LANGUAGE, COGNITION AND NEUROSCIENCE
2025, VOL. 40, NO. 10, 1446–1464
https://doi.org/10.1080/23273798.2025.2558640

Routledge
Taylor & Francis Group

REGULAR ARTICLE

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Teasing apart the impact of different forms of overlap on cross-linguistic structural priming

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ABSTRACT
In the current paper, we examined the extent to which cross-linguistic structural priming effects can be found in genetically-unrelated languages, assessing the sensitivity of priming to varying degrees of overlap between the prime and target languages. In three experiments (*N*s = 59, 57, 52), we tested the priming of L2 English passive sentences in response to patient-initial prime sentences in Tagalog (Experiments 1, 2) and Indonesian (Experiment 3). The linguistic properties of Tagalog and Indonesian allowed us to manipulate prime-target overlap in thematic role order, syntactic–thematic role mapping, and constituent order. Cross-linguistic priming effects were moderated by the degree of linguistic overlap between prime and target: priming effects were stronger given an overlap in syntactic–thematic role mapping, and strongest for shared constituent order. The results suggest that cross-linguistic priming effects can have different loci, and that each one has an additive effect on priming magnitude.

ARTICLE HISTORY
Received 7 March 2025
Accepted 26 August 2025

KEYWORDS
Cross-linguistic priming; constituent order overlap; Tagalog; Indonesian; passives

Introduction

It is well known that speakers tend to re-use recently heard structures – a phenomenon called structural priming (see Mahowald et al., 2016; Pickering & Branigan, 1999; Pickering & Ferreira, 2008). For example, speakers are more likely to produce a passive sentence after hearing another passive such as “the grandmother is being tickled by the girl” compared to an equivalent active sentence like “the girl is tickling the grandmother”. Priming effects have also been observed in bilingual speakers when switching between their two languages (Bernolet et al., 2009; Cai et al., 2011; Hartsuiker et al., 2004; Hsin, et al., 2013; Loebell & Bock, 2003; Rodrigo et al., 2020; Salamoura & Williams, 2007; Schoonbaert et al., 2007; Shin & Christianson, 2009; see Bencini, 2025; Hartsuiker & Pickering, 2008; Van Gompel & Arai, 2018 for reviews). In other words, language structure does not only prime utterances of the same language but also utterances in another language with a different lexical and morphosyntactic inventory. Such cross-linguistic priming effects have been taken as evidence that the mental representation of syntax is shared between languages (Hartsuiker et al., 2004), or at least directly connected (Ahn & Ferreira, 2024; Van Gompel & Arai, 2018). However, most of these studies have focused on genetically-related bilingual language pairs such as Dutch and English (e.g. Bernolet et al., 2009) or Spanish and English (e.g. Hartsuiker et al., 2004), which reflects the broader lack of linguistic diversity in psycholinguistic research (Berghoff & Bylund, 2025). Languages like Dutch and Spanish share many linguistic properties with English. For example, on the lexical level, Dutch and Spanish have many English cognates (e.g. “to accept” is *aceptar* in Spanish and *accepteren* in Dutch), and their shared genetic relationship means that many of their syntactic processes are similar (e.g. SVO word order in main clauses and tense marking on the verb).

The extent to which cross-linguistic priming occurs in languages that are typologically more diverse is unclear. Importantly, focusing on languages that are genetically closely related, and thus possess similar linguistic

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/23273798.2025.2558640.

properties, limits our understanding of how linguistic factors moderate structural priming effects and therefore how syntax is represented in both monolingual and bilingual speakers. In this study, we investigated cross-linguistic priming in proficient L2 speakers of English whose L1 is an Austronesian language. Austronesian is the world's second largest language family, spanning a geographical range that spans half the planet, with over 1200 hundred extant languages spoken in countries from Madagascar to Easter Island (Eberhard et al., 2025), and yet it is rarely studied in the psycholinguistic literature. In this study, we focused on Tagalog and Indonesian, which allowed us to test whether and to what extent cross-linguistic priming effects are moderated by overlap in linguistic features (i.e. thematic role order, syntactic role assignment, and constituent order).

Cross-linguistic priming and its limits

The observation that structural priming effects can be observed across languages suggests a degree of integration of linguistic properties of the two (or more) languages in the minds of multilingual speakers (Hartsuiker et al., 2004). Cross-linguistic priming effects have been observed across a range of structures typically studied in within-language priming research; for instance, in the active–passive voice alternation for transitive sentences (Bernolet et al., 2009; Fleischer et al., 2012; Hartsuiker et al., 2004; Hwang & Shin, 2019; Kutasi et al., 2018; Rodrigo et al., 2020). Hartsuiker et al. (2004) showed that Spanish-English bilinguals produced more English passives (e.g. "The truck is chased by the taxi") after encountering Spanish passive primes compared to encountering Spanish active and Spanish intransitive primes. Cross-linguistic priming has also been found in dative alternation (Cai et al., 2011; Kantola & Van Gompel, 2011; Kootstra & Şahin, 2018; Loebell & Bock, 2003; Salamoura & Williams, 2007; Schoonbaert et al., 2007), high and low relative clause attachment (Desmet & Declercq, 2006; Hartsuiker et al., 2016), and adjective–noun order for languages that allow both noun-initial and noun-final phrase structures (Bernolet et al., 2007; Hsin et al., 2013).

The extent to which cross-linguistic priming can be observed appears to depend on the degree to which languages share structural properties. For example, cross-linguistic priming is not always observed when there is no overlap in constituent order (i.e. verb position differs between prime and target). Loebell and Bock (2003) found no priming of passives between English (SVO) and German (SOV), but found priming for dative alternations, which have the same constituent order in the two languages. Furthermore, Jacob et al. (2017) found that priming in dative alternations between English and German was only found when sentences had the same verb-medial constituent structure; priming effects disappeared for verb-final structures in German. Bernolet et al. (2007) found priming of relative clauses between German and Dutch which have a similar verb-final constituent order, but not between Dutch and English, where constituent order can differ (English: verb-medial, Dutch: verb-final, see also Kidd et al., 2015).

In contrast, other studies found cross-linguistic priming effects despite the difference in syntactic structure (Bernolet et al., 2009; Chen et al., 2013; Fleischer et al., 2012; Hwang & Shin, 2019; Kutasi et al., 2018; Rodrigo et al., 2020; Shin & Christianson, 2009; Son, 2020). For example, dative priming effects were found across English and Korean even though the languages differ in constituent order (Korean is SOV; Shin & Christianson, 2009; Son, 2020; though see Ahn & Ferreira, 2024). Passive priming has also been found between Mandarin and English (Mandarin is SOV; Chen et al., 2013; Hwang & Shin, 2019), and Scottish Gaelic and English (Scottish Gaelic *go*-passives have an auxiliary verb-first structure, e.g. go-subject-verbal noun-object; Kutasi et al., 2018). Bernolet et al. (2009) also found that Dutch passives primed English passives regardless of whether the Dutch sentence used a verb-final or verb-medial structure. However, the priming effects were stronger for the verb-medial (similar to English) than verb-final condition; which suggests that similarity in constituent order moderates the strength of cross-linguistic priming.

For the cross-linguistic priming effects reported above, even in the absence of overlap between constituent order, there are other shared linguistic properties between the languages. For example, they share the same mapping between syntactic and thematic roles (Chen et al., 2013; Hwang & Shin, 2019; Kutasi et al., 2018; Rodrigo et al., 2020; Shin & Christianson, 2009; Son, 2020). More specifically, in studies priming the passive structure, the thematic patient is also the syntactic subject in both prime and target sentences. Moreover, the syntactic subject often appears before the syntactic object, and only the position of the verb is different (although see Bernolet et al., 2009 which also used object-before-subject structures). The rigid mapping between syntactic and thematic role means that there is also overlap in the thematic role order of primes and targets (Chen et al., 2013; Hwang & Shin, 2019; Kutasi et al., 2018; Shin & Christianson, 2009; Son, 2020), such that for passive priming, the prime and target both have a patient-before-agent order. This raises ambiguity as to the locus of priming: priming could occur at the functional level of syntactic–thematic role mapping, or because of similarity in information structure or thematic emphasis between primes and targets (Bernolet et al., 2009; Fleischer et al., 2012; Son, 2020).

The different levels at which priming occurs were dissociated in a cross-linguistic study of Salamoura and Williams (2007). They tested the extent to which dative priming depends on prime and target similarity in (1) syntactic structure (i.e. type of data: prepositional object [PO] vs. double object [DO]), (2) constituent order (e.g. verb-prepositional phrase, verb-noun phrase order), (3) thematic role order (i.e. whether the verb was followed by a theme or a recipient/goal), (4) or a combination of all three factors. They found that Greek-English bilinguals were more likely to use PO datives in English utterances only when the immediately postverbal argument of the prime and target overlapped in both syntactic structure and thematic role, independent of the syntactic structure and thematic role order of the whole sentence. Greek *provide-with* sentences ("The president provided the winner with the gold medal" of the form NP-V-NP-PP) primed English DO datives (in which the recipient/goal also immediately follows the verb, but which has the syntactic structure NP-V-NP-NP) but not English PO (which is also NP-V-NP-PP, but the immediately postverbal argument is a theme). Additionally, Greek locatives ("The president kept the gold medal in the drawer", NP-V-NP-PP) primed English PO (which also has a theme as the first postverbal argument).

In summary, the past empirical literature reports varying results concerning the conditions under which cross-linguistic priming does and does not occur, which makes the mechanisms underlying the effect difficult to isolate. This is perhaps also exacerbated by convenience sampling of language combinations across participant populations, such that language combinations are not typically chosen to tease apart different linguistic cues to priming effects (e.g. conflating thematic and grammatical role). In the current paper, we purposefully selected Tagalog and Indonesian, whose linguistic properties allowed us to isolate the influences of different sources of information on priming.

Explanations of cross-linguistic priming

Different theoretical accounts have been proposed regarding multilinguals' language representation, aiming to explain how cross-linguistic priming can occur. Hartsuiker et al.'s (2004) *shared syntax* model, an extension of the residual activation account (Pickering & Branigan, 1998), proposed that bilinguals have shared linguistic representations across languages. For example, for an English-Spanish bilingual, the translational equivalent lemmas *chase* and *perseguir* are linked to the same conceptual (CHASE) and combinatorial nodes (e.g. passive). This means that the Spanish passive sentence "El camión es perseguido por el taxi" activates the lemma *perseguir* and its associated language-independent nodes (CHASE, passive), resulting in an increased likelihood to produce a passive not only in Spanish, but also in English. The extent to which two languages overlap depends on their syntactic features. Hartsuiker et al. (2004, p. 412) wrote: "the syntax of a particular construction is shared between languages only if it is formed in the same way in both languages". Therefore, Hartsuiker and Pickering (2008) predict cross-linguistic priming only for languages with shared grammatical rules, and hence, no difference in cross-linguistic priming is expected in genetically-related languages (e.g. Dutch and English) and genetically-unrelated languages (e.g. Korean and English) provided that the languages have similar syntactic rules. Specifically, changes in word order would block cross-linguistic priming because "different languages only share syntactic representations for constructions that involve the same word order" (Hartsuiker & Pickering, 2008, p. 486).

In this paper, we tested the predictions of two computational models that offer different explanations for why structural priming can be observed across languages: First, Reitter et al.'s (2011) ACT-R model puts stronger constraints on whether priming effects can be observed across different languages. Their model operates on the basis of the principles of implicit learning and spreading activation (referred to as *hybrid* model of structural priming). Retrieving a syntactic structure from memory enhances its activation and its association with lexical items in working memory, while also increasing its base-level activation in long-term memory. More importantly, in the hybrid model, surface word order and hierarchical organisation of phrases are computed in a single step. Therefore "cross-linguistic priming can only occur in structures that share both linear precedence and immediate dominance relationships" (Reitter et al., 2011, p. 625). In other words, the hybrid model rules out cross-linguistic priming for prime-target pairs with different constituent order and syntactic relationships.

Second, a more moderate view on the role of constituent structure in cross-linguistic priming can be found in the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024; Tsoukala et al., 2017), which is a bilingual implementation of Chang et al.'s (2006) connectionist model. In the model, grammatical representations are learned via a serial recurrent network that predicts the upcoming word in a sentence and updates its knowledge when a word is not predicted correctly. Word prediction error is used to strengthen the connections related to the prime's syntactic structure, making the structure more expected in the future. In contrast to Reitter et al. (2011), the model predicts cross-linguistic priming even when prime and target differ in constituent order. In particular, Khoe et al. (2023, p. 553) predict that "priming can occur for syntactic structures that differ in their target language as well as for those that differ in a part of their word order" and that in "cases of partial overlap between the syntactic representations involved, priming is weaker compared to cases where syntactic representations are more similar". In other words, the size of cross-linguistic priming effects is moderated by the degree of structural overlap. Furthermore, simulations of the Bilingual Dual-path model predict cross-linguistic priming across genetically-unrelated languages, i.e. Indonesian and Dutch (Khoe & Frank, 2024).

Tagalog and Indonesian

To examine whether cross-linguistic priming occurs across genetically-unrelated languages and to test the predictions of cross-linguistic priming accounts, we tested Tagalog and Indonesian priming of English passive sentences. Tagalog and Indonesian are both Western Malayo-Polynesian Austronesian languages with symmetrical voice, which means that the languages have more than one basic transitive construction that are equally marked by voice morphology, and without demotion of an argument to an oblique (e.g. unlike the agent in English passives; see Himmelmann, 2005; Riesberg, 2014). However, they differ in constituent order: Tagalog is verb-initial, while Indonesian has an SVO order like English. Tagalog and Indonesian are not related to languages that have been previously tested in the cross-linguistic priming literature, and their linguistic properties are essential to understanding the mental representations which are shared or linked between languages and the individual contributions of different forms of structural overlap in cross-linguistic priming.

Tagalog is primarily spoken in the Philippines, with almost 33 million native speakers (Eberhard et al., 2025). In Tagalog, the voice marking on the verb determines the thematic role of the noun phrase that is marked by *ang*, which is also considered as the subject (see examples 1–4; Himmelmann, 2005). In the agent voice (AV), the verb infix "-um-" assigns the subject the agent role (1, 2). Conversely, in the patient voice (PV), the infix "-in-" marks the subject as the patient (3, 4). Tagalog has a canonical verb-initial structure, but it has a relatively flexible post-verbal argument order (Schachter, 2015). This results in both agent-initial (1, 3) and patient-initial (2, 4) orders across different voices.

(1) Agent voice	K<**um**>i~kiliti	**ang**	kambing	ng	kabayo
agent-initial	<AV>$_{1}$IPFV~tickle	SBJ	goat	NSBJ	horse
(2) Agent voice	K<**um**>i~kiliti	ng	kabayo	**ang**	kambing
patient-initial	<AV>IPFV~tickle	NSBJ	horse	SBJ	goat
(3) Patient voice	K<**in**>i~kiliti	ng	kambing	**ang**	kabayo
agent-initial	<PV>IPFV~tickle	NSBJ	goat	SBJ	horse
(4) Patient voice	K<**in**>i~kiliti	**ang**	kabayo	ng	kambing
patient-initial	<PV>IPFV~tickle	SBJ	horse	NSBJ	goat
	"The/A goat is tickling the/a horse".				

Patient-initial sentences in Tagalog are different from English passives. Unlike the Tagalog verb-initial constituent order, English has an SVO order. However, Tagalog patient-initial sentences (2, 4) share the same thematic role order with English passives, while Tagalog patient voice sentences (3, 4) share the same syntactic–thematic role mapping as English passives, where the patient is the subject. Tagalog patient voice patient-initial sentences (4) also share the same subject-before-object order as English. This crucial separation of syntactic and thematic role is essential to the design of our studies.

Indonesian (or *Bahasa Indonesia*), which is part of the Malay macrolanguage, is the national language of Indonesia spoken by around 72 million native speakers (Badan Pusat Statistik Indonesia, 2023). In this study, we focus on Standard Indonesian, the formal register used in official and formal contexts. Standard Indonesian (henceforth, Indonesian) has a subject-first order in declaratives, and thematic roles are assigned by the verbal affixes on the verb. In the active or agent voice, the agent is the subject (which is also the first noun phrase), and it is followed by a verb with the verbal prefix "me*N*[2]-" (5, Sneddon, 1996). In the passive voice, the patient is the subject, followed by a verb marked with verbal prefix "di-" (6).[3] Similar to English passives, the agent is optional and is preceded by a by-phrase headed by *oleh*. *Oleh* itself may also be omitted but only when the agent immediately follows the verb (other clause elements can be positioned between the verb and the agent). In examples 5 and 6, the determiner *itu* follows the subject, but this can be omitted in non-subject positions when the context clarifies its meaning.

(5) Active /	Kambing	itu	sedang	**meng**-gelitik	kuda	
Agent	goat	DET	PROG	AV-tickle	horse	
voice	"The goat is tickling the horse".					
(6) Passive	Kuda	itu	sedang	**di**-gelitik	oleh	kambing
voice	horse	DET	PROG	PV-tickle	by	goat
	"The horse is being tickled by the goat".					

Although there are similarities between Indonesian and English, the Indonesian voice system is different from the English active–passive alternation as there is a distinct voice prefix in each construction and no construction is derived from the other (Chen & McDonnell, 2019).

Moreover, Indonesian passive sentences are frequent (Gil, 2006; Sneddon, 1996), which means that thematic patients often occur as syntactic subjects. In English, subjects are typically agents, and the passive voice is infrequent. Indonesian passive sentences are also acquired as early as two years of age (Gil, 2006), contrary to English-speaking children who make mistakes with passives even at the age of six (Messenger et al., 2012).

Current study

In three pre-registered structural priming experiments, we used the grammatical properties of Tagalog and Indonesian to investigate the individual contributions of linguistic sources of prime-target overlap in cross-linguistic priming (see Table 1 for a comparison of prime-target overlap in Experiments 1–3). We aimed to answer whether and to what extent cross-linguistic priming occurs across genetically-unrelated languages, specifically when the prime and target do or do not overlap (1) in thematic role order, (2) mapping between syntactic and thematic roles, and/or (3) constituent order.

In Experiments 1 and 2, we tested whether Tagalog-English bilinguals produced more English passives after encountering Tagalog patient-initial primes compared to Tagalog agent-initial primes. Importantly, Tagalog's voice system allowed us to vary the overlap between syntactic functions independent of thematic roles (see Table 1). In Experiment 1, verbs were agent-voice marked. Hence, patient-initial primes had the same thematic role order as English passive sentences, but the syntactic–thematic role mapping was different (Tagalog: agent is the subject, English: patient is the subject). In Experiment 2, the verb of the Tagalog prime was patient-voice marked. Hence, prime and target shared both thematic role order and the mapping between syntactic and thematic roles (i.e. patient is the subject). However, Tagalog's constituent order differed from English (i.e. Tagalog: verb-initial, English: SVO). Therefore, in Experiment 3, we tested cross-linguistic priming between Indonesian and English passives to allow for overlap in thematic role order, syntactic–thematic role mapping, and constituent order (SVO).

Table 1. Comparisons of properties of patient-initial structures (e.g., passive for English) across languages as used in Experiments 1 to 3.

Exp.	Language	Thematic role order	Thematic role of sentence subject	Constituent order
1	Tagalog AV	patient-before-agent	agent	VOS
2	Tagalog PV		patient	VSO
3	Indonesian		patient	SVO
1, 2, 3	English		patient	SVO

Note. AV refers to agent voice, PV to patient voice.

In all three experiments, participants saw the same conceptual action, e.g. *tickling*, depicted in both prime and target, and hence participants used the same verb as in the prime (when following an English prime sentence) or a translational equivalent (when following a Tagalog / Indonesian prime sentence) in the target utterance. The repetition of the same action has frequently been reported to increase the size of structural priming effects (Pickering & Branigan, 1998; for meta-analytic evidence, see Mahowald et al., 2016). In the current study, we maximised the chances to observe priming by using conceptual overlap. This is because findings from Tagalog showed that structural priming effects are weak when there is a structural mismatch between the prime and target (i.e. when there is a voice difference) even when the verb is repeated (Garcia et al., 2023). Because of structural differences between Tagalog and English, we expected cross-linguistic priming between the two languages to be weak. We took this as a first step in determining whether cross-linguistic priming exists between the languages, and in examining how different forms of structural overlap moderate the cross-linguistic priming effect.

On the basis of the two computational models we introduced above, we derived the following predictions for cross-linguistic priming in Tagalog / Indonesian and English. First, the hybrid spreading-activation and learning-based model (Reitter et al., 2011) predicts that, when constituent order differs, priming will be blocked. In other words, this model predicts priming between Indonesian and English (Experiment 3), but not between Tagalog and English (Experiments 1 and 2).

Second, the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024) predicts cross-linguistic priming even when constituent order differs between the prime and target. Therefore, it predicts cross-linguistic priming in all three experiments but to different degrees because of differences in the extent to which prime and target overlap. More specifically, Tagalog agent voice patient-initial, as in example sentence (2), and patient voice patient-initial, as in sentence (4), should prime the production of English passives. However, there is likely to be a difference in priming magnitude. Notably, for the agent voice, where there is only thematic role overlap, priming is predicted to be weak because it solely occurs within the meaning pathway of the model, which is prior to syntactic formulation. In contrast, for the patient voice, where there is overlap in syntactic–thematic role mapping, priming is predicted to be stronger because it implicates form–

meaning mappings as the model's meaning and sequencing pathways interact. Finally, priming is expected to be stronger still for Indonesian, where there is full overlap between English in terms of thematic role order, syntactic–thematic role mapping, and constituent structure order, and where the speaker is likely to acquire shared abstract knowledge between the languages based on their overlapping and ordered sequencing of form–meaning units.

Experiment 1: Tagalog agent voice

In this pre-registered experiment (OSF: https://osf.io/9zm5v), we tested the extent to which Tagalog agent voice patient-initial sentences prime English passives, given their shared thematic role order, but differences in syntactic–thematic role mapping and constituent order. We also tested English to English passive priming to assess the strength of within-language priming in the participants' second language. Additionally, this ensured that our participants were proficient enough to replicate the priming effects observed in other studies involving monolingual (see Pickering & Branigan, 1999 for a review) and bilingual English speakers (e.g. Bernolet et al., 2009; Hartsuiker et al., 2004).

Method

Participants

We tested a total of 100 Tagalog speakers from the Greater Manila area. They reported not having any past nor present diagnosis of a psychological / neurological illness nor speech-language impairment. Participants who contributed less than 19 trials (i.e. 60% of 32 trials; $n = 14$) were excluded, as well as those who did not follow the instructions (e.g. only repeated the verb prompts or produced Tagalog sentences, $n = 3$),[4] scored lower than 50% on the sentence-picture matching task ($n = 2$), scored lower than 70%[5] on an English lexical decision test ($n = 11$) called Lexical Test for Advanced Learners of English (LexTALE, Lemhöfer & Broersma, 2012; for more details see *Procedure*), and used an infinitive form of the English verb prompt (e.g. "trying to tickle") in more than 50% of all valid trials ($n = 11$).[6] Excluded participants were replaced so that the final sample included a minimum of six participants for each of the 8 experimental lists (see next section). We analysed the data of a final sample of 59 participants (mean age = 25.2, SD = 5.2, age range = 18–35, women: 42, men: 17), who had a mean LexTALE score of 86.3% (SD = 8.3). The final sample included 58% college graduates, 39% college students or individuals who started but did not finish college, and 3% high school graduates. Participants received a voucher to a local convenience store worth P250 (approximately €4). All participants provided informed consent to join the study. The ethics committee of the University of Potsdam waives the requirement for ethics approval for non-invasive studies with adults.

Design and materials

Participants were asked to describe a picture (i.e. target) in English using a transitive sentence, after deciding whether a sentence presented either in Tagalog or English (prime language) was an appropriate description of a picture. Prime language (English, Tagalog) was experimentally crossed with the order of the thematic roles used in the prime (henceforth "prime order"). Prime order had two levels: agent-initial (agent-before-patient) and patient-initial (patient-before-agent). All the Tagalog primes had verbs which were in the agent voice. In all items, the depicted actions in prime and target pictures were identical but with different entities as agents and patients. In other words, there was lexical verb overlap in prime-target pairs in the English prime condition, and a semantic verb overlap in the prime-target pairs in the Tagalog prime condition. For the production task, we provided English prompts of the depicted action. These prompts were infinitive forms identical to (English prime) or a translation of (Tagalog prime) the verb used in the prime sentence. See Table 2 for a sample item. The dependent variable was whether participants produced an English passive (patient-initial) or active (agent-initial).

Table 2. Sample item with the prime picture of *a goat tickling a horse* and the target prompt "to tickle" for the target picture of *a pig tickling a chicken* for Experiments 1 to 3.

Exp.	Prime language	Prime order	Subject	Prime sentence
1, 2, 3	English	agent-initial	agent	The goat is tickling the horse.
		patient-initial	patient	The horse is being tickled by the goat.
1	Tagalog	agent-initial	agent	Kumikiliti ang kambing ng kabayo.
		patient-initial	agent	Kumikiliti ng kabayo ang kambing.
2	Tagalog	agent-initial	patient	Kinikiliti ng kambing ang kabayo.
		patient-initial	patient	Kinikiliti ang kabayo ng kambing.
3	Indonesian	agent-initial	agent	Kambing itu sedang menggelitik kuda.
		patient-initial	patient	Kuda itu sedang digelitik oleh kambing.

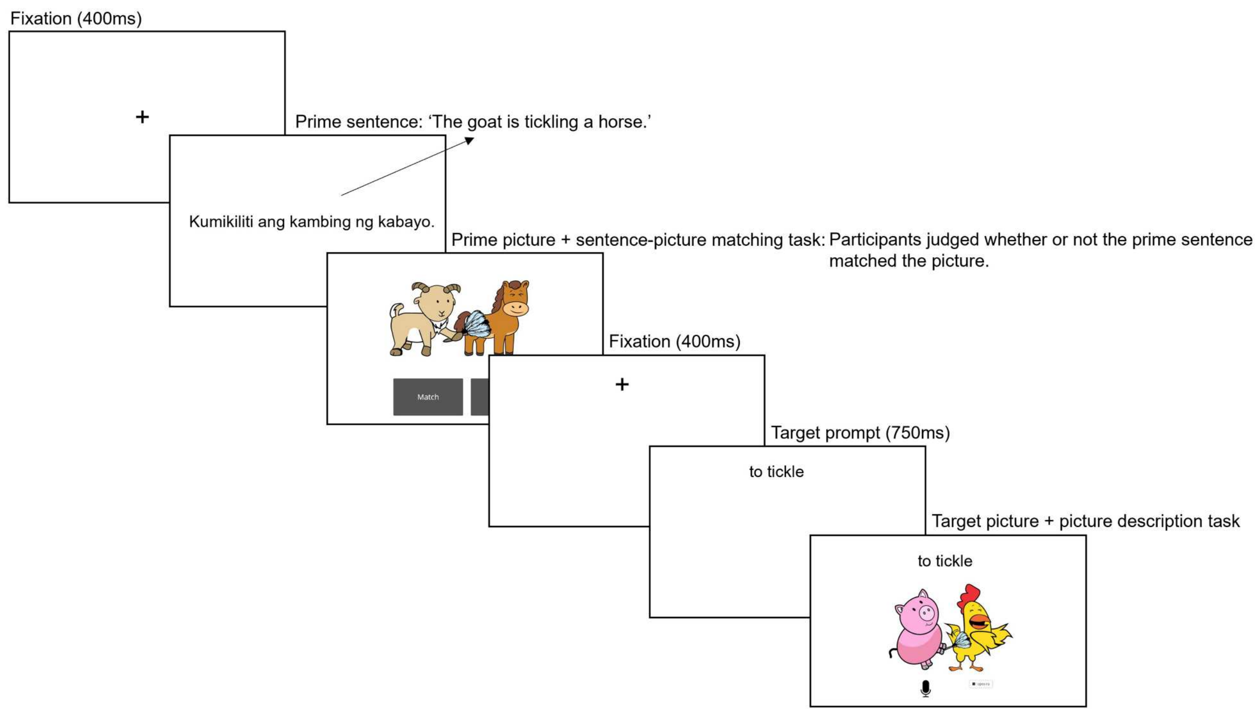

Figure 1. Sample of an experimental trial in Experiment 1.

The trial flow is illustrated in Figure 1. Each trial started with the presentation of a fixation cross at the centre of the screen (400 ms), followed by the presentation of the prime sentence. A button click (to indicate that one has finished reading the prime sentence) then triggered the display of a picture that either matched or did not match the prime sentence. In all the experimental trials, the prime pictures matched the prime sentence. The mismatches were from the fillers. Below the picture were "Match" and "Mismatch" buttons for indicating whether the picture corresponded to the prime sentence. Once one of the buttons had been selected, a new fixation cross appeared at the top of the screen (400 ms) followed by the English target prompt. For the experimental items, the target prompts were infinitives, e.g. "to tickle". After 750 ms of target prompt preview, the target picture appeared beneath the target prompt. Participants were instructed to describe the target picture by using the target prompt in a simple English sentence. Responses were automatically audio-recorded. Clicking the "Stop" button ended the trial and triggered the presentation of the next one.

We created a total of 32 prime-target items using sixteen actions (The complete list of items can be found in OSF: https://osf.io/a8kd4/). Visual stimuli were taken from Garcia et al. (2023). Each action was depicted by four animal pairs: two depictions were used for primes and the other two for targets. Sixteen different animals were used as agents and patients. Eight animals appeared only in primes, and the other eight only in targets, ensuring no overlap in the noun phrases between the prime and target. All animals occurred equally often as agent and patient.

The 32 items were distributed across eight Latin square lists to counterbalance prime order, prime language, and the direction of action depicted in the picture (levels: left to right, or right to left) so that each participant saw all conditions an equal number of times, and each item only once. The action depicted in the pictures had the same direction for each prime-target pair.

There were 64 filler items, which had a prime-target structure similar to the experimental items. Filler images were taken from Garcia et al. (2023). Fillers comprised pictures of simple objects (e.g. dirty towel), an animal performing an action on an inanimate entity (e.g. lion eating a lime), two animals next to each other (e.g. cow next to a pig). For the sentence picture matching task, 25% of filler prime sentences matched the filler prime picture, and 75% were mismatching. Therefore, 50% of all trials (experimental trials and fillers) showed a matching sentence-picture pair, while 50% showed a mismatching pair. Identically to the experimental items, half of the filler prime sentences were presented in English, and the other half in Tagalog. Also, all the filler target prompts were in English but involved adjectives like "dirty" (instead of infinitives).

Procedure

Data were collected using an unsupervised web-based experiment via the platform Gorilla (Anwyl-Irvine et al., 2020).[7] The experiment was accessible online via laptops / desktop computers, tablets, and smartphones, through a link that we shared via social media. Participants were instructed to perform the tasks in a quiet environment.

Prior to the start of the experiment, participants' microphones were tested using Gorilla's built-in microphone check. Participants who did not have a working microphone were automatically excluded. Those with a functional microphone were asked to read aloud a short Tagalog passage (the first half of the revised *Halo-Halo Espesyal*, Ligot et al., 2004). The passage recording was used to screen and exclude non-native Tagalog speakers, as judged by a native speaker of Tagalog (one of the co-authors).

The reading aloud task was followed by LexTALE (Lemhöfer & Broersma, 2012) using a Gorilla version created by Declerck and Kirk (2023). LexTALE is an unspeeded visual lexical decision task (60 trials), which provides a standardised measure of vocabulary that acts as a relatively sensitive index of English proficiency (Lemhöfer & Broersma, 2012). In this task, check and cross buttons were presented below each word/ pseudoword. Participants had to click the check button to indicate that the presented item is a real word in English, and the cross to indicate that it is not.

After the LexTALE, participants were randomly assigned by Gorilla to one of the eight Latin square lists for the priming task. Instructions for the priming task (in English) were displayed, followed by a short video clip demonstrating two practice trials. Participants then completed four practice trials that were similar to the filler materials. Before proceeding, participants were informed that there would be breaks after around every five minutes (after each block). Trials were divided into four blocks: each block contained eight experimental trials (in different prime order and prime language conditions) and 16 fillers, with no repetition of an action in the experimental trials. Order of blocks was randomised. Order within blocks was pseudorandomised: each block started with a filler and no experimental trials were presented consecutively. An experimental session took approximately 35 min.

Data processing and analysis

Audio-recordings of the picture descriptions in the priming task were coded by a native Tagalog speaker (a co-author), who was blind to the structure and language of the corresponding prime sentence. Each response was categorised as active, passive or NAs. NA responses included trials with no audio recording, the use of a different structure ("The dog is laughing because it's being tickled by the monkey"), and single-argument responses ("shoot the chicken"). All included productions were full passive sentences (i.e. not truncated passives). Responses marked as NAs (0.53%) were excluded from the analysis, as well as trials where there was an incorrect sentence picture matching accuracy (6.39%), indicating that the prime sentence might not have been processed correctly.

Data were analysed using Bayesian mixed-effects models (Gelman et al., 2014; McElreath, 2016). We used the Bernoulli link function for binomial target sentence data (passive = 1, active = 0). Model predictors were the main effects of prime order (agent-initial, patient-initial) and prime language (English, Tagalog), and their interaction. Sum contrasts were used for all predictors. We fitted a maximal random effects model (Barr et al., 2013; Bates et al., 2015) which included random intercepts for participants and items, along with by-participant and by-item slopes for main effects and interaction.

From the posterior, we obtained Bayes Factors (henceforth, BF) for each predictor as the basis of our statistical inference. BFs were calculated using the Savage-Dickey method (see for example, Dickey & Lientz, 1970; Wagenmakers et al., 2010). We calculated the evidence for the alternative hypothesis over the null hypothesis given the data. As a general guideline, a Bayes Factor (BF) greater than 3 indicates support for a statistically meaningful effect; a BF greater than 10 indicates strong evidence (see Baguley, 2012; Jeffreys, 1961; Lee & Wagenmakers, 2014). We also report the most probable posterior parameter value (the population mean) and the interval around this parameter value that contains 95% of the posterior probability mass; 95% probability intervals (henceforth, PI) (Kruschke et al., 2012). For all predictors, we used weakly informative priors (see McElreath, 2016). The R (R Core Team, 2020) package brms (Bürkner, 2017, 2018) was used to model the data using the probabilistic programming language Stan (Carpenter et al., 2016; Hoffman & Gelman, 2014). Models were run with 10,000 iterations on 3 chains with a warm-up of 5,000 iterations and no thinning. Model convergence was confirmed by the Rubin-Gelman statistic ($\hat{R} = 1$) (Gelman & Rubin, 1992) and inspection of the Markov chain Monte Carlo chains. The data and scripts can be found on OSF: https://osf.io/a8kd4/

Results

Bayesian logistic mixed-effects model showed evidence for a prime order by prime language interaction (est. =

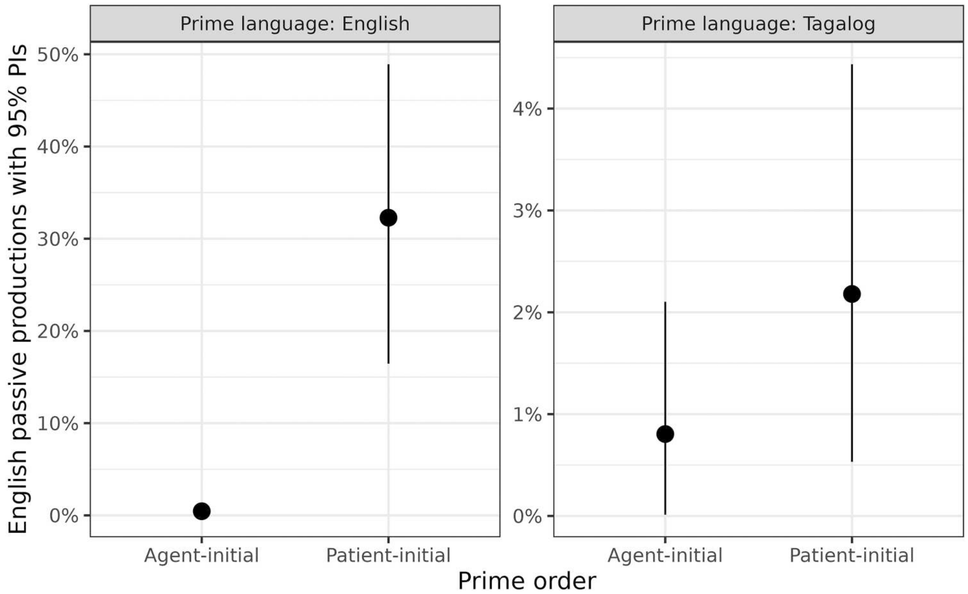

Figure 2. Inferred population means with 95% probability intervals (PIs) in Experiment 1. The y-axes had to be adjusted by prime language to make the priming effect for Tagalog-English condition visible.

−4.26, PI: −6.45, −2.19, BF > 100), and for a main effect of prime order (est. = −6.21, PI: −8.62, −4.27, BF > 100). However, the evidence for a main effect of prime language was weak (est. = 1.90, PI: 0.02, 3.80, BF = 2.55). The estimated population means are shown in Figure 2. For English primes, there was an increase in the frequency of passive productions following a patient-initial prime (i.e. passive) vs. an agent-initial prime (i.e. active) (est. = 4.70, PI: 3.43, 6.08, BF > 100). This priming effect was substantially smaller and statistically negligible for Tagalog primes (est. = 1.08, PI: −0.40, 3.02, BF = 1.91).

Discussion

Experiment 1 examined whether there is evidence for cross-linguistic priming in bilingual speakers of Tagalog and English, two genetically-unrelated languages. In particular, we tested if participants produced more passive voice structures in English following a patient-initial sentence. We found evidence for a priming effect following English primes, establishing that our sample is sensitive to structural priming in their second language. However, priming effects in English for Tagalog primes were substantially reduced and statistically negligible.

There are two possible explanations for this result for cross-linguistic priming: First, it is possible that genetically-unrelated languages do not prime. Second, cross-linguistic priming effects might have been substantially smaller than reported in previous work because of differences in constituent order (English: subject-initial, Tagalog: verb-initial) and in the thematic role of the most privileged argument (English passives: patient is the subject, subject-before-object order; Tagalog agent voice patient-initial: agent is the subject, object-before-subject order). We addressed both concerns in Experiment 2. We once again used Tagalog in a cross-linguistic priming context. Importantly though, we used Tagalog patient voice primes to test if cross-linguistic priming effects increase when, aside from thematic role order, the prime and target also overlap in syntactic–thematic role mapping. In the patient voice, the patient is the subject, similar to an English passive. Additionally, like English, patient voice patient-initial sentences have a subject-before-object order.

Experiment 2: Tagalog patient voice

In this pre-registered experiment (OSF: https://osf.io/9zm5v), we tested the extent to which Tagalog patient voice patient-initial sentences could prime English passives, given their shared thematic role order and syntactic–thematic role mapping, but differing constituent order. English primes were also included to test for within-language priming.

Method

Participants

We tested a total of 151 Tagalog speakers from the Greater Manila area. They reported no past nor present diagnosis of a psychological / neurological illness or speech-language impairment. Participant exclusion followed Experiment 1: participants who contributed less than 19 trials (i.e. 60% of 32 trials; $n = 14$), did not follow the instructions ($n = 4$), had completed the experiment previously ($n = 23$),[8] did not satisfy the inclusion criteria ($n = 7$), scored lower than 70% in the LexTALE ($n = 35$), or used an infinitive form of the English verb prompt (e.g. "trying to tickle") in more than 50% of all valid trials ($n = 11$). Excluded participants were replaced so that the final sample included a minimum of six participants per experimental list. We analysed the data of a final sample of 57 participants (mean age = 24.3, SD = 5.5, age range = 18–35, females: 32), comprising 54% college students or those who started but did not finish college, 39% college graduates, and 7% high school graduates. The final sample had a mean LexTALE score of 87% (SD = 9.3). Participants received an electronic voucher to a local convenience store worth P250 (approximately €4).

Design, materials, procedure, data processing and analysis

Experiment 2's design, materials, procedure, data processing and analysis methods were the same as in Experiment 1. The only difference was that the verb of the Tagalog prime sentences was in the patient voice instead of the agent voice. This change resulted in the patient role being the syntactic subject, whereas in Experiment 1, the patient role was the syntactic object.

As in Experiment 1, responses marked as NAs (2.03%) were excluded from the analysis, as well as trials where there was an incorrect sentence picture matching accuracy (10.53%).

Results

We found evidence for a prime order by prime language interaction (est. = −2.42, PI: −3.84, −1.15, BF > 100). We also found main effects of prime order (est. = −4.79, PI: −6.53, −3.18, BF > 100) and prime language (est. = 1.90, PI: 0.40, 3.51, BF = 5.46). The estimated population means are shown in Figure 3. We found evidence for a within-language priming effect for English primes (est. = 3.37, PI: 2.46, 4.36, BF > 100). Again, the priming effect for Tagalog primes was substantially smaller but, in contrast to Experiment 1, the evidence for such a cross-language priming effect was stronger (est. = 1.62, PI: 0.22, 3.35, BF = 9.82).

Discussion

The results showed that Tagalog patient-initial sentences primed the production of English passives. We found evidence for a cross-linguistic priming effect when prime-target combinations overlapped in thematic role order and syntactic–thematic role mapping, even without an overlap in constituent order (i.e. VSO vs. SVO).

Consistent with the predictions of the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024), the cross-linguistic priming effect for English passives was stronger in Experiment 2 (6.3% more passive sentences following a patient-initial Tagalog prime in patient voice) than in Experiment 1 (2.3% more passives following a patient-initial Tagalog prime in agent voice). Indeed, a combined analysis of data from Experiments

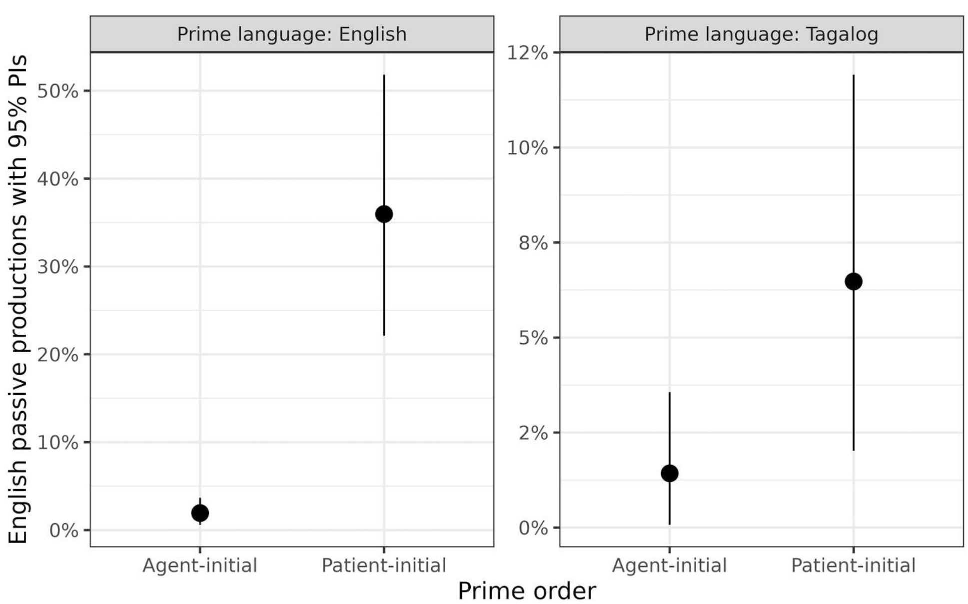

Figure 3. Inferred population means with 95% probability intervals (PIs) in Experiment 2. The y-axes had to be adjusted by prime language to make the priming effect in the Tagalog-English condition visible.

Table 3. Posterior cell means of percentage of passive sentences and priming effect, based on the pooled analysis of the data from the three experiments. The 95% probability intervals are shown in brackets.

Exp.	Prime language	Agent-initial	Patient-initial	Priming effect
1	Tagalog	0.9 [0.2, 2.2]	3.2 [1.5, 5.7]	2.3 [0.5, 4.6]
2	Tagalog	1.5 [0.4, 3.3]	7.8 [4, 12.9]	6.3 [2.6, 11.2]
3	Indonesian	4.3 [1.7, 8.1]	43 [29.4, 56.8]	38.7 [26.1, 51.3]
1	English	0.6 [0.2, 1.3]	33.7 [21.1, 48]	33 [20.6, 47.2]
2	English	1.6 [0.7, 3]	32.9 [20.4, 47]	31.3 [19.1, 45]
3	English	4.7 [2.4, 7.9]	70.1 [55.2, 82.4]	65.5 [51.6, 76.7]

1 and 2 (see Table 3 for the estimated priming effects, and the Appendix for the model results) showed evidence for an interaction of prime language, prime order, and voice (Experiment 1: agent voice, Experiment 2: patient voice; est. = −2.53, PI: −4.54, −0.68, BF = 12.56). These results show that cross-linguistic priming is stronger when both thematic role order and the syntactic–thematic role mapping are consistent between prime and target, which echoes previous findings for Tagalog in monolingual priming contexts (Garcia et al., 2023).

However, the cross-linguistic priming effect remained small. In order to test if cross-linguistic priming between genetically-unrelated languages is generally weak or subject to syntactic differences between Tagalog and English (in particular, verb location), Experiment 3 tested cross-linguistic priming between English and Indonesian, a language that is genetically-unrelated to English but closely related to Tagalog. Importantly, Indonesian allowed us to keep prime sentences structurally close to Experiment 2 (i.e. matched in thematic role order, syntactic–thematic role mapping) but with a verb-medial constituent order. In other words, we tested the extent to which the lack of overlap in constituent order was responsible for the weak Tagalog-English priming effects.

Experiment 3: Indonesian

In this pre-registered experiment (OSF: https://osf.io/ujrqe), we tested cross-linguistic priming between Indonesian and English passive sentences. Although Indonesian and English are genetically-unrelated languages, there is a substantial overlap in their passive structures, in particular, in thematic role order, syntactic–thematic role mapping, and constituent order. Also in both languages, the agent role is optional in passives. The Indonesian passive primes included the optional by-phrase *oleh* which precedes the agent, in order to make the structure more similar to English passives. Indonesian passives with or without *oleh* are considered as the same constructions (Cole et al., 2008). As in Experiments 1 and 2, we also tested within-L2 priming using English primes.

Method

Participants

We tested a total of 145 Indonesian speakers from the Jakarta Metropolitan area. They reported not having any past nor present diagnosis of a psychological / neurological illness nor speech-language impairment. Similar to Experiments 1 and 2, we excluded participants who did not follow the instructions (e.g. produced Indonesian sentences instead of English, produced only the verb prompts, $n = 21$), contributed less than 19 trials (i.e. 60% of 32 trials; $n = 19$), had completed the experiment previously ($n = 17$), scored lower than 70% in the LexTALE ($n = 25$), or used an infinitive form of the English verb prompt (e.g. "trying to tickle") in 50% or more of all valid trials ($n = 11$). Excluded participants were replaced so that the final sample included a minimum of six participants per experimental list. We analysed the data of a final sample of 52 participants (mean age = 23.5, SD = 4.1, age range = 18–33, females: 28), and their mean LexTALE score was 82.7% (SD = 10). The final sample included 60% college graduates and 40% high school graduates. Participants received an electronic voucher to a local convenience store worth IDR 75,000 (~€4).

Design, materials, procedure, data processing and analysis

The design, materials, procedure, data processing and analysis were the same as in Experiments 1 and 2. However, the non-English primes were in Indonesian instead of Tagalog. Additionally, since the English verbs *catch* and *capture* correspond to the same Indonesian word, *capture* was replaced by the verb *kiss*. Additionally, the visual stimuli for *capture* were used for the *catch* trials because data from Experiments 1 and 2 indicated that participants hesitated to use "is capturing" in their descriptions. Four new pictures for the verb *kiss* were created by the same professional artist who had produced the rest of the stimuli. There were also three trials in the practice video (compared to two trials in Experiments 1 and 2) to provide more opportunities for learning the task and preventing the use of the target prompt as an infinitive.

For the reading aloud task, participants read a short passage adapted from the Indonesian fable *The Mouse Deer Challenges the Snail*. The passage recording was used to screen and exclude non-native Indonesian

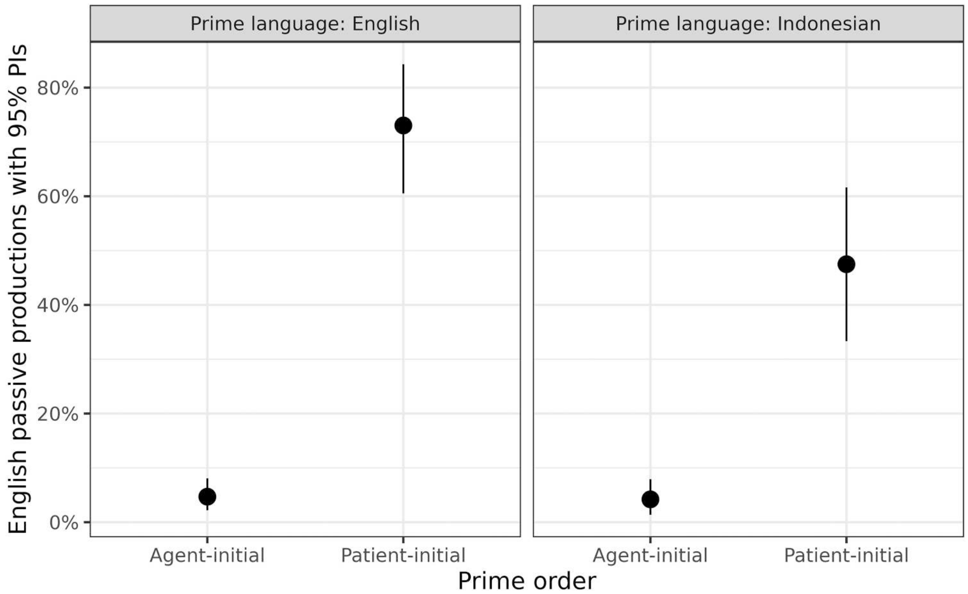

Figure 4. Inferred population means with 95% probability intervals (PIs) in Experiment 3.

speakers, as judged by a native Indonesian speaker (one of the co-authors).

As in Experiment 1, responses marked as NAs (1.50%) were excluded from the analysis, as well as trials where there was an incorrect sentence picture matching accuracy (2.29%).

Results

We found evidence for a prime order by prime language interaction (est. = −1.19, PI: −1.98, −0.39, BF = 8.60). There was also a main effect of prime order (est. = −6.94, PI: −8.10, −5.89, BF > 100) and prime language (est. = 1.00, PI: 0.24, 1.78, BF = 3.98). The estimated population means and PIs for all conditions are shown in Figure 4. We found priming effects for English (est. = 4.02, PI: 3.46, 4.61, BF > 100), showing substantially more passive productions after patient-initial (i.e. passive) primes compared to agent-initial (active) primes. This priming effect was weaker but nonetheless substantial for patient-initial Indonesian primes (est. = 3.05, PI: 2.35, 3.87, BF > 100).

Discussion

Experiment 3 showed strong cross-linguistic priming effects between Indonesian and English even though the languages are not genetically related, in line with the simulations of the Bilingual Dual-path model on Indonesian–Dutch passive priming (Khoe & Frank, 2024). More importantly, cross-linguistic priming was substantially stronger in Indonesian compared to Tagalog. The pooled analysis of data from Experiments 1–3 (see Table 3 and the Appendix) showed that Indonesian passive primes resulted in 38.7% more English passives. Cross-linguistic priming from Tagalog to English, in contrast, was on average only 2.3% (Experiment 1) and 6.3% (Experiment 2). This demonstrates that constituent order overlap between prime and target drastically increases the cross-linguistic priming effect, consistent with the predictions of the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024). Aside from an overlap in constituent order, Indonesian and English passives both feature an optional agent, a similarity that we explore further in the General Discussion.

General discussion

Across three experiments, we investigated the extent to which cross-linguistic priming in genetically-unrelated languages is sensitive to linguistic properties, in particular (1) thematic role order, (2) syntactic–thematic role mapping, and (3) constituent order. We demonstrated – for two understudied, multilingual Austronesian language communities – that cross-linguistic priming can be found in genetically-unrelated languages and that its magnitude is modulated by the degree of overlap between the prime and target.

In particular, we found evidence for cross-linguistic priming for English passive sentences in both Tagalog and Indonesian. For Tagalog, priming effects were observed even though the tested sentence structures did not share the same constituent order (Tagalog is verb-initial and English has an SVO order). However, cross-linguistic passive-priming effects were small when prime and target languages overlapped only in thematic role order (Experiment 1: agent voice) yet stronger when prime and target languages shared not only thematic role order but also the syntactic–thematic role mapping (Experiment 2: patient voice), in which case prime and target had patient subjects and a subject-before-object order. In contrast, cross-linguistic priming was substantially stronger in Indonesian (Experiment 3) compared to Tagalog. Indonesian passives are similar to English passives, not only in terms of thematic role order and syntactic–thematic role mapping (as in Experiment 2), but also, importantly, in constituent order (i.e. SVO).

The results are inconsistent with the predictions of Reitter et al.'s (2011) hybrid model of priming, which does not predict priming of passive sentences when the constituent orders of the prime and target language differ. In contrast, the results are consistent with the predictions of the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024), which predicts attenuated cross-linguistic priming in the absence of overlap in constituent order between two languages but greater priming effects in cases of constituent order overlap. Our results are also in line with previous findings of cross-linguistic priming in absence of overlap in constituent order (Bernolet et al., 2009; Chen et al., 2013; Fleischer et al., 2012; Hwang & Shin, 2019; Kutasi et al., 2018; Rodrigo et al., 2020) and the predictions of modelling results showing stronger priming for more similar language pairs (Arnett et al., 2025). The current results extend this line of research, for the first time, to priming between Austronesian and Indo-European languages, confirming the predictions of the Bilingual Dual-path model (Khoe & Frank, 2024).

Contributions of different structural features in cross-linguistic priming

The current findings demonstrate that priming in cross-linguistic contexts (and to some extent in L2 contexts) is sensitive to the linguistic features of the prime and target language. We found that an overlap solely in thematic role order did not lead to strong cross-linguistic priming. However, when there was an additional overlap in the mapping of syntactic roles to thematic roles (which also resulted in the same subject-before-object order), more substantial priming was observed. Cross-linguistic priming of passive sentences substantially benefited from when the prime language shared the same constituent order (i.e. verb position) as the target language.

Cross-linguistic priming between languages with similar constituent order is predicted by different theories (Hartsuiker et al., 2004; Khoe et al., 2023; Reitter et al., 2011). However, not all these models – e.g. Reitter et al.'s (2011) hybrid model of priming, as discussed above – can explain priming effects for different constituent structures like we observed for priming of English passives in response to Tagalog primes. The Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024) explains these differences by assuming a syntactic representation that is separate from the surface constituent order. Therefore, two languages that have different constituent order can share deep structural similarities which are activated in response to a different-language prime (e.g. Hartsuiker et al., 2004). An additional overlap in constituent order amplifies priming on the level of abstract representations as the result of additive priming on two different levels of representation. This is similar to classical models of language production that distinguish between conceptual and grammatical levels of language planning (e.g. Bock & Levelt, 1994).

The weaker cross-linguistic priming effect – when there is only a thematic role order overlap between prime and target – resembles findings from within-language priming in Tagalog. Garcia et al. (2023) found that production of patient-initial utterances was only primed when both the prime and target had the same voice or syntactic–thematic role mapping. It is possible that in Garcia et al. and in the current study, priming was weak when there was no overlap in syntactic–thematic role mapping because the sentences could prime contrasting structures. Patient-initial structures in Tagalog agent voice (Experiment 1) can prime the production of a patient-initial order (e.g. English passive) but also of an agent as the subject (e.g. English active voice). This competition can substantially weaken priming effects in passive productions. However, it is unlikely that thematic role order and syntactic–thematic role mapping are equal in priming strength and just cancel each other out. This is because Garcia et al. (2023) found different patterns of response variation in both of their across-voice priming conditions, which is not expected if two distinct response strategies were used. Instead, it is more likely that thematic role order, as opposed to syntactic role order, has a weaker influence on structural priming, as has been shown previously (Chang et al., 2003).

The finding that within-Tagalog priming only occurs when the voice of the prime and target overlap can be explained by Chang et al.'s (2006) Dual-path model. According to this model, syntactic knowledge is initially acquired in a lexicalised, non-decomposed manner (see

Chang, 2009; Chang et al., 2015). Garcia et al. (2023) explained that this acquisition process leads to separate structural representations for each voice, resulting in voice-specific priming in Tagalog. The current finding shows that the constraints on priming in L1 are also observed in cross-linguistic priming to an L2, which has implications on the mental representation of bilinguals' two languages. As the Dual-path (Chang et al., 2003) and Bilingual Dual-path models (Khoe et al., 2023; Khoe & Frank, 2024; Tsoukala et al., 2017) assume that syntax is represented at an abstract level separately from surface linear order (and constituent order), they allow priming and cross-linguistic priming to occur even when constituent order differs between prime and target. Exposure to a syntactic structure in one language adjusts the activation in shared syntactic representations, making similar structures more accessible in the other language. It may indicate that for highly proficient Tagalog-English bilinguals, structural representations of Tagalog patient voice, compared to agent voice, have a stronger link to English passives (similar syntactic–thematic role mapping).

Alternative explanations for the strength of priming effects

We interpreted the different sizes of the cross-linguistic priming effects that we report in this paper on the basis of linguistic features of the prime and their similarity to the target English passive structure. We discuss six factors that might contribute to the size of the cross-linguistic priming effects we reported.

First, the differences in cross-linguistic priming effects cannot be explained on the basis of the genetic relationship between the different prime-target language pairs (i.e. Tagalog-English versus Indonesian-English). Our choice of languages accounts for this: Tagalog and Indonesian are both Western Malayo-Polynesian languages and are thus genetically related. Crucially, they are not related to English, and yet their cross-linguistic priming effects for English passives are very different. The cross-linguistic priming effects for English passive in response to Tagalog primes were 2.3% and 6.3%, with a stronger effect for a syntactic–thematic role mapping akin to English. In comparison, for Indonesian we found a 38.7% increase in passive productions. In fact, genetic relatedness seems to be unrelated to the magnitude of the priming effect across comparable past studies. For example, Chen et al. (2013) reported a 6% increase in English passive production following a Mandarin patient-initial sentence. This priming effect is comparable to work on Scottish Gaelic-English passive priming (7%, Kutasi et al., 2018), even though Scottish Gaelic and English are Indo-European languages and thus related. In contrast, higher priming effects have been found for passive priming in other Indo-European language pairs (Polish-English 21%, Fleischer et al., 2012; Dutch-English 34%, Bernolet et al., 2009). Thus, genetic relatedness is not a barrier to priming and seems unrelated to the size of crosslinguistic priming effects.

Second, the weak cross-linguistic priming effects we reported for Tagalog might be due to low L2 English proficiency. This is because shared language representations in bilinguals are only assumed for high proficiency levels (Hartsuiker & Bernolet, 2017). Previous studies have also shown stronger cross-linguistic priming effects for more proficient L2 speakers compared to less proficient speakers (Bernolet et al., 2013). However, we do not believe that proficiency is a likely explanation for the results from Tagalog-English priming (Experiments 1, 2). This is because our participants showed strong English competence: The within-English (L2) priming effects that we observed are comparable to priming in L1 (Bock, 1986). Additionally, we only analysed the data from participants with high LexTALE scores (indicating native or native-like English proficiency) that were similar to those of the Indonesian-speaking participants (who showed substantial cross-linguistic priming effects). Therefore, the differences in cross-linguistic priming effects are unlikely to be explained by a low proficiency in English.

Third, our studies primed translational equivalent verbs, and thus it is possible that the findings are wholly contingent on conceptual overlap between the prime and target pictures. Stronger structural priming when the verb is re-used in the target sentence, compared to when it is not, is well established in the literature (i.e. "lexical boost", Pickering & Branigan, 1998; for meta-analytic evidence, see Mahowald et al., 2016). Additionally, translational-equivalent verbs have been shown to result in stronger cross-linguistic priming effects (Schoonbaert et al., 2007). Our use of conceptual overlap was important because previous findings from Tagalog showed that structural priming effects are weak when there is a structural mismatch between the prime and target (i.e. when there is a voice difference) even when the verb is repeated (Garcia et al., 2023). Future work should focus on investigating abstract cross-linguistic priming from Tagalog / Indonesian to English. Without the use of translational equivalents, we predict that there will be a reduction of priming effects across all experiments (and therefore for both Tagalog and Indonesian), but importantly, the pattern of results will not change but the magnitude will just be lower. It remains to be seen whether the weaker cross-linguistic effects in Tagalog will still be observed when there is no semantic overlap between the prime and target.

Fourth, the stronger cross-linguistic priming effect for Indonesian – compared to previous cross-linguistic priming research – might also be related to the particular experimental context. In our three experiments, within-English and cross-language prime pairs were mixed and presented in randomised (rather than blocked) order. The need to frequently switch between the two languages might have made both languages highly accessible and active, resulting in an increase in cross-linguistic priming effects compared to when trials are blocked by language (Ahn & Ferreira, 2024). Even though cross-linguistic priming is therefore more likely in a mixed presentation, effects for Tagalog were weak. This difference suggests that overlap in constituent structure is the main contributor to the cross-linguistic priming effect.

Fifth, the difference between cross-linguistic priming effects in Tagalog and Indonesian might be due to the frequency distribution of structures in either language. Indonesian has a particularly high frequency of passives (Gil, 2006; Sneddon, 1996). Given the common use of passives among Indonesian speakers, their accessibility might make the use of English passives more likely. However, also in Tagalog, transitive sentences are frequently patient voice-marked (and thus, the patient is the subject; Garcia & Kidd, 2022). In contrast though, Tagalog patient voice sentences tend to have an agent-initial order, while Indonesian passive sentences are always patient-initial. Therefore, an alternative explanation to our results might be an overall tendency for Tagalog-speaking participants to avoid patient-initial sentences. While possible, this is not an obvious explanation for two reasons: (1) Tagalog-speakers equally produce both agent-initial and patient-initial sentences in the agent voice (Garcia et al., 2018); (2) it is well established in the L1 structural priming literature that it is the dispreferred (infrequent) structures – such as passives in e.g. Dutch (Konopka & Meyer, 2014) – that prime, and not frequent structures such as actives (see Ferreira & Bock, 2006). Therefore, in both Indonesian and Tagalog, we would expect weaker or no priming effects if frequency would be the main explanation for the differences in cross-linguistic priming effects. This result – similar to effects from L1 priming in Tagalog priming (Garcia et al., 2023) – contrasts what we know from L1 priming in Indo-European languages. Therefore, the role of frequency in priming of understudied languages warrants more research.

Sixth, the similarity in how the agent is encoded in passives in Indonesian and English might increase cross-linguistic priming. Beyond the verb-medial constituent order, both Indonesian and English passives include an optional *by*-phrase, resulting in a surface overlap. A comparison of the priming effect when the "oleh" is dropped in Indonesian primes awaits further research. Another potential reason for the stronger cross-linguistic priming from Indonesian compared to Tagalog is the similarity between Indonesian and English passives, both of which allow for an optional agent. In contrast, in Tagalog patient voice sentences, the agent is neither optional nor is it indicated by a preposition. Future studies can test the Indonesian Type 2/bare passives. These bare passives are similar to Tagalog, in that the agent is not demoted to an oblique. However, such a comparison is not straightforward because Indonesian bare passives have an SOV order, resulting also in a lack of constituent order overlap with English passives.

Nature of shared representations

A final open issue concerns the nature of shared representations between languages. Notably, there is debate as to whether syntactic representations are in fact integrated or separate-but-linked (see Ahn & Ferreira, 2024; although see Nielsen & Christiansen, 2025 for an explanation of structural priming which does not assume that syntax is mentally represented). Teasing apart this subtle distinction on the basis of behavioural data is no easy task, but our data provide some potential clues. The weaker results in Tagalog-English bilinguals minimally suggest linked structural representations derived from a common representational vocabulary for mapping between thematic and core syntactic roles. Such linked representations have been proposed for passives in Turkish-Dutch bilinguals given that the structures might differ too much to be shared (Van Lieburg et al., 2023). In contrast, our much stronger result for Indonesian is indicative of much greater and likely shared structural knowledge. This may explain the greater within-language priming in English in Experiment 3, since a common structural representation for Indonesian and English passives may have led to greater cumulative priming from Indonesian to English-English prime-target pairs. Since our participants were all L2 speakers of English, such an effect may have derived from Indonesian speakers using their knowledge of the Indonesian passive to bootstrap their learning of the English passive. For instance, its acquisition may have been parasitic on existing knowledge of the frequent Indonesian form because of the close alignment between the two. This is consistent with studies that have observed cross-linguistic influence from L1-to-L2, where thematic role mappings from the L1 persist based on structural cues derived from constituent word order (e.g. Kidd et al., 2015; Nitschke et al., 2010, 2014).

Conclusion

The present research shows, for the first time, that cross-linguistic priming occurs between genetically-unrelated languages with different voice systems, and, to some extent, even in the absence of overlap in constituent order. As predicted by the Bilingual Dual-path model (Khoe et al., 2023; Khoe & Frank, 2024), we demonstrated that cross-linguistic priming effects were modulated by the grammatical features of the prime sentence and the grammatical constraints of the target language. In particular, we found that both a shared constituent order and a shared mapping between syntactic and thematic roles increased the cross-linguistic priming effects over and above the order of thematic roles.

Our investigation on under-researched populations highlights how expanding our psycholinguistic evidence to a wider set of languages with grammatically different properties is fundamentally important for developing and testing the validity of language processing models. Our focus on understudied languages enabled us to uncover to what extent different sources of structural overlap contribute to cross-linguistic priming. Because of grammatical limitations, such an investigation would not have been possible in well-researched populations.

Notes

1. AV refers to agent voice, PV to patient voice, SBJ to subject, NSBJ to non-subject, and IPFV to imperfective.
2. *N* refers to a nasal phoneme that varies depending on the initial consonant of the verb's base form.
3. Indonesian also has another structure type where the patient is the subject (described in the literature as *Type 2 passive, bare passive, object voice,* or *bare undergoer voice*) similar to Tagalog patient voice. In this voice, the agent remains as a core argument and is placed before an unmarked verb (SOV) without the preposition *oleh* (Cole et al., 2008).
4. The experiment was unsupervised, so participants could not be corrected if they were not following the instructions.
5. The minimum 70% lexTALE criterion was based on Lemhöfer and Broersma (2012) who showed that Dutch and Korean advanced learners of English scored an average of 70.7.
6. We excluded participants who produced a larger number of infinitive constructions because infinitive constructions cannot be expressed in passive voice. Therefore, the systematic use of infinitives could impact the priming results.
7. We have made the experiment available at Gorilla's Open Materials website: https://app.gorilla.sc/openmaterials/992815.
8. As the experiment was unsupervised, participants could, in principle, attempt completion more than once. Experiment sessions of participants who had completed the same experiment previously were manually excluded during data cleaning, and we only included data from their first completion.

Acknowledgements

We would like to thank all the participants and those who helped with participant recruitment. We also thank Andreas Pregla, I Wayan Arka, Bernard Jap, Francisco Rosario, Jr. and Victoria Chen for helpful discussions. Lastly, we are grateful to the audience of the 31st Meeting of Austronesian Formal Linguistics Association (AFLA) and the 15th International Symposium on Bilingualism (ISB) for their insightful feedback.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The research was partially supported by the Australian Research Council (CE140100041: CI Kidd), and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project ID 317633480 – SFB 1287 (Project C07). JR was supported by UKRI ESRC [grant number: ES/W011832/1].

Data availability statement

The experimental data and R scripts are available in an open access repository: https://osf.io/a8kd4/.

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