

## Constructing dependencies with optional elements: Insights from Vietnamese

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**Abstract.** The cognitive mechanisms that underlie the phenomenon of similarity-based interference during language processing remain a controversial issue. One well-known approach attributes the source of interference to activation patterns during the retrieval process. We report research on Vietnamese that examines the possibility of similarity-based interference effects during the processing of an optional dependency between a *wh*-phrase and a Question-particle (Q-particle). In this dependency, the presence of the second element is optional. Using acceptability ratings and self-paced reading methods, we provide evidence for a retrieval-based account. We also provide evidence that a sub-part of a word – specifically, the *wh*-morpheme inside existential expressions in Vietnamese – can result in similarity-based interference. Overall, our study contributes to understanding of similarity-based interference using a previously-under-researched type of dependency, namely one where the second element is optional and thus not wholly predictable.

**Keywords.** Vietnamese; similarity-based interference; optional dependency; cue-based retrieval; *wh*-construction; question particle; self-paced reading

**1. Introduction.** The formation of dependencies between non-adjacent words is a central issue in language processing. These dependencies can hold between different kinds of linguistic elements such as subjects and verbs, or anaphors and antecedents. To understand how such dependencies are processed and represented, researchers have investigated whether they are susceptible to the presence of an interfering element between the two components of the dependency. For example, in (1), there is a dependency between the verb and the subject; the verb agrees with the subject in number. Syntactically, whether an intervening non-subject noun is present should be irrelevant. But what happens during real-time processing when another noun (e.g. the object *the middle manager(s)* in the relative clause) intervenes between the verb and its target? Psycholinguistic research suggests this noun can interfere in the retrieval process. (e.g. McElree 2006).

More specifically, in prior work, researchers have manipulated whether the *attractor* (*the middle manager(s)*) matches the feature that the verb is looking for, as in (1a) and (1c), or does not match it, as in (1b) and (1d). This configuration allows us to test for similarity-based interference. Prior psycholinguistic studies show that in ungrammatical conditions (1c and 1d), presence of a number-matching attractor (e.g. *the middle managers*) facilitates processing of the ungrammatical sentence. This is reflected in shorter reading times in eye-tracking and self-paced reading (e.g. Dillon, Mishler, Sloggett, & Phillips 2013, Wagers, Lau, & Phillips 2009).

- (1) a. *Grammatical: Singular subject + singular verb; attractor number matches verb number*  
 The new executive who oversaw the middle manager was dishonest...  
 b. *Grammatical: Singular subject + singular verb; attractor number mismatches verb number*  
 The new executive who oversaw the middle managers was dishonest...

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c. *Ungrammatical: singular subject + plural verb; attractor number matches verb number*  
The new executive who oversaw the middle managers were dishonest...

d. *Ungrammatical: singular subject + plural verb; attractor number mismatches verb number*

The new executive who oversaw the middle manager were dishonest...

(Dillon et al. 2013)

However, presence of intervening elements in the grammatical conditions (1a and 1b) has yielded less consistent results. Some studies found that presence of a number-matching attractor increases processing load, as shown by longer processing times in self-paced reading (e.g. Nicenboim, Vasishth, Engelmann, & Suckow 2018). This has been taken as evidence for inhibitory interference. However, other studies failed to find this effect (e.g. Wagers, et al. 2009).

So far, similarity-based interference has been examined in various dependency types including the subject-verb dependency exemplified in (1), antecedent-reflexive dependencies (e.g. Dillon et al. 2013; Parker & Phillips 2014), antecedent-reciprocal dependencies (e.g. Kush & Phillips, 2014), and classifier-noun dependencies (e.g. Hao et al. 2024). Importantly, these are all dependencies that require the presence of the two elements, e.g. for a verb to agree with a noun, that noun needs to be present. In the present work, we contribute to our understanding of linguistic dependency processing by exploring a dependency where the overt presence of the second element is optional: we test the real-time processing of *wh*-dependencies in Vietnamese.

In the next section, we outline the cue-based retrieval account of similarity-based interference, introduce Vietnamese *wh*-constructions as our test case, and present the two experiments.

1.1. CUE-BASED RETRIEVAL ACCOUNT: The cue-based retrieval account (e.g. Lewis & Vasishth 2005; Lewis, Vasishth & Van Dyke 2006) proposes that the formation of subject-verb dependencies and other non-adjacent dependencies involves a content-addressable search in memory (e.g. McElree 2003). Under this view, upon encountering the verb *was/were* in (1), a search process is triggered that looks for a noun phrase bearing the relevant features. For example, in (1), the verb *was* searches for two specific features, namely [+subject] and [+singular], while the verb *were* searches for [+subject] and [+plural]. These are called ‘retrieval cues’ in this account.

This model uses the Adaptive Control of Thought-Rational (ACT-R) architecture shown in (2). The probability and latency (speed) of retrieving from memory item  $i$  is determined by its activation level ( $A_i$ ). This  $A_i$  is calculated by summing up the base-level  $B_i$  (a function of decay), the spreading activation  $S_i$ , the mismatch penalty  $P_i$ , and the Gaussian noise  $\epsilon_i$ . The item that is successfully retrieved is the one with the highest activation level; and the latency to retrieve it is a function of its activation level,  $A_i$ . The spreading activation  $S_i$  will decrease as the number of matching features for each cue increases, which results in inhibitory interference.

$$(2) \quad A_i = B_i + S_i + P_i + \epsilon_i, \text{ where } \epsilon_i \sim \text{Normal}(0, \sigma)$$

Let us now see how this applies to contexts like those in (1). In the grammatical conditions (1a) and (1b), this account predicts inhibitory interference when the attractor matches the target (attractor-match condition, (1a)), compared to conditions where the attractor does not match the target in number (1b). This is reflected in longer reading times and lower acceptability ratings (e.g. McElree 2006). In the attractor-match condition, there are two nouns that match the [+singular] cue that the verb *was* is searching for (*the new executive* and *the middle manager*), so this similarity is predicted to interfere and lead to more errors in processing and production. Sentences like (1b), conversely, only have one item that matches the features (*the new executive*

match both [+singular] and [+subject], while *the middle managers* does not match any of these). Thus, these are predicted to be easier to process, as there are no similar elements to interfere.

In ungrammatical conditions (1c and 1d), the cue-based retrieval account predicts that effects of interference are facilitatory. Again, upon encountering a verb like *were*, a search is triggered for [+subject] and [+plural] features. In a sentence like (1c), the target and the attractor each have one feature that matches the cue (*the new executive* bears [+subject] while *the middle managers* bears [+plural]). These two searches happen at the same time and in parallel, and thus, trigger a race process between the two features to be realized or matched at the retrieval site (the verb *was* in this example). This facilitates the process compared to the other ungrammatical condition (1d), where neither option matches the [+plural] feature and only *the new executive* matches the [+subject] cue.

1.2. WH-CONSTRUCTIONS IN VIETNAMESE: Unlike *wh*-fronting languages like English, Vietnamese is a *wh*-in-situ language. Thus, in a *wh*-question, the *wh*-phrase stays in its base position as in (3). Questions in Vietnamese can be formed with *or* without the final Q-particle *thế*, as shown in (3) (e.g. Tsai 2009). Without an overt Q-particle, the *wh*-phrase *ai* ‘who’ in Vietnamese is ambiguous: it can take lower scope in the embedded clause and function as a relative clause pronoun, or it can take higher scope over the whole sentence to form a question as in (4a). However, the presence of the Q-particle *thế* (ex.4b) means that only an interrogative interpretation is possible.

- (3) Lan đã ăn cái gì (thế)?  
 Lan PST eat what (Q-particle)?  
 ‘What did Lan eat?’
- (4) a. Lan đã thấy ai đi ra ngoài?  
 Lan PST see who go out side?  
 ‘Lan saw who has gone out.’  
 ‘Who was X such that Lan saw x go out?’
- b. Lan đã thấy ai đi ra ngoài thế?  
 Lan PST see who go out side Q-particle?  
 ‘Who was X such that Lan saw x go out?’

It is also important to note that *wh*-phrases in Vietnamese are part of indefinite existentials. When the *wh*-phrase combines with the distal demonstrative *đó* ‘that,’ this yields an indefinite interpretation (Tran & Bruening 2013). For example, when the *wh*-phrase *ai* ‘who’ is combined with *đó* ‘that,’ the resulting word *ai đó* means ‘somebody.’ Similarly, the *wh*-phrase *cái gì* ‘what’ combined with *đó* ‘that’ means ‘something’, and the *wh*-phrase *ở đâu* ‘where’ combined with *đó* ‘that’ means ‘somewhere’.

When the *wh*-phrase is combined with these other elements, it cannot receive an interrogative interpretation. This is shown in (5). Example (5a), with the presence of the Q-particle to force an interrogative interpretation, is ungrammatical. In contrast, example (5b), without the Q-particle, can only be interpreted as ‘Somebody has just gone out,’ although *ai đó* contains a *wh*-phrase. In short, *ai đó* ‘somebody’ in Vietnamese, although containing *ai* ‘who’, is not a *wh*-expression and has only an existential interpretation.

- (5) a. \*Ai đó đã ra ngoài thế?  
 \*Who that PST go out Q-particle?
- b. Ai đó đã ra ngoài.  
 Who that PST go out.

‘Somebody went out.’

The properties of Vietnamese questions provide an interesting testing ground for similarity-based interference for the following three reasons.

First, the overt Q-particle provides allows us to test whether we can observe similarity-based interference between the Q-particle and a preceding *wh*-phrase. Only a limited number of studies have examined this type of dependency in *wh*-in-situ language. Using self-paced reading, Xiang et al. (2015) found evidence in Chinese for similarity-based interference between a *wh*-phrase and an invisible Q-operator (introduced by predicate like ‘wonder’). In our study, however, we examine the dependency between the *wh*-phrase and a morphologically overt element (the Q-particle), allowing exploration of the nature of dependency formation in a previously-under-researched configuration.

Additionally, as the Vietnamese Q-particle is optional and occurs at the end of the sentence, there should be no predictive processing involved. As the Q-particle is not compulsory in Vietnamese, when a person reads a sentence like (6), at the point where they encounter the *wh*-phrase *cái gì* ‘what’, they can interpret it either as a relative pronoun or an interrogative *wh*-phrase. Even if it is interpreted it as an interrogative, the reader is not able to reliably predict an upcoming Q-particle, because the interrogative interpretation can also be achieved without Q-particle (as in examples 3, 4 and 6 below). Therefore, a comprehender can only start to build a dependency when they encounter the Q-particle at the end of the sentence, Thus, this process is expected to only involve retrieval, not prediction.

- (6) Lan biết cái gì đã được chuyển ra khỏi căn phòng (thế)?  
Lan know what PST PASS move out of the room (Q)?  
‘Who was X such that Lan saw X moved the table this morning?’

Lastly, unlike prior work on similarity-based interference which used features possessed by the target and distractor elements, such as [+plural], [+subject], and [+animacy] (e.g. Dillon et al 2013) – i.e., retrieval cues accessible during search, assuming a content-addressable architecture – we manipulated a morphological cue by introducing the attractor *ai đó* (who-that) ‘somebody’, which contains the *wh*-phrase *ai* ‘who’ but does not allow an interrogative interpretation.

1.3. *AI ĐÓ* ‘SOMEBODY’ AS A POTENTIAL ATTRACTOR IN SIMILARITY-BASED INTERFERENCE. Before continuing to the details of our study, it is important to discuss why we think it is plausible that *ai đó* ‘somebody’ could function as an attractor during the retrieval process triggered by the Q-particle. In other words, what provides the grounds for the idea that the sub-part *ai* ‘who’ of the word *ai đó* ‘somebody’ (who-that) can cause interference during the retrieval process?

Here, we build on a large crosslinguistic literature on morphological processing of compound nouns and morphologically complex words. Existing theories (e.g., Schreuder & Baayen, 1995; Pollatsek, Hyönä, & Bertram 2000) propose that morphologically complex words can be interpreted through two parallel competing pathways: the holistic route (whole word processing) or the decomposition route. In the decomposition route, a morphologically complex word is initially broken down into its constituent morphological parts, followed by recognition through accessing these components. This route can operate concurrently with the holistic route, and if the decomposition route is faster, the word is recognized that way. Take the word *unhappiness* as an example. This word can be processed either via the holistic route as *unhappiness* or via the decomposition route by splitting it into *un-*, *happy*, *-ness*. The two pathways are activated at the same time and the final word will be recognized via the fastest route. The speed of activation depends on other factors like frequency of the word and the elements inside (e.g. Cui, et al. 2017).

This proposal was later extended for compound nouns (Ji, Gagné, & Spalding 2011). Ji et al.'s findings show that readers engage with the individual components of compound words during recognition. This process enhances processing speed compared to monomorphemic words, likely because the constituents of the compounds have higher frequency than monomorphemic words.

In our design, both *ai* 'who' and *đó* 'that' have very high frequencies in Vietnamese compared to the frequency of the combined word *ai đó* 'somebody'. For instance, in the Vietnamese web corpus viWaC (available on Sketch Engine, consisting of online texts, 100 million words), *ai đó* 'somebody' has a frequency of only 5.012 occurrences per million words (pmw), while *đó* 'that' has a frequency of 525.012 pmw and *ai* 'who' has a frequency of 124.492 pmw. This asymmetry suggests that the decomposition route is likely fastest when comprehenders process *ai đó*. This suggests that it is likely that both *ai* 'who' and *đó* 'that' are activated when a comprehender encounters *ai đó*. Consequently, we think it is plausible that *ai* 'who' might be activated and able to function as a competitor (attractor) during the retrieval process triggered when the comprehender encounters the Q-particle. Thus, we treat *ai đó* as being [+wh-morpheme], but as lacking a [+interrogative] feature (see Section 2.2). We test this idea empirically in our study, to see if a sub-part of a word can act as an attractor during dependency formation.

1.4. CURRENT STUDY. Our study has two primary goals: (1) to contribute to the understanding of similarity-based interference by examining an under-researched type of dependency, namely one where the second element is optional, and (2) to examine whether a sub-part of a word can be an attractor in the traditional similarity-based interference paradigm.

Regarding goal (1), we note that, to the best of our knowledge, the dependencies examined in configurations involving potential similarity-based interference (in prior experimental work) have involved a compulsory element at the retrieval site (e.g. a reflexive pronoun in antecedent-reflexive dependency or a verb in subject-verb agreement) – in other words, researchers looked at structures where, if there's a dependency to be built, it's triggered by an overt element present at the retrieval site. In our study, the Q-particle is optional, as interrogative interpretation can be derived from the *wh*-phrase alone. This optionality may reveal distinct processing patterns, prompting us to test whether cue-based retrieval can account for what we observe.

Regarding goal (2), we note that instead of using features possessed by the target and attractor nouns (e.g., [+plural], [+animacy], i.e., retrieval cues accessible in a content-addressable architecture), our study uses a morphological element as an attractor cue to interfere between the retrieval site (Q-particle) and the target (interrogative *wh*-phrase). Building on the morphological processing model (Schreuder, et al. 1995), we used a low-frequency compound containing a *wh*-phrase as the attractor in our design. We hypothesize that the *wh*-phrase inside the compound, although it cannot form a question interpretation, will be activated due to its high frequency and thus can interfere in the retrieval process.

Next, we present two experiments: Experiment 1 is an acceptability judgment task that examines offline processing and Experiment 2 is a self-paced reading examining the incremental processing of the dependency between the *wh*-phrase and the Q-particle in Vietnamese.

**2. Experiment 1: Acceptability judgment task.** We conducted an acceptability judgment task with two aims. First, we test to what extent speakers accept *ai đó* (who-that) 'somebody' as a *wh*-phrase to form a question with Q-particle. Given native speaker intuitions, we expect such sentences to be degraded/less than fully acceptable. Second, we test for potential effects of similarity-based interference in a task with no timing constraints, to see if we can find gradient effects on acceptability ratings.

2.1. PARTICIPANTS: 47 adult Vietnamese native speakers participated in exchange for \$2.05 Tiki gift cards. The study took around 15 minutes. The studies reported in this paper were all reviewed and approved by the Institutional Review Board of the University of Southern California.

2.2. MATERIALS: We constructed 32 target sets and 50 filler items. Each target set contained 4 conditions in a 2x2 design manipulating Grammaticality (grammatical vs. ungrammatical) and Attractor type (match vs. mismatch). This design yields four conditions, as in (7).

In the grammatical conditions (grammatical-attractor match and grammatical-attractor mismatch as shown in (7a, b)), the dependency will be built between the Q-particle *thế* at the end and the interrogative *wh*-phrase *cái gì* ‘what’. This *wh*-phrase is introduced in the embedded clause following the main verb. For main verbs, we used neutral predicates that can take either interrogative or declarative complement like *biết* ‘know’, *thấy* ‘see’, *hiểu* ‘understand’, and *nhớ* ‘remember’. This setup ensures that when the *wh*-phrase is first encountered, it is ambiguous between a relative pronoun construal and an interrogative *wh*-phrase construal.

(7) a. *Condition 1: Grammatical – Attractor match (Gram-match)*

“An biết cái gì đã được ai đó chuyển ra khỏi căn phòng thế?”  
 “An know what PST PASS who that move out of the room Q?”  
 , chàng trai thì thầm.  
 , the boy whisper.  
 ‘What was X such that An knew X was moved out of the room by someone?’, whispered the boy.

b. *Condition 2: Grammatical – Attractor mismatch (Gram-mismatch)*

“An biết cái gì đã được tổ trưởng chuyển ra khỏi căn phòng thế?”  
 “An know what PST PASS manager move out of the room Q?”  
 , chàng trai thì thầm.  
 , the boy whisper.  
 ‘What was X such that An knew X was moved out of the room by the manager?’, whispered the boy.

In these conditions, we treat the *wh*-phrase *cái gì* ‘what’ as bearing both the [+interrogative] and [+wh-morpheme] features. When encountering the Q-particle at the end of the sentence, the parser starts to retrieve and look for these [+interrogative] and [+wh-morpheme] cues, which will be found at *cái gì* ‘what’. In the grammatical-attractor match condition, this retrieval process is intervened by *ai đó* ‘somebody’ (who-that). Crucially, we treat this element as containing a [+wh-morpheme] feature but not an [+interrogative] feature. In the grammatical-attractor mismatch condition (7b), the compound *ai đó* ‘somebody’ (who-that) is replaced by an occupation noun, e.g. *tổ trưởng* ‘the manager’. Thus, in this condition, the retrieval process from Q-particle to the target *cái gì* ‘what’ is not interfered by any elements with similar features.

Ungrammatical conditions (ungrammatical-attractor match, ungrammatical-attractor mismatch) were created by replacing the *wh*-phrase *cái gì* ‘what’ with a noun (e.g. *cái bàn* ‘the table,’ (7c,d)), which contains none of the features that the Q-particle is looking for.

(7) c. *Condition 3: Ungrammatical – Attractor match (Ungram-match)*

“An biết cái bàn đã được ai đó chuyển ra khỏi căn phòng thế?”  
 “An know table PST PASS who that move out of the room Q?”  
 , chàng trai thì thầm.  
 , the boy whisper.  
 \*‘An knew the table was moved out of the room by someone?’, whispered the boy.

d. *Condition 4: Ungrammatical – Attractor mismatch (Ungram-mismatch)*

“An biết cái bàn đã được tổ trưởng chuyển ra khỏi căn phòng thế?”  
“An know table PST PASS manager move out of the room Q?”

, chàng trai thì thầm.

, the boy whisper.

\*“An knew the table was moved out of the room by the manager?”, whispered the boy.

This design is different from the typical similarity-based interference set-up we saw in (1). In the configuration in (1), in ungrammatical conditions, the target contains one of the cues that the retrieval process is looking for, the [+subject] feature. However, in our design, at the position of the target in the grammatical conditions, the noun contains neither the [+wh-morpheme] nor the [+interrogative] feature. In the ungrammatical-attractor mismatch condition (7d), there are no items that match the retrieval cues, while in the ungrammatical-attractor match condition (7c), we assume that the attractor *ai đó* ‘somebody’ (who-that) bears the [+wh-morpheme] feature.

We use these same stimuli in the self-paced reading study (see Section 3.1). In order to extend the spill-over region to detect any effects after the critical region (the Q-particle), we used direct speech and inserted phrases like ‘whispered the boy,’ as in (7). All of the targets were in passive voice. This allows the attractor to interfere between the target and the Q-particle.

2.3. PROCEDURE: The Experiment was conducted using Qualtrics software (Provo, UT, USA). Participants were instructed to rate the acceptability of each sentence using a 1-7 scale (7 = completely acceptable, 1 = completely unacceptable). Sentences were displayed as a whole on the screen along with the 1-7 scale. Each item was shown on a separate screen. Prior to the main experiment, participants answered some questions relating to their language background, and completed four practice trials.

2.4. PREDICTIONS: We expect to observe a main effect of grammaticality, because *ai đó* ‘somebody’ is not a *wh*-expression and thus, the presence of the Q-particle at the end of the sentence yields ungrammaticality when there are no *wh*-expressions in the sentence.

The cue-based retrieval account predicts inhibitory interference in grammatical conditions and facilitatory interference in ungrammatical conditions. In grammatical conditions, an attractor that matches the same cue sought by the Q-particle might interfere with the retrieving process and thus can render the grammatical-attractor *match* condition less acceptable than the grammatical-attractor *mismatch* condition. In ungrammatical conditions, our setup is different from the traditional setup but we still predict the same basic pattern of results. Specifically, in the ungrammatical-attractor *match* condition, the Q-particle can find at least one ‘*wh*-phrase’ cue, while in the ungrammatical-attractor *mismatch* condition it can find nothing. This should make the penalty mismatch ( $P_i$ ) in the ungrammatical-attractor mismatch condition higher than in the ungrammatical-attractor match condition. The larger the  $P_i$ , the more negative the impact on the item’s activation level. As a result, the ungrammatical-attractor match condition should be more acceptable than the ungrammatical-attractor mismatch condition.

2.5. DATA ANALYSIS AND RESULTS: Raw acceptability scores were z-score transformed to normalize the data. Fig.1 illustrates the average z-scored ratings for the four conditions, and Fig.2 shows the average raw rating scores. Visual observation suggests that the grammatical conditions are rated more acceptable than ungrammatical conditions, as we predicted.

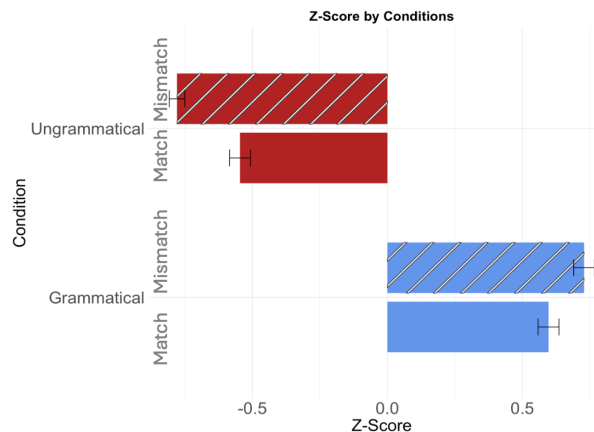


Figure. 1 Exp. 1 Average Z-scores

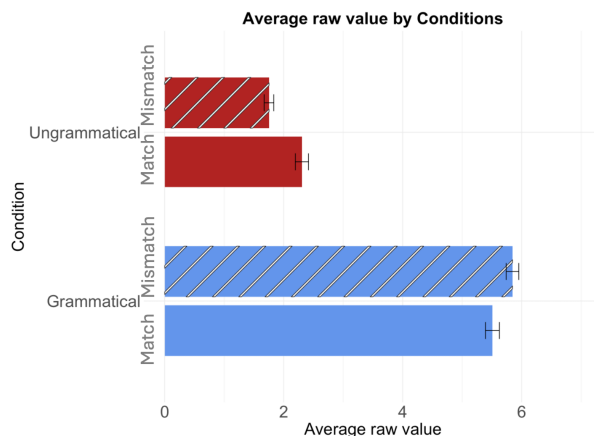


Figure. 2: Exp. 2 Average raw scores

In the statistical analyses, we used the raw scores (to avoid singularity errors) and analyzed them using mixed effects models (*lmer*, version 3.1-1, Kuznetsova et al. 2017). We first fitted a full model with all possible random slopes and intercepts by subject and item with Grammaticality and Attractor as two main predictors. We took out the random slopes (started with by-item effects) until the model converged. Via model comparison, we kept only those that have significant effects ( $p < 0.05$ ) on the model (Baayen et al. 2008). The final model includes main effects of grammaticality, attractor and their interaction, and random effects include random intercept by items and random intercept by subjects.

We found a main effect of grammaticality ( $\beta = -3.64$ ,  $p < 0.0001$ ). Grammatical conditions are rated more acceptable than ungrammatical conditions. We also found an interaction between grammaticality and attractor ( $\beta = -0.89$ ,  $p < .001$ ). There was no main effect of Attractor.

Given the presence of an interaction, planned comparisons were conducted. A main effect of attractor is found in grammatical conditions ( $\beta = 0.35$ ,  $p < 0.5$ ): Grammatical conditions with attractor match are rated less acceptable than those with attractor mismatch. In ungrammatical conditions, a main effect of Attractor ( $\beta = -0.54$ ,  $p < 0.01$ ) indicated a reverse pattern: In ungrammatical conditions, the attractor match was rated more acceptable than attractor mismatch.

2.6. DISCUSSION: Experiment 1 investigated whether *ai đò* (‘somebody’) can be used to form questions with a Q-particle in Vietnamese and tested for possible similarity-based interference effects in the offline processing of the dependency between the *wh*-phrase and the Q-particle.

The main effect of Grammaticality shows that sentences that contain a Q-particle but lack the interrogative *wh*-phrase *cái gì* ‘what’ are rated significantly less acceptable than sentences with this *wh*-morpheme. This confirms our expectation that *ai đò* ‘somebody’ (who-that) cannot replace an interrogative *wh*-morpheme – in other words, the *wh*-element inside an existential expression cannot be used to form a question interpretation with the Q-particle.

More importantly for our research question, Experiment 1 found facilitatory interference in ungrammatical conditions and inhibitory interference in grammatical conditions. First, let’s consider ungrammatical conditions. Here, presence of the existential *ai đò* (who-that) ‘somebody’ – which contains the *wh*-morpheme (*ai* ‘who’) – results in higher acceptability ratings relative to sentences without this expression (with regular nouns). We take this as evidence that the *wh*-element inside the existential facilitates processing of the Q-particle and that this makes the ungrammatical condition more acceptable compared to its counterpart with a regular noun.

Furthermore, our data also suggests that the presence of the *wh*-element inside the existential also has consequences for the processing of grammatical sentences: we found that the

grammatical match-attractor match condition is less acceptable than grammatical match-attractor mismatch condition. These patterns align with the predictions of the cue-based retrieval account. Thus, in Experiment 1, we find evidence for similarity-based interference in a new type of dependency, which supports the cue-based retrieval account.

As a whole, these results suggest that a sub-part of a word can function as an attractor in the similarity-based interference setup. We take our data as suggesting that the existential *ai đố* ‘somebody’, it although cannot form interrogative interpretation, triggers the activation of *ai* ‘who’, which interferes in the dependency forming process.

Although many studies found that interference effects are less robust in offline tasks (Lewis & Phillips 2015; Parker 2019), the fact that we found clear effects of both inhibitory and facilitatory interference is intriguing. This might stem from the kind of dependency that we are examining (between the Q-particle and the *wh*-morpheme) or the optionality of the second element in this dependency.

In the next experiment, we examine this dependency using an online task to better understand the magnitude and timing of the effects. Furthermore, in Experiment 1, participants saw the whole sentence and had no time limits, which means they could reanalyze and re-read the sentence if they wanted to. In Experiment 2, using self-paced reading, we examine this dependency during real-time processing to see when these effects occur.

**3. Experiment 2: Self-paced reading.** Findings from Experiment 1 confirm that a sentence with *ai đố* (who-that) ‘somebody’ and a Q-particle in Vietnamese cannot be interpreted as a grammatically acceptable question. Importantly, Experiment 1 also suggests that *ai đố* ‘somebody’ can function an attractor that interferes in the retrieval process triggered by the Q-particle. This is novel evidence that a sub-part of word can interfere in the cue-based retrieving process and function as an attractor that causes similarity-based interference. The findings from Experiment 1 also support cue-based retrieval accounts, as the acceptability judgments point to inhibitory interference in grammatical and facilitatory interference in ungrammatical conditions. In Experiment 2, we examine the effects found in Experiment 1 in incremental processing using an online task, self-paced reading (SPR).

3.1. PARTICIPANTS AND MATERIALS: 84 native Vietnamese speakers were recruited at FPT University in Vietnam in exchange for a \$2.05 gift card to the online store Tiki. These participants were separate from those in Experiment 1. The targets were the same as in Experiment 1. Fifty new fillers were created for Experiment 2, balanced between ambiguous and unambiguous sentences.

3.3. PROCEDURE: The experiment used self-paced-reading, implemented in PCIBEX (Zehr & Schwarz 2018; <https://www.pcibex.net/>). Prior to the main study, participants completed some questions regarding their language background and did three practice items. Each sentence was presented word-by-word in the center of the screen. After each sentence, participants answered a comprehension question. The questions were designed so that they asked about different regions of the sentence, to encourage participants to pay attention to the whole sentence.

3.4 PREDICTIONS: As we discussed for Experiment 1, the cue-based retrieval account predicts that encountering the sentence-final Q-particle triggers a search for an item with [+wh-morpheme] and [+interrogative] features. In the grammatical-attractor match condition, the presence of another item that contains the [+wh-morpheme] is predicted to slow down processing. This slowdown is expected to occur at or after the Q-particle. As a result, relative to the grammatical-attractor *mismatch* condition, there might be slowdowns after the Q-particle in the grammatical-attractor *match* condition. What about ungrammatical conditions? In the ungrammatical-attractor

*match* condition, the attractor *ai dō* ‘somebody’ (who-that) satisfies one of the two cues that the Q-particle is searching for, and thus might facilitate the process compared to the ungrammatical-attractor *mismatch* condition where there no element with even partially matching features. In other words, we might observe faster reading times after the Q-particle in the ungrammatical-attractor match condition compared to the ungrammatical-attractor mismatch condition.

3.5 DATA ANALYSIS AND RESULTS: Prior to data analysis, reading times above 4000ms and below 100ms were removed, which resulted in the removal of 13% of the data. Statistical analyses were conducted in R (Baayen et al. 2008; R Core Team 2015, see also Baayen 2008). Raw RTs were log-transformed before analysis. We analyzed the critical word (the Q-particle), as well as the following four spillover regions (SR 1-4) to detect potential spill-over effects. For each region, mixed-effects linear regression models (*lmer*, version 3.1-1, Kuznetsova et al. 2017) were fitted with grammaticality and attractor as the fixed-effect predictors. These two-level categorical predictors were contrast-coded (ungrammatical = -0.5, grammatical = 0.5; and attractor mismatch = -0.5, attractor match = 0.5). The final model includes main effects of grammaticality, attractor and their interaction, and random effects include random intercept by items and random intercept by subjects.

Fig.3 shows the averaged word-by-word reading times (RTs) for the four conditions, starting with the region preceding the Q-particle and ending with the fourth spillover region.

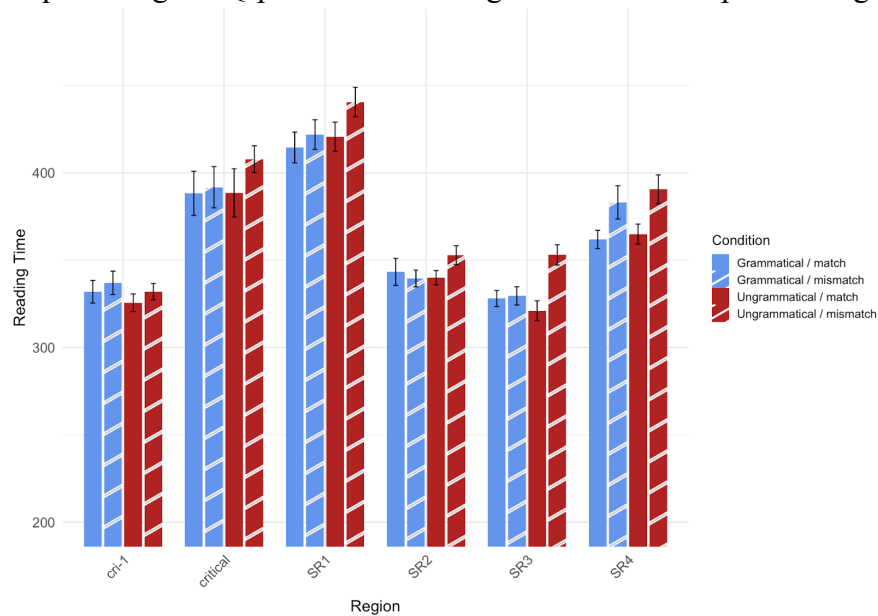


Figure 3. Average RTs in the four conditions (from the region preceding the critical word until the fourth spillover region)

Visually, Figure 3 suggests that only the ungrammatical-attractor mismatch condition (fourth bar in each group) was read more slowly than the other conditions. The effect numerically starts at the Q-particle (critical region) and reaches significance at spillover region 3. Statistical analyses show that at spillover region 3 (SR3), there is a main effect of grammaticality ( $\beta = -0.02, p < .05$ ) as expected – ungrammatical sentences are read more slowly than grammatical sentences – as well as a significant interaction between grammaticality and attractor type ( $\beta = 0.05, p < .05$ ). We used planned comparisons to further understand the interaction effect. At spillover region 3, in the ungrammatical conditions, reading times are faster in the attractor match conditions than in the attractor mismatch conditions (a main effect of attractor,  $\beta = 0.04, p < .05$ ).

In other words, when the intervening expression is the existential *ai đố* ‘somebody’ (who-that) (which crucially has a *wh*-expression inside it), reading times downstream of the Q-particle are faster compared to conditions where the intervenor lacks any kind of expression containing a *wh*-word. In grammatical conditions, planned comparison reveal no significant effect of attractor ( $\beta=-0.0005$ ,  $p=0.7$ ).

3.6 DISCUSSION: Experiment 2 used self-paced reading to explore the real-time processing of Vietnamese sentences involving a dependency between a Q-particle and a *wh*-phrase, to see whether we can find evidence of similarity-based interference. Analyses of reading times (RTs) provide initial evidence for facilitatory interference in ungrammatical conditions, which is predicted cue-based retrieval account. Specifically, we find hints that the ungrammatical condition without a matching attractor is processed slower than the other three conditions. While we see numerical hints of this starting already at the Q-particle, the effect reaches significance at spillover region 3. Planned comparison confirmed the effect of attractor in ungrammatical conditions. Noticeably, ungrammatical conditions with a matching attractor are read as fast as the grammatical conditions. The partially matching feature of *ai đố* ‘somebody’ (who-that) might have satisfied the requirements of the Q-particle and thus, facilitated processing.

We also found the predicted effect of grammaticality, such that ungrammatical sentences were read more slowly than grammatical sentences, at spillover 3. This grammaticality effect provides a sanity check indicating that participants were indeed paying attention to the sentences.

In grammatical conditions, however, we did not find inhibitory interference in the presence of a partially matching distractor. Numerically, in the critical region (the Q-particle), the matching attractor seemed to facilitate processing: the grammatical-attractor match condition is read numerically faster than the grammatical-attractor mismatch condition. However, this difference is not statistically significant. After the critical region Q-particle, the two grammatical conditions are read approximately equally quickly.

In sum, Experiment 2 points to facilitatory interference effects in ungrammatical conditions but did not detect any interference effects in grammatical conditions. This asymmetry has also been observed in subject-verb attraction (e.g. Wagers et al, 2009) and processing of ellipsis (Parker 2022), and we return to it in the General Discussion. Furthermore, Experiment 2 corroborates the results of Experiment 1 in showing that the sub-part of a word (*ai* ‘who’ in *ai đố* ‘somebody’) can function as an attractor that causes similarity-based interference.

**4. General discussion.** The two experiments reported in this paper have two main aims. First, we examine similarity-based interference during the processing of a dependency between a *wh*-phrase and an optional Q-particle in Vietnamese questions. Second, we test whether, in addition to well-known interference effects resulting from attractors matching in terms of featural cues like number, we can also detect interference in a situation where it’s the sub-part of a word that is associated with the relevant features. In Experiment 1, which used an acceptability judgment task, we found inhibitory interference in grammatical conditions and facilitatory interference in ungrammatical conditions. In particular, grammatical conditions with a matching attractor (*ai đố* ‘somebody’) were rated *less* acceptable than attractor-mismatch conditions, while ungrammatical conditions with a matching attractor were rated *more* acceptable than attractor-mismatch conditions. Experiment 2 used self-paced reading to examine incremental processing and to explore when these effects occur. The results show that ungrammatical conditions with a matching attractor (*ai đố* ‘somebody’) were read as fast as grammatical conditions, which points to

facilitatory interference in ungrammatical conditions. In short, Experiment 1 found both inhibitory interference in grammatical conditions as well as facilitatory interference in ungrammatical conditions, while Experiment 2 found only facilitatory effects in ungrammatical conditions.

These results point to two main conclusions, one concerning the question of what can act as an attractor to trigger similarity-based interference, and another concerning the processing of dependencies where the second element (the ‘tail’ of the dependency) is optional.

First, the results show that the features of a sub-part of a word or a morphological element can, under appropriate conditions, cause similarity-based interference. In our design, *ai đó* was used as the attractor. This element, although it contains the word *ai* ‘who’, only has the existential interpretation ‘somebody’ and does not allow interrogative interpretation even when combined with the Q-particle *thế*. Nevertheless, our results suggest that the *wh*-word inside this existential expression is capable of triggering similarity-based interference when comprehenders encounter the Q-particle which triggers the search for a [+wh] feature. This finding is intriguing, as it suggests that a feature that is not part of the ultimate meaning of the compound word – recall that *ai đó* is semantically and syntactically an indefinite existential, not a *wh*-word – can nevertheless interfere during dependency formation. This goes beyond prior work which focused on features such as gender and number, which are expected to be available in a content-addressable search architecture.

Although our findings seem surprising, we regard it as compatible with prior work on morphological processing. It is widely agreed that morphologically complex words can be processed holistically or via decomposition (e.g. Schreuder & Baayen, 1995) (see Section 1.3). Building on this, we assume that there are two routes for the recognition of the compound word *ai đó* ‘somebody’: holistic (whole word) ‘somebody’ and decomposition (sub-components) *ai* ‘who’ and *đó* ‘that’. Given that *ai* and *đó* are more frequent than the compound *ai đó* ‘somebody’, decomposition is expected to be faster and be chosen. This predicts the activation of *ai* ‘who’ during *ai đó* processing. Our findings suggest that *ai*’s *wh*-feature becomes sufficiently activated to interfere with dependency formation. Thus, the observed similarity-based interference supports the idea that the activation of *ai* ‘who’ and its [+wh-morpheme] feature disrupts retrieval of the target *cái gì* ‘what’, during the retrieval process triggered by the Q-particle.

More broadly, these findings suggest that, apart from cues such as number and gender that are well-known to be accessible in content-addressable searches, other cues can also cause similarity-based interference. Further research is needed to confirm our finding, using different types of ‘word sub-parts’ and different types of similarity.

The second main conclusion we want to highlight concerns the nature of the dependency that we investigated. The two experiments reported here provide evidence for similarity-based interference in a what one might call an ‘optional’ dependency. Previous work on retrieval in sentence processing mainly focuses on obligatory dependencies, where the presence of two elements is required to construct the meaning of the sentence (see Jaeger et al. 2017 for a review).

Results from our two experiments align with the predictions of the cue-based retrieval account. In grammatical conditions, the cue-based retrieval account predicts inhibitory interference, which was found in Experiment 1. In the grammatical-attractor match condition, while looking for the [+wh-morpheme] and [+interrogative] features, the Q-particle was interfered by *ai đó* ‘somebody’, which contains the [+wh-morpheme] *ai* ‘who’. This similarity makes the activation level of the target *cái gì* ‘what’ lower than its counterpart in the grammatical-attractor mismatch condition. Therefore, the grammatical-attractor match condition is more difficult to process or comprehend, which explains the lower acceptability ratings we found. The facilitatory

interference predicted by the cue-based retrieval account was also found in both Experiments 1 and 2. However, the explanation for this interference in our setup might be different from the typical setup.

In traditional similarity-based interference studies, the target in ungrammatical conditions still contains one of the retrieval cues, whereas in our study, the target *cái gì* ‘what’ was replaced by a noun like *cái bàn* ‘table’ in the ungrammatical conditions, which contains none of the cues sought by the Q-particle. Thus, the explanation of facilitatory effects in ungrammatical conditions using the race process of two searches (see e.g. Jäger et al. 2020) might not apply in our setup. However, the activation formula (see (2)) from the cue-based retrieval account still provides a possible explanation for the facilitatory interference we observed. The ungrammatical-attractor match condition with *ai đó* ‘somebody’ (who-that) provides one feature that satisfies the retrieval process, which makes the mismatch penalty  $P_i$  of the ungrammatical-attractor match condition slightly lower than that of the ungrammatical-attractor mismatch condition, where no cues are matched at all. The lower  $P_i$  adds less negative impact to the activation, making the item easier to activate. Thus, in the ungrammatical-attractor match condition with lower  $P_i$ , the retrieval process is facilitated. Thus, this line of reasoning captures the results we obtained.

An intriguing open question is the asymmetry we found between online and offline tasks. The fact that we observed clearer effects in the offline task than in the online task deviates from previous findings in the similarity-based interference literature. Typically, online measures yield more robust effects than offline tasks (e.g. Parker, 2022; Hammerly et al., 2019).

One possible explanation for this discrepancy lies in differences across processing stages. Because the Q-particle is optional in Vietnamese (i.e. not reliably predictable), the link between the *wh*-word and the Q-particle may be somehow weaker. Thus, encountering a Q-particle may not serve as a strong, automatic retrieval cue in Vietnamese. If this reasoning is on the right track, it may be that at early stages of processing, the parser is superficially satisfied by the presence of a preceding *wh*-word, without engaging in a full retrieval of its licenser. Thus, in Experiment 2 (self-paced reading), when encountering the *wh*-phrase *cái gì* ‘what’, participants might start to anticipate an interrogative interpretation, *without* actively expecting a Q-particle. Under this view, since the Q-particle is *optional*, participants do not actively ‘wait’ for it. Thus, when they do encounter the Q-particle, retrieval of the *wh*-phrase might not occur, which would explain the lack of observed effects. Another way to think of this might be as a type of ‘Good-Enough’ processing strategy (e.g., Ferreira et al., 2022).

Furthermore, it seems reasonable to posit that, at later processing stages participants have more time for deeper analysis or re-analysis. Under this line of thinking, in the offline acceptability judgment task (Experiment 1), when participants could re-read the entire sentence without time constraints, they could reanalyze the structure and attempt to form the correct dependency between the Q-particle and the *wh*-phrase *cái gì* ‘what.’ It seems plausible that this deeper processing can increase the likelihood of forming a dependency between the Q-particle and the *wh*-phrase, thereby resulting in the observed interference effects. This line of reasoning thus explains why inhibitory interference in grammatical conditions and facilitatory interference in ungrammatical conditions emerged more clearly in our offline data.

**5. Conclusion.** In two experiments, one using self-paced reading and one using acceptability judgments, we found evidence for similarity-based interference during the formation of a dependency between a Q-particle and a *wh*-phrase in Vietnamese. Specifically, in online processing, facilitatory interference was found in ungrammatical conditions. In an offline task,

we found inhibitory interference in grammatical conditions as well as facilitatory effects in ungrammatical conditions. As a whole, our findings align with the cue-based retrieval account and the one-system hypothesis in language processing (Hammerly & Phillips 2014; Parker 2019). We also found that offline data shows stronger interference effects than online data, which may seem surprising. We suggest that this difference may stem from the interplay of (i) the optional nature of the Q-particle in Vietnamese and (ii) cognitive constraints on processing.

Our work adds to the still-limited literature on similarity-based interference in the processing of *wh*-dependencies in *wh*-in-situ languages. Our results are compatible with Xiang et al.'s (2015) work on Chinese, showing that similarity-based interference can also occur in an in-situ language. While their work demonstrated interference between a *wh*-phrase and a covert Q-operator within the syntactic structure, our results reveal similar effects between a *wh*-phrase and an overt Q-particle. Furthermore, our results go beyond prior work by showing that similarity-based interference can arise even in dependencies involving an optional element.

Another key part of our findings has to do with the observation that an overt morphological element (the *wh*-expression inside the Vietnamese existential) can interfere in the retrieval process between the Q-particle at the retrieval site and the target word *cái gì* 'what.' A more detailed investigation of the implications of this finding for theories of cue-based retrieval is a valuable direction for future work.

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