/f/	f og		–	<i>Nebel</i>
	CONTINUANT	/θ/	th ug		–	<i>Schlägertyp</i>
	PLOSIVE	/p/	p ig		–	<i>Schwein</i>
	PLOSIVE	/t/	t ake		–	<i>nehm-</i>

Table 5: Word-initial phonemes of the English targets, with example stimuli and the relevant phonological features. The initial phoneme and relevant phonological features of the German cognate are provided. For examples of words with no existing cognate, a German translation equivalent is provided.

Note that the facts of activation should hold regardless of any differences in meaning arising from the historical semantic development of the items (e.g. *fish* and *Fisch* have retained equivalent meaning across both languages, in contrast to *town* and *Zaun* ‘fence’, where the English has come to mean that which was enclosed by a fence, i.e. a settlement). In the case of words with divergent meanings, however, phonological form overlap remains (allowing for the results of systematic sound change). This relationship is *phonological* and these words rarely count as so-called “interlingual homographs”, due to orthographic differences. Given the fragment-priming methodology, both the L2 target and its L1 cognate should be co-activated by the prime (provided there is no featural mismatch). Semantic overlap was controlled for as far as the conditions would allow; there are simply fewer items to choose from in the NO-MISMATCH and MISMATCH conditions. In our experiment, the English meaning is included in the possible translations of the German cognate for all stimuli in the IDENTITY condition and, for both the NO-MISMATCH and MISMATCH conditions, this was also true of all but five stimuli in each condition (see Appendix B). As we make differential predictions for these two conditions, this does not therefore represent a potential confound. (Of course, by definition, the NON-EXISTENT condition has no German counterpart.)

In addition to the experimental stimuli, 96 orthographically and phonotactically permissible nonwords were also created which matched the real words in the distribution of onset consonants (e.g. *thrudge* [θɪɹdʒ], *fretch* [fɹɛtʃ], *meech* [mi:tʃ], *numble* [nʌmbɫ], *prike* [pɹɪk], *tave* [teɪv]). In order for the lexical decision task to be effective, nonwords must be as realistic as possible (i.e. challenging for participants) and *phonologically plausible*. Rather than simply swapping phonemes in existing words or automatically generating items, these nonwords carefully imitated typical syllable structures of English, generated by a native speaker of British English and evaluated by three linguistically trained researchers with high or native proficiency in both English and German. Importantly, these nonwords were also absent from the German lexicon.

All four experimental conditions (as well as the nonwords) were matched as closely as possible for mean number of syllables in English, mean number of syllables for the German cognate (where applicable), mean phonological length (number of phonemes) and mean orthographic length (number of graphemes). Additionally, all experimental conditions were matched on mean frequency per million words for both the English target and (where applicable) its German cognate, based on the English and German portions of the CELEX database (Baayen, Piepenbrock & van Rijn, 1993, accessed via the simple search interface *Relex*, version 0.4.5; Reetz, 2014). We also conducted an online familiarity rating task for all real-word targets with a separate group of 60 German university students of English to ensure that our experimental conditions did not differ significantly in mean familiarity ratings.

A summary of means and SDs for the norming parameters is displayed in Appendix C. Non-parametric Kruskal-Wallis tests, followed by Dunn tests with Bonferroni adjustments for multiple planned pairwise comparisons, revealed no significant differences in means between any of the conditions for any of the measurements reported in Appendix C. The only

exception was mean number of graphemes ($X^2(4) = 35.49, p < 0.0001$), which was significantly higher for the NO-MISMATCH condition, due to the fact that the initial phoneme is represented with a digraph <th> in English and a monograph <d> in German (/θ/ and /d/, respectively).

Each target word was matched to a test and a control fragment prime. The test primes comprised the initial onset–vowel sequence of each target word, whereas the control primes differed from the target’s initial sequence in terms of phonological features. To ensure that the onset consonants in our test primes did not immediately cue participants towards a match between prime and target, 50% of the control primes only shared manner features with the test prime onsets and differed for PLACE (i.e. /t/ vs. /p/, /θ/ vs. /f/ and /n/ vs. /m/). An additional 25% contrasted with the test prime for (i) major class feature ([SONORANT]/[OBSTRUENT]) and—for [OBSTRUENT] test primes—for (ii) PLACE (i.e. /l/ controlled for /p/ and /f/, /w/ for /θ/ and /t/ and /s/ for /m/ and /n/). The remaining 25% of control primes were divided between the [DORSAL] onsets /k/ and /g/, which contrasted for PLACE with all test primes (which were either [CORONAL] or [LABIAL]). Finally, each control prime was assigned a vowel which contrasted with the vowel of the test prime for TONGUE HEIGHT and/or PLACE features (some pairs additionally differ in quantity). The distribution of control vowels was matched to the proportion of different test vowels for each condition. To ensure the naturalness of our control fragments, we matched each onset–vowel sequence to an existing word in the English lexicon.

Due to the distribution of the phonemes relevant to our experimental manipulation, it is not possible fully to control cohort size across conditions, as the fact exists that the /θ/-initial cognates represent a small cohort initially (note that this does not mean that the phoneme itself is this rare, as it also appears in medial and final position, as well as in many borrowed words). The mean cohort size of the IDENTITY, MISMATCH and NON-EXISTENT

conditions (provided in Table 6, based on the type frequency of words beginning with each fragment prime in the CELEX database) are close, ranging from 84.9 to 100.9, although it is much lower for the NO-MISMATCH condition (at 18.8). To avoid potential confounds, we therefore attempted to match each condition’s TEST and CONTROL primes as closely as possible. A non-parametric Kruskal-Wallis test, followed by Dunn tests with Bonferroni adjustments for multiple planned pairwise comparisons, showed no significant differences for any condition other than NO-MISMATCH, where a difference is unavoidable given the comparative rarity of word-initial /θ/ in the English lexicon. However, in this case, the cohort size does not appear to be a confounding factor, as the test primes’ mean cohort size is smaller than that of the control primes, which would predict facilitation, rather than the inhibition we expect. As will be seen in §4, no such facilitation was found.

	IDENTITY	NO-MISMATCH	MISMATCH	NON-EXISTENT
mean cohort size TEST primes	96.88 (70.29)	18.79 (11.28)	100.92 (69.21)	84.88 (67.61)
mean cohort size CONTROL primes	80.25 (62.19)	112.13 (92.01)	114.58 (79.14)	113.25 (94.04)

Table 6: Mean (SD) phonological cohort size for TEST and CONTROL primes by condition.

A further potential confound comes from (i) the degree of orthographic activation from the prime and (ii) the extent of the orthographic overlap between the relevant English and German cognates. Mean normalised Levenshtein distances between English and German cognates is provided in Table 7 (Levenshtein distance cannot be calculated for the NON-EXISTENT condition, as no cognates exist).

	Count	Mean	SD
IDENTITY	24	0.632	0.262
MISMATCH	24	0.490	0.203
NO-MISMATCH	24	0.452	0.162

Table 7: Mean normalised Levenshtein distance by condition.

In addition to phonological form activation, the auditory prime would potentially activate an orthographic representation which might conflict with the German cognate's orthography. However, this would be true of both the NO-MISMATCH (<TH>~<D>) and MISMATCH (<P>~<PF>; <T>~<Z>) conditions, as well as two-thirds of the NON-EXISTENT condition, as the onset consonant is only identical across the two languages in the IDENTITY condition (<F>~<F>; <M>~<M>; <N>~<N>). This might potentially have implications for the degree of cross-language activation (and thus facilitation or inhibition). However, this is unlikely to act as a confound in the present experiment, as this is true across conditions for which we make different predictions, and it is only in the IDENTITY condition where initial-consonant orthographic overlap is found across languages in all (or even the majority of) cases.

2.3 *Materials*

All primes were recorded in Audacity (version 3.4.2) by a male native speaker of Standard Southern British English in a soundproof booth on a Røde NT-USB microphone. To ensure that the priming fragments imitated natural speech as closely as possible, full words were recorded for both test and control primes, including nonword test primes. The recordings were digitized at 44.1 kHz (16 bit, mono) and normalized in Praat (Boersma & Weenink 2009), with peak amplitudes scaled to 0.99 Pa. For each target word in our study, a matching fragment prime was created by cutting the word-initial onset–vowel sequence, as well as a non-matching control fragment prime (which crucially differed in terms of its underlying phonological features). The fragment primes were extracted from the recordings by cutting each word at the zero crossing closest to the offset of the initial syllable nucleus (e.g. [pɑ:] for *path*, [pɪɪ̯] for *prike*). The beginning of each recording was trimmed such that the fragment onsets were not preceded by any delay. Example waveforms and spectrograms

of nasal, plosive and fricative-initial fragments are provided in Figure 2 (with a full list of test fragments provided in Appendix B).

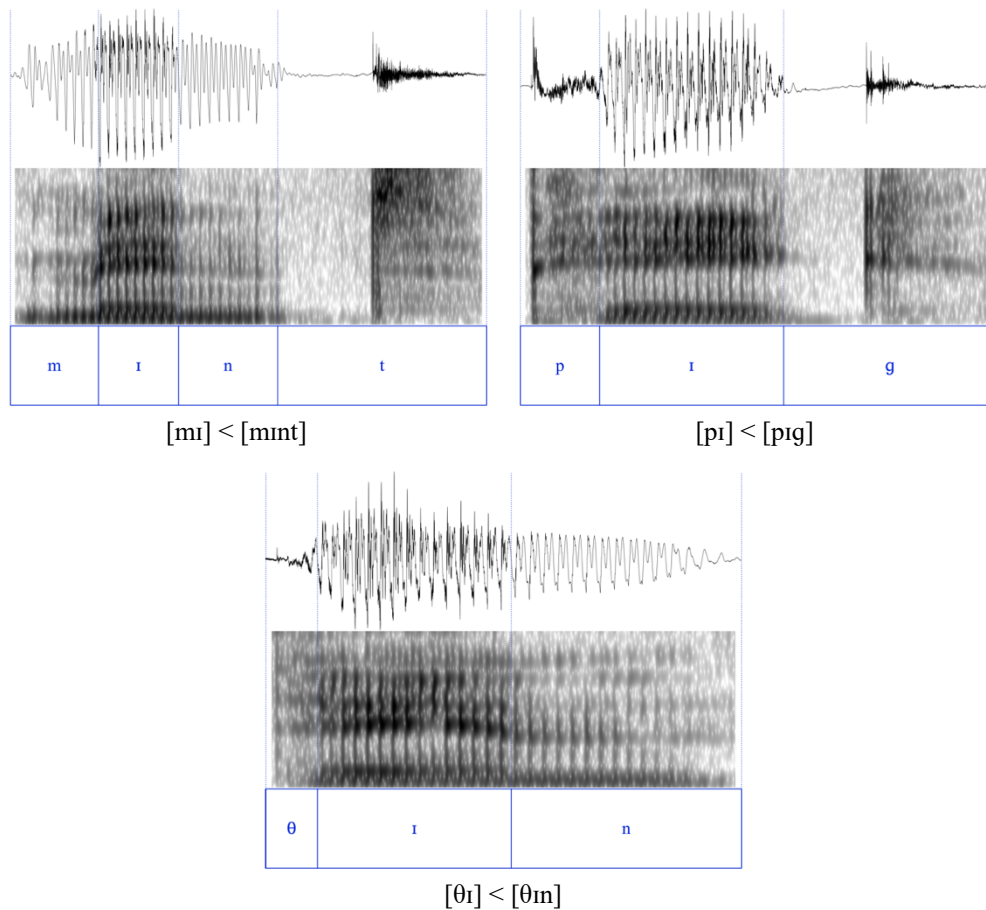


Figure 2: Example waveforms and spectrograms of three fragment primes, beginning with a (i) [NASAL] ([mi]), (ii) [PLOSIVE] ([pi]) and (iii) [CONTINUANT] ([θi]) consonant.

The stimuli were distributed across two blocks such that each target word appeared with its test prime in one block and its control prime in the other, with TARGET and PRIME conditions counterbalanced across blocks. Items appeared in pseudo-randomised order within each block (kept constant across participants). Every participant saw both blocks and thus saw each target word twice for a within-subjects design (once with the test prime and once with the control prime) for a total of 384 trials.

2.4 Procedure

The experiment was not conducted under conventional laboratory conditions, but rather in a quiet and light-attenuated basement classroom at the Ludwig Maximilian University of Munich. The language context of the experiment was English (the L2) and participants were not exposed to German (the non-target L1) at any point during the experiment, communicating with researchers only in English. Participants read the information sheet and gave informed written consent before completing a screening questionnaire on their language background, handedness and medical history (all in English). Afterwards, they completed a language history questionnaire and the online LexTale test (Lemhofer & Broersma, 2012). For the experiment itself, participants were fitted with an EEG cap and headphones and seated approximately 1m from a monitor. Participants were told that they would hear sounds being played through the headphones before seeing a word displayed on the screen, with their task being to ignore what they hear and—as quickly and as accurately as possible—to decide whether or not the word they were seeing was a real English word.

At the start of each trial, a fixation cross was displayed in the middle of the screen for 500ms, after which the fragment prime was heard. After an ISI of 250ms (with natural jitter added by the durational differences between the individual priming fragments), the target item was presented for 500ms in white 70pt Arial font against a black background. Uppercase letters were used in order to eliminate any bias stemming from German capitalisation rules. Participants were given 1500ms to respond by pressing the YES or NO button on a gaming controller, with YES always assigned to the participant's dominant hand. After receiving instructions, participants completed a practice block of 15 trials. They then completed two experimental blocks of 192 trials each, the order of which was counterbalanced across participants. In addition to a longer break between the two blocks, participants were given short 5s breaks every 36 trials in order to reduce fatigue, indicated by a beep and a blank

screen. Participants were instructed to minimise muscle movement during trials. The whole experiment took approximately 30 minutes to complete.

Continuous EEG was recorded from 32 active electrodes (ActiCap, Brain Products, Inc.), using the *BrainVision Recorder* software (BrainProducts, Inc.). Electrodes were placed according to the International 10–20 system. TP9 and TP10 were placed directly on participants' left and right mastoids, as the cap positions of these electrodes did not fully correspond to the actual position of the mastoids. Horizontal and vertical eye movements were monitored with the help of the fronto-polar electrodes Fp1 and Fp2, which were placed on the elastic cap just above the eyebrows. Impedance was kept below 20kOhm wherever possible. Data were sampled at 1,000Hz, with FCz as the online reference channel.

3. Data analysis

3.1 Behavioural analysis

All data analysis was conducted in R (version 4.4.1; R Core Team, 2024) with RStudio (version 2024.09.0; RStudio Team, 2024). Six participants with an accuracy rate below 75% across all targets (and/or real-word targets only) were excluded from the analysis. The accuracy and reaction time (RT) analyses are based on the resulting data set. For the RT analysis, 157 outliers which were more than ± 3 SDs away from a participant's mean were additionally excluded (1.36% of trials), as well as all nonwords and incorrect responses (439 trials, i.e. 8.31% of real-word trials). RTs were log-transformed to cope with positive skew. A linear mixed-effects regression model was fitted to the log-transformed RT data using the *lmer* function from the *lme4* package (version 1.1-35.5; Bates et al. 2015), with PRIME condition (CONTROL vs. TEST) and TARGET condition (NE vs. ID vs. MM vs. NM), as well as their interaction, as fixed effects. Both PRIME and TARGET variables were dummy coded, with CONTROL and NON-EXISTENT as the respective baseline factors. The random effects structure

included random intercepts for participants and items, as well as random slopes for PRIME and TARGET by participant and PRIME by item (nested within TARGET condition). However, as the model failed to converge, the random effects structure was simplified to exclude the by-participant random slope for TARGET. Only those results based on the final converging model are reported here. *P*-values for the model estimates were obtained through the Satterthwaite approximation as implemented in the *lmerTest* package (version 3.1-1; Kuznetsova et al., 2017). In addition to examining the overall effects of our predictors and their interaction on lexical decision RTs, we also conducted planned pairwise comparisons on the model between TEST and CONTROL trials for each TARGET group to assess whether priming effects were significant in each condition. Pairwise χ^2 -tests were performed with the *testInteractions* function implemented in the *phia* package (version 0.3-1; De Rosario-Martinez, 2024).

3.2 EEG pre-processing and analysis

Pre-processing and analysis of the EEG data were conducted in *EEGlab* (version 2024.0; Delorme & Makeig, 2004) and *ERPlab* (version 10.11; Lopez-Calderon & Luck, 2014). All EEG channels were first re-referenced to the mastoids (TP9 and TP10), before filtering the signal with a band-pass filter of 0.1–30.0Hz. EEG triggers were time-locked to the onset of the target words and the data were epoched from 200ms before each target onset (baseline-corrected) to 800ms after each target onset. Following the procedure outlined in Nunez and colleagues (2016), eyeblinks were identified and removed via Independent Component Analysis using the infomax algorithm implemented in *EEGlab* (confirmed through visual inspection). An automatic artefact detection algorithm was then employed which rejected all epochs in which any electrode exceeded a threshold of $\pm 75\mu\text{V}$ within a 250ms window which moved in 50s steps (followed by visual inspection). For seven participants, this process resulted in the rejection of more than 25% of epochs per experimental condition, resulting in

their exclusion from further analysis. The increased amount of noise in the data was largely due to the fact that this experiment was conducted under fieldwork conditions in a quiet basement classroom (rather than in a soundproofed, air-conditioned and electromagnetically-shielded recording booth in a laboratory), exacerbated by high temperatures which amplified sweat-induced electrode drift. As above, accuracy rates below 75% led to the exclusion of four more participants (two participants with low accuracy had already been excluded due to excessive artefacts). For the remaining 25 participants, a total of 314 experimental epochs were rejected as artefacts (6.5% of the data, not including nonwords). Across all data sets, only one electrode (T7) had to be interpolated for one participant. Finally, all nonword epochs were removed from further analysis (although all real-word trials with incorrect behavioural responses were kept).

Previous ERP fragment priming studies reported positivities with left-anterior distribution in the 300–400ms time window as well as centro-parietal negativities in the 300–500ms time window post target onset, which were interpreted as P350 and N400 effects, related to phonological matching and lexical access and integration respectively (Scharinger & Felder, 2011; Friedrich et al., 2004; Fritz et al., 2023). However, studies with L2 speakers have also revealed prolonged positivities extending beyond the 300–400ms time window until 700ms, or the end of the epoch (Kobor et al., 2018; Fritz et al., 2023). In addition, Fritz and colleagues (2023) found late-stage positivities with a broad posterior distribution for those English targets which were most similar to their German cognates, which they interpreted as a potential P600 effect, indicative of lexical reanalysis from L2 into L1 (cf. Peeters, Dijkstra & Grainger, 2013). In order to capture potential late-stage effects, as well as variabilities in the time course of lexical access by L2 speakers, we defined five successive windows of interest with a length of 100ms each, ranging from 300ms post target onset to the end of the epoch at 800ms. Based on the topographical distribution of effects identified by

Fritz and colleagues (2023), we also selected two regions of interest (ROIs) for observing our expected effects: left-anterior (Fp1, Fz, F3, F7, FCz, FC1, FC5) for the P350 and centroparietal (Cz, CPz, CP1, CP2, Pz, P3, P4, Oz) for the N400 and P600. For each of these time windows and regions, we then conducted a two-way repeated-measures ANOVA (type III) with the averaged ERP voltages as the dependent by-subject variable, using the `anova_test` function as implemented in the `rstatix` package (version 0.7.2; Kassambara, 2023). An interaction between PRIME condition (CONTROL vs. TEST) and TARGET condition (NE vs. ID vs. MM vs. NM) was entered as a fixed factor, with both variables sum-coded. Afterwards, we performed planned pairwise *t*-tests between TEST and CONTROL items in each TARGET condition for each ROI and time window. This was done regardless of whether a significant interaction had been detected by the omnibus test, as the primary purpose of our experimental design was to determine how priming effects differed between TARGET conditions. Indeed, we expected that subtle—but significant—differences between TEST and CONTROL in individual TARGET conditions might be obscured in the omnibus test because of insignificant differences in all other conditions.

4. Results

4.1 Behavioural data

A descriptive summary of the accuracy data is displayed in Table 8. Accuracy rates were generally high, with only two TARGET conditions (NO-MISMATCH and NONWORD) slightly below 90%. The lower accuracy rate for the NM condition probably stems from the low token frequency of some /θ/-initial target words (e.g. *thistle*, *throng*, *throb*), which may not have been familiar to all participants. In fact, *thistle* and *throng* were the only real-word targets with overall accuracy rates of below chance (42% and 27%), consistent with relatively low familiarity ratings in the separate norming study (48% and 23%). In addition, a number of

participants were particularly permissive in identifying nonwords as real words. Given the near-ceiling effects across conditions, however, no further statistical analyses were performed on the accuracy data.

Target Condition	Mean (SD) Accuracy TEST Items	Mean (SD) Accuracy CONTROL Items
IDENTITY	0.91 (0.07)	0.92 (0.08)
NO-MISMATCH	0.89 (0.06)	0.85 (0.08)
MISMATCH	0.97 (0.07)	0.94 (0.07)
NON-EXISTENT	0.97 (0.04)	0.92 (0.07)
NONWORD	0.83 (0.10)	0.85 (0.10)

Table 8: Mean (SD) accuracy rates for TEST and CONTROL items by TARGET condition.

Reaction times (RTs) for TEST and CONTROL items by TARGET condition, as well as results for the pairwise comparisons, can be found in Table 9. Mean priming effects for each condition are displayed in Figure 3, demonstrating that the effect is largest in the NON-EXISTENT condition, followed by the MISMATCH condition and the NO-MISMATCH condition, with the IDENTITY condition having the smallest priming effect.

	Mean (SD) RTs TEST Items	Mean (SD) RTs CONTROL Items	Priming Effect	χ^2	<i>p</i> -value
IDENTITY	554 (71)	576 (70)	21 (37)	7.45	0.006 **
NO-MISMATCH	566 (75)	609 (80)	42 (33)	26.32	< 0.001 ***
MISMATCH	553 (79)	604 (70)	51 (32)	39.98	< 0.001 ***
NON-EXISTENT	542 (78)	599 (82)	57 (49)	55.46	< 0.001 ***

Table 9: Mean (SD) reaction times (in milliseconds) for TEST and CONTROL items as well as mean (SD) priming effect size (CONTROL minus TEST) by TARGET condition, with results for pairwise comparisons.

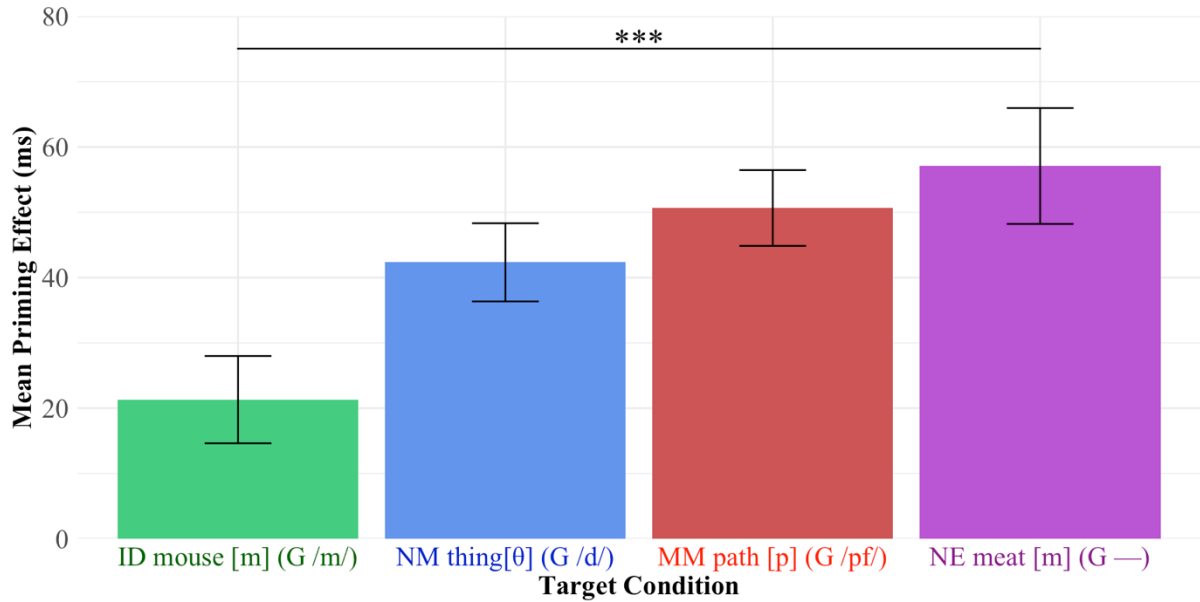


Figure 3: Mean priming effect (in milliseconds) by PRIME and TARGET condition. Error bars represent the standard error of the mean.

To test whether the differences in priming effects across TARGET conditions reached significance, we fitted a linear mixed-effects regression model. The full model output is reported in Table 10. In addition to a significant main effect for PRIME ($p < 0.001$), we found a significant interaction between PRIME and TARGET, which reveals differences in the size of the priming effects across conditions. Priming was found for all conditions, but priming effects in the IDENTITY condition were reduced in comparison to the NON-EXISTENT condition (which did not differ from the MISMATCH and NO-MISMATCH conditions). We did not find a significant main effect of TARGET on RT, nor a significant priming effect in the NO-MISMATCH or MISMATCH condition, as compared to the NON-EXISTENT condition.

	Estimate	95%-CI	SE	<i>t</i> -value	<i>p</i> -value
Intercept	6.378	6.324; 6.433	0.028	228.759	< 0.001 ***
PRIME	- 0.111	- 0.140; - 0.082	0.015	- 7.447	< 0.001 ***
TARGET (NE VS. ID)	- 0.031	- 0.082; - 0.020	0.026	- 1.189	0.238
TARGET (NE VS. NM)	0.024	- 0.027; 0.076	0.026	0.912	0.364
TARGET (NE VS. MM)	0.006	- 0.045; 0.057	0.026	0.234	0.816
PRIME X TARGET (NE VS. ID)	0.070	0.032; 0.108	0.020	3.540	< 0.001 ***
PRIME VS. TARGET (NE VS. NM)	0.033	0.006; 0.071	0.020	1.634	0.106
PRIME VS. TARGET (NE VS. MM)	0.017	- 0.021; 0.055	0.020	0.871	0.386

Table 10: Summary of the model. Syntax: $\log RT \sim \text{prime} * \text{target} + (1 + \text{prime} | \text{participant}) + (1 + \text{prime} | \text{target} : \text{item})$; optimizer: nloptwrap. CIs obtained via Wald method.

4.2 ERP data

Topographic plots of the priming effects (CONTROL items minus TEST items) in 100ms windows from 300ms post target onset until the end of our epochs at 800ms are depicted in Figure 4, averaged by TARGET condition. Figure 5 shows the averaged ERPs elicited by both CONTROL and TEST primes in each TARGET condition for the electrodes F3 and Pz, selected to represent the left-anterior and centro-parietal regions of interest (ROI).

4.2.1 Left-anterior region (P350)

Results from the ANOVAs performed on the joint effect of PRIME and TARGET on electrophysiological activity in the left-anterior region for all time-windows are reported in Table 11. We found no evidence for a significant interaction between PRIME and TARGET in any of the time-windows. Instead, there were significant main effects of PRIME in all 100ms time windows from 300ms to the end of our epoch at 800ms, as well as significant main effects of TARGET in the first two time-windows (300–399ms and 400–499ms).

	300–399ms	400–499ms	500–599ms	600–699ms	700–799ms
PRIME	$F = 4.314$ $p = 0.049 *$	$F = 13.912$ $p = 0.001 **$	$F = 11.156$ $p = 0.003 **$	$F = 12.872$ $p = 0.001 **$	$F = 5.925$ $p = 0.023 *$
TARGET	$F = 9.435$ $p < 0.001 ***$	$F = 4.982$ $p = 0.003 **$	$F = 2.043$ $p = 0.134$	$F = 2.817$ $p = 0.057$	$F = 1.694$ $p = 0.176$
PRIME X TARGET	$F = 1.582$ $p = 0.201$	$F = 1.975$ $p = 0.125$	$F = 1.963$ $p = 0.127$	$F = 1.367$ $p = 0.260$	$F = 1.052$ $p = 0.375$

Table 11: ANOVA results for ERPs from the left-anterior ROI in 100ms time-windows. No correction was performed, as the data were independent, not compared more than once across conditions.⁷

Pairwise *t*-tests between CONTROL and TEST items were carried out for each separate TARGET condition, summarised in Table 12.⁸ For the IDENTITY condition, significant positive differences were found between the two PRIME conditions from the 400–499ms time-window onwards, with CONTROL exhibiting a stronger positive deflection than TEST condition. The duration of these effects was prolonged until the end of our epochs at 800ms. We also found significant positive differences in the NO-MISMATCH condition, where they arose slightly

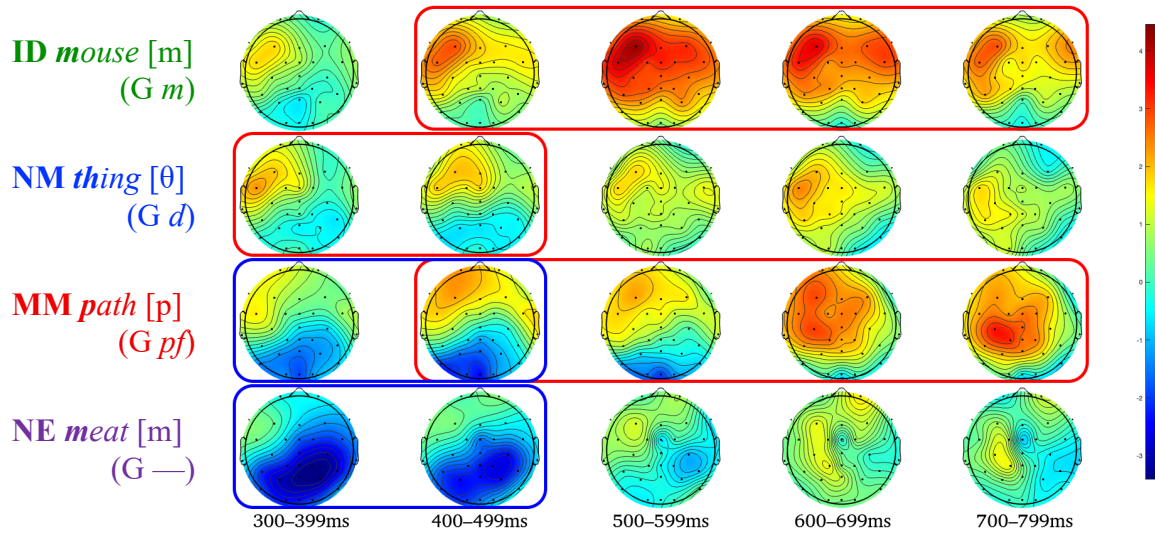


Figure 4: Topographic plots of the priming effects (CONTROL - TEST) in 100ms windows from 300–800ms post target onset (averaged by TARGET condition). Significant N400 effects are indicated by blue boxes and significant positivities by red boxes.

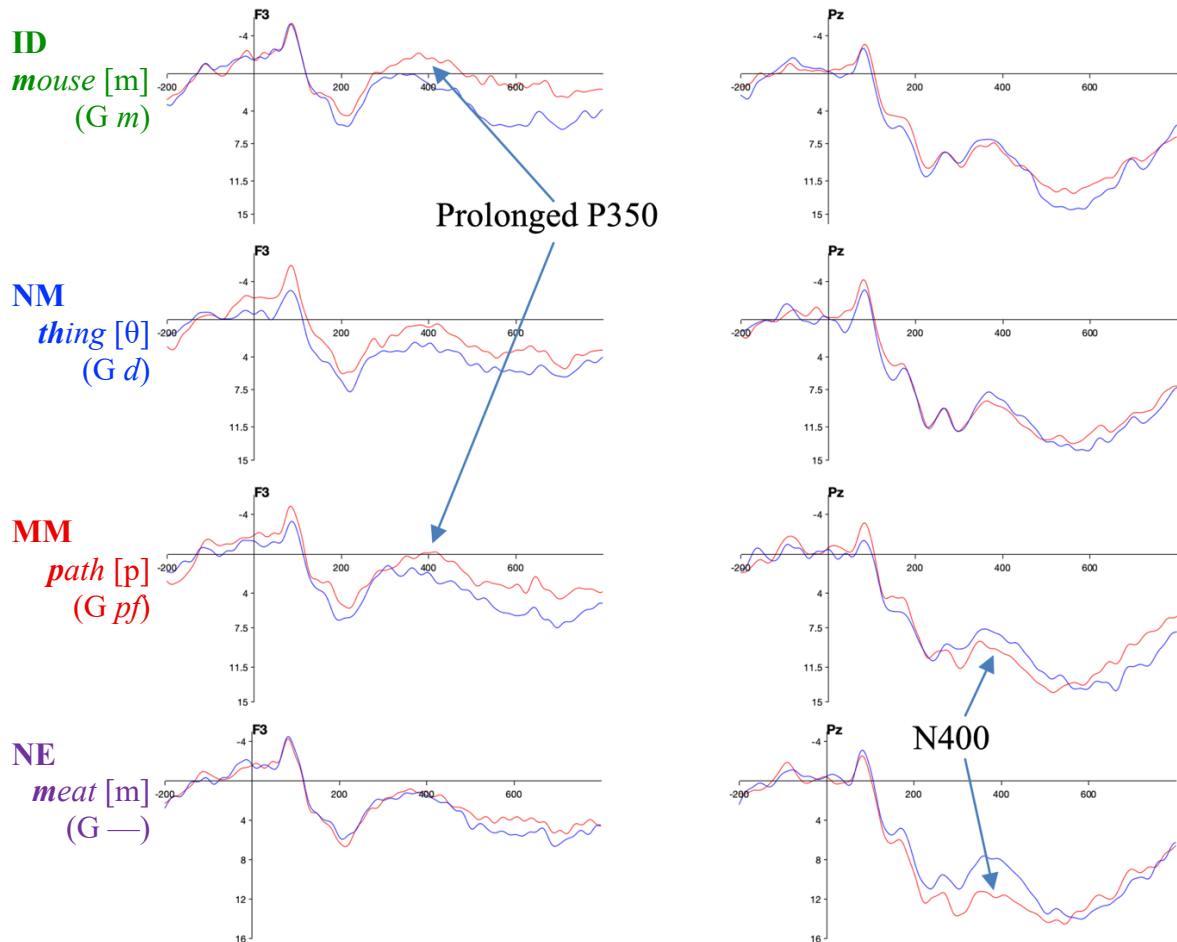


Figure 5: Averaged ERP plots elicited by CONTROL and TEST primes in each TARGET condition for the representative electrodes F3 (left-anterior) and Pz (centro-parietal). The red line represents the TEST condition and the blue line the CONTROL. Significant positivities and N400 effects are indicated by arrows.

earlier and subsided much more quickly, lasting from the 300–399ms to the 400–499ms time-window only. Strikingly, we found exactly the same pattern for the MISMATCH condition as the IDENTITY condition, with significant positive differences appearing from the 400–499ms time-window until the end of the epoch. No significant differences were found in the NON-EXISTENT condition.

	300–399ms	400–499ms	500–599ms	600–699ms	700–799ms
IDENTITY	$t = 1.66$ $p = 0.109$	$t = 2.72$ $p = 0.012 *$	$t = 3.45$ $p = 0.002 **$	$t = 3.06$ $p = 0.005 **$	$t = 2.16$ $p = 0.041 *$
NO-MISMATCH	$t = 2.41$ $p = 0.024 *$	$t = 2.43$ $p = 0.023 *$	$t = 1.28$ $p = 0.212$	$t = 1.67$ $p = 0.108$	$t = 0.89$ $p = 0.380$
MISMATCH	$t = 1.53$ $p = 0.138$	$t = 2.58$ $p = 0.017 *$	$t = 2.42$ $p = 0.023 *$	$t = 3.68$ $p = 0.001 **$	$t = 2.42$ $p = 0.023 *$
NON-EXISTENT	$t = -0.47$ $p = 0.640$	$t = -0.22$ $p = 0.829$	$t = 0.53$ $p = 0.602$	$t = 0.65$ $p = 0.524$	$t = 0.14$ $p = 0.894$

Table 12: Pairwise comparisons between TEST and CONTROL ERPs from the left-anterior ROI by TARGET condition in 100ms time-windows.

4.2.2 Centro-parietal region (N400, P600)

The output of the ANOVAs examining the joint effect of PRIME and TARGET on ERPs in the centro-parietal region for all time-windows are reported in Table 13. The interaction between PRIME and TARGET was significant in the two earliest time-windows (300–399ms and 400–499ms). In addition, we found significant main effects of PRIME in the 300–399ms and 600–699ms time-windows, as well as early significant effects of TARGET in the 300–399ms time-window.

	300–399ms	400–499ms	500–599ms	600–699ms	700–799ms
PRIME	$F = 11.421$ $p = 0.002 **$	$F = 3.241$ $p = 0.084$	$F = 1.484$ $p = 0.235$	$F = 4.916$ $p = 0.036 *$	$F = 3.247$ $p = 0.084$
TARGET	$F = 7.641$ $p < 0.001 ***$	$F = 2.299$ $p = 0.085$	$F = 0.418$ $p = 0.741$	$F = 0.698$ $p = 0.556$	$F = 0.735$ $p = 0.534$
PRIME X TARGET	$F = 3.883$ $p = 0.012 *$	$F = 3.157$ $p = 0.030 *$	$F = 2.359$ $p = 0.079$	$F = 0.320$ $p = 0.811$	$F = 0.601$ $p = 0.572$

Table 13: ANOVA results for ERPs from the centro-parietal ROI in 100ms time-windows.

As with the left-anterior ROI, pairwise *t*-tests between CONTROL and TEST items were also carried out on the data for each of the four individual TARGET conditions in this ROI, reported in Table 14. No significant negative differences were found in the IDENTITY condition. However, we did find significant positive differences in this ROI (with CONTROL exhibiting a stronger positive signal than TEST), although this effect was constrained to a single time window (500–599ms). No significant positive or negative differences were found in any time window for the the NO-MISMATCH condition in this ROI. In contrast, significant negative differences between the two PRIME conditions were found in the MISMATCH condition. These differences arose in the earliest two time windows (300–399ms and 400–499ms), with more negative deflections for CONTROL than for TEST. In addition, later positive differences were found, again with CONTROL more positive than TEST (similarly to the IDENTITY condition). However, unlike the IDENTITY condition, they arose slightly later in the 600–699ms and lasted until the end of the epoch at 800ms. The same pattern of negativity differences was found for the NON-EXISTENT condition, arising in the first two time windows, albeit with a higher level of significance in the first time window (300–399ms). However, no positive differences were found for this condition in any of the later time windows.

	300–399ms	400–499ms	500–599ms	600–699ms	700–799ms
IDENTITY	$t = -0.13$ $p = 0.901$	$t = 0.91$ $p = 0.374$	$t = 2.49$ $p = 0.020 *$	$t = 1.60$ $p = 0.123$	$t = 0.94$ $p = 0.358$
NO-MISMATCH	$t = -0.16$ $p = 0.877$	$t = -0.20$ $p = 0.843$	$t = 0.85$ $p = 0.402$	$t = 1.08$ $p = 0.290$	$t = 0.98$ $p = 0.339$
MISMATCH	$t = -2.19$ $p = 0.039 *$	$t = -2.12$ $p = 0.044 *$	$t = -0.32$ $p = 0.750$	$t = 2.42$ $p = 0.024 *$	$t = 2.15$ $p = 0.042 *$
NON-EXISTENT	$t = -4.25$ $p < 0.001 ***$	$t = -2.74$ $p = 0.012 *$	$t = -0.39$ $p = 0.698$	$t = 0.64$ $p = 0.530$	$t = 0.21$ $p = 0.838$

Table 14: Pairwise comparisons between TEST and CONTROL ERPs from the centro-parietal ROI by TARGET condition in 100ms time-windows.

5. Discussion

This study explored the role of historically-related cognates in L2 perception. Both RT data and ERP modulations in response to different classes of German–English cognates were compared, according to the degree of featural overlap between the cognates’ initial phonemes. For the experiment, L1 German speakers completed an English lexical decision task with fragment priming; the ease of lexical access was expected to depend on the nature of the correspondence between the underlying, abstract feature representations of the relevant consonants in the L1 and L2 items. At all times, participants were hearing and responding to their L2 but we hypothesised that coactivation of L1 cognates would increase the size of the cohort and result in greater competition for lexical access, impeding selection of the L2 target. Our predictions are summarised in Figure 6 (for full details, see §1) and our results indicate that cognates are indeed systematically activated, with the degree of activation corresponding to the matching or mismatching of the phonological features of the initial consonants.

	English	Extracted features	German cognate feature representation	Feature matching	
(i) IDENTITY	/m/ <i>mouse</i>	[NASAL]	→ [NASAL]	MATCH	German activated COMPETITION (harder)
(ii) NO-MISMATCH	/θ/ <i>thick</i>	[CONTINUANT]	→→ [UNDERSPECIFIED [PLOS]]	NO-MISMATCH	
(iii) MISMATCH	/t/ <i>tin</i>	[PLOSIVE]	→ [STRIDENT]	MISMATCH	Not activated NO COMPETITION (easier)
(iv) NON-EXISTENT	/p/ <i>pig</i>	[PLOSIVE]	—	—	

Figure 6: Summary of predictions, with ID and NM leading to activation of the German cognate (and thereby increasing competition, impeding lexical selection). In contrast, MM and NE are expected to result in no German cognate activation (resulting in greater facilitation).

5.1 Behavioural Findings

The results of the RT data analysis were in line with our expectations: priming effects were observed across TARGET conditions, with experimental manipulations resulting in differing degrees of facilitation. Descriptively, results are gradated, with the priming effect

increasing from smallest (IDENTITY) to largest (NON-EXISTENT) and NO-MISMATCH and MISMATCH lying in between. This ordering is perfectly in line with our predictions (see Figure 6), although priming-induced effect size differences only reached statistical significance between the NE condition (exhibiting the largest reduction in RTs) and the ID condition (where the priming effect was smallest). The prediction that an L1 cognate would be activated in ID (but not in NE, where no cognate exists), leading to inhibition, is therefore corroborated by these findings. In contrast, compared to NE, no significant reduction in priming effect was observed in the MM or NM conditions (although the effect was qualitatively slightly smaller in MM and smaller still in NM).

The behavioural results indicate, therefore, that responses to cognates with total featural overlap (ID) are significantly slower than noncognates with no such phonological overlap (NE), suggesting interference from the L1 phonology in lexical access. In contrast, faster responses in the NE condition suggest no such interference, resulting in easier processing. This cognate inhibition effect has not always been observed in behavioural data from priming studies involving lexical decision tasks (see §1), possibly because this effect is too subtle to be captured in reaction time data without paying very careful attention to phonological representations in stimulus design (cf., for instance, Fritz et al., 2023, where stimuli were organised according to their phonology and congruent results were found).

5.2 ERP Findings

The picture emerging from the ERP data provides a richer picture, particularly in relation to the positivity effect found in the later time window (interpreted as a prolonged P350), where the experimental conditions appear to pattern differently to the N400 effect found in earlier time windows following target onset. This is unsurprising, given the persistent lack of clarity over the import of this late positivity relative to bilingual processing and priming studies

more generally (resulting from the fact that few previous studies have investigated this time window or reported comparable effects). Our results add further clarity to this emerging picture, but our interpretation must remain speculative. In contrast, the results of the earlier time windows are in line with our predictions, as well as the findings of previous studies.

The data presented in §4.2 are partially consistent with a P350 effect, as reported by previous studies and taken to represent shallow phonological mapping at an early stage of processing, prior to lexical access (see §1.3). In terms of the temporal distribution of positivities, the condition which most closely corresponds to the canonical extension of the P350 (300–400ms post target onset) is NO-MISMATCH (e.g. *thing–Ding*), where the effect is only slightly prolonged into the following time window (400–499ms). Left-anterior positivities were also found in the MISMATCH and IDENTITY conditions. However, the onset of these positivities is slightly delayed (past what is typically expected for the P350), extending towards the end of the epoch. No significant effect was found in the NE condition. It is possible to interpret the effects in the MISMATCH (e.g. *path–Pfad*) and IDENTITY (e.g. *nest–Nest*) conditions as a delayed and prolonged P350 effect (as found in other L2 fragment priming studies, cf. Kobor et al., 2018; Fritz et al., 2023). Across the conditions, the P350 is generally delayed, appearing slightly earlier in the NM condition, most likely due to the fact that the dental fricative /θ/ (the onset of all words in this condition) is (i) uncommon in onset position in English content words and (ii) non-existent in German participants' L1. We interpret the absence of a significant P350 in the NON-EXISTENT (e.g. *pig*) condition as being due to the overlapping N400 effect, which is much stronger in this condition than in MISMATCH, where the N400 is weaker and the P350 reaches the level of statistical significance.

In a similar time window, but concentrated in the centro-parietal region, significant negative differences were found between test and control primes for two experimental

conditions, NE and MM. In both cases, deflections were significantly more negative when the target was preceded by an unrelated control prime than when preceded by a matching test fragment prime. Although the effect arises earlier in the NE condition, we interpret this negative deflection as an N400 effect, which is more attenuated in these two conditions. This suggests that the L2 targets were easier to access in the NE and MM conditions than in ID and NM, where no significant differences in negativity were found (i.e. the target was not significantly easier to access when preceded by a matching fragment prime than an unrelated control fragment). These findings align perfectly with our predictions, with the conditions patterning together in two groups: the “tolerated” MISMATCH condition behaves like the IDENTITY condition, where a matching cognate exists in German (being more difficult to process), whilst the MISMATCH condition behaves like the NON-EXISTENT (cognateless) condition (where processing is easier). Lexical access is not facilitated in the former two (where we assume cognates to be coactivated) but *is* facilitated in the latter (where no cognate exists or no cognate is expected to be activated).

In contrast, the patterning of the conditions in the later time window appears to be slightly different. In the left-anterior ROI, a significant positive effect is found in both the ID and MM conditions, which subsequently spreads to the centro-parietal region. In these two conditions, the positive effect was more attenuated when preceded by a matching fragment prime than a control, suggesting that reduced costs were associated with processing the target words in this time window, unlike the NE and NM conditions (where it was more difficult). These results are slightly different to what was found for the N400 effect; ID and NE still behave differently, but now ID is the easier and NM and MM pattern with the opposite condition (i.e. ID and MM vs. NE and NM).

It is difficult to interpret this positivity as a P600, given that it is centred on the left-anterior ROI and does not display the broad posterior distribution expected of a P600. In the

centro-parietal ROI, the effect is weaker and briefer (only achieving a low level of significance in a single time window for ID), apparently spreading from the left-anterior region, where the significant effect is greater and more prolonged. It is possible, however, to view this effect as a prolonged P350, reflecting an extended mapping process (cf. Kobor et al., 2018; Fritz et al., 2023; Fritz & Lahiri, 2025, where P350 effects up to 700ms post-target onset have been found). Our interpretation must remain speculative, but we suggest that this effect may be orthographically driven, reflecting a resolution conflict, not due to any similarity between the presented target and an L1 word *per se*, but between an L1 and L2 reading of the target (cf. Peeters et al., 2013; Fritz & Lahiri, 2025).⁹ In this way, words which better conform to L1 letter-to-sound correspondences (or in this case share greater orthographic overlap with their cognate) may be more easily processed at this later stage of processing, following word-level activation.

Consideration of the orthography of the stimuli in our conditions corroborates this interpretation. The ID condition naturally features the greatest degree of orthographic overlap between the English and German cognates, followed by the MM condition (which both exhibit this attenuation of the late positivity). The greatest orthographic distance is found in NM (where no significant positivity effect is found). The NE condition cannot be directly compared to the others, as no cognates exist. However, every word in this condition contains letter-sound correspondences which are impossible in German, such as ⟨th⟩~/θ/,¹⁰ ⟨oa⟩~/əʊ/, ⟨ea⟩~/i:/, ⟨oo⟩~/u:/. In German, such sequences may (i) not occur, e.g. word-final ⟨ap⟩~/æp/; (ii) have different sound correspondences, e.g. ⟨oo⟩~/o:/, or (iii) only occur across syllable boundaries, e.g. ⟨Oase⟩ /o.a:.zə/. Additionally, a third of words defy a strong orthographic principle of German that long vowels are followed by a single consonant and short vowels by a double consonant, e.g. ⟨nag⟩ /næg/, ⟨pad⟩ /pæd/, ⟨thug⟩ /θʌg/ (compare German ⟨Tag⟩ /ta:g/, ⟨Bad⟩ /ba:d/, ⟨trug⟩ /tʁu:g/).

6. Conclusion

Studies into L2 perception frequently assume that similarities in form and meaning across two languages inevitably equate to faster processing, despite mounting evidence from the auditory modality that greater phonological overlap increases competition for selection, slowing lexical access. The question asked here is whether historical L1 cognates impact the perception of L2 words by speakers of two closely-related West Germanic languages, German and English. The shared history of these languages means that the native lexicon of each partially draws on (i) a mutual set of phonemes but also (ii) a set of phonemes which have changed systematically in one language or the other. In other words, English–German cognates beginning with [m, n, f] have identical onsets (e.g. *mast–Mast*, *nest–Nest*, *frost–Frost*), whereas—due to regular sound change—English words beginning with [p, t, θ] correspond to [pf, ts, d] in German (e.g. *path–Pfad*, *tongue–Zunge*, *thing–Ding*). We exploited the well-established relationships of MATCH, MISMATCH and NO-MISMATCH to explore the question of whether cognates facilitate or hinder L2 lexical access. Earlier research has demonstrated that an initial consonant will activate a given cohort of words, depending on whether the features are a MATCH, MISMATCH or NO-MISMATCH, (see §1.2) but does the same apply in an L2 context and result in the activation of cognates?

The results of this experiment are consistent with our predictions. First, the priming effect was affected by condition, with “identical” cognates having the **slowest** reaction time (and thus the smallest priming effect), which we take to reflect activation of competing cognate forms, hindering access. However, the phonological features of the initial consonant were crucial. In behavioural data, only the IDENTITY condition (e.g. *fish*) was significantly slower than the NON-EXISTENT condition (e.g. *meat*, where there was no competition and

access was facilitated). This was not true of the MISMATCH condition (which showed no activation of an L1 competitor, behaving as though no cognate existed), nor the NO-MISMATCH condition (although reaction times here were qualitatively slower than the MISMATCH and NON-EXISTENT conditions). Most strikingly, in EEG data, the N400 was *only* significantly attenuated for the MISMATCH and NON-EXISTENT conditions. These words were therefore easier to access than the other conditions (where the competing L1 cognate *was* activated, leading to competition and inhibition). Results are summarised in Table 15 (cf. §1.3).

		English		German	Priming Effect	N400
(i)	IDENTITY	<i>fish, mouse</i>	→	<i>Fisch, Maus</i>	21.3ms	—
(ii)	NO-MISMATCH	<i>thorn, thing</i>	↔	<i>Dorn, Ding</i>	42.3ms	—
(iii)	MISMATCH	<i>path, tongue</i>	↔	<i>Pfad, Zunge</i>	50.7ms	attenuated
(iv)	NON-EXISTENT	<i>pig, thug</i>	—	—	57.1ms	attenuated

Table 15: Summary of experimental results

This study has implications for theories of bilingual language perception, as well as for how phonological distance is defined and operationalised. It is our hope that future studies increasingly incorporate spoken language input into their experimental design and move away from an exclusive focus on orthographic representations. After all, the majority of the world’s languages do not have a written form and, in the case of many of those which do have writing systems, the correspondence between orthography and phonology is neither transparent nor direct. What is clear is that a “slight mismatch is not sufficient to exclude word candidates from another language from the cohort” (Dijkstra & van Heuven, 2002: 94) and that this coactivation goes across categories of cognates and shared loans (cf. Jiang, 2019). This issue has received recent attention, for instance by Miwa and colleagues (2014) and Tiffin-Richards (2024), who provides evidence from visual lexical decision and eye-tracking, arguing that cognate effects are not reliant on identity (but rather vary along a continuum of orthographic and phonological similarity). However, it remains an open

question whether all differences in “near cognates” are equal, or how such differences can be defined or quantified in studies on bilingual perception (particularly in terms of spoken language).

The contribution of this paper is to provide a phonological perspective, suggesting that similarity can be described in relation to the abstract phonological representation in speakers’ mental lexicons and quantified in terms of phonological features. Although some studies (e.g. Dijkstra et al., 1999; Comesaña et al., 2015) have considered phonological features, they have been approached in terms of algorithms based on surface properties rather than abstract phonological representations. Our assumption is that, in perception, features are extracted from the acoustic signal and mapped onto these representations, and that differences in featural specifications are not always symmetrical. These asymmetries can be exploited in order to tease apart issues of lexical representation and access, particularly providing additional insights into the degree to which the L1 system might constrain L2 perception. Considering phonological representations in this way allows us to be even more fine-grained in our analysis, disentangling precisely which factors (e.g. featural, segmental or prosodic) influence bilingual lexical access and exploiting systematic correspondences to explore the effect of variation along certain phonological dimensions on cohort activation.

A further insight which this paper provides into theories of bilingual perception and lexical access is the systematicity of phonological variation (which may differ in cognates and shared loan words). Importantly, languages are structured systems and language change is *systematic*, leading to regular sound correspondence patterns in related languages which share cognates. This study therefore began with a more traditional definition of “cognate”, as such words will have been affected by different changes in the two languages and may therefore diverge in both form and meaning to a greater or lesser extent. Ultimately, this study asks how the structure of the system affects perception and whether this goes across

languages. As sound change is not random, but is constrained by the phonological grammar, differences between phonemes in historical cognates will be small in terms of features (invariably involving just one or two), producing subclasses of words across the lexicon. Proficient L2 speakers may be sensitive to these correspondences, even where form overlap is not total. The question is how the lexicon is structured. Are the representations of cognates somehow connected in bilingual speakers' lexicons and does the degree of phonological divergence matter? Sound changes might have happened centuries ago, but they are not restricted to historical periods: the results remain a systematic feature of the modern language.

Although the focus in this paper has been on English and German, this research has much broader scope, as similar correspondences will exist across other language families, such as Romance, as is illustrated by Table 16. Phonological and historical insights thus offer a rich source of information which can guide experimental design. Even for more distantly-related languages, cognates of this kind may exist (cf. English [nəʊz], Russian [nos], Italian [naso], Bengali [na:k]), even though many words may have diverged too far for speakers to be aware of the relationship (without a course in historical linguistics). Nevertheless, in the case of more distantly-related (or even unrelated) languages, loans provide similar opportunities. Here, one also finds sound correspondences, particularly when the two languages' phonological systems are substantially different.

French	Italian	Romanian	Spanish	
<i>cité</i> /site/	<i>città</i> /tʃit:a/	<i>cetate</i> /tʃetate/	<i>ciudad</i> /θjudad/	'city'
<i>ciel</i> /sjel/	<i>cielo</i> /tʃelo/	<i>cer</i> /tʃer/	<i>cielo</i> /θjelo/	'sky'

Table 16: Systematic word-initial correspondences in Romance words beginning with /s/ – /tʃ/ – /θ/.

The ways in which non-native phonemes are adapted from one language into another via loans is also systematic, being constrained by the structure of speakers' phonological systems and the underlying features of the relevant phoneme (see Kennard & Lahiri, 2020).

For instance, both English and German have borrowed a large number of Greek words beginning with ⟨ps⟩ (representing Greek [ps]). In English, this is not a permissible sequence syllable-initially (contrary to syllable-final [ps], as in *lips*), meaning that it has been adapted to [s], e.g. *psyche* [saɪki], but German permits initial [ps], producing correspondences, not just between English or German and Greek, but between English and German in shared Greek loans. Whenever German has word-initial [ps], English will have [s]: e.g. *pseudonym* ['sjʊ:dənɪm] ~ *Pseudonym* [psɔɪdo'ny:m]; *psoriasis* [sə'ɪlɪəsis] ~ *Psoriasis* [psɔ'bi:azis]; *psychology* [saɪ'kɒlədʒi] ~ *Psychologie* [psyçolo'gi:]. In a similar way, English [t] is adapted into Bengali as [t̪], despite the existence of the phoneme [t̪] (e.g. English *hotel* [heʊ'tel], Bengali হোটেল ['hoʊtel]; English *table* ['teɪbl̪] – Bengali টেবিল ['tebil]). The place of the two phonemes is thus the same, but the corresponding sound is additionally specified as [HIGH] in Bengali, whereas it is unspecified for height in English, as no height contrast exists for coronal stops.

Bilingual speakers appear to be sensitive to these systematic correspondences and—provided the phonological representations do not diverge too significantly, as with *twig* [twɪɡ] and G *Zweig* [t͡svaɪk̪]—such sounds may lead to coactivation of both languages. In other words, the *direction* of change and *degree* of mismatch matter. However, both historical change and phonological adaptation should proceed in a phonologically coherent, systematic direction: differences and correspondences are not random and have profound implications for bilingual perception. The results of this study indicate that differences in phonological features (along with asymmetric processing of such contrasts, cf. Lahiri & Marslen-Wilson, 1992) are key; *not all differences are equal*. In contrast to loans (i.e. non-native material in the L1 lexicon), cognates allow us to explore these contrasts, comprising as they do a special subset of the lexicon which is characterised by systematic differences in a small number of phonological features.

¹ Examples taken from Dijkstra and colleagues (2010) and Broersma and colleagues (2016), respectively.

² This is not the only study to have reported effects in both directions (i.e. inhibition and facilitation). For instance, Broersma and colleagues (2016) ascribe the discrepancy to the source of the cognates (which were all loans from one language under investigation into the other), whilst others have variously found the direction of the effect to be determined by task (e.g. Li & Gollan, 2018; Dijkstra et al., 1999, 2010), morphological complexity (e.g. Balling, 2013) and/or relative language dominance (e.g. Blumenfeld & Marian, 2007; Muntendam et al., 2022; Taylor & Mukai, 2023).

³ Fritz and colleagues (2023) and Fritz & Lahiri (2025) have demonstrated that such prosodic differences can have significant consequences for lexical access.

⁴ Participants were not excluded based on poor performance in the LexTale. Although only a moderate correlation was found between participants' scores and their performance in the experiment ($r(34) = 0.52$, $p = 0.001$), perhaps due to the added difficulty of the timed nature of the experimental task, the robustness of this association was confounded by near-ceiling effects in both variables.

⁵ Due to the restricted set of inherited English words with initial /θ/, we also included some shared early modern loans of Greek origin where the <th> onset was adapted into German as [PLOS] /t/ (e.g. *throne* /θrɒn/ ~ *Thron* /tʁo:n/).

⁶ Syllable-final obstruents are devoiced in German as the result of a regular phonological rule, but are underlyingly (phonemically) voiced. Compare, for instance [p̥fa:t] “path.SG” and [p̥fa:də] “path-PL”.

⁷ This decision was influenced by several factors. Firstly, we see these components as independent, as no data were compared more than once across conditions in our analysis. Instead, these represent independent cases which only appear together in this experiment.

Furthermore, all comparisons were driven by our hypotheses, testing defined predictions and planned from the outset. We had clear predictions regarding ERP components, regions of interest and windows of interest based on previous studies conducted by our lab, such that there was no exploratory aspect to our analysis. It is also for this reason that we chose not to make additional and unplanned post-hoc comparisons which were unrelated to our predictions. As the data were not compared multiple times across conditions, the only dependencies in the data being compared were due to the fact that the data came from successive time windows. In all other respects, they were independent (see also n.8).

⁸ The *rstatix* package's *pairwise_t_test* function used in this analysis corrects for multiple comparisons by default (using the Holm correction). However, as each of the planned pairwise comparisons involved a single *t*-test, it had no effect.

⁹ Fritz & Lahiri's (2025) fragment-priming study of Bengali–English bilinguals found no late positivity effect. The authors ascribed this to a lack of conflict when reading L2 English words, due to Bengali's wholly separate orthography; in contrast, German speakers reading English stimuli in a previous study (2023) were obliged to suppress a “German” reading of the L2 targets.

¹⁰ Note also that ⟨th⟩ /θ/ occurs in all words in the NO-MISMATCH condition, and five of the 24 words in the NON-EXISTENT condition.

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The authors report there are no competing interests to declare.

Ethics

The study was reviewed by and received ethics approval through The Central University Research Ethics Committee at the University of Oxford (reference number R77464/RE002).

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Data availability statement

Datasets and analysis scripts are available upon request.

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Appendix A

Languages spoken other than German and English:	
French	n = 22
Spanish	n = 11
Italian	n = 8
Dutch	n = 2
Norwegian	n = 2
Swedish	n = 1
Slovenian	n = 1
Quechua	n = 1

Percentage of time you are currently exposed to each of your languages on an average day:¹	
German	mean = 65.62%; SD = 11.88
English	mean = 30.51%; SD = 10.29
Other	mean = 3.73%; SD = 4.02

Age when you:	
Started acquiring English	mean = 8.76 years; SD = 1.88
Became conversationally fluent in English	mean = 15.08 years; SD = 1.92
Became fluent reading in English	mean = 14.78 years; SD = 1.90

Amount of time spent in an English-speaking country:	
	mean = 3.83 months; SD = 6.22
	range = 0.00–24.00 months
	median = 0.00 months

Table A.1: Summary of participants' language background as determined by the abridged Language Experience and Proficiency Questionnaire (Marian et al. 2007).

¹ One participant's responses added up to 95% instead of 100%, resulting in a discrepancy in the mean percentage across participants.

Appendix B

Acoustic fragment	Target	Transcription	German Cognate	Transcription	Translation (if different)
fi	fish	fɪʃ	Fisch	fɪʃ	—
fɔ	fox	fɔks	Fuchs	fʊks	—
fiɛ	fresh	fiɛʃ	frisch	fɪʃ	—
fiɔ	frost	fiɔst	Frost	fɪɔst	—
fʊ	foot	fʊt	Fuß	fu:s	—
fʊ	full	fʊl	voll	fɔl	—
fi:	fever	fi:və	Fieber	fi:bɛ	—
fi	finger	fiŋgə	Finger	fiŋə	—
maʊ	mouse	maʊs	Maus	maʊs	—
mɑ:	mast	mɑ:st	Mast	mast	—
mɪ	milk	mɪlk	Milch	mɪlç	—
mɪ	mint	mɪnt	Minze	mɪntsə	—
mɔ:	malt	mɔ:lt	Malz	malts	—
mɪl̩	mild	mɪl̩d	mild	mɪlt	—
mɪl̩	mile	mɪl̩	Meile	maɪlə	—
mæ	mangle	mæŋgəl	Mangel	maŋəl	—
nɛ	nest	nɛst	Nest	nɛst	—
nɛ	net	nɛt	Netz	nɛts	—
nɔ:	north	nɔ:θ	Nord	nɔ:t	—
nʌ	nun	nʌn	Nonne	nɔnə	—
nʌ	nut	nʌt	Nuss	nʊs	—
nɪn̩	nine	nɪn̩	neun	nɔɪn	—
nɛ	nettle	nɛtəl	Nessel	nɛsəl	—
nu:	noodle	nu:dəl	Nudel	nu:dəl	—

Table B.1: List of stimuli for the IDENTITY condition (acoustic fragment test prime and English visual target), along with the relevant German cognate. Where the English meaning is not a possible translation of the German, the German translation has been provided.

Acoustic fragment	Target	Transcription	German Cognate	Transcription	Translation (if different)
θæ	thank	θæŋk	dank-	daŋk	—
θæ	thatch	θætʃ	Dach	dax	roof
θɜ:	thirst	θɜ:st	Durst	dɔʁst	—
θi:	thesis	θi:sɪs	These	te:zə	—
θi:	thief	θi:f	Dieb	di:p	—
θɪ	thick	θɪk	dick	dɪk	—
θɪ	thin	θɪn	dünn	dʏn	—
θɪ	thing	θɪŋ	Ding	dɪŋ	—
θɪ	think	θɪŋk	denk-	deŋk	—
θɔ:	thaw	θɔ:	tau-	taʊ	—
θɔ:	thorn	θɔ:n	Dorn	dɔʁn	—
θɪæ	thrash	θɪæʃ	dresch-	dʁɛʃ	—
θɪəʊ	throne	θɪəʊn	Thron	tʁo:n	—
θɪəʊ	throw	θɪəʊ	dreh-	dʁe:	turn
θɪɛ	thread	θɪɛd	Draht	dʁa:t	wire
θɪɛ	threaten	θɪɛtŋ	droh-	dʁo:	—
θɪi:	three	θɪi:	drei	dʁaɪ	—
θɪɔ	throng	θɪɔŋ	Drang	dʁaŋ	urge; impulse
θɪu:	through	θɪu:	durch	dɔʁç	—
θʌ	thumb	θʌm	Daume	daʊmə	—
θaʊ	thousand	θaʊznd	Tausend	taʊznt	—
θɪ	thistle	θɪsl̩	Distel	dɪstl̩	—
θɪɔ	throttle	θɪɔtl̩	Drossel	dʁɔsl̩	thrush
θʌ	thunder	θʌndə	Donner	dɔnə	—

Table B.2: List of stimuli for the NO-MISMATCH condition (acoustic fragment test prime and English visual target), along with the relevant German cognate. Where the English meaning is not a possible translation of the German, the German translation has been provided.

Acoustic fragment	Target	Transcription	German Cognate	Transcription	Translation (if different)
pæ	pan	pæn	Pfanne	pfanə	—
paʊ	pound	paʊnd	Pfund	pfʊnt	—
pɑ:	path	pɑ:θ	Pfad	pfɑ:t	—
pɪ	pit	pɪt	Pfütze	pfʏtsə	puddle
pɛ	penny	pɛni	Pfennig	pfɛnɪç	—
pɛ	pepper	pɛpə	Pfeffer	pfɛfə	—
plɑ:	plant	plɑ:nt	Pflanze	pfplant̩sə	—
plɑ:	plaster	plɑ:stə	Pflaster	pfplastə	—
plʌ	pluck	plʌk	pflueck-	pflyk	—
plʌ	plum	plʌm	Pflaume	pfplaʊmə	—
pʌɪ	pile	pʌɪl	Pfeil	pfajl	arrow; bolt; dart
pʌɪ	pipe	pʌɪp	Pfeife	pfajfə	—
taʊ	town	taʊn	Zaun	tʰsaʊn	fence
teɪ	tame	teɪm	zahn	tʰsa:m	—
təʊ	toll	təʊl	Zoll	tʰsəl	—
tɛ	tell	tɛl	(er)zähl-	(ɐ)tʰsɛ:l	—
tɛ	ten	tɛn	zehn	tʰsɛ:n	—
tɪ	tick	tɪk	Zecke	tʰsekə	—
tɪ	tin	tɪn	Zinn	tʰsɪn	—
tʌ	tongue	tʌŋ	Zunge	tʰsʊŋə	—
tʌɪ	tide	tʌɪd	Zeit	tʰsaɪt	time
twe	twelve	twelv	zwölf	tʰsvɛlf	—
twɪ	twig	twɪɡ	Zweig	tʰsvaɪk	—
tɪ	timber	tɪmbə	Zimmer	tʰsɪmə	room

Table B.3: List of stimuli for the MISMATCH condition (acoustic fragment test prime and English visual target), along with the relevant German cognate. Where the English meaning is not a possible translation of the German, the German translation has been provided.

Acoustic fragment	Target	Transcription	German Cognate
fəʊ	foam	fəʊm	NA
fi	filth	fiɪθ	NA
fɔ	fog	fɔg	NA
fɛ	fellow	fɛleʊ	NA
mʌ	mug	mʌg	NA
məʊ	moan	məʊn	NA
mi:	meat	mi:t	NA
meɪ	maple	meɪpl̩	NA
næ	nag	næg	NA
næ	nap	næp	NA
nu:	noon	nu:n	NA
nʌ	numb	nʌm	NA
pæ	pad	pæd	NA
pɪ	pig	pɪg	NA
pɔ	poppy	pɔpi	NA
pʌ	puddle	pʌdl̩	NA
teɪ	take	teɪk	NA
təʊ	toad	təʊd	NA
tɔ:	talk	tɔ:k	NA
tu:	tool	tu:l	NA
θɪ	thrift	θɪft	NA
θɪɔ	throb	θɪɔb	NA
θɪʌɪ	thrive	θɪʌɪv	NA
θʌ	thug	θʌg	NA

Table B.4: List of stimuli for the NON-EXISTENT condition (acoustic fragment test prime and English visual target), along with the relevant German cognate.

Appendix C

	IDENTITY	NO-MISMATCH	MISMATCH	NON-EXISTENT	NONWORDS
Mean frequency in English (pmw)	61.48 (84.68)	212.79 (454.32)	94.57 (211.23)	110.95 (382.83)	—
Mean frequency in German (pmw)	41.93 (70.36)	147.01 (322.67)	90.33 (252.27)	—	—
Mean number of syllables	1.21 (0.41)	1.25 (0.44)	1.17 (0.38)	1.17 (0.38)	1.16 (0.36)
Mean number of syllables for German cognate	1.33 (0.48)	1.25 (0.44)	1.46 (0.51)	—	—
Mean number of phonemes	3.67 (0.70)	3.71 (0.86)	3.63 (0.88)	3.38 (0.58)	3.74 (0.77)
Mean number of graphemes	4.38 (0.97)	5.83 (1.17)	4.46 (1.10)	4.25 (1.03)	5.09 (0.92)
Mean familiarity rating (%)	93.26 (14.77)	84.65 (25.48)	95.42 (6.94)	95.42 (7.36)	—

Table C.1: Mean (SD) norming data by condition: token frequency in English and German (words per million), number of syllables in English and for the German cognate, length in English (phonemes and graphemes) and familiarity rating by native German speakers with high proficiency in English (percentage).