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The interplay of animacy and thematic role in structural persistence

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ABSTRACT

Models of human sentence production often propose a clear distinction between syntactic and semantic processes. We examined this assumption by investigating the interaction between animacy and thematic roles in active–passive structural priming. Study 1 found that the active or passive structure of a preceding sentence (*prime*) influenced structural choice in a subsequent sentence (*target*). This priming effect increased when the prime and target sentences shared the same animacy features in their thematic roles, which affected the persistence of the prime subject's animacy. While verb repetition enhanced active–passive priming, the persistence of the prime subject's animacy was not affected by lexical repetition. Studies 2 and 3 demonstrated that repeated animacy features in the thematic roles increase the likelihood of preserving both the thematic role order of the prime (e.g., maintaining the agent-first order in *It was the thief that chased the lorry*) and its argument structure (e.g., assigning the agent as the subject) in English cleft constructions. In Japanese declarative sentences, where particles indicate the sentential topic, the repeated animacy features strengthened argument structure persistence but not the persistence of thematic role order. These findings suggest that thematic role animacy repetition boosts structural priming by reinforcing thematic emphasis.

Introduction

A central focus in cognitive science is understanding how humans construct sentences to convey meaning. One key area of investigation examines how speakers choose different word orders to express the same event. For example, in transitive events—where an agent (actor) acts upon a patient (undergoer)—sentences can take an active form, with the agent preceding the patient (e.g., *The hiker carried the canoe*), or a passive form, with the patient preceding the agent (e.g., *The canoe was carried by the hiker*). This flexibility in word order allows researchers to distinguish between *structure building* (sentence organization) and *message encoding* (content selection). However, it also makes it possible to examine the interactions between these processes.

One way to explore this relationship is by examining *animacy*, the distinction between living and non-living entities. Studies have shown that animacy affects content selection: Animate entities are more likely to be mentioned (Givón, 1983) and chosen as the sentence topic (Clark & Begun, 1971; Dahl & Fraurud, 1996; Itagaki & Prideaux, 1985) than inanimate entities. For example, Fukumura and Van Gompel (2011) found that after sentences like *The hikers carried the canoes* …or *The canoes carried the hikers…,* speakers were more likely to continue referring to the animate entity (hikers) than the inanimate one (canoes) (e.g., *The hikers/they were tired*). This tendency may reflect several cognitive biases, such as speakers' preference to narrate events from an animate perspective (Dahl & Fraurud, 1996; Ehrlich, 1990; Kuno & Kaburaki, 1977), their inclination to attribute event causality to animates rather than inanimates (Corrigan, 1988), or their natural empathy toward animate entities (e.g., Kuno & Kaburaki, 1977; Langacker, 1991).

Animacy also affects structural choice, influencing the assignment of syntactic subject (e.g., Christianson & F. Ferreira, 2005; F. Ferreira, 1994; Gennari & MacDonald, 2009; McDonald et al., 1993; Prat-Sala & Branigan, 2000; Tanaka et al., 2011). McDonald et al. (1993) found that English passive sentences with animate subjects (e.g., *The child was soothed by the music*) are more likely to be recalled in their original form, whereas those with inanimate subjects (e.g., *The refrigerator was purchased by a farmer*) often shift to active voice. Because subjects typically appear first in English sentences, this preference for animate subjects may reflect an *animate-first* bias. Indeed, animacy influences word order in freer word-order languages, including German (Kempen & Harbusch, 2004; Van Nice & Dietrich, 2003), Greek (Branigan et al., 2008), Japanese (Tanaka et al., 2011), Odawa (Christianson & F. Ferreira, 2005), and Spanish (Prat-Sala & Branigan, 2000).

While animacy is key in structural choice, *thematic roles*—the semantic relationships between participants in an event—also play a crucial role in mapping nouns onto sentence structures. Linguistic (e.g., Dowty, 1991; Fillmore, 1968; Foley & Van Valin, 1985; Givón, 2001)

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and psycholinguistic (e.g., Christianson & F. Ferreira, 2005; F. Ferreira, 1994; Prat-Sala & Branigan, 2000) evidence suggests that certain roles, such as agents, are more strongly associated with the subject function than others: Active structures, in which the agent is the subject, occur more frequently than passive structures, in which the patient is the subject.

Linguistic theory suggests that both animacy and thematic roles are structured in hierarchies (e.g., Fillmore, 1968; Givón, 2001). These hierarchies influence the assignment of syntactic functions, which are themselves organized hierarchically (e.g., Keenan & Comrie, 1977). For example, humans rank high in the animacy hierarchy, while agents rank high in the thematic role hierarchy. As a result, being human or acting as an agent typically results in the assignment of more prominent grammatical roles, such as the subject. Additionally, animacy and thematic roles influence *topicality*—the degree to which an entity is the focus of attention in a discourse—with humans, animates, and agents being more topical (e.g., Givón, 2001). This, in turn, affects subject selection and word order. Grammatical subjects often function as sentence topics (Chafe, 1976; Halliday, 1985; Reinhart, 1981) and typically appear early in sentences (e.g., Greenberg, 1966; Tomlin, 1986).

Research aims

Despite these theoretical proposals, the precise mechanisms by which animacy and thematic roles interact with structural representations remain unclear. This research aims to address this gap by examining these interactions in sentence production and exploring the cognitive architecture underlying them.

Structural priming as a window into representation

To this end, we examined *structural priming*—a phenomenon in which speakers tend to reuse recently encountered sentence structures. For instance, exposure to a passive structure increases the likelihood of producing a passive form in subsequent sentences (e.g., Bock, 1986; Bock et al., 1992). Studying how the structure of one sentence (the *prime*) influences another (the *target*) offers insights into the underlying representations and their role in sentence construction (see Mahowald et al., 2016; Pickering & Ferreira, 2008, for reviews). Intriguingly, however, standard views in the priming literature suggest that structural representations are primed independently of animacy (e.g., Bock et al., 1992; Carminati et al., 2008; Chen et al., 2020, 2022; Huang et al., 2016; Xiang et al., 2022). Bock et al. (1992) was the first to reach such a conclusion. They presented participants with sentences such as:

(1) Prime sentences
  a. *Inanimate agent/Active/Inanimate subject*
     The boat carried five people.
  b. *Inanimate agent/Passive/Animate subject*
     Five people were carried by the boat.
  c. *Animate agent/Active/Animate subject*
     Five people carried the boat.
  d. *Animate agent/Passive/Inanimate subject*
     The boat was carried by five people.

(2) Target sentences
  a. *Inanimate agent/Active/Inanimate subject*
     The alarm awakened the boy.
  b. *Inanimate agent/Passive/Animate subject*
     The boy was awakened by the alarm.

The goal was to determine how the animacy features and structures of the prime sentences (1a–1d) influenced participants' choice of target sentences (2a & 2b) when describing an image of a subsequent event. Passive primes (1b & 1d) elicited more passive responses (2b) and fewer active responses (2a) than active primes (1a & 1c) did, demonstrating an effect of structural priming. Critically, when participants were instructed to focus on the primes' meanings, primes with animate subjects (1b & 1c) elicited more passive responses with animate subjects (2b) than primes with inanimate subjects (1a & 1d) did. This effect was unaffected by whether the prime sentence had an active structure or a passive structure. Bock et al. (1992) interpreted this as evidence that animacy influences the selection of the subject in the target independently of active–passive structural priming.

An alternative interpretation of Bock et al. (1992)

However, in Bock et al. (1992), target sentences featured an inanimate agent acting on an animate patient. Some primes (1a & 1b) matched this pattern, while others (1c & 1d) featured an animate agent acting on an inanimate patient. In the former case (1a & 1b), maintaining the prime's structure preserved the subject's animacy (i.e., animacy order), whereas in the latter (1c & 1d), it reversed it. Thus, the apparent persistence of the prime subject's animacy may have resulted from stronger structural persistence when the thematic roles in the prime and target matched in animacy (1a & 1b) than when they did not (1c & 1d). Specifically, passive primes elicited more passive responses, and active primes elicited more active responses in the inanimate agent condition (1a & 1b) than in the animate agent condition (1c & 1d). This alternative hypothesis aligns with Vasilyeva and Gámez's (2015) interpretation of their study: 5–6-year-olds produced passive structures more frequently when the passive prime featured an inanimate agent and an animate patient than when these roles were reversed. This effect was significant only when the target's animacy features matched those in the prime. Though no significant prime animacy by target animacy interaction was found, the findings have been taken to suggest that animacy feature overlap facilitates passive priming.

The two-stage model of sentence production

This alternative explanation was overlooked by Bock et al. (1992), as they adopted the two-stage grammatical encoding model (e.g., Bock & Levelt, 1994; Garrett, 1975, 1980), which has remained a standard psycholinguistic theory of sentence production. According to this model, structure building occurs in two stages: (1) *function assignment*, where grammatical functions are assigned to thematic roles, and (2) *positional processing* (*constituent assembly*), where constituents are organized linearly based solely on syntactic information. For example, in constructing a passive sentence like *The hiker was carried by the canoe*, the first stage assigns the patient role (*hiker*) to the subject and the agent role (*canoe*) to the prepositional object. The second stage then arranges these constituents linearly (e.g., placing the subject before the prepositional object) based on syntactic categories (e.g., noun, verb), grammatical functions (e.g., subject, object), and their hierarchical relations. Under this account, the animacy of the prime's subject influences function assignment in the target, while active–passive priming occurs during constituent assembly, driven by the persistence of abstract syntactic information devoid of semantic features like animacy and thematic roles. Although this assumption is counterintuitive—given that the active–passive alternation involves different function assignments (assigning the subject to the agent or patient role)—early structural priming studies supported the two-stage model, suggesting that priming operates independently of thematic roles.

Bock (1989) found that the likelihood of using a prepositional object dative (*The girl handed a paintbrush to a man*) was unaffected by whether the prime also involved a recipient (*The secretary was taking a cake to her boss*) or a beneficiary (*The secretary was baking a cake for her boss*). Similarly, Bock and Loebell (1990) reported that a prepositional object dative could be primed by locative constructions (*The wealthy widow drove the Mercedes to the church*), where the prepositional object refers to a location, not a recipient. In active–passive alternations, Bock and Loebell (1990) also found that intransitive primes like *The plane was landing by the control tower* elicited passive responses, even though *by the* *control tower* describes a location rather than an agent. Aligning with these findings, Messenger et al. (2012) showed that passive responses involving verbs with agent-patient roles (*The king is being scratched by the tiger*) were unaffected by whether the prime featured agent-patient roles (*The girl is being hit by the sheep*) or stimulus-experiencer roles (*The girl is being shocked by the sheep*).

Challenges to the two-stage model

However, Potter and Lombardi (1998) challenged Bock and Loebell's (1990) findings showing that structural priming is sensitive to thematic role overlap. They found that the rate of prepositional object structures with a dative verb and a recipient role (e.g., *The tycoon willed the mansion to his young nephew*) decreased when the prime contained a motion verb and a location role (e.g., *Lenore drove her new convertible to the beach*). In their study, the recipient role (e.g., *nephew*) was animate, whereas the location role (e.g., *beach*) was inanimate. Ziegler and Snedeker (2018) corroborated this finding, using animate nouns for both recipient and location roles in the prime (e.g., *The woman threw the ball to the bird* vs. *The woman raised the ball above the bird*). These findings suggest that structural priming interacts with the overlap in thematic roles. From this perspective, dative priming is unaffected by the distinction between beneficiary and recipient roles (Bock, 1989) since both imply possession of the theme (e.g., Pinker, 1989). Similarly, both stimulus-experiencer psych verbs (e.g., *shock*) and action verbs (e.g., *hit*) in Messenger et al. (2012) involve an agent-like role (someone causing the action, such as a person shocking or hitting someone) and a patient-like role (someone affected by the action, such as the person being shocked or hit). Hence, active–passive priming is unaffected by these verb types.

Thematic emphasis

Moreover, researchers have suggested that structural priming is influenced by persistent *thematic emphasis* (e.g., Bernolet et al., 2009; Vasilyeva & Waterfall, 2012; Vernice et al., 2012). In their cross-linguistic priming study from Dutch to English, Bernolet et al. (2009) found that patient-initial Dutch passives (e.g., *De bokser wordt achtervolgd door de non*, meaning 'The boxer is chased by the nun') elicited more patient-initial English passives (e.g., *The skier is chased by the pirate*) than agent-initial Dutch passives (e.g., *Door de non wordt de bokser achtervolgd*, meaning 'By the nun the boxer is chased') did (see Fleischer et al., 2012; Heydel & Murray, 2000 for similar findings). Furthermore, agent-initial Dutch passives elicited more patient-initial English passives than agent-initial Dutch actives did, suggesting the persistence of the prime's function assignment. All these constructions involve different constituent structures; hence, the results cannot be explained if structural priming is driven solely by abstract syntactic information. These findings were therefore interpreted as evidence of a persisting thematic emphasis on the agent or patient role, which influenced both function assignment and linear order. Supporting this, their norming data showed that the agent role was perceived as more emphasized in agent-initial active sentences than in agent-initial passive sentences, although both received higher ratings for agent emphasis than patient-initial passives.

Recent evidence for interactive priming

However, the two-stage account may be reconciled with these findings by positing that different levels of representation are primed additively rather than interactively (e.g., Bernolet et al., 2009; Ziegler & Snedeker, 2018). For example, Bernolet et al. (2009) proposed that structural priming occurs at two levels: Information structure (emphasis on thematic roles) and constituent structure, similar to how Bock et al. (1992) regarded the persistence of the prime subject's animacy feature as a phenomenon separate from constituent structure persistence. However, more recent findings suggest that different representations may interact. Fukumura and Zhang (2023) found that *conceptual order priming*, as seen in the persistence of adjective category order (Fukumura, 2018), interacts with syntactic priming. Specifically, following primes such as *green bow that's spotted*, participants were more likely to repeat the prime's syntactic structure (i.e., relative clauses) when repeating its color-before-pattern order than when using a pattern-before-color order, and vice versa.

Similar interactive priming has been observed in sentence production, showing that the persistence of function assignment (repeated thematic role-function mappings) interacts with that of *thematic role order* (repeated thematic role-position mappings). In the English *spray-load* locative alternation (e.g., *load straw onto a truck* vs. *load a truck with straw*; e.g., Chang et al., 2003), thematic role orders and argument structures underpinning function assignments co-vary in declarative sentences; a location-theme order (e.g., *load a truck with straw*) assigns the direct object to the location role (*with-argument structure*), while a theme-location order (e.g., *load straw onto a truck*) assigns it to the theme role (*locative argument structure*). Fukumura and Yang (2024) disentangled these structures using what-cleft constructions as primes, demonstrating the persistence of both thematic role order and argument structure. For instance, participants were more likely to produce a *with*-argument structure in declarative sentences (e.g., *The man loaded the van with boxes*) after encountering a *with*-argument what-cleft prime (e.g., *What the assistant packed the lift with was the equipment / What the assistant packed with the equipment was the lift*) compared to a locative what-cleft prime (e.g., *What the assistant packed into the lift was the equipment / What the assistant packed the equipment into was the lift*), demonstrating argument structure persistence. Crucially, when what-cleft targets followed what-cleft primes, the prime's argument structure persisted in the target regardless of whether its thematic role order was also repeated. However, this priming effect was stronger when participants chose the same thematic role order as in the prime rather than a different thematic role order. This suggests that argument structure priming interacts with thematic role order priming. On the other hand, abstract constituent structure (e.g., whether the verb was followed by a prepositional phrase or a noun phrase) persisted only when both argument structure and thematic roles were maintained, challenging the idea that constituent structure independently contributes to structural priming.

Summary

Growing evidence challenges the two-stage model, demonstrating that thematic roles play a critical role in structural persistence. This calls into question Bock et al.'s (1992) interpretation of the animacy effect in active–passive priming, which was based on the premise that thematic roles play no role in structural persistence; the prime subject's animacy feature directly influences function assignment in the target, independent of active–passive structural priming, with neither process affected by thematic roles. An alternative hypothesis suggests that the persistence of the prime subject's animacy feature results from interactions between animacy and thematic roles during active–passive structural priming. Study 1 tested these hypotheses by examining the impact of lexical repetition on the persistence of both the prime subject's animacy feature and its syntactic structure. Studies 2 and 3 further explored whether and how animacy interacts with the persistence of thematic role order, argument structure (function assignment), or both in English cleft and Japanese declarative constructions.

Study 1

The goal of Study 1 was to test whether the persistence of the prime subject's animacy (i.e., animacy order priming) occurs independently of active–passive priming. Research shows that the magnitude of active–passive priming increases when the prime and target share the same verb (Branigan & McLean, 2016; Hardy et al., 2017; Segaert et al., 2013). This so-called *lexical boost effect* was first demonstrated in the dative alternation by Pickering and Branigan (1998), who proposed that verb repetition increases structural persistence by enhancing (or 'boosting') the activation of the syntactic structure associated with the verb. Recent findings further suggest that this effect occurs specifically with head verb repetition but not with repetition of non-head nouns (Carminati et al., 2019; Fukumura & Yang, 2024; Huang et al., 2023; Kantola et al., 2023; Van Gompel et al., 2023).

However, Fukumura and Zhang (2023) found that conceptual order priming can be enhanced differently from syntactic priming. In their study, the likelihood of repeating the pattern-color order of the prime, such as *spotted lock that's green*, increased when either *green* or *spotted* was repeated in the target. In contrast, neither *blue* nor *striped* in the prime increased the probability of reusing its relative clause structure in the target. Relative clause priming was enhanced only by the repetition of the noun *lock*. Compared to *spotted lock that's green*, *spotted bow that's green* was more likely to prime a relative clause structure like *striped bow that's blue*. Fukumura and Zhang proposed that adjective category orders are activated based on the conceptual categories associated with each adjective. For instance, processing *spotted green lock* activates the pattern-color order based on the conceptual categories SPOTTED and GREEN. Consequently, repeating an adjective in the prime increases the likelihood of maintaining the same adjective order in the target due to the primed association between the concept and order.

Thus, we examined whether repeating the verb or noun from the prime differentially impacts the likelihood of the prime's active or passive structure persisting, as well as its animacy order. We manipulated lexical repetition across three experiments: Verb repetition (Experiment 1), animate noun repetition (Experiment 2), and inanimate noun repetition (Experiment 3). Table 1 presents example prime and target sentences. Following Bock et al. (1992), each active or passive prime featured either an animate-first order (animate subject) or an inanimate-first order (inanimate subject). This was achieved by manipulating the animacy of the thematic roles in the prime. In the inanimate-agent prime condition, the agent and patient roles were inanimate and animate, respectively. In the animate-agent prime condition, the agent was animate, and the patient was inanimate. In the target sentence, the agent was always inanimate, and the patient was animate. Thus, in the inanimate-agent prime condition, the thematic roles in the prime and target matched in animacy, whereas in the animate-agent prime condition, they did not.

If the active–passive alternation is primed, as previously demonstrated, passive primes (b & d) should lead to more passive responses than active primes (a & c), indicating a main effect of prime structure. This effect should be stronger with verb repetition: When the prime verb is repeated in the target, it should boost the activation of its associated structure, increasing the likelihood of structural persistence (e.g., Pickering & Branigan, 1998; Fukumura & Yang, 2024). According to Bock et al. (1992), the prime's animacy order (or its subject's animacy feature) should also influence structural choices in the target, with animate-first primes (a & d) leading to more animate-first responses than inanimate-first primes (b & c). They proposed that this effect occurs because animacy-function mappings in the prime directly influence how nouns assume syntactic roles in the target. A noun boost effect would support this hypothesis: Repeating either the animate or inanimate noun should reinforce the prime's animacy order in the target—similar to how adjective category order priming strengthens through lexical repetition, independently of syntactic priming. Repeated activation of a noun's concept reinforces its associated animacy order, making it more likely to persist in the target. For instance, *The hunter was chased by the car* is more likely to follow *The hunter was approached by the lorry* or *The hunter approached the lorry* than *The thief was approached by the lorry* or *The thief approached the lorry*. This is because repeated activation of HUNTER would strengthen the prime's animacy-to-subject and animacy-to-position mappings, independent of its underlying structure.

However, an alternative hypothesis suggests that the effect of prime animacy order arises from strengthened active–passive priming (i.e., repeated thematic role-to-function or role-to-position mappings) rather than from repeated animacy-to-subject or animacy-to-position mappings. When the thematic roles in the prime and target share the same animacy configuration—both featuring an inanimate agent and an animate patient—the agent and patient roles in the prime are more likely to retain their syntactic function and position in the target. Specifically, in the inanimate-agent prime condition (c & d), compared to the animate-agent prime condition (a & b), active primes (which assign the agent to the subject position) are more likely to bias active responses, while passive primes (which assign the patient to the subject position) are more likely to bias passive responses in the target. Thus, when the animacy features of the prime and target align, the difference between active and passive primes in their likelihood of eliciting passive responses should increase, leading to an interaction between prime structure and prime animacy (animate vs. inanimate agent). According to this hypothesis, animacy order persistence results from active-passive priming. Since active–passive priming is unlikely to be influenced by noun repetition, animacy order persistence should also remain unaffected by it.

Data availability: Supplementary materials, data, and analyses codes are available from: https://osf.io/82469/?view_only = e73f18568bfe4b558ef527e60c46c31a.

Table 1
Example prime and target sentences in Study 1.

Agent animacy	Structure	Sentence
	Experiment 1: Prime sentence (verb repetition)	
Animate	Active/Animate-first	3a. The sergeant attacked/chased the jet.
Animate	Passive/Inanimate-first	3b. The jet was attacked/chased by the sergeant.
Inanimate	Active/Inanimate-first	3c. The jet attacked/chased the sergeant.
Inanimate	Passive/Animate-first	3d. The sergeant was attacked/chased by the jet.
	Experiment 2: Prime sentence (animate repetition)	
Animate	Active/Animate-first	4a. The thief/hunter approached the lorry.
Animate	Passive/Inanimate-first	4b. The lorry was approached by the thief/hunter.
Inanimate	Active/Inanimate-first	4c. The lorry approached the thief/hunter.
Inanimate	Passive/Animate-first	4d. The thief/hunter was approached by the lorry.
	Experiment 3: Prime sentence (inanimate repetition)	
Animate	Active/Animate-first	5a. The thief approached the lorry/car.
Animate	Passive/Inanimate-first	5b. The lorry/car was approached by the thief.
Inanimate	Active/Inanimate-first	5c. The lorry/car approached the thief.
Inanimate	Passive/Animate-first	5d. The thief was approached by the lorry/car.
	Target sentences	
Inanimate	Active/Inanimate-first	6a. The car chased the hunter.
Inanimate	Passive/Animate-first	6b. The hunter was chased by the car.

Note. The words before and after the slash represent the not-repeated condition and repeated conditions, respectively.

Method

Participants

We recruited 240 participants from Prolific (https://www.prolific.com) for cash compensation, with 80 participants assigned to each of the three experiments. As explained below, we had 40 experimental items per experiment. The sample size was based on similar web-based experiments conducted previously, such as Fukumura and Yang (2024), who showed verb boost effects with 80 participants and 32 items per experiment, and Fukumura and Zhang (2023), who showed adjective/noun boost effects with 48 participants and 36 items. We also ensured that the combined power for detecting the animacy effect observed by Bock et al. (1992) exceeded that of Bock et al., who had 192 participants and 16 experimental items, with an exclusion rate of 47 % of responses. All participants self-reported as native speakers of British English, raised monolingually, university or college students aged between 18 and 30, without any language processing difficulties.

Procedure

All experiments were conducted on the Gorilla platform (https://gorilla.sc). Before starting, participants gave informed consent and confirmed their eligibility by providing age, language background, and information on any language or visual processing difficulties. In a web-based picture description task, participants described simple cartoon images in a conversational exchange with a recorded partner. Fig. 1 shows the procedure with example prime and target images. In *prime* trials, participants listened to a sentence describing a cartoon image and judged if it matched the image by selecting “Yes” or “No” (descriptions always matched the cartoon in experimental trials). In *target* trials, participants verbally described a target image using words displayed on the screen. This helped ensure that participants repeated the words used in the prime when their referents were repeated in the target. Verbal responses were audio-recorded for transcription. Pressing the ’Stop recording’ button proceeded to the next prime trial. The experiment lasted around 30 min. In the practice trials, participants were instructed to use all the words displayed (which reduced the rates of truncated passives), while they were free to vary word order. The project was approved by the University of Stirling’s General University Ethics Panel.

Materials

We manipulated the repetition of the verb (Experiment 1), animate noun (Experiment 2), or inanimate noun (Experiment 3) in the prime as a within-participant/item variable in separate experiments. Each experiment had 40 experimental items, with each comprising eight prime sentences, two prime images, and one target image. The prime and target images consisted of short movies, lasting a few seconds, in MP4 format. Both prime and target pictures depicted transitive events involving an animate and an inanimate character. Table 1 shows example prime and target sentences (see Supplementary Materials for a full list). As shown in the table, each prime sentence had either an active structure (involving the agent-first order) or a passive structure (involving the patient-first order). Each structure occurred with either an *animate-first order*, where the animate noun appeared as the subject, or an *inanimate-first order*, where the inanimate noun appeared as the subject. In the *animate-agent prime* events, the agent was animate and the patient was inanimate, whereas this was reversed in *inanimate-agent prime* events. In the target, the agent was always inanimate and the patient was always animate. In items where the characters appeared on either the left or right side, the positioning of the agent and patient roles was counterbalanced across items: Half of these items had the agent and patient roles in the same positions across prime and target displays, while the other half had the roles in opposite positions.

In addition to the experimental trials, 80 filler trials and 10 practice trials were constructed. Filler trials featured various constructions,

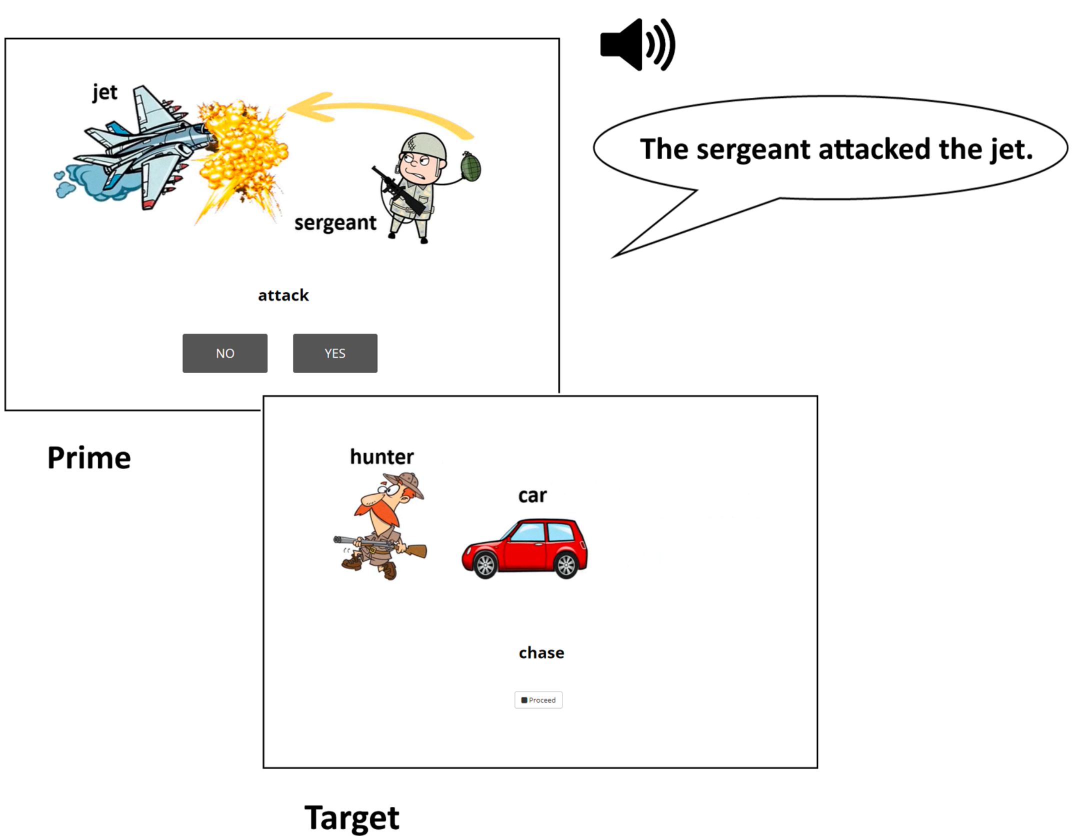

Fig. 1. Example prime and target displays.

including intransitive sentences, ditransitive sentences, *spray-load* locative constructions, copular constructions, and expletive (there-is/are) constructions. All prime sentences were presented auditorily. We generated the audio stimuli using the Google Cloud Text-to-Speech API with a British English male voice profile, with a speaking rate of 0.85 and a pitch adjustment of + 0.3.

Design

Each experiment had a 2 (*prime structure*: active vs. passive) × 2 (*prime animacy*: animate vs. inanimate agent) × 2 (*lexical repetition*: repeated vs. not-repeated) repeated measures design, leading to the creation of eight lists, each list having 40 experimental items and 80 filler items, with one condition per item and five experimental items per condition. Ten participants were randomly assigned to each list. The trials were presented in a fixed order with the following constraints: conditions were randomly distributed, ensuring no variable level persisted for more than three consecutive trials; identical verbs were spaced as widely as possible; the same character or object did not appear in the same half of the experiment; similar filler items did not occur consecutively; and YES/NO responses for filler primes, as well as animacy and role placements in the display for experimental items, were randomly dispersed with minimal repetition.

Scoring

We scored whether participants produced an active or passive structure. Responses were coded as *others* when participants produced non-target constructions or meanings ($n = 48$, e.g., *The castaway watched the kayak pass; taxi driver* rather than *taxi*); participants mistakenly swapped the thematic roles between the characters (though we included cases where participants self-corrected errors) ($n = 124$); participants did not use the specified verb in the verb-repeated condition ($n = 1$) or they omitted the agent ($n = 1$); passive responses contained a different preposition than *by* (e.g., *The druid was carried in a dinghy*) ($n = 48$); the patient role was identified as a location (e.g., *The yacht passed over the diver*) ($n = 19$) (though we included responses with *pass by*); there was a recording failure or missing response ($n = 26$). In total, 267 trials (Experiment 1 = 90, Experiment 2 = 77, Experiment 3 = 100) (2.8 % of total responses) were excluded from analyses.

Results

Fig. 2 presents the means of passive responses out of all active and passive responses, plotted by *prime structure* (active vs. passive), *prime animacy* (animate agent vs. inanimate agent), and *lexical repetition* (repeated vs. not repeated) for each experiment (see Appendix A for count data). Because the agent was inanimate and the patient was animate in the target, passive responses followed an animate-first (AI) order, while active responses followed an inanimate-first (IA) order. The animacy order of the prime sentence is marked on the x-axis.

In the following section, we report the analyses of the choice between

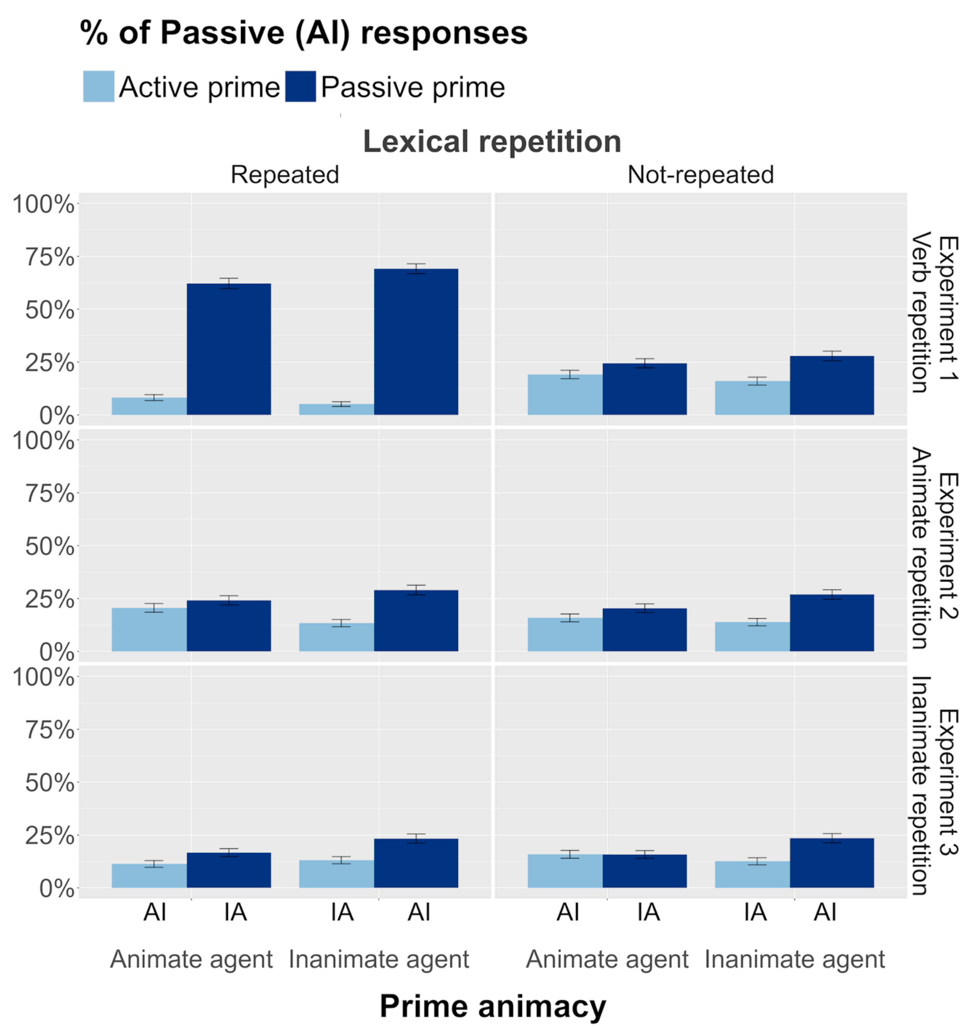

Fig. 2. Percentage of passive (vs. active) responses by condition across Experiments 1, 2, and 3. AI = Animate-first order; IA = Inanimate-first order.

active (inanimate-first) and passive (animate-first) responses. These binary outcomes were analyzed using Wald-z statistics from logit mixed-effects models (Baayen et al., 2008; Barr et al., 2013) implemented in the lme4 package (Bates et al., 2015b) in R (version 4.0.3; R Core Team, 2021). Analyses adopted a maximal effects structure; we included all theoretically relevant fixed effects to statistically control for confounding variables while allowing for the examination of interactions, along with by-participant and by-item random slopes and intercepts (Barr et al., 2013), with correlations between them suppressed (Bates et al., 2015a, 2015b; Kliegl, 2014; Singmann & Kellen, 2020). When models with a full random-effects structure exhibited singularity, random effects with near-zero variances were removed to prevent overfitting (Bates et al., 2015; Matuschek et al., 2017), while all fixed effects were retained. Model convergence in R was further facilitated by mean-centering and standardizing fixed effects (Gelman & Hill, 2007), which also enabled the interpretation of results in terms of main effects and interactions (Baayen et al., 2008). Simple effects were analyzed by excluding irrelevant conditions and mean-centering the relevant fixed effects.

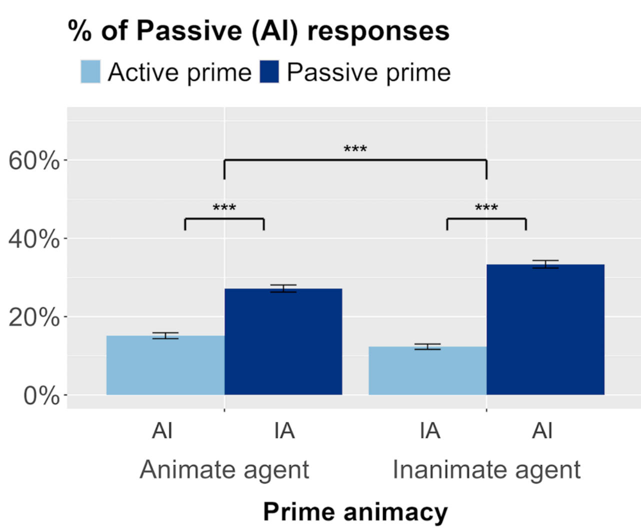

Fig. 3. Percentage of passive (vs. active) responses by prime structure and prime animacy, collapsed across experiments in Study 1. AI = Animate-first order; IA = Inanimate-first order.

We examined how the choice between active (coded as 0) and passive (coded 1) responses in the target was influenced by *prime structure* (active = 0, passive = 1), *prime animacy* (whether the prime agent was inanimate as in the target, coded 1, or not, coded 0), *lexical repetition* (repeated = 1, non-repeated = 0). To compare verb and noun boost effects and maximize statistical power, the initial analysis combined data from all three experiments. The variable *experiment* was coded using a Helmert contrast, with Experiment 1 (verb repetition) coded as 0.6667 and Experiments 2 and 3 (noun repetition) coded as −0.3333, following previous work (Fukumura & Zhang, 2023; Fukumura & Yang, 2024).

Influence of animacy on active–passive priming

The analysis revealed an interaction between prime structure and prime animacy (*Estimate* = 0.21, *SE* = 0.04, $z = 5.12$, $p < .001$), with no significant interaction with experiment ($p = .827$). As shown in Fig. 3, the advantage of passive primes over active primes in eliciting passive responses was greater in the inanimate-agent prime condition (21.1 %) than in the animate-agent prime condition (12.1 %). Specifically, active primes featuring inanimate agents (inanimate-first order) elicited more inanimate-first active responses than active primes featuring animate agents (animate-first order) (87.7 % vs. 84.9 %) (*Estimate* = -0.16, *SE* = 0.05, $z = -3.28$, $p = .004$). Likewise, passive primes featuring inanimate agents (animate-first order) elicited more animate-first passive responses than passive primes featuring animate agents (inanimate-first order) (33.4 % vs. 27.2 %) (*Estimate* = 0.20, *SE* = 0.04, $z = 4.93$, $p < .001$).

Animacy order persistence

Thus, the interaction between prime structure and prime animacy explains the main effect of prime animacy order found in Bock et al. (1992): Overall, there were more animate-first responses following animate-first primes (24.3 %, *SE* = 0.6 %) than inanimate-first primes (19.7 %, *SE* = 0.6 %). However, the prime's animacy order only persisted into the target in the inanimate prime agent condition, where the prime and target shared animacy features in their thematic roles. As shown in Fig. 3, animate-first passive primes elicited more animate-first passive responses than inanimate-first active primes in the inanimate-agent condition. In contrast, in the animate-agent condition, animate-first active primes elicited *fewer* animate-first passive responses than inanimate-first passive primes. This was because passive primes elicited more passive responses than active primes in both the inanimate-agent prime condition (*Estimate* = 0.88, *SE* = 0.06, $z = 14.98$, $p < .001$) and

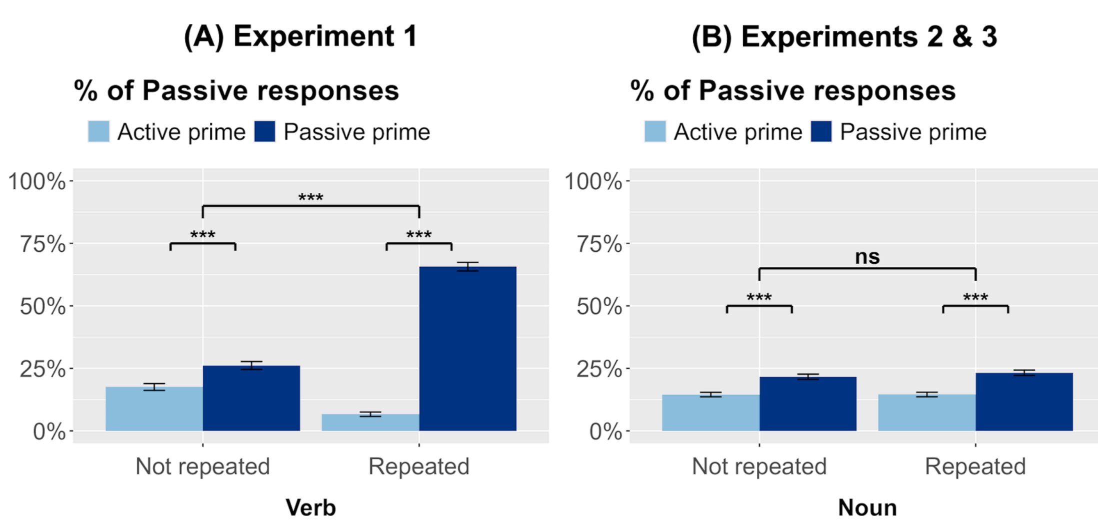

Fig. 4. Percentage of passive (vs. active) responses by (A) verb repetition and (B) noun repetition in Study 1.

the animate-agent prime condition (*Estimate* = 0.51, *SE* = 0.06, z = 9.01, $p < .001$). Thus, the prime's animacy order did not affect the structural choice in the target beyond the influence of its syntactic structure.

Lexical boost effects

Animacy order. The analysis revealed neither a prime structure × prime animacy × lexical repetition interaction (*Estimate* = 0.03, *SE* = 0.03, z = 0.85, p = .396) nor a prime structure × prime animacy × lexical repetition × experiment (verb vs. noun repetition) interaction (*Estimate* = 0.06, *SE* = 0.07, z = 0.87, p = .387). This suggests that lexical repetition did not enhance the persistence of the prime's animacy order (see Appendix B1 for full details).

Verb vs noun repetition effects. In contrast, a significant interaction between prime structure, lexical repetition, and experiment (*Estimate* = 0.92, *SE* = 0.08, z = 10.82, $p < .001$) indicated a lexical boost effect on active–passive priming that varied between experiments. As shown in Fig. 4A, in Experiment 1, prime structure had a larger effect when the verb was repeated (59.0 % priming effect) than when it was not (8.6 % priming effect) (*Estimate* = 3.88, *SE* = 0.35, z = 11.10, $p < .001$) Active primes led to a greater reduction in passive responses in the repeated-verb condition, relative to the non-repeated-verb condition (*Estimate* = -0.67, *SE* = 0.11, z = -6.14, $p < .001$), while passive primes in the repeated verb condition led to a greater increase in passive responses (*Estimate* = 1.23, *SE* = 0.11, z = 11.19, $p < .001$). Unlike Experiment 1, no prime structure × noun repetition interaction was found in Experiments 2 and 3 combined (*Estimate* = 0.04, *SE* = 0.04, z = 1.02, p = .308), despite having twice the number of observations (Fig. 4B, Appendix B). No noun boost effect was found in either Experiment 2 (p = .854) or Experiment 3 (p = .270) individually (see Appendix C).

Discussion

In summary, animate-first primes did not influence the assignment of the subject to animate nouns, independent of their thematic roles. The animacy of the prime subject (or its order) persisted into the target only when both the prime and target featured an inanimate agent and an animate patient—conditions under which this shared animacy feature enhanced active–passive priming. When the prime and the target differed in thematic role animacy, animate-first (active) primes elicited *fewer* animate-first (passive) responses than inanimate-first (passive) primes did. Moreover, neither animate nor inanimate noun repetition contributed to the persistence of the prime's animacy order. Taken together, these findings challenge the view that the prime's animacy order can persist independently of its syntactic structure.

The current findings contrast with those from adjective category order priming (Fukumura & Zhang, 2023), where the prime's adjective order persisted even when the syntactic structure differed between the prime and target. For adjective order priming, the effect was strengthened by either type of repetition, while syntactic priming was enhanced by noun repetition rather than adjective repetition. Our conclusions about the interaction between animacy and active–passive priming differ from those of Bock et al. (1992). They interpreted the absence of an interaction between prime structure and the prime subject's animacy as evidence for the independence of active–passive priming. Indeed, Fig. 3 shows that the difference between animate-first and inanimate-first active primes is similar to the difference between animate-first and inanimate-first passive primes. However, this merely reflects the absence of a main effect of prime animacy (animate vs. inanimate agent) (*Estimate* = 0.03, *SE* = 0.04, z = 0.71, p = .481). Specifically, the passive rates in the animate-agent condition (animate-first active primes and inanimate-first passive primes) did not significantly differ from those in the inanimate-agent condition (inanimate-first active primes and animate-first passive primes). Our analysis revealed that prime animacy interacts with active–passive priming, with the magnitude of the active–passive priming effect increasing when the animacy features of the prime's thematic roles are repeated in the target. The persistence of the prime's animacy order is a by-product of the prime thematic role animacy × prime structure interaction.

As for methodological differences, in Bock et al. (1992), the animacy effect emerged only when participants were instructed to focus on the meaning of the prime sentence. Rather than explicitly directing participants to focus on meaning, the current study presented prime sentences alongside images and asked participants to verify their semantic match. This likely directed attention to meaning while also reducing the chance of animacy influencing the misinterpretation of the prime sentence, as observed by Christianson et al. (2010). Similar to Bock et al. (1992), Christianson et al. presented prime sentences without images. They found that less plausible passive primes (e.g., *The angler was caught by the fish*) elicited fewer passive responses than more plausible ones (e.g., *The fish was caught by the angler*). This effect was attributed to thematic role misassignment during the comprehension of passive sentences (see also Christianson et al., 2023; F. Ferreira, 2003; cf. Bader & Meng, 2018). For example, *The angler was caught by the fish* was often misinterpreted as *The angler caught the fish*, biasing responses toward the active voice. Although we did not observe a similar effect, we did find that participants occasionally made errors in assigning thematic roles in their target responses. However, these errors—swapping the roles of animate and inanimate nouns without correction—were generally low (see Appendix D). Thus, Christianson et al.'s findings did not generalize to the current study.[1]

Finally, the finding that verb repetition enhances active–passive priming, while noun repetition does not, aligns with previous research on the dative alternation (Carminati et al., 2019; Kantola et al., 2023; Huang et al., 2023; Van Gompel et al., 2023) and the *spray-load* locative alternation (Fukumura & Yang, 2024). Fukumura and Yang (2024) proposed that thematic roles are associated with verb selection rather than noun selection. The assignment of thematic roles to nouns is context-dependent. For example, a car can serve different roles depending on context, functioning as an agent in *A car hit a witch* or as a patient in *A witch hit a car*. Thus, speakers may not associate the nouns with specific thematic roles or their corresponding mappings to sentence structures. Another possible explanation is that structural choices are made before the lexical retrieval of 'filler' nouns occurs. Griffin and Bock (2000) reported eye movement data indicating that speakers decide on sentence structure extremely rapidly—within a few hundred milliseconds of picture onset—without displaying systematic eye movement patterns. Subsequent eye movements closely corresponded to the order of mention. Assuming fixation durations reflect lexical retrieval, these findings suggest that structural choices precede noun retrieval, thus preventing syntactic priming from being influenced by noun repetition.

Study 2

Study 1 demonstrated that animacy interacts with active–passive priming in declarative sentences: Repeating the prime's animacy-thematic role mappings in the target increases structural persistence. Studies 2 and 3 explored the nature of this animacy boost effect. Research suggests that the active–passive alternation is influenced by the persistence of thematic role ordering and function assignment (e.g., Bernolet et al., 2009; Vasilyeva & Waterfall, 2012; Vernice et al., 2012). Study 2 examined whether animacy affects the persistence of the prime's thematic role order, the argument structure underlying function assignment, or both. To test this, we used English it-cleft constructions, examples of which are shown in Table 2. Unlike declarative sentences,

[1] In Study 2, errors occurred primarily after agent-first passive primes, with higher rates when the prime agent was animate (n = 59) compared to when it was inanimate (n = 25). However, this pattern did not extend to Study 3, where error rates were much lower. These responses were excluded to isolate the effect of thematic role animacy repetition on structural persistence.

Table 2
Example prime and target sentences in Experiments 4 and 5.

Structure	Animate agent event	Inanimate agent event
	Experiment 4 Prime (Verb not repeated)	
	Agent-first	*Agent-first*
Active	7a. It was the admiral that attacked the battleship.	8a. It was the battleship that attacked the admiral.
Passive	7b. It was the admiral that the battleship was attacked by.	8b. It was the battleship that the admiral was attacked by.
	Patient-first	*Patient-first*
Active	7c. It was the battleship that the admiral attacked.	8c. It was the admiral that the battleship attacked.
Passive	7d. It was the battleship that was attacked by the admiral.	8d. It was the admiral that was attacked by the battleship.
	Experiment 5 Prime (Verb repeated)	
	Agent-first	*Agent-first*
Active	9a. It was the general that chased the cruiser.	10a. It was the cruiser that chased the general.
Passive	9b. It was the general that the cruiser was chased by.	10b. It was the cruiser that the general was chased by.
	Patient-first	*Patient-first*
Active	9c. It was the cruiser that the general chased.	10c. It was the general that the cruiser chased.
Passive	9d. It was the cruiser that was chased by the general.	10d. It was the general that was chased by the cruiser.
	Target sentences	
	Agent-first	*Agent-first*
Active	11a. It was the thief that chased the lorry.	12a. It was the lorry that chased the thief.
Passive	11b. It was the thief that the lorry was chased by.	12b. It was the lorry that the thief was chased by.
	Patient-first	*Patient-first*
Active	11c. It was the lorry that the thief chased.	12c. It was the thief that the lorry chased.
Passive	11d. It was the lorry that was chased by the thief.	12d. It was the thief that was chased by the lorry.

where active structures follow an agent-first order and passive structures a patient-first order, cleft constructions allow both orders in both structures.

As shown in Table 2, agent-first (a & b) and patient-first (c & d) orders appear in both active and passive structures, with active structures assigning the subject to the agent (in a & c) and passive structures assigning the subject to the patient (in b & d). For example, in an agent-first active structure (7a), the agent (*admiral*) precedes the patient (*battleship*), whereas in a patient-first active structure (7c), the patient precedes the agent, but the structure remains active. Unlike in Study 1, the animacy features of thematic roles varied in both the primes and targets, allowing us to separate the effects of animacy feature repetition from those of prime and target animacy. In the *animacy-repeated condition*, animate-agent primes were paired with animate-agent targets, and inanimate-agent primes with inanimate-agent targets. In the *animacy-not-repeated condition*, animate-agent primes were followed by inanimate-agent targets, and inanimate-agent primes by animate-agent targets.

A thematic role order priming effect should result in more patient-first responses after patient-first primes (c & d) than after agent-first primes (a & b). If animacy repetition enhances thematic role order persistence, this effect should be stronger in the animacy-repeated condition than in the animacy-not-repeated condition. Similarly, an argument structure priming effect should lead to more passive responses after the passive primes than after the active primes. If animacy repetition strengthens argument structure persistence, the priming effect should be stronger in the animacy-repeated condition than in the animacy-not-repeated condition. These predictions were assessed in two experiments. In Experiment 4, primes and targets had different verbs, while in Experiment 5, they shared the same verbs. This was done to examine whether the animacy boost effect would be more detectable with stronger thematic role order and argument structure priming following verb repetition (Fukumura & Yang, 2024).

Method

Participants

We recruited 160 participants (80 participants each for Experiments 4 and 5) from the University of Stirling student community and from Prolific, in exchange for course credits and cash, respectively. All participants were monolingually-raised native speakers of British English, aged 17 to 35, with no reported language processing difficulties. An additional 19 participants (nine from Experiment 4 and 10 from Experiment 5) were excluded for failing to use cleft constructions or producing invalid responses (e.g., thematic role assignment errors) in more than eight trials (20 %).

Materials, design, and procedure

Forty experimental items were adapted from Study 1. All prime sentences had *it*-cleft constructions. In the target trials, the preamble '*It was …*' prompted a completion using a cleft construction. Except for the prompt, the procedure was the same as in Study. Table 2 shows examples of prime and target sentences. Sentences (a & b) represent agent-first order primes, where the agent role fronted in the *it*-cleft clause is emphasised, while sentences (c & d) represent patient-first order primes, where the patient role is fronted in the *it*-cleft clause and thus emphasised. Each order had an active (a & c) or passive (b & d) structure, assigning the subject role to the agent or patient, respectively. Prime and target animacy were varied as follows. In animate-agent prime (7 & 9) and animate-agent target events (11), the agent was animate, whereas the patient was inanimate. This was reversed in the inanimate-agent prime (8 & 10) and inanimate-agent target events (12). In the *animacy-repeated condition*, the thematic roles in the prime and the target had the same animacy; in the *animacy-not-repeated condition*, they differed in animacy.

The primes and the targets involved different verbs in Experiment 4, whereas they had the same verbs in Experiment 5. In each experiment, we manipulated *prime structure* (active vs. passive), *prime thematic role order* (agent-first vs. patient-first) and *prime animacy* (animate agent vs. inanimate agent) as within-participant/item variables and we varied *target animacy* (animate agent vs. inanimate agent) as a between-participant/within-item variable. This resulted in the creation of 16 lists, where 40 experimental items and 78 filler items were distributed, with one version from each item and five items per condition. The filler items were similar to those used in Study 1, except that some filler prime sentences (n = 21) had cleft-constructions, none of which involved transitive verbs. Five participants were randomly assigned to each list in both experiments.

Scoring

We scored the choice of thematic role order (agent-first vs. patient-first) and function assignment (active vs. passive) in target responses. Responses were excluded for the following reasons: failure to produce cleft constructions (n = 95); non-target meanings or constructions (n = 31); the mention of the patient as a location (n = 11); swapping thematic roles between animate and inanimate nouns (n = 128); use of a non-repeated verb in the repeated verb experiment (n = 2); missed or incomplete responses (n = 9); unclear or cut-off audio recordings (n = 3); and technical errors (n = 31). Responses were included when participants omitted *that* (e.g., *It was the sled the mountaineer pushed*) or produced relative clause responses (e.g., *It was the astronaut chasing the missile* or *It was the boat carried by the Viking*). In total, 310 responses (4.8 %) were excluded from further analyses.

Results

Our analyses examined whether participants' choice of thematic role order (agent-first = 0, patient-first = 1) or function assignment (active = 0, passive = 1) was influenced by the prime's thematic role order (agent-first = 0, patient-first = 1) or function assignment (active = 0,

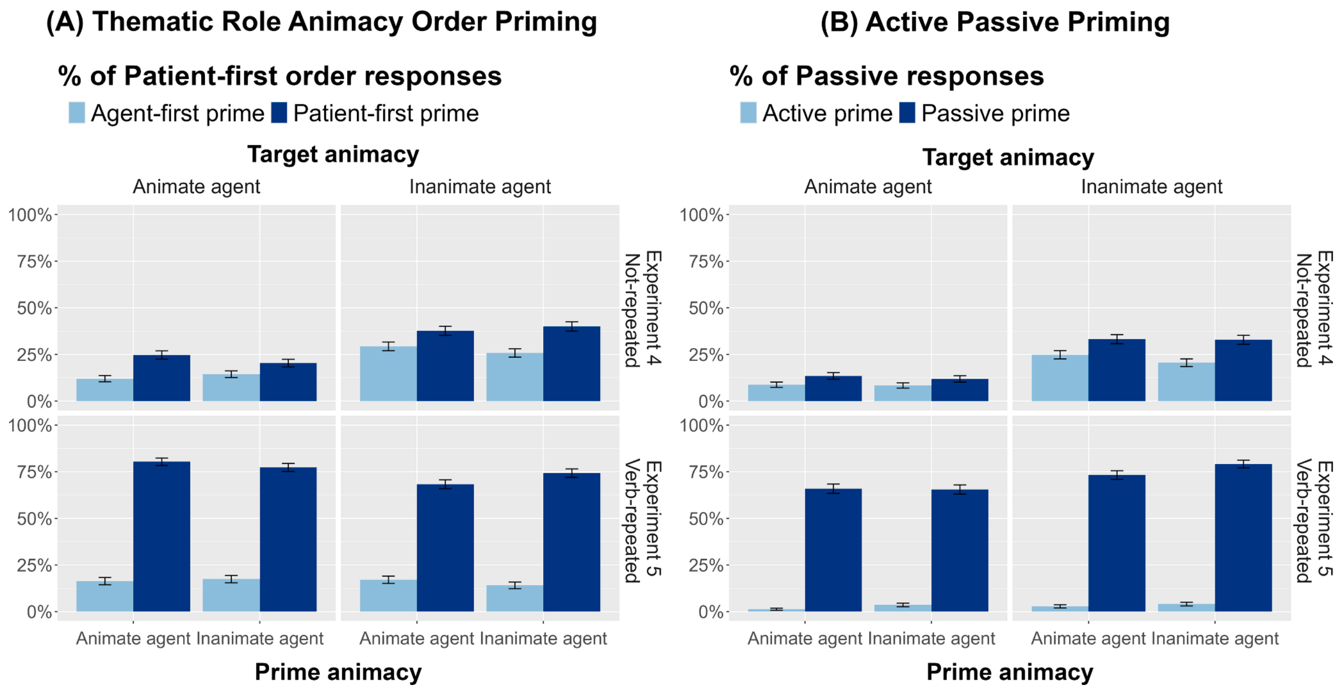

Fig. 5. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by prime animacy and target animacy in Study 2.

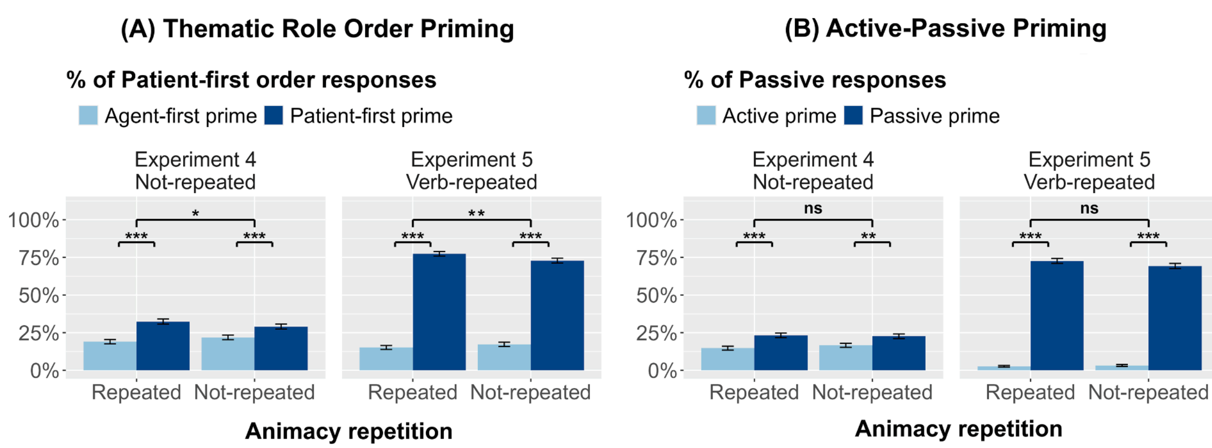

Fig. 6. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by animacy repetition in Study 2.

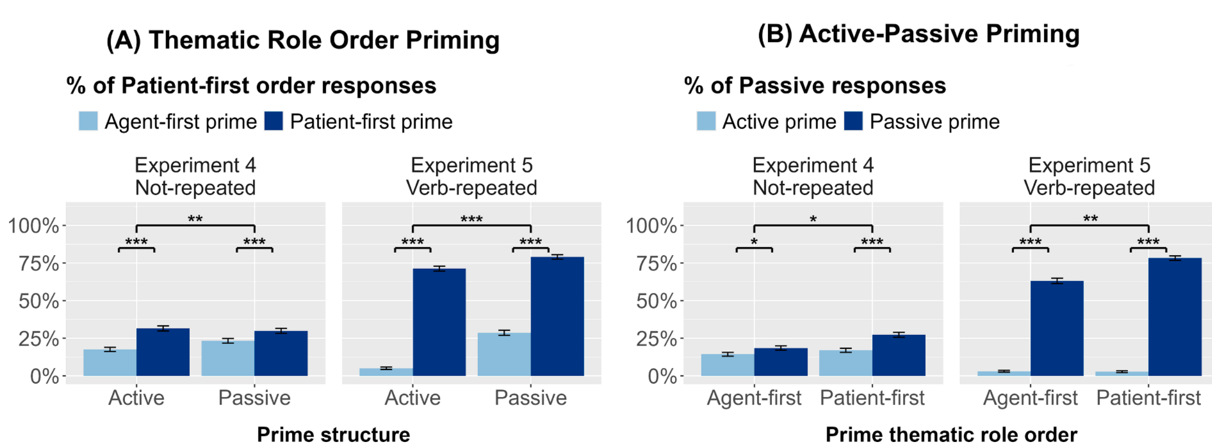

Fig. 7. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by prime thematic role order and structure in Study 2.

passive = 1), respectively. Critically, we investigated whether these effects interacted with prime animacy (animate agent = 0, inanimate agent = 1), target animacy (animate agent = 0, inanimate agent = 1), or their interaction. Fig. 5A presents the means of patient-first responses, while Fig. 5B shows the means of passive responses. For the combination of these responses, see Appendix E.

Animacy boost effect on thematic role order priming

The analysis of thematic role ordering revealed a prime thematic role order × prime animacy × target animacy interaction (*Estimate* = 0.13, *SE* = 0.04, *z* = 3.61, *p* < .001) (see Appendix F for a full summary), with no interaction with experiment (*p* = .998). This three-way interaction reflected a prime thematic role order × animacy feature repetition interaction. As illustrated in Fig. 6A, the advantage of patient-first order primes over agent-first primes in eliciting patient-first orders was larger in the animacy-repeated condition than in the animacy-not-repeated condition, indicating an animacy boost effect on thematic role order priming. Separate analyses confirmed that this interaction was significant in both Experiment 4 (*Estimate* = 0.13, *SE* = 0.06, *z* = 2.05, *p* = .041) and Experiment 5 (*Estimate* = 0.19, *SE* = 0.07, *z* = 2.78, *p* = .005) and was not influenced by prime structure (active vs. passive) in either experiment (*ps* > .900) (Appendix G).

Marginal animacy boost effect on active–passive priming

In contrast to the clear animacy boost on thematic role ordering, the analysis of functional assignment revealed only a marginal interaction between prime structure, prime animacy, and target animacy for active–passive priming (*Estimate* = 0.10, *SE* = 0.06, *z* = 1.79, *p* = .074) (Appendix H). This suggested a marginally larger effect of prime structure when animacy features were repeated (39.0 % priming effect) compared to when they were not (35.8 % priming effect). This interaction did not approach significance in either experiment individually (*ps* > .10) (see Fig. 6B, Appendix I). The main effect of prime structure was highly significant, showing more passive responses following passive primes (46.6 %, *SE* = 0.9 %) than following active primes (9.2 %, *SE* = 0.5 %) (*Estimate* = 1.49, *SE* = 0.08, *z* = 19.19, *p* < .001).

Additional findings

Prime structure by prime thematic role order interactions. Although the animacy boost effect on thematic role order priming (i.e., the interaction between prime thematic role order and animacy feature repetition on thematic role ordering) was not modulated by prime structure, thematic role order persistence interacted with prime structure in both experiments (Fig. 7A, Appendix G). Across experiments, agent-first passive primes elicited fewer agent-first responses (i.e., they resulted in more patient-first orders) than agent-first active primes did (74.1 % vs. 88.7 %) (*Estimate* = 0.63, *SE* = 0.07, *z* = -8.61, *p* < .001). In contrast, patient-first passive primes elicited marginally more patient-first responses than patient-first active primes did (54.5 % vs. 51.5 %) (*Estimate* = 0.11, *SE* = 0.06, *z* = 1.76, *p* = .078). Similarly, argument structure persistence interacted with prime thematic role in both experiments (Fig. 7B, Appendix I). Overall, agent-first passive primes were less likely to elicit passive responses than patient-first passive primes (40.1 % vs. 52.8 %) (*Estimate* = 0.42, *SE* = 0.06, *z* = 7.44, *p* < .001). In contrast, the rates of active responses were similar following agent-first and patient-first active primes (*Estimate* = 0.09, *SE* = 0.08, *z* = 1.16, *p* = .246). These results suggest that agent-first passive primes were weaker than other prime types in influencing both thematic role ordering and function assignment (discussed further in the General Discussion).

Animacy-first and animate-subject preferences. Across experiments, participants preferred animate-first ordering (Fig. 5A), with the main effect of target animacy on thematic role ordering showing more patient-first (i.e., fewer agent-first) responses when the target events featured animate-patients/inanimate agents (38.4 %, *SE* = 0.9 %) rather than inanimate-patient/animate agents (33.3 %, *SE* = 0.9 %) (*Estimate* = 0.20, *SE* = 0.10, *z* = 1.99, *p* = .046) (Appendix F). Similarly, a main effect of target animacy on function assignment (Fig. 5B) indicated an animate-as-subject preference: More passive (i.e., fewer actives) responses for target events featuring animate patients/inanimate agents (33.3 %, *SE* = 0.9 %) rather than inanimate patient/animate agents (21.8 %, *SE* = 0.7 %) (*Estimate* = 0.52, *SE* = 0.10, *z* = 5.10, *p* < .001) (Appendix H).

Verb boost effects. As shown in all graphs, the effect of prime thematic role order on target thematic role ordering was stronger in Experiment 5 (58.9 % priming effect) than in Experiment 4 (10.3 % priming effect) (*Estimate* = 0.71, *SE* = 0.06, *z* = 11.37, *p* < .001), indicating a verb boost on thematic role order priming. Similarly, the effect of prime argument structure on target function assignment was larger in Experiment 5 (68.1 % priming effect) than in Experiment 4 (7.2 % priming effect) (*Estimate* = 1.21, *SE* = 0.08, *z* = 14.74, *p* < .001), indicating a verb boost effect on active–passive (argument structure) priming.

Discussion

When the prime and target shared the same animacy features in their thematic roles, it increased the tendency to repeat the prime's thematic role order relative to when their animacy features differed. This demonstrated an animacy boost effect on thematic role order priming. In contrast, the magnitude of active–passive priming—the tendency to maintain the same syntactic function assignment from the prime to the target—was only marginally enhanced by the overlap in thematic role animacy. Additionally, both priming effects were stronger in Experiment 5 than in Experiment 4, indicating verb boost effects on thematic role order and argument structure priming.

Study 3

One possible explanation for the significant animacy boost effect on thematic role order priming—but only a marginal effect on argument structure priming—in Study 2 is that thematic role order conveys thematic emphasis in English cleft constructions, and animacy influences how strongly this emphasis persists. However, research suggests that subject assignment also contributes to thematic emphasis in English (e.g., Bernolet et al., 2009; Fillmore, 1968). Thus, if animacy repetition interacts with thematic emphasis, it should also enhance argument structure persistence. One factor that may have obscured this effect is the high processing demands of cleft constructions in spoken language, as reflected in the high participant exclusion rate in Study 2. These constructions are rare in speech (Roland et al., 2007) and become particularly complex when combined with passive structures, which are also infrequent in spoken English (Biber, 1988; Chafe, 1982).

Thus, Study 3 investigated whether animacy repetition enhances argument structure persistence in written language. Unlike spoken language, written text allows readers to process sentences at their own pace, potentially facilitating semantic processing and strengthening associations between animacy features and the functional structures of the primes. Study 3 also included Japanese declarative sentences, which offer a less syntactically complex environment for assessing the animacy boost effect. As shown in Table 3, Japanese declarative sentences use particles to mark syntactic functions and topic status, allowing word order to vary independently of argument structure, similar to English cleft constructions. In sentences (a) and (d), the subject—marked by the subject particle が (*ga*)—appears in the sentence-initial position. In contrast, sentences (b) and (c) begin with the object (marked by を, *o*) (b) or the prepositional object (marked by に, *ni*) (c). The particle *ga* was chosen over *wa* because *ga* can serve a topic-marking function similar to how cleft constructions in English signal new or contrastive information (Kuno, 1972;1973; Shibatani, 1990). Although *wa* is often considered a topic marker, as it can mark non-subjects as topical (Shibatani, 1990), it generally indicates information already given in the discourse. As in English, function assignment in Japanese co-varies with argument structure; the subject particle denotes the agent in active sentences and

Table 3
Example prime and target sentences in Study 3.

Structure	Animate agent event	Inanimate agent event
	Experiment 6: English prime sentence	
	Agent-first	*Agent-first*
Active	13a. It was the sergeant that chased the jet.	14a. It was the jet that chased the sergeant.
Passive	13b. It was the sergeant that the jet was chased by.	14b. It was the jet that the sergeant was chased by.
	Patient-first	*Patient-first*
Active	13c. It was the jet that the sergeant chased.	14c. It was the sergeant that the jet chased.
Passive	13d. It was the jet that was chased by the sergeant.	14d. It was the sergeant that was chased by the jet.
	Experiment 6: English target sentence	
	Agent-first	*Agent-first*
Active	15a. It was the hunter that chased the car.	16a. It was the car that chased the hunter.
Passive	15b. It was the hunter that the car was chased by.	16b. It was the car that the hunter was chased by.
	Patient-first	*Patient-first*
Active	15c. It was the car that the hunter chased.	16c. It was the hunter that the car chased.
Passive	15d. It was the car that was chased by the hunter.	16d. It was the hunter that was chased by the car.
	Experiment 7: Japanese prime sentence (with corresponding meanings as in English)	
	Agent-first	*Agent-first*
Active	17a. 軍曹が戦闘機を追い回した。 Gunso-ga sentoki-o oimawasi-ta.	18a. 戦闘機が軍曹を追い回した。 Sentoki-ga gunso-o oimawasi-ta.
Passive	17b. 軍曹に戦闘機が追い回された。 Gunso-ni sentoki-ga oimawas-are-ta.	18b. 戦闘機に軍曹が追い回された。 Sentoki-ni gunso-ga oimawas-are-ta.
	Patient-first	*Patient-first*
Active	17c. 戦闘機を軍曹が追い回した。 Sentoki-o gunso-ga oimawasi-ta.	18c. 軍曹を戦闘機が追い回した。 Gunso-o sentoki-ga oimawasi-ta.
Passive	17d. 戦闘機が軍曹に追い回された。 Sentoki-ga gunso-ni oimawas-are-ta.	18d. 軍曹が戦闘機に追い回された。 Gunso-ga sentoki-ni oimawas-are-ta.
	Experiment 7: Japanese target sentence (with corresponding meanings as in English)	
	Agent-first	*Agent-first*
Active	19a. 猟師が車を追い回した。 Ryōshi-ga kuruma-o oimawasi-ta.	20a. 車が猟師を追い回した。 Kuruma-ga ryōshi-o oimawasi-ta.
Passive	19b.猟師に車が追い回された。 Ryōshi-ni kuruma-ga oimawas-are-ta.	20b. 車に猟師が追い回された。 Kuruma-ni ryōshi-ga oimawas-are-ta.
	Patient-first	*Patient-first*
Active	19c. 車を猟師が追い回した。 Kuruma-o ryōshi-ga oimawasi-ta.	20c. 猟師を車が追い回した。 Ryōshi-o kuruma-ga oimawasi-ta.
Passive	19d. 車が猟師に追い回された。 Kuruma-ga ryōshi-ni oimawas-are-ta.	20d. 猟師が車に追い回された。 Ryōshi-ga kuruma-ni oimawas-are-ta.

the patient in passive sentences. If the animacy boost effect on argument structure persistence was obscured by the complexity of English cleft constructions in Study 2, it should emerge in Japanese declarative sentences, which are structurally simpler. However, if animacy repetition primarily strengthens thematic role order persistence rather than argument structure persistence, it should enhance thematic role order priming in both English and Japanese but not function assignment persistence in either language.

Method

Participants

We recruited 80 native English speakers (Experiment 6) and 80 native Japanese speakers (Experiment 7). English speakers were recruited as before, and Japanese speakers via https://www.jikken-baito.com, in exchange for a voucher. Participants reported being 18–35 years old, raised monolingually, having higher education backgrounds, and no language or visual processing difficulties.

Materials, design, and procedure

Each experiment included 40 experimental items and 78 filler items. English prime sentences employed *it*-cleft constructions as in Study 2, while Japanese primes used declarative constructions. Example items are presented in Table 3 (full lists are available in Supplementary Materials). In both experiments, the argument structure (active vs. passive), thematic role order (agent-first vs. patient-first), and animacy features of thematic roles (animate agent vs. inanimate patient) were manipulated as in Study 2. English primes were translated into Japanese, where the subject in both active and passive structures was marked by the particle が (*ga*). In active structures, the object (patient) was marked by を (*o*), while in passive structures, the prepositional object (agent) was marked by に (*ni*). The passive form was also morphologically marked with the suffix れた (*re-ta*), the past-tense version of the passive suffix (ら)れ ([*ra*]*re*). In both experiments, primes and targets always used the same verbs. Fewer verbs (*chase, pursue, overtake, follow, carry, pass, attack, push*) were used compared to Study 2 because the Japanese equivalents of two verbs from Study 2 (*approach* and *hit*) did not allow for the accusative marker を (*o*) in active sentences. The same images were used in both experiments, with character labels translated into Japanese for Experiment 7. The procedure was identical to Study 2, except that primes were presented in written format, and participants wrote their responses in text boxes. In the English experiment, responses followed the written prompt *It was*, eliciting continuations using cleft constructions. In the Japanese experiment, participants produced declarative sentences without a preceding prompt.

Scoring

In both experiments, participants' target descriptions were scored based on their thematic role order and functional structure. In the English experiment, responses were excluded if participants did not use cleft constructions (n = 10), produced sentences with non-target meanings or constructions (n = 8), mentioned the agent in the passive as a location (n = 4), made thematic role assignment errors (n = 37), used a verb different from the one in the prime (n = 1), or missed responses or produced incomplete responses (n = 6). In total, 66 responses (2.1 %) were excluded from further analyses. In the Japanese experiment, responses were excluded if participants made thematic role assignment errors (n = 33), produced non-target meanings (n = 1), identified the agent role as a tool or location (for the verb *carry*) (n = 38), missed responses or produced incomplete responses (n = 2), reported a technical error (n = 1), erroneously repeated the same particle (*ga* or *wa*) for both the agent and patient roles (n = 3), or marked the patient role with *wa* while marking the agent role with *ga* (n = 1). Responses where the subject was marked by *wa* (n = 110) were included. In total, 78 responses (2.4 %) were excluded from analyses.

Results

Fig. 8A presents the means of patient-first (relative to agent-first) responses and Fig. 8B shows the means of passive (relative to active) responses for both English (Experiment 6) and Japanese (Experiment 7) (see Appendix J for distributions of combinations of these variables). The analyses followed the same procedures as in Study 2.

Animacy boost effect on thematic role order priming in English but not in Japanese

The analysis of thematic role ordering (Appendix J) revealed a significant four-way interaction between prime thematic role order, prime animacy, target animacy, and experiment (*Estimate* = 0.10, *SE* = 0.04, z = 2.88, p = .004). A significant prime order × animacy repetition interaction was found in English (*Estimate* = -0.48, *SE* = 0.05, z = -9.22, p < .001). As shown in Fig. 9A, the effect of prime thematic role order on

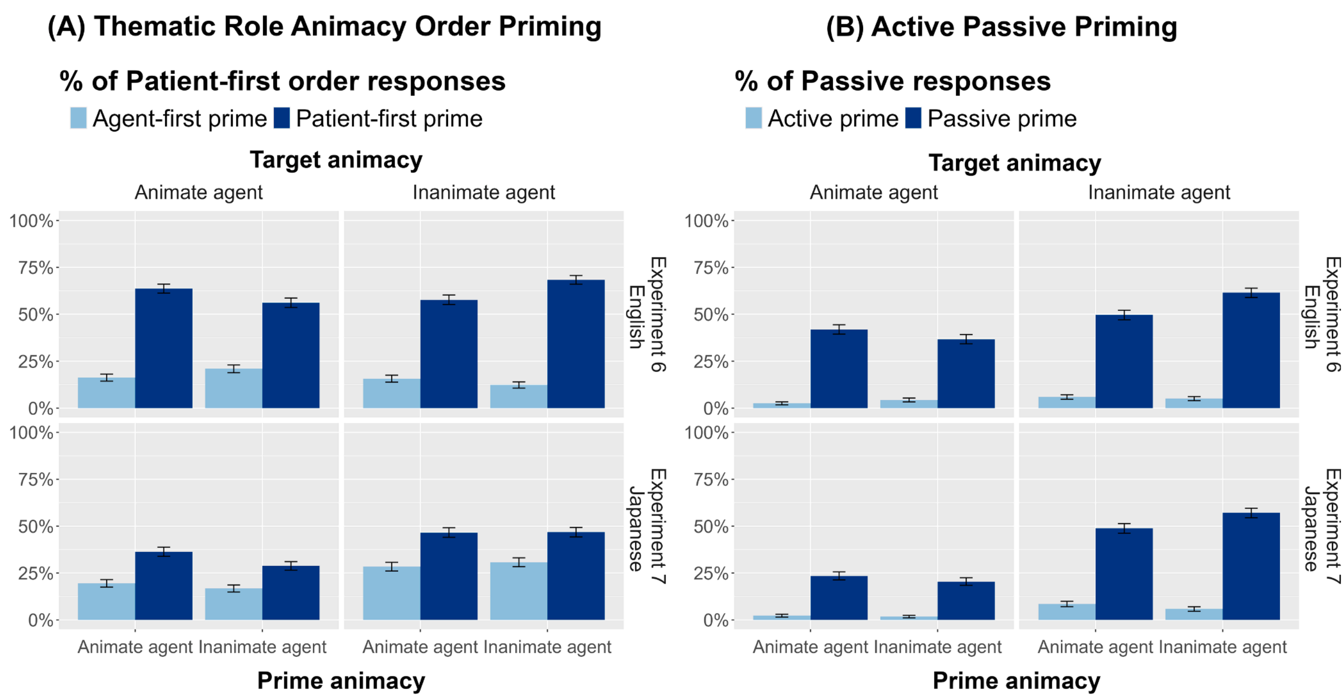

Fig. 8. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by prime animacy and target animacy in Study 3.

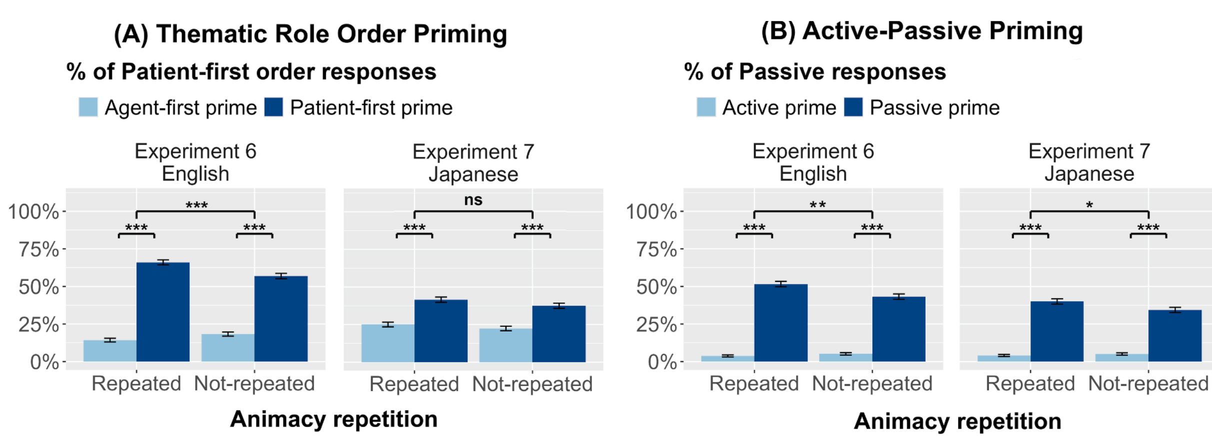

Fig. 9. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by animacy feature repetition in Study 3.

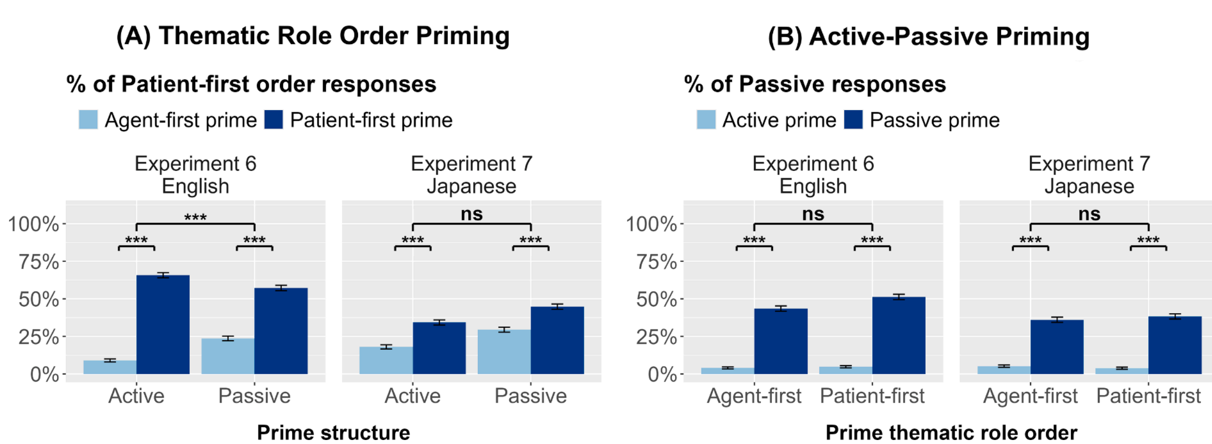

Fig. 10. (A) Percentage of patient-first (vs. agent-first) responses and (B) percentage of passive (vs. active) responses by prime thematic role order and structure in Study 3.

target thematic role ordering was 13 % larger in the animacy-repeated condition than in the animacy-not-repeated condition in English, while simple effects were significant in both conditions ($ps < .001$). No such interaction was found in Japanese (*Estimate* = 0.02, *SE* = 0.05, z = 0.34, p = .733) (Appendix L), although the main effect of prime thematic role was highly significant ($p < .001$), albeit smaller than in English (45 % vs. 16 % priming effects).

Animacy boost effect on active–passive priming in both languages

The analysis of functional assignment (Appendix M) showed a significant interaction between prime structure, prime animacy, and target animacy (*Estimate* = 0.18, *SE* = 0.06, z = 3.18, p = .001), which did not interact with experiment (*Estimate* = 0.06, *SE* = 0.06, z = 0.96, p = .335). As shown in Fig. 9B, in both English (*Estimate* = 0.21, *SE* = 0.07, z = 2.96, p = .003) and Japanese (*Estimate* = 0.18, *SE* = 0.08, z = 2.36, p = .019), the advantage of passive primes over active primes in eliciting passive responses was greater in the animacy-repeated condition than in the animacy-not-repeated condition, demonstrating an animacy boost effect on active–passive priming (Appendix N). Simple effects of prime structure were significant in all conditions ($ps < .001$). The main effect of prime structure did not interact with experiment (p = .350) and was significant in both languages ($ps < .001$).

Additional findings

Animacy-first and animate-subject preferences. In Japanese, there was an animate-first order preference, with more agent-first (i.e., fewer patient-first) responses for animate agents/inanimate patients in the target (38.2 %, *SE* = 1.2 %) rather than inanimate agents/animate patients (25.3 %, *SE* = 1.1 %) (*Estimate* = 0.48, *SE* = 0.14, z = 3.38, p = .001) (see Fig. 8A). No such effect was found in English (*Estimate* = -0.03, *SE* = 0.12, z = -0.28, p = .782). An animate-as-subject preference was found across languages, with more passive responses for animate-patients/inanimate agents (30.2 %, *SE* = 0.8 %) compared to inanimate-patients/animate agents (16.6 %, *SE* = 0.7 %) (*Estimate* = 0.71, *SE* = 0.13, z = 5.53, $p < .001$) (see Fig. 8B). This animate-as-subject preference was stronger in Japanese (18.0 %) than in English (9.2 %) (*Estimate* = -0.28, *SE* = 0.13, z = -2.21, p = .027).

Prime structure by thematic role order interaction in English. As in Study 2, in English, the prime's thematic role order had a larger effect on target thematic role ordering when the prime had an active structure (56.7 % priming effect) rather than a passive structure (33.6 % priming effect) (*Estimate* = -0.48, *SE* = 0.05, z = -9.22, $p < .001$). As in Fig. 10A, more patient-first (fewer agent-first) orders followed agent-first passive primes than agent-first active primes (*Estimate* = -0.25, *SE* = 0.06, z = -3.93, $p < .001$), indicating that agent-first orders were primed more frequently with active primes than with passive primes. Likewise, more patient-first orders followed patient-first active primes than patient-first passive primes (*Estimate* = 0.67, *SE* = 0.08, z = 7.94, $p < .001$), indicating that patient-first orders were primed better with active primes than with passive primes. No such interaction was observed in Japanese thematic role ordering (*Estimate* = -0.04, *SE* = 0.05, z = -0.93, p = .353). However, a main effect of prime structure on target thematic role ordering in Japanese revealed that patient-first orders were more frequent following passive primes (37.2 %, *SE* = 1.2 %) than following active primes (26.2 %, *SE* = 1.1 %) (*Estimate* = 0.5, *SE* = 0.08, z = 6.43, $p < .001$).

Discussion

Repeating the prime's thematic role animacy strengthened both argument structure and thematic role order persistence in English. This contrasts with Study 2, where animacy repetition enhanced thematic role order persistence in the spoken modality but only had a marginal effect on argument structure. Comparisons between Experiments 5 and 6 (see Appendix O for summaries) did not reveal significant modulation of modality on the argument structure × animacy repetition interaction, let alone on the thematic role × animacy repetition interaction, which was robust across both modalities. This was likely because the marginal argument structure × animacy repetition interaction in Study 2 showed a similar numerical pattern to that observed in Study 3. Thus, the marginal effect on argument structure persistence in Study 2 may reflect difficulties in associating the prime's animacy features with its argument structure during the processing of spoken *it*-clefts.

In Japanese, both argument structure and thematic role order persisted in the target; however, animacy repetition enhanced only the persistence of argument structure. Corpus analyses by Yamashita (2002) suggest that scrambling in Japanese is more influenced by incremental production constraints, such as producing readily available words earlier (e.g., Bock & Irwin, 1980; V. Ferreira & Yoshita, 2003) and long-before-short preferences (Yamashita & Chang, 2001), rather than by information-structural functions like signaling topic shifts or given-new status (see Kondo & Yamashita, 2011, for related analyses). Consistent with this, while a patient-first order prime increased passive responses in English (by 4.4 %, p = .043), no such effect was found in Japanese (p = .558) (Fig. 10B, Appendix N). This suggests that, unlike in English cleft constructions, the earlier mention of a role in the prime does not influence the probability of assigning the subject to that role in the target in Japanese declarative constructions. Thus, in Japanese, animacy repetition interacted with function assignment (active vs. passive) persistence but not thematic role order persistence, because repeating the prime's thematic role animacy feature affects the persistence of topic selection, which is conveyed via subject particles rather than linear order.

General discussion

This study explored the relationship between message encoding and structure building, focusing on how animacy influences structural persistence. We began by reviewing the dominant perspective in psycholinguistic research, which asserts that structural priming operates independently of animacy. Specifically, Bock et al. (1992) proposed that when a prime assigns the subject role to an animate noun, it creates a preference for an animate subject in the target—regardless of whether the prime's structure is repeated. This interpretation was based on the two-stage grammatical encoding model, which attributes structural priming to the persistence of abstract syntactic structures—without the involvement of semantic information, such as animacy and thematic roles—during a later stage of grammatical encoding. However, an alternative interpretation of Bock et al.'s findings is that active–passive priming is influenced by the animacy of thematic roles. When the animacy of the thematic roles in the prime is repeated in the target, structural persistence becomes more likely. That is, structural priming involves the persistence of semantic information—not only thematic roles but also their animacy—contrary to the predictions of the two-stage model.

Summary of findings

Study 1 contrasted these hypotheses by examining whether lexical repetition enhances the persistence of the prime's animacy order, independent of its active–passive alternation—similar to how lexical repetition enhances adjective category order priming (e.g., color-pattern vs. pattern-color) (Fukumura & Zhang, 2023). Table 4 summarizes the key results. The prime's animacy order persisted in the target only when the thematic roles in the prime and target shared the same animacy features—specifically, inanimate agents and animate patients. However, active–passive priming occurred regardless of thematic role animacy repetition, though it was stronger when animacy features were repeated, suggesting an *animacy boost effect* on structural priming. Importantly, while verb repetition enhanced active–passive priming, neither noun nor verb repetition increased the persistence of the prime's animacy order. These findings suggest that, unlike adjective category order, the

Table 4
Key findings of the current work.

Study 1: English Declaratives
• See Table 1 for example sentences.
• Animacy boost effect on active–passive priming: Enhanced priming when the thematic roles in the prime and target have the same animacy rather than different animacy.
• No independent animacy order priming: Prime animacy order persisted into the target only when the prime's structure (active or passive) was maintained.
• No lexical boost on animacy order persistence.
• Verb boost effect on active–passive priming: Enhanced priming following verb repetition but not following noun repetition.
Study 2: English *It*-Clefts
• See Table 2 for example sentences.
• Animacy boost effect on thematic role order priming.
• Verb boost effect on thematic role order priming and active–passive (argument structure) priming.
Study 3: English *It*-Clefts vs Japanese Declaratives
• See Table 3 for example sentences.
• Animacy boost effect on thematic role order priming and active–passive (argument structure) priming in English.
• Animacy boost effect on active–passive priming, but no animacy boost effect on thematic role order priming in Japanese.

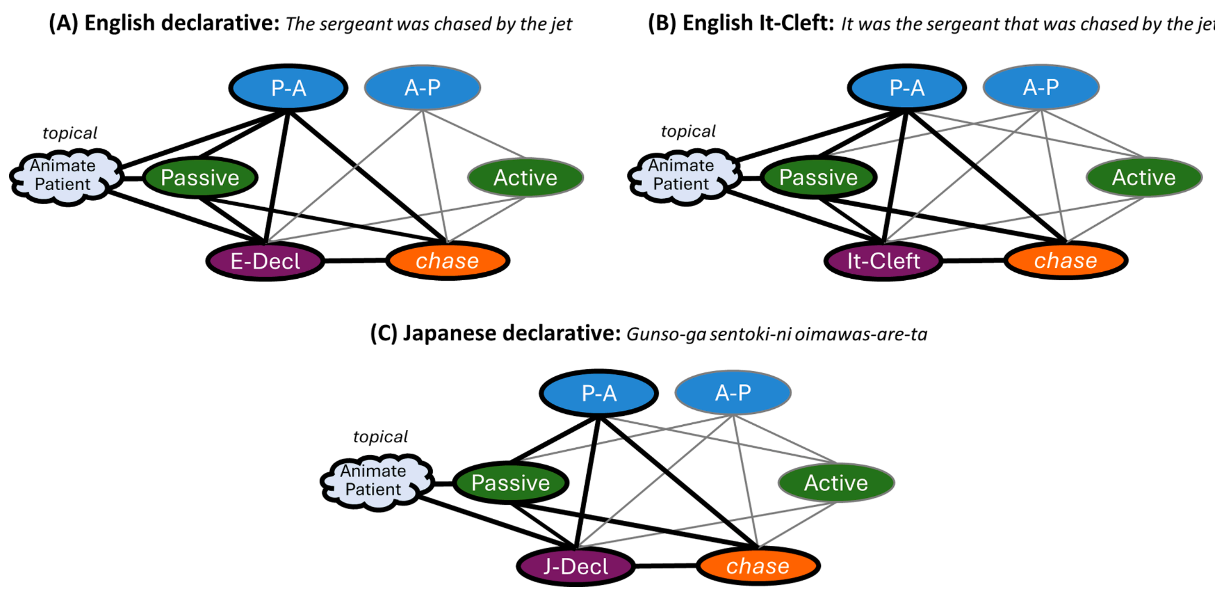

Fig. 11. Activation following patient-first passive primes in (A) English declarative (E-Decl), (B) *it*-cleft (*It*-Cleft), and (C) Japanese declarative (J-Decl) constructions, indicated by bold lines. A-first = Agent-first, P-first = Patient-first.

prime's animacy order (or the prime subject's animacy) does not function as an independent structural feature. Rather, animacy influences structural choice by interacting with the thematic roles underlying the active–passive alternation.

Study 2 examined the locus of the animacy boost effect observed in Study 1, specifically testing whether it stems from strengthened thematic role order priming, argument structure priming, or both. Repeating animacy features led to stronger thematic role order persistence, increasing the tendency to front the same role earlier in the sentence. However, animacy repetition did not reliably enhance the persistence of function assignment (argument structure)—particularly the tendency to assign the subject function to the same thematic role as in the prime. Study 3 extended these findings by examining written English cleft constructions and Japanese declarative sentences. In both constructions, animacy repetition strengthened active–passive (argument structure) persistence. However, its effect on thematic role order persistence differed. In English cleft sentences, animacy repetition strengthened thematic role order persistence, whereas in Japanese declarative sentences, the prime's thematic role order persisted independently of animacy repetition. In English, both function assignment and thematic role ordering contribute to thematic emphasis (Bernolet et al., 2009). In Japanese, however, thematic emphasis is primarily indicated by particles and argument omission (Kondo & Yamashita, 2011). Thus, animacy influences active–passive priming by interacting with structural features that shape thematic emphasis.

Interactive structure-building

Overall, our findings provide evidence against the traditional two-stage model, according to which active–passive structural priming occurs independently of animacy. To explain our findings, we build on the interactive structure-building account proposed by Fukumura and Yang (2024). According to this account, the active–passive alternation involves selecting both argument structure (active vs. passive) and thematic role order (agent-first vs. patient-first). Specifically, the diagrams in Fig. 11 illustrate how argument structure and thematic role order are activated following patient-first passive primes in three types of constructions; an English declarative (A), an English *it*-cleft (B), and a Japanese declarative (C). For instance, an English declarative passive prime, such as *The sergeant was chased by the jet*, activates the Passive node (representing the processes for generating a passive structure), the P-first node (representing the processes for generating a patient-first order), and the E-Decl node (representing a cluster of conceptual and syntactic features typical of English declarative sentences, such as asserting information, e.g., Searle, 1979, and positioning the subject first).[2]

We propose extending this account by introducing the 'Animate-Patient node', a feature representing the animate patient as the sentence topic. This node is activated as part of the message and depicted in a cloud shape in each diagram. The assumption is that when individuals process a prime sentence, they activate not only its thematic role order and argument structure but also its message features, including the animacy feature of the thematic role emphasized by the sentence. The activation of these message features—specifically, the animacy feature of the emphasized thematic role in the prime—affects thematic emphasis in the target sentence, because it biases emphasis toward the same role when the thematic roles in the target share the same animacy features as those in the prime. This increases the likelihood of repeating the thematic role order and/or argument structure that contributed to the thematic emphasis in the prime.

For example, in Fig. 11A, representing an English declarative passive, the Animate-Patient node links to structural features that specify the patient as the sentence topic; the P-first node, the Passive node, and the English declarative node. When speakers produce another declarative sentence about an event where the patient is also animate (e.g., *a hunter being chased by a car*), both the Animate-Patient and English declarative nodes are reactivated. This reactivation boosts the activation of the P-first and Passive nodes, which were co-activated in the prime. This effect may result from spreading activation originating from the Animate-Patient and declarative nodes and propagating to the P-first and Passive nodes via their pre-activated links, or from residual activation within these links (Pickering & Branigan, 1998). Either way, the likelihood of repeating a patient-first order and passive structure increases.

The activation patterns shown in Fig. 11 also explain several additional findings from our studies. First, this account does not include an independent node for animacy order or for the animacy of syntactic functions and positions. Therefore, these features of a prime can only transfer to the target sentence along with their underlying argument structure or thematic role, as demonstrated in Study 1. Second, in Fig. 11C, the Animate-Patient node links to the Passive and Japanese declarative sentence node (J-Decl), but not to the P-first node, because topic selection in Japanese is primarily influenced by argument structure and subject/topic particles, not word order. Hence, in Japanese, the repeated thematic role animacy reinforces argument structure persistence without affecting thematic role order, as shown in Study 3. Finally, verb selection is closely tied to the selection of both thematic role order and argument structure. In all diagrams, the thematic role order and argument structure nodes are connected to the semantic and syntactic properties of the verb (e.g., *chase*) and the construction nodes. The primed thematic role order and argument structure can influence structural choice in the target, even with a different verb. However, the likelihood of structural persistence increases when the same verb is used. For instance, when the verb *chase* is repeated in an English *it*-cleft sentence following *It was the sergeant that was chased by the jet*, co-activation of the verb and the *It*-Cleft node in the target strengthens the P-first node through their pre-activated links. Similarly, the Passive node is also enhanced when the same verb appears in the same construction in the target, increasing its activation due to links to both the verb *chase* and the *It*-Cleft node. This explains the verb boost effects on thematic role order priming and active–passive priming observed in Study 2 (see Fukumura & Yang, 2024, for further details).

As with many psycholinguistic theories, our account lacks computational specification and requires further development. A promising direction involves investigating how baseline activation levels of nodes and links modify the interactive priming effects we have observed, particularly regarding frequency effects. For example, active structures occur more frequently and are generally more preferred over passive ones (Dick & Elman, 2001; Roland et al., 2007). The less preferred passive structure typically drives active–passive priming—a phenomenon known as the *inverse frequency effect* (e.g., Bock, 1986; Hartsuiker & Kolk, 1998; Segaert et al., 2016). The active structure is often selected even after a passive prime, whereas the passive structure is primarily chosen when strongly primed. The assumption is that structural priming is stronger for less frequent structures because the occurrence of less 'expected' structures in the prime induces greater adjustments in expectations (Chang et al., 2006; Jaeger & Snider, 2013), or because a less frequent structure benefits from higher residual activation when primed, while active structures are generally favored due to their higher baseline activation levels (Segaert et al., 2016).

However, a lower baseline frequency does not necessarily predict a larger interactive priming effect. While previous research (Segaert et al., 2016) found a verb boost effect for passives but not for actives, Study 1 observed verb and animacy boost effects across both passives and actives. In Study 2, the thematic role order priming effect in the English cleft construction was stronger when the prime had an active structure (more frequent) than when it had a passive structure (less frequent). Agent-first active primes elicited more agent-first orders than agent-first passive primes. Similarly, in Study 3, patient-first active primes elicited more patient-first orders than patient-first passive primes did. This finding aligns with a stronger conceptual order priming effect observed for simpler, more frequent structures (e.g., adjective-adjective-noun) compared to more complex structures (e.g., a noun followed by a relative clause), as reported by Fukumura and Zhang (2023). They suggested that conceptual order priming is stronger with more frequent structures, as these are more often repeated in the target, increasing the likelihood that the prime's conceptual order will also persist in the target through interactive priming. Additionally, in Study 2, patient-first passive primes led to more passive responses than agent-first passive primes. This suggests that less frequent structures, such as passives, are more likely to be primed when paired with a patient-first order, to which they are more strongly associated due to their co-occurrence in declarative sentences. This suggests that baseline activation levels of links between nodes may modulate interactive priming.

Alternative interpretations

Linguistic theory often considers animacy—along with related features like volition and sentience (Dowty, 1991)—as a defining characteristic of the agent role, with animates being prototypical agents (Dowty, 1991; see also Aissen, 1999; Davis & Koenig, 2000, following Dowty). On this view, our findings align with a Dowty-like conception of thematic roles: Inanimate agents are similar to—but distinct from—-prototypical animate agents, and structural priming is stronger between identical roles than between those that are similar but distinct. However, it is unclear whether animacy indeed influences role similarity or whether structural priming can occur between distinct roles (see discussion below). If role similarity were the sole factor behind the animacy effect observed in the current study, we would expect repeated animacy features to influence both active–passive priming and thematic role order priming in Japanese, but our findings show only the former is affected. In our account, the role information conveyed by argument structure and thematic role order remains distinct from animacy.

[2] The nodes and the links between them are shaped not only by recent linguistic input (priming) but also by lifelong language experience. In English declarative sentences, the active structure typically features the agent-patient order, while the passive structure features the patient-agent order. Thus, in Fig. 11A, the Active node is connected to the A-P node and to the E-Decl node, but not to the P-A node. This contrasts with the English it-cleft and Japanese declarative constructions, shown in Fig. 11B and Fig. 11C, respectively, where both the Active and Passive nodes are connected to both thematic role order nodes. Although argument structures and thematic role orders co-vary in English declarative sentences, prior research (e.g., Bernolet et al., 2009; Fukumura & Yang, 2024) demonstrates that these elements can be primed separately, indicating that the corresponding nodes must be distinct.

Animacy can nevertheless influence active–passive priming because the animacy features of roles influence thematic emphasis and topic selection—the message feature underlying argument structures and/or thematic role orders, depending on the language. In Japanese, thematic emphasis and topic selection are primarily guided by function assignment, which co-varies with argument structure selection, rather than by thematic role order. Thus, repeated thematic role animacy interacts with argument structure persistence rather than thematic role order persistence.

Animacy effect in other constructions

Findings from other studies challenge the idea that animacy affects role similarity or that structural priming occurs between distinct roles. For example, several studies have failed to find animacy effects in dative priming (Carminati et al., 2008; Chen et al., 2020; Huang et al., 2016; Xiang et al., 2022), showing no evidence that animacy influences structural priming by increasing role similarity.[3] One explanation for the absence of animacy effects in dative priming is that recipients are typically animate, and double-object structures in English rarely feature inanimate recipients (Bresnan & Hay, 2008). These constraints limit experimental designs and the ability to observe animacy effects. For instance, Carminati et al. (2008) and Xiang et al. (2022) manipulated only the animacy of the theme role in the prime, while Chen et al. (2020) manipulated both the theme and recipient animacy, but only for prepositional-object structure primes. Huang et al. (2016) manipulated only recipient role animacy, and their combined analysis interestingly showed a marginal animacy × prime interaction. Another reason may be that the dative alternation depends less on shifts in thematic role prominence than the active–passive alternation, which involves a topical shift between the agent and patient. In the dative alternation, the agent remains the topic across the structural variants. Cai et al. (2012) found that while thematic role order persisted in Mandarin Chinese, their norming data indicated that the theme role was rated as more emphasized than the recipient role, regardless of the order of the thematic roles.

Interestingly, however, Ziegler and Snedeker (2018) found that the animacy order from *spray-load* locative primes persists when speakers produce dative constructions in the target. Locative primes had inanimate themes and animate locations, while dative targets had inanimate themes and animate recipients. Inanimate-first locative primes (e.g., *sprayed the cologne onto the man*) led to more inanimate-first dative responses (e.g., *fed the strawberry to the goose*) than animate-first primes (e.g., *sprayed the man with the cologne*). Similarly, animate-first primes (e.g., *loaded the horses onto the trailer*) resulted in more animate-first dative responses (e.g., *fed the goose the strawberry*) than inanimate-first primes (e.g., *loaded the trailer with the horses*). Importantly, no priming occurred from locative primes to dative targets when both the theme and location roles in the prime were inanimate (e.g., *sprayed the water onto the plant, sprayed the plant with the water*), while priming did occur within the locative alternation regardless of the animacy of the location role. This suggests that priming does not occur between locative and dative constructions unless they share animacy.

The persistence of animacy order from locative to dative constructions is unlikely a result of increased role similarity, as *horses* (theme) in *loaded the horses onto the trailer* and *goose* (recipient) in *fed the goose the strawberry* bear quite different thematic roles. One possibility is that animacy does not directly affect role similarity but instead influences how information structure transfers from locative primes to dative prepositional-object targets. In locative sentences, the direct object is typically assigned to the role undergoing the most salient change in location or state (e.g., *sprayed the water onto the plant* emphasizes the water's movement, while *sprayed the plant with the water* emphasizes the plant's change of state) (Rappaport Hovav & Levin, 1988). Similarly, in dative prepositional-object structures, the direct object is typically perceived as more "affected" than the prepositional object (Anderson, 1971; Gropen et al., 1991; Jackendoff, 1983; Pinker, 1989; Rappaport Horav & Levin, 1988). Thus, rather than increasing role similarity, animacy bridges distinct constructions by influencing how speakers distribute prominence across arguments. As a result, inanimate-first locative primes led to more prepositional-object datives, with speakers treating the inanimate noun as the more "affected" participant. Conversely, locative primes describing changes to an animate direct object reduced the likelihood of prepositional-object datives. Similar mechanisms may account for priming effects observed between dative verbs and other verbs involving distinct roles when the post-verbal roles differed in animacy (Hare & Goldberg, 1999; Potter & Lombardi, 1998; Ziegler & Snedeker, 2018). These findings suggest that animacy can create parallels in information structure.

Animacy, agency, and structural adaptability

Finally, in line with previous findings, the experiments in the current study revealed preferences for animate-first order, animate-as-subject, as well as agent-first order and agent-as-subject (active over passive voices) (as indicated by negative intercepts). While addressing fundamental questions about why these preferences exist across languages is beyond the scope of this study, linguistic theories provide explanations for the correlations among agency, animacy, subjecthood, and linear order (e.g., Givón, 2001) and how various constraints and hierarchies achieve optimal alignment within grammar (Aissen, 1999; Christianson, 2001; McCarthy, 2007). Our findings suggest that these constraints or preferences are highly flexible and sensitive to priming, enabling speakers to describe less prototypical or even novel events with varying degrees of thematic emphasis. This adaptability implies that structural preferences can evolve with language experience (e.g., Chang et al., 2006). Such flexibility may also enhance language production efficiency, as the reuse of recent linguistic input speeds up production processes (e.g., Smith & Wheeldon, 2001; Segaert et al., 2016). Our account seeks to capture this adaptability in structure building by modeling interactions between animacy and thematic roles in influencing structural persistence.

Summary and conclusions

By investigating the active–passive alternation, the current study demonstrated that animacy features do not directly map onto syntactic functions and positions. Instead, animacy influences the active–passive alternation through its interplay with thematic roles in topic selection. Thus, when the animacy features of the thematic roles in the prime are repeated in the target, the same role tends to remain as the sentence topic, as the structural feature contributing to thematic emphasis in the prime is more likely to persist. These findings challenge theories that assume a strict separation between syntax and semantics in structure building, such as the two-stage model of grammatical encoding. Instead, the results align with models that emphasize the interactive nature of sentence generation, where structure building occurs alongside topic selection, allowing animacy and thematic roles to jointly influence both processes.

CRediT authorship contribution statement

Kumiko Fukumura: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration,

[3] Buckle et al. (2017) found that in children, animate-first order primes (e.g., *brought the monkey a ball*) elicited more animate-first order responses than inanimate-first order primes (e.g., *brought a ball to the monkey*), but only when the animacy of the thematic roles in the prime matched those in the target. Thus, the effect may primarily be driven by the persistence of thematic role order rather than animacy order.

Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A: Study 1 count data

			Target Response			
Agent in Prime	Lexical Repetition	Prime	Active	Passive	% of Active	*SE*
		Experiment 1: Verb repetition				
Animate	Not repeated	Active	313	74	19.1	2.0
Animate	Not repeated	Passive	294	95	24.4	2.2
Animate	Verb repeated	Active	358	32	8.2	1.4
Animate	Verb repeated	Passive	146	240	62.2	2.5
Inanimate	Not repeated	Active	326	62	16.0	1.9
Inanimate	Not repeated	Passive	279	108	27.9	2.3
Inanimate	Verb repeated	Active	371	20	5.1	1.1
Inanimate	Verb repeated	Passive	121	271	69.1	2.3
		Experiment 2: Animate repetition				
Animate	Not repeated	Active	324	61	15.8	1.9
Animate	Not repeated	Passive	308	79	20.4	2.0
Animate	Animate repeated	Active	305	79	20.6	2.1
Animate	Animate repeated	Passive	295	94	24.2	2.2
Inanimate	Not repeated	Active	336	54	13.8	1.7
Inanimate	Not repeated	Passive	285	105	26.9	2.2
Inanimate	Animate repeated	Active	337	52	13.4	1.7
Inanimate	Animate repeated	Passive	274	112	29.0	2.3
		Experiment 3: Inanimate repetition				
Animate	Not repeated	Active	324	61	15.8	1.9
Animate	Not repeated	Passive	331	62	15.8	1.8
Animate	Inanimate repeated	Active	345	44	11.3	1.6
Animate	Inanimate repeated	Passive	330	66	16.7	1.9
Inanimate	Not repeated	Active	341	49	12.6	1.7
Inanimate	Not repeated	Passive	296	91	23.5	2.2
Inanimate	Inanimate repeated	Active	345	52	13.1	1.7
Inanimate	Inanimate repeated	Passive	296	90	23.3	2.2

Appendix B: Combined analyses of Study 1

Fixed Effect	*Estimate*	*SE*	*z*	*p*
(1) Combined analysis of Experiments 1-3				
(Intercept)	−2.03	0.17	−12.04	<.001
Prime structure (active vs. passive)	0.70	0.05	15.31	<.001
Prime animacy (animate vs. inanimate agent)	0.03	0.04	0.71	.481
Lexical repetition (repeated vs. not repeated)	0.11	0.04	2.93	.003
Experiment (noun vs. verb repetition)	0.63	0.21	3.06	.002
Prime structure × Prime animacy	0.21	0.04	5.12	<.001
Prime structure × Lexical repetition	0.34	0.04	8.71	<.001
Prime animacy × Lexical repetition	−0.02	0.03	−0.61	.544
Prime structure × Experiment	0.93	0.10	9.68	<.001
Prime animacy × Experiment	−0.08	0.08	−0.98	.328
Lexical repetition × Experiment	0.24	0.08	2.99	.003
Prime structure × Prime animacy × Lexical repetition	0.03	0.03	0.85	.396
Prime structure × Prime animacy × Experiment	−0.02	0.07	−0.22	.827
Prime structure × Lexical repetition × Experiment	0.92	0.08	10.82	<.001
Prime animacy × Lexical repetition × Experiment	< 0.01	0.07	< 0.01	.998
Prime structure × Prime animacy × Lexical repetition × Experiment	0.06	0.07	0.87	.387
(2) Combined analysis of Experiments 2-3				
(Intercept)	−2.26	0.19	−11.96	<.001
Prime structure	0.39	0.05	8.05	<.001
Prime animacy (animate vs. inanimate agent)	0.06	0.04	1.33	.184
Noun repetition	0.02	0.04	0.52	.605
Experiment (animate vs. inanimate repetition)	−0.18	0.12	−1.50	.133
Prime structure × Prime animacy	0.21	0.04	4.75	<.001
Prime structure × Noun repetition	0.04	0.04	1.02	.308

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Fixed Effect	*Estimate*	*SE*	*z*	*p*
Prime animacy × Noun repetition	−0.01	0.04	−0.34	.737
Prime structure × Experiment	−0.02	0.05	−0.44	.661
Prime animacy × Experiment	0.07	0.04	1.61	.107
Noun repetition × Experiment	−0.05	0.04	−1.28	.202
Prime structure × Prime animacy × Noun repetition	< 0.01	0.04	0.11	.910
Prime structure × Prime animacy × Experiment	−0.03	0.05	−0.54	.587
Prime structure × Noun repetition × Experiment	0.03	0.05	0.74	.458
Prime animacy × Noun repetition × Experiment	0.07	0.04	1.64	.101
Prime structure × Prime animacy × Noun repetition × Experiment	−0.06	0.04	−1.40	.161

Appendix C: Separate analyses of Study 1

Fixed Effect	*Estimate*	*SE*	*z*	*p*
Experiment 1 Verb repetition				
(Intercept)	−1.64	0.21	−7.91	<.001
Prime structure	2.68	0.20	13.59	<.001
Prime animacy (animate vs. inanimate agent)	−0.02	0.06	−0.33	.742
Verb repetition	0.55	0.15	3.60	<.001
Prime structure × Prime animacy	0.41	0.12	3.36	.001
Prime structure × Verb repetition	3.88	0.35	11.10	<.001
Prime animacy × Verb repetition	−0.03	0.12	−0.28	.778
Prime structure × Prime animacy × Verb repetition	0.30	0.24	1.23	.220
Experiment 2: Animate noun repetition				
(Intercept)	−2.05	0.22	−9.14	<.001
Prime structure	0.81	0.12	6.83	<.001
Prime animacy (animate vs. inanimate agent)	−0.02	0.06	−0.27	.788
Noun repetition	0.15	0.12	1.28	.200
Prime structure × Prime animacy	0.47	0.11	4.25	<.001
Prime structure × Noun repetition	0.04	0.22	0.19	.854
Prime animacy × Noun repetition	−0.16	0.11	−1.54	.123
Prime structure × Prime animacy × Noun repetition	0.27	0.23	1.19	.234
Experiment 3: Inanimate noun repetition				
(Intercept)	−2.48	0.23	−10.75	<.001
Prime structure	0.77	0.15	4.99	<.001
Prime animacy (animate vs. inanimate agent)	0.13	0.06	2.01	.044
Noun repetition	−0.06	0.12	−0.53	.599
Prime structure × Prime animacy	0.39	0.15	2.56	.011
Prime structure × Noun repetition	0.27	0.25	1.10	.270
Prime animacy × Noun repetition	0.11	0.13	0.84	.400
Prime structure × Prime animacy × Noun repetition	−0.23	0.26	−0.91	.365

Appendix D: Frequences of thematic role assignment errors

			Prime thematic role order	
Prime structure	Prime agent	Target agent	Agent-first	Patient-first
		Study 1		
Active	Animate	Inanimate	1.4 % (34)	NA
Active	Inanimate	Inanimate	1.0 % (25)	NA
Passive	Animate	Inanimate	NA	1.3 % (30)
Passive	Inanimate	Inanimate	NA	1.5 % (35)
		Study 2		
Active	Animate	Animate	0.8 % (3)	1.0 % (4)
Active	Animate	Inanimate	1.3 % (5)	1.0 % (4)
Active	Inanimate	Animate	0.5 % (2)	0.8 % (3)
Active	Inanimate	Inanimate	0.3 % (1)	1.3 % (5)
Passive	Animate	Animate	7.5 % (30)	0.5 % (2)
Passive	Animate	Inanimate	7.3 % (29)	1.3 % (5)
Passive	Inanimate	Animate	4.0 % (16)	1.0 % (4)
Passive	Inanimate	Inanimate	2.3 % (9)	1.5 % (6)
		Study 3		
Active	Animate	Animate	0.8 % (3)	0.3 % (1)
Active	Animate	Inanimate	2.0 % (8)	2.5 % (10)
Active	Inanimate	Animate	0.3 % (1)	0.8 % (3)
Active	Inanimate	Inanimate	0.3 % (1)	0
Passive	Animate	Animate	1.0 % (4)	0.3 % (1)
Passive	Animate	Inanimate	1.8 % (7)	1.3 % (5)
Passive	Inanimate	Animate	2.5 % (10)	1.5 % (6)
Passive	Inanimate	Inanimate	2.3 % (9)	0.3 % (1)

Note. Numbers in brackets represent counts.

Appendix E: Distributions of target responses in Study 2

Animacy	Prime role order	Prime structure	Target responses	Experiment 4 count	Experiment 4 %	Experiment 4 *SE*	Experiment 5 count	Experiment 5 %	Experiment 5 *SE*
Repeated	Agent-first	Active	Agent-first/Active	319	83.3	1.9	383	96.0	1.0
Repeated	Agent-first	Active	Agent-first/Passive	1	0.3	0.3	0	0	0
Repeated	Agent-first	Active	Patient-first/Active	15	3.9	1.0	4	1.0	0.5
Repeated	Agent-first	Active	Patient-first/Passive	48	12.5	1.7	12	3.0	0.9
Repeated	Agent-first	Passive	Agent-first/Active	289	76.1	2.2	94	26.3	2.3
Repeated	Agent-first	Passive	Agent-first/Passive	9	2.4	0.8	165	46.1	2.6
Repeated	Agent-first	Passive	Patient-first/Active	26	6.8	1.3	40	11.2	1.7
Repeated	Agent-first	Passive	Patient-first/Passive	56	14.7	1.8	59	16.5	2.0
Repeated	Patient-first	Active	Agent-first/Active	256	66.7	2.4	107	27.3	2.3
Repeated	Patient-first	Active	Agent-first/Passive	1	0.3	0.3	1	0.3	0.3
Repeated	Patient-first	Active	Patient-first/Active	64	16.7	1.9	276	70.4	2.3
Repeated	Patient-first	Active	Patient-first/Passive	63	16.4	1.9	8	2.0	0.7
Repeated	Patient-first	Passive	Agent-first/Active	260	68.1	2.4	67	17.6	2.0
Repeated	Patient-first	Passive	Agent-first/Passive	1	0.3	0.3	0	0	0
Repeated	Patient-first	Passive	Patient-first/Active	10	2.6	0.8	1	0.3	0.3
Repeated	Patient-first	Passive	Patient-first/Passive	111	29.1	2.3	313	82.2	2.0
Not Repeated	Agent-first	Active	Agent-first/Active	309	80.5	2.0	365	93.8	1.2
Not Repeated	Agent-first	Active	Agent-first/Passive	3	0.8	0.4	0	0	0
Not Repeated	Agent-first	Active	Patient-first/Active	14	3.6	1.0	12	3.1	0.9
Not Repeated	Agent-first	Active	Patient-first/Passive	58	15.1	1.8	12	3.1	0.9
Not Repeated	Agent-first	Passive	Agent-first/Active	268	72.2	2.3	98	28.2	2.4
Not Repeated	Agent-first	Passive	Agent-first/Passive	10	2.7	0.8	146	42.1	2.7
Not Repeated	Agent-first	Passive	Patient-first/Active	29	7.8	1.4	28	8.1	1.5
Not Repeated	Agent-first	Passive	Patient-first/Passive	64	17.3	2.0	75	21.6	2.2
Not Repeated	Patient-first	Active	Agent-first/Active	270	69.8	2.3	113	29.2	2.3
Not Repeated	Patient-first	Active	Agent-first/Passive	1	0.3	0.3	3	0.8	0.4
Not Repeated	Patient-first	Active	Patient-first/Active	50	12.9	1.7	261	67.4	2.4
Not Repeated	Patient-first	Active	Patient-first/Passive	66	17.1	1.9	10	2.6	0.8
Not Repeated	Patient-first	Passive	Agent-first/Active	273	71.8	2.3	92	23.8	2.2
Not Repeated	Patient-first	Passive	Agent-first/Passive	0	0	0	2	0.5	0.4
Not Repeated	Patient-first	Passive	Patient-first/Active	11	2.9	0.9	7	1.8	0.7
Not Repeated	Patient-first	Passive	Patient-first/Passive	96	25.3	2.2	285	73.8	2.2

Appendix F: Combined analysis of thematic role ordering in Study 2

Fixed effect	*Estimate*	*SE*	*z*	*p*
(Intercept)	−0.91	0.12	−7.66	<.001
Prime thematic role order	1.06	0.08	13.98	<.001
Prime animacy	−0.02	0.04	−0.55	.584
Target animacy	0.20	0.10	1.99	.046
Experiment (verb not repeated vs. verb repeated)	0.63	0.10	6.46	<.001
Prime thematic role order × Prime animacy	< 0.01	0.04	0.13	.894
Prime thematic role order × Target animacy	−0.07	0.06	−1.08	.279
Prime animacy × Target animacy	0.01	0.04	0.33	.739
Prime thematic role order × Experiment	0.71	0.06	11.37	<.001
Prime animacy × Experiment	< 0.01	0.04	0.12	.904
Target animacy × Experiment	−0.38	0.09	−4.17	<.001
Prime thematic role order × Prime animacy × Target animacy	0.13	0.04	3.61	<.001
Prime thematic role order × Prime animacy × Experiment	0.02	0.04	0.71	.480
Prime thematic role order × Target animacy × Experiment	−0.06	0.06	−0.94	.348
Prime animacy × Target animacy × Experiment	0.02	0.04	0.52	.601
Prime thematic role order × Prime animacy × Target animacy × Experiment	< 0.01	0.04	< 0.01	.998

Appendix G: Separate analysis of thematic role ordering in Study 2

Fixed effect	*Estimate*	*SE*	*z*	*p*
Experiment 4: Verb not repeated				
(Intercept)	−1.53	0.19	−8.12	<.001
Prime thematic role order	0.38	0.06	6.62	<.001
Animacy feature repetition	−0.02	0.05	−0.31	.754
Prime structure	0.09	0.05	1.73	.084
Prime thematic role order × Animacy feature repetition	0.13	0.06	2.05	.041
Prime thematic role order × Prime structure	−0.14	0.05	−2.87	.004
Prime structure × Animacy feature repetition	0.00	0.05	−0.10	.924
Prime thematic role order × Animacy feature repetition × Prime structure	0.00	0.05	0.09	.927

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Fixed effect	*Estimate*	*SE*	*z*	*p*
Animacy repeated				
Prime thematic role order	0.47	0.08	6.26	<.001
Animacy not-repeated				
Prime thematic role order	0.24	0.09	2.72	.007
Experiment 5: Verb repeated				
(Intercept)	−0.49	0.16	−3.12	.002
Prime thematic role order	2.19	0.17	13.00	<.001
Animacy feature repetition	0.01	0.07	0.14	.888
Prime structure	0.80	0.09	8.81	<.001
Prime thematic role order × Animacy feature repetition	0.19	0.07	2.78	.005
Prime thematic role order × Prime structure	−0.51	0.07	−6.91	<.001
Prime structure × Animacy feature repetition	0.10	0.07	1.30	.195
Prime thematic role order × Animacy feature repetition × Prime structure	−0.01	0.06	−0.08	.936
Animacy repeated				
Prime thematic role order	2.04	0.15	13.36	<.001
Animacy not-repeated				
Prime thematic role order	1.60	0.14	11.33	<.001

Appendix H: Combined analyses of function assignment in Study 2

Fixed effect	*Estimate*	*SE*	*z*	*p*
(Intercept)	−1.79	0.13	−14.1	<.001
Prime structure	1.49	0.08	19.19	<.001
Prime animacy	0.08	0.05	1.45	.148
Target animacy	0.52	0.10	5.10	<.001
Experiment (verb not repeated vs. verb repeated)	0.23	0.10	2.27	.023
Prime structure × Prime animacy	−0.06	0.05	−1.17	.242
Prime structure × Target animacy	0.03	0.07	0.44	.661
Prime animacy × Target animacy	−0.04	0.05	−0.66	.512
Prime structure × Experiment	1.21	0.08	14.74	<.001
Prime animacy × Experiment	0.14	0.06	2.56	.011
Target animacy × Experiment	−0.23	0.1	−2.29	.022
Prime structure × Prime animacy × Target animacy	0.10	0.06	1.79	.074
Prime structure × Prime animacy × Experiment	−0.08	0.05	−1.59	.112
Prime structure × Target animacy × Experiment	−0.02	0.07	−0.24	.809
Prime animacy × Target animacy × Experiment	−0.01	0.05	−0.18	.861
Prime structure × Prime animacy × Target animacy × Experiment	0.04	0.05	0.80	.423

Appendix I: Separate analyses of function assignment in Study 2

Fixed effect	*Estimate*	*SE*	*z*	*p*
Experiment 4: Verb not repeated				
(Intercept)	−2.08	0.19	−10.86	<.001
Prime structure	0.29	0.07	3.94	<.001
Animacy feature repetition	−0.06	0.05	−1.12	.265
Prime thematic role order	0.25	0.06	4.24	<.001
Prime structure × Animacy feature repetition	0.06	0.05	1.14	.256
Prime structure × Prime thematic role order	0.11	0.05	1.99	.046
Prime thematic role order × Animacy feature repetition × Prime structure	0.11	0.06	1.75	.081
Prime structure × Animacy feature repetition × Prime thematic role order	0.03	0.07	0.45	.656
Experiment 5: Verb repeated				
(Intercept)	−1.65	0.16	−10.00	<.001
Prime structure	2.88	0.18	15.68	<.001
Animacy feature repetition	0.00	0.09	0.04	.972
Prime thematic role order	0.21	0.10	2.21	.027
Prime structure × Animacy feature repetition	0.12	0.09	1.38	.167
Prime structure × Prime thematic role order	0.28	0.10	2.79	.005
Prime thematic role order × Animacy feature repetition × Prime structure	0.04	0.09	0.42	.672
Prime structure × Animacy feature repetition × Prime thematic role order	0.14	0.09	1.59	.113

Appendix J: Distributions of target responses in Study 3

				Experiment 6			Experiment 7		
Animacy	Prime role order	Prime structure	Target responses	count	%	*SE*	count	%	*SE*
Repeated	Agent-first	Active	Agent-first/Active	364	91.9	1.4	318	80.7	2.0
Repeated	Agent-first	Active	Agent-first/Passive	1	0.3	0.3	2	0.5	0.4
Repeated	Agent-first	Active	Patient-first/Active	18	4.5	1.0	56	14.2	1.8
Repeated	Agent-first	Active	Patient-first/Passive	13	3.3	0.9	18	4.6	1.1
Repeated	Agent-first	Passive	Agent-first/Active	171	44.1	2.5	209	53.9	2.5
Repeated	Agent-first	Passive	Agent-first/Passive	136	35.1	2.4	57	14.7	1.8
Repeated	Agent-first	Passive	Patient-first/Active	36	9.3	1.5	30	7.7	1.4
Repeated	Agent-first	Passive	Patient-first/Passive	45	11.6	1.6	92	23.7	2.2
Repeated	Patient-first	Active	Agent-first/Active	120	30.3	2.3	256	64.8	2.4
Repeated	Patient-first	Active	Agent-first/Passive	0	0.0	0.0	0	0.0	0.0
Repeated	Patient-first	Active	Patient-first/Active	261	65.7	2.4	127	32.1	2.3
Repeated	Patient-first	Active	Patient-first/Passive	16	4.0	1.0	12	3.0	0.9
Repeated	Patient-first	Passive	Agent-first/Active	149	37.5	2.4	199	50.8	2.5
Repeated	Patient-first	Passive	Agent-first/Passive	1	0.3	0.3	5	1.3	0.6
Repeated	Patient-first	Passive	Patient-first/Active	24	6.0	1.2	30	7.7	1.3
Repeated	Patient-first	Passive	Patient-first/Passive	223	56.2	2.5	158	40.3	2.5
Not Repeated	Agent-first	Active	Agent-first/Active	352	89.8	1.5	320	82.5	1.9
Not Repeated	Agent-first	Active	Agent-first/Passive	0	0.0	0.0	1	0.3	0.3
Not Repeated	Agent-first	Active	Patient-first/Active	22	5.6	1.2	47	12.1	1.7
Not Repeated	Agent-first	Active	Patient-first/Passive	18	4.6	1.1	20	5.2	1.1
Not Repeated	Agent-first	Passive	Agent-first/Active	180	46.9	2.5	232	59.8	2.5
Not Repeated	Agent-first	Passive	Agent-first/Passive	102	26.6	2.3	49	12.6	1.7
Not Repeated	Agent-first	Passive	Patient-first/Active	49	12.8	1.7	25	6.4	1.2
Not Repeated	Agent-first	Passive	Patient-first/Passive	53	13.8	1.8	82	21.1	2.1
Not Repeated	Patient-first	Active	Agent-first/Active	148	37.9	2.5	258	66.7	2.4
Not Repeated	Patient-first	Active	Agent-first/Passive	2	0.5	0.4	0	0.0	0.0
Not Repeated	Patient-first	Active	Patient-first/Active	221	56.5	2.5	111	28.7	2.3
Not Repeated	Patient-first	Active	Patient-first/Passive	20	5.1	1.1	18	4.7	1.1
Not Repeated	Patient-first	Passive	Agent-first/Active	185	47.6	2.5	222	57.1	2.5
Not Repeated	Patient-first	Passive	Agent-first/Passive	1	0.3	0.3	5	1.3	0.6
Not Repeated	Patient-first	Passive	Patient-first/Active	25	6.4	1.2	31	8.0	1.4
Not Repeated	Patient-first	Passive	Patient-first/Passive	178	45.8	2.5	131	33.7	2.4

Appendix K: Combined analysis of thematic role ordering in Study 3

Fixed effect	*Estimate*	*SE*	*z*	*p*
(Intercept)	−0.94	0.11	−8.66	<.001
Prime thematic role order	0.91	0.06	14.10	<.001
Prime animacy	−0.02	0.03	−0.58	.564
Target animacy	0.23	0.09	2.42	.015
Experiment (English vs. Japanese)	0.19	0.10	1.94	.052
Prime thematic role order × Prime animacy	−0.02	0.03	−0.53	.599
Prime thematic role order × Target animacy	0.06	0.06	0.97	.332
Prime animacy × Target animacy	0.08	0.03	2.47	.014
Prime thematic role order × Experiment	0.44	0.07	6.67	<.001
Prime animacy × Experiment	0.05	0.03	1.58	.114
Target animacy × Experiment	−0.26	0.10	−2.66	.008
Prime thematic role order × Prime animacy × Target animacy	0.12	0.03	3.61	<.001
Prime thematic role order × Prime animacy × Experiment	0.03	0.03	0.82	.413
Prime thematic role order × Target animacy × Experiment	0.09	0.06	1.36	.175
Prime animacy × Target animacy × Experiment	−0.03	0.04	−0.83	.409
Prime thematic role order × Prime animacy × Target animacy × Experiment	0.10	0.04	2.88	.004

Appendix L: Separate analyses of thematic role ordering in Study 3

Fixed effect	*Estimate*	*SE*	*z*	*p*
Experiment 6: English				
Analysis of prime thematic role order × prime animacy × target animacy				
(Intercept)	−0.75	0.13	−5.58	<.001
Prime thematic role order	1.36	0.12	11.80	<.001
Prime animacy	0.03	0.05	0.67	.505
Target animacy	−0.03	0.12	−0.28	.782
Prime thematic role order × Prime animacy	0.01	0.05	0.24	.813
Prime thematic role order × Target animacy	0.16	0.11	1.46	.145
Prime animacy × Target animacy	0.05	0.05	1.00	.320

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Fixed effect	*Estimate*	*SE*	*z*	*p*
Prime thematic role order × Prime animacy × Target animacy	0.22	0.05	4.62	<.001
Analysis of prime thematic role order × animacy feature repetition				
(Intercept)	−0.83	0.14	−5.82	<.001
Prime thematic role order	1.46	0.12	11.94	<.001
Animacy feature repetition	0.22	0.06	3.72	<.001
Prime structure	0.05	0.05	0.88	.381
Prime thematic role order × Animacy feature repetition	−0.48	0.05	−9.22	<.001
Prime thematic role order × Prime structure	0.23	0.05	4.52	<.001
Prime structure × Animacy feature repetition	0.01	0.05	0.12	.902
Prime thematic role order × Animacy feature repetition × Prime structure	0.02	0.05	0.37	.715
Animacy feature repeated				
Prime thematic role order	1.61	0.14	11.71	<.001
Animacy feature not-repeated				
Prime thematic role order	1.14	0.11	9.97	<.001
Experiment 7: Japanese				
Analysis of prime thematic role order × prime animacy × target animacy				
(Intercept)	−1.13	0.16	−7.27	<.001
Prime thematic role order	0.46	0.07	6.29	<.001
Prime animacy	−0.07	0.04	−1.60	.111
Target animacy	0.48	0.14	3.38	.001
Prime thematic role order × Prime animacy	−0.04	0.04	−0.97	.334
Prime thematic role order × Target animacy	−0.02	0.07	−0.34	.731
Prime animacy × Target animacy	0.11	0.04	2.47	.013
Prime thematic role order × Prime animacy × Target animacy	0.02	0.05	0.34	.733
Analysis of prime thematic role order × animacy feature repetition				
(Intercept)	−1.2	0.18	−6.86	<.001
Prime thematic role order	0.5	0.08	6.43	<.001
Animacy feature repetition	0.11	0.05	2.33	.020
Prime structure	0.38	0.08	4.86	<.001
Prime thematic role order × Animacy feature repetition	0.02	0.05	0.34	.733
Prime thematic role order × Prime structure	−0.04	0.05	−0.93	.353
Prime structure × Animacy feature repetition	0.05	0.05	1.00	.319
Prime thematic role order × Animacy feature repetition × Prime structure	0.02	0.05	0.44	.657

Appendix M: Combined analysis of function assignment in Study 3

Fixed effect	*Estimate*	*SE*	*z*	*p*
(Intercept)	−2.44	0.14	−17.19	<.001
Prime structure	1.85	0.12	15.17	<.001
Prime animacy	0.02	0.06	0.28	.782
Target animacy	0.71	0.13	5.53	<.001
Experiment (English vs. Japanese)	0.29	0.13	2.30	.022
Prime structure × Prime animacy	0.07	0.06	1.15	.249
Prime structure × Target animacy	0.13	0.11	1.14	.254
Prime animacy × Target animacy	0.05	0.06	0.92	.359
Prime structure × Experiment	0.10	0.11	0.94	.350
Prime animacy × Experiment	0.09	0.06	1.56	.118
Target animacy × Experiment	−0.28	0.13	−2.21	.027
Prime structure × Prime animacy × Target animacy	0.18	0.06	3.18	.001
Prime structure × Prime animacy × Experiment	−0.06	0.06	−0.98	.328
Prime structure × Target animacy × Experiment	0.01	0.11	0.08	.933
Prime animacy × Target animacy × Experiment	−0.03	0.06	−0.47	.640
Prime structure × Prime animacy × Target animacy × Experiment	0.06	0.06	0.96	.335

Appendix N: Separate analyses of function assignment in Study 3

Fixed effect	*Estimate*	*SE*	*z*	*p*
Experiment 6: English				
(Intercept)	−2.12	0.17	−12.42	<.001
Prime structure	1.92	0.17	11.57	<.001
Animacy feature repetition	0.05	0.07	0.62	.536
Prime thematic role order	0.17	0.08	2.02	.043
Prime structure × Animacy feature repetition	0.21	0.07	2.96	.003
Prime structure × Prime thematic role order	0.07	0.08	0.84	.403
Prime thematic role order × Animacy feature repetition	0.02	0.07	0.30	.766
Prime structure × Animacy feature repetition × Prime thematic role order	0.04	0.07	0.54	.587
Animacy feature repeated				
Prime structure	2.19	0.21	10.48	<.001

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Fixed effect	*Estimate*	*SE*	*z*	*p*
	Animacy feature not-repeated			
Prime structure	1.61	0.16	10.11	<.001
	Experiment 7: Japanese			
(Intercept)	−2.87	0.27	−10.68	<.001
Prime structure	1.86	0.17	10.72	<.001
Animacy feature repetition	0.03	0.08	0.44	.659
Prime thematic role order	−0.05	0.09	−0.59	.558
Prime structure × Animacy feature repetition	0.18	0.08	2.36	.019
Prime structure × Prime thematic role order	0.16	0.09	1.80	.073
Prime thematic role order × Animacy feature repetition	−0.02	0.08	−0.29	.776
Prime structure × Animacy feature repetition × Prime thematic role order	0.07	0.08	0.85	.393
	Animacy feature repeated			
Prime structure	2.01	0.22	9.08	<.001
	Animacy feature not-repeated			
Prime structure	1.64	0.18	8.89	<.001

Appendix O: Comparisons between Experiment 5 and Experiment 6

Fixed effect	*Estimate*	*SE*	*z*	*p*
	Comparison on thematic role order priming			
(Intercept)	−0.51	0.09	−5.53	<.001
Prime thematic role order	1.58	0.09	17.78	<.001
Animacy feature repetition	0.04	0.04	1.21	.226
Experiment (spoken vs. written)	−0.23	0.09	−2.44	.015
Prime thematic role order × Animacy feature repetition	0.18	0.03	5.10	<.001
Prime thematic role order × Experiment	−0.21	0.09	−2.46	.014
Animacy feature repetition × Experiment	0.01	0.04	0.21	.832
Prime thematic role order × Animacy feature repetition × Experiment	0.05	0.03	1.39	.165
	Comparison on argument structure priming			
(Intercept)	−1.84	0.11	−16.18	<.001
Prime argument structure	2.32	0.12	19.78	<.001
Animacy feature repetition	0.02	0.06	0.29	.775
Experiment (spoken vs. written)	−0.23	0.11	−2.10	.036
Prime argument structure × Animacy feature repetition	0.16	0.06	2.84	.004
Prime argument structure × Experiment	−0.47	0.11	−4.31	<.001
Animacy feature repetition × Experiment	0.02	0.06	0.36	.717
Prime argument structure × Animacy feature repetition × Experiment	0.05	0.06	0.95	.340

Data availability

I have shared the link to the data/codes.

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