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The Effect of Referential Forms on Incremental Processing of Long-distance Dependencies: Evidence from English Cleft Sentences*

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ABSTRACT

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This study examines how the referential form of the noun phrase, intervening the dependency between the filler and gap, modulates the long-distance dependency formation. (e.g., *It was the actor who the director graciously thanked before the show*). Two theories are evaluated in two self-paced reading tasks: expectation-based and memory-based accounts. The memory-based theories predict later difficulty at the verb (e.g., *thanked*), whereas the expectation-based process predicts earlier difficulty at the intervenor (e.g., *the director*). In terms of memory-based theories, this paper explores the reading time at the verb region to determine whether the same referential form of the intervenor with the filler exhibits processing load (*similarity-based interference*) or whether the parser is sensitive to the gradient status of the intervenor in a discourse within the framework of the dependency locality theory (Givenness Hierarchy). Experiment 1 showed that the verb was read faster with a pronoun intervenor compared to a definite or indefinite intervenor, indicating the binary nature of the Givenness Hierarchy. No interaction between the filler and the intervenor was revealed, indicating no similarity-based interference effects. Experiment 2 confirmed that the insensitivity to different types of full NPs at the verb region cannot be due to contextual support and did not observe similarity effects. Expectation-based processing was also evident at the intervenor region in both Experiments 1 and 2. In Experiment 1, immediate processing difficulty emerged upon encountering an unexpected referential form. In Experiment 2, processing ease for the intervenor was observed when the previously parsed filler NP led to a strong prediction of the NP type of an intervenor. This study contributes to the growing body of evidence that both memory- and expectation-based processes contribute to the incremental processing of complex sentences involving long-distance dependencies, highlighting distinct processing patterns at different regions.

KEYWORDS

filler-gap dependencies, referential processing, memory-based parsing, expectation-based parsing, cleft sentences

1. Introduction

The construction of English *it*-clefts has received considerable attention in theoretical syntax, leading to various proposed viewpoints on their underlying structure. Some studies propose that *it* and the cleft clauses behave like "a discontinuous definite description" (Hedberg 1990, 2000, Reeve 2011). For instance, Reeve (2010) claims that

the cleft clause operates as a syntactic modifier of the clefted element, implying that the clefted element is initially generated as a cleft and does not originate from within the clefted clause. Alternatively, other studies suggest that the clefted clause can be extraposed from the subject position to the right, simultaneously replaced by the expletive *it* (Belletti 2015). The traditional approach to cleft sentences involves a movement, wherein the clefted element, akin to relative clauses, originates in its position inside the cleft clause and moves to a focused position (Chomsky 1977, Cottell 2002, Delahunty 1981, Gazdar et al. 1985, Heggie 1988, Rochemont 1986). According to this movement analysis, *the client* in (1), is moved to the front of a main clause to create a head noun in the cleft sentence. The dependent element, or *a filler*, is the fronted noun phrase (NP), while the controlling element, or *a gap*, is the base position of the extracted NP, marked by underlining in (1).

(1) It was the client$_i$ that *the lawyer* interviewed ___$_i$ in a small office.
FILLER INTERVENOR GAP

Numerous psycholinguistic studies have adopted this movement analysis and have demonstrated that the referential form of intervening nouns (hereafter *intervenors*) between the filler and gap dependencies (i.e., *the lawyer* in (1)) can affect the processing difficulty associated with establishing dependencies between the filler and its gap (Gordon et al. 2001, Warren and Gibson 2002, among others). This paper, in line with the approach of prior research, embraces the movement analysis and investigates how referential processing influences the formation of long-distance dependencies in cleft sentences. The examination of long-distance dependency processing has provided insights into how linguistic factors, such as semantic and syntactic features of nouns, interact with extra-linguistic factors like working memory and expectation-based knowledge in language comprehension. Specifically, this paper explores the time point and degree to which referentiality impacts the process of integrating the filler into its gap.

The current paper investigates two theories of syntactic processing in language comprehension: memory- and expectation-based accounts. Memory-based accounts, such as memory interference theory (Lewis et al. 2006, Lewis and Vasishth 2005, Van Dyke and McElree 2006, 2011) and Gibson's (1998) Dependency Locality Theory (DLT), propose that processing long-distance dependencies can be challenging due to the additional memory load incurred while processing other elements during the integration process between the filler and the gap. One potential source of this additional memory burden is the processing of the intervenor's referential forms (Gibson 1998, 2000, Gordon et al. 2001, 2002, 2004). In contrast, expectation-based accounts suggest that processing difficulty arises once an unexpected word is encountered during language comprehension, with parsers anticipating a certain type of referential form based on probabilistic knowledge. (Hale 2001, Levy 2008, MacDonald and Christiansen 2002, Smith and Levy 2013).

Importantly, these two accounts make distinct predictions about when the difficulty arises. Memory-based theories predict that the difficulty emerges during the formation of the dependency between the filler and the gap, typically at the verb (e.g., *interviewed* in (1)). Expectation-based accounts, on the other hand, posit that difficulty initially arises when an unexpected or less common lexicon is encountered, i.e., at the embedded subject (hereafter intervenor; *the lawyer* in (1)).

The following section introduces existing studies related to these two accounts. Section 3, based on the literature background, illustrates the motivation of the current experiment. Sections 4 and 5 present the results of two experiments, followed by a general discussion in section 6. Finally, section 7 summarizes the main finding of the current paper, providing a structured overview of the research.

2. Literature Review

2.1 Memory-based Accounts: Similarity-based Interferences vs Givenness Hierarchy

Complex sentences involving long-distance dependencies require different processing mechanisms compared to parsing simple sentences. To account for processing long-distance dependencies, memory-based accounts draw upon working memory mechanisms, which encompass the encoding of elements and the retrieval of the stored information. In the context of establishing long-distance dependencies, it is presumed that parsers must retrieve information about the dependent element until they reach the controlling element. At the controlling element, parsers reaccess previously parsed elements to identify an appropriate element for integration. This process differs significantly from simple incremental processing, which does not require retrieval for integration. Consequently, during this retrieval process, parsers are prone to be susceptible to linguistic information related to intervening elements due to memory constraints.

For instance, the representation of the filler *the barber* in (2) is encoded in memory and subsequently retrieved in memory until the verb (i.e., *admired*) is encountered to establish its dependency with the gap.

(2) a. The barber$_i$ that the lawyer admired ___$_i$ climbed the mountain.
b. The barber that {the lawyer/you/Joe} admired climbed the mountain.

(Gordon et al. 2001)

Two primary hypotheses have been proposed to account for the effect of referential processing during dependency formation: similarity-based interferences and the Givenness Hierarchy (GH), within the framework of Gibson (2000)'s dependency locality theory (DLT). Importantly, both approaches predict that referential forms impact the point of integration when establishing dependencies, i.e., the verb *admired* in (2). First, similarity-based interferences propose that similarities in NP type between the filler and the intervenor result in processing costs during the integration of the filler into its gap. According to Gordon et al. (2001)'s Memory Interference Theory, other intervening NPs (i.e., *the lawyer* in (2a)), as well as the filler (i.e., *the barber*), are retained in memory until the verb (i.e., *admired*) is reached at which point retrieval is necessary. During this retrieval, the presence of an NP with the same featural type as the target filler may interfere with the proper integration of the filler into its gap, resulting in 'similarity-based interference effects' (Gordon et al. 2006, Jäger et al. 2017, Laurinavichyute 2020, Villata and Franck 2020). For instance, in object relative clauses as in (2a), Gordon et al. (2001, 2004, 2006) demonstrated that intervenors sharing the same NP featural type as the filler (e.g., *definite; the lawyer*) increased processing difficulty at the verb, compared to those with different referential forms such as *pronouns* (e.g., *you*) or *names* (e.g., *Joe*).

Conversely, the GH (Gundel 2010, Gundel et al. 1993, 2012), as conceived within the framework of Gibson (2000)'s DLT, can alternatively account for Gordon et al (2001)'s findings. The DLT explains the processing loads of complex sentences in terms of computational resources: (i) storage of structure, and (ii) integration cost. Regarding integration cost, it considers discourse processing costs as well as structural processing costs as determinants of processing difficulty. For instance, Gibson suggests that new discourse referents, occurring between elements being integrated, incur higher processing costs than previously accessed discourse referents. Building upon Gibson's work, Warren and Gibson (2002, 2005) propose a more gradient hierarchy in discourse rather than a binary concept. They contend that the gradient status of an intervenor influences dependency processing, introducing the role of the GH as presented in (3). In this hierarchy, the lower an intervenor is on the

hierarchy, the more challenging it is to form dependencies because it holds a less central role in the discourse. For example, an intervenor that is most central in the discourse (e.g., *pronoun*) is associated with the least processing cost, followed by less central NPs on the hierarchy (e.g., *pronoun, names*), and the least central NP (e.g., *indefinite descriptions*).

(3) 1st/2nd pronouns < 3rd-person pronouns < first names < full names < definite descriptions < indefinite descriptions

(<: harder to process)
(Warren and Gibson 2002)

A series of their experiments provided a piece of evidence that the parser is sensitive to the gradient status of an intervenor in discourse. Warren and Gibson (2002) tested the role of the GH in the comprehension of complex sentences containing filler-gap dependencies in both complexity rating and self-paced reading tasks as shown in (4).

(4) a. Complexity rating study
The old lady who the government assistance program which {you/ Brad/ Bill Clinton/ the reporter/ a reporter} praised had saved did not have enough money to heat her house.
b. Self-paced reading study
The consultant who {we/Donald Trump/ the chairman/a chairman} called advised wealthy companies...

In their studies, they found the effect of the GH in both complexity rating and self-paced reading studies, such that a significant correlation between the GH and the complexity rating /reading time at critical regions was observed: a monotonically increasing trend. That is, the complexity rating becomes higher and the reading time at the main verb (e.g., *called*) and the following spillover region (e.g., *advised*) becomes longer as the intervenor becomes more peripheral in discourse.

2.2 Expectation-based Account

To offer a comprehensive explanation for the primary source of processing difficulty in sentence comprehension, numerous studies have centered their attention on the role of expectations. Experimental research has lent support to the notion that probabilistic information plays a central role in language acquisition and comprehension (Corley and Crocker 2000, Jacoby and Brooks 1984, MacDonald et al. 1994a, 1994b, MacDonald and Christiansen 2002, Spivey-Knowlton and Sedivy 1995, Trueswell 1996). According to the surprisal model (Hale 2001, Levy 2008), one of the main expectation-based processing models, parsers employ probabilistic knowledge derived from previous experiences during incremental sentence processing. This knowledge enables them to anticipate upcoming lexicon items before encountering them and, consequently, establish potential interpretations. Under this model, the pivotal determinant of processing difficulty is expectation, which is expected to manifest upon the encounter of an unexpected noun phrase (NP). The underlying idea is that when a predictable word (given its context and syntactic configuration) is encountered during sentence processing, the processing cost diminishes, whereas an unpredictable word incurs processing burdens due to its violation of the parser's predictions (Hale 2001, Jurafsky 2003). Several reading-time studies have found empirical evidence in support of the surprisal model

(Boston et al. 2008, Demberg and Keller 2008, Roark et al. 2009, Smith and Levy 2013).

In terms of referential processing, processing difficulty aligns with the lexical probabilities associated with NPs. A word that is less frequent within a particular syntactic configuration and its contextual context is more surprising than a word that is more frequent and commonly encountered. For instance, parsing more frequent NP types in the subject position is generally easier than processing less common NP types. It's important to note that subjects typically function as background constituents, providing given information or serving as the topic of a sentence, rather than introducing new discourse referents (Erteschik-Shir 1973, Goldberg 2006, Takami 1992, Van Valin 1995). On this view, numerous studies have provided empirical evidence that indexical pronouns like first or second-person pronouns are the most prevalent type of subjects in a clause (Arnold 2001, Arnold et al. 2000, Fletcher 1984, Fukumura and van Gompel 2010). Although other full noun phrases are considerably less common than pronouns, when comparing definite and indefinite NPs, indefinite NPs are less frequently observed as subjects of a sentence or clause, primarily because they play a more peripheral role in discourse and are employed to introduce new referents, in contrast to definite NPs (Abeillé et al. 2020, Givon 1984, Heim 1982, 1983).

The exploration of expectation-based processing of referential forms has extended beyond simple sentence structures. Research on long-distance dependencies, such as relative clauses, has expanded these findings to complex sentences, demonstrating that a similar pattern of referential processing occurs when encountering subjects in embedded clauses. For instance, in object-extracted relative clauses, an extensive corpus study of spoken English has indicated that indexical pronouns like first or second-person pronouns are the most common type of embedded subject, mirroring the trends observed in sentential subjects (Gordon et al. 2004, Reali and Christiansen 2007, Roland et al. 2007, Roland and Jurafsky 2002). In a comparison between definite and indefinite descriptions, definite descriptions are found to be more prevalent than indefinite descriptions in embedded subjects, as in sentential or clausal subjects (Abeillé et al. 2020, Givon 1984, Gordon et al. 2004, Leonetti 2004). Building on the previous findings related to NP-type frequency, expectation-based theories predict a higher frequency of pronoun intervenors, followed by definite descriptions, and then indefinite descriptions in the embedded subject of cleft clauses.

3. Motivation of the Current Experiment

The majority of existing studies on the impact of an intervenor’s referential forms on processing long-distance dependencies have mainly assessed memory-based accounts. These studies have typically reported processing difficulties at the verb regions, assuming that the challenge arises at the point of integration (Gordon et al. 2001, 2004, Warren and Gibson 1999, 2002, 2005). However, experience-based approaches, while suitable for general word processing, have not been thoroughly tested in the context of complex sentences involving long-distance dependencies. Recent research on processing relative clauses, a typical structure involving long-distance dependencies, has indicated that processing difficulties occur at both the intervenor and verb regions (Price and Witzel 2017, Staub 2010). This suggests the contributions of both interferences in memory and expectation-based processes during dependency formations. Their findings raise a question about whether the previously observed processing costs at the verb, as explained by memory-based accounts, genuinely reflect integration costs or the ongoing challenge of processing an unpredicted NP type in an intervenor, which appears immediately before the verb. It's essential to note that the experimental designs of previous studies have this confounding factor, as discussed later in this section.

Building upon recent studies, the current paper takes a step forward by exploring the realm of cleft constructions,

an area that has received limited attention in previous research. The primary aim of this paper is to conduct a comprehensive investigation of how and to what extent the two primary sources of processing difficulty impact the processing of long-distance dependencies. This investigation is achieved by scrutinizing two crucial regions in the sentence—the intervenor and the verb regions. The current research not only builds on the findings of prior studies but also addresses and refines certain confounding factors present in previous research. One notable challenge lies within memory-based integration costs, where previous studies have been unclear in teasing apart two theories: similarity-based interference and Givenness Hierarchy (GH) effects. Another confounding factor pertains to disentangling memory-based integration costs from the potential spillover effects of expectation-based processing. This approach allows for a more thorough examination of the intricate relationship between these factors and the processing of long-distance dependencies within cleft sentences.

Firstly, cleft constructions offer a significant advantage over relative clauses in enabling a more comprehensive examination of similarity-based effects, alongside GH effects, thereby advancing our understanding of memory-based retrieval mechanisms. Crucially, cleft sentences impose fewer restrictions on the NP types of the filler. For example, the filler in clefts can be a linguistic expression like a name or an indefinite, as opposed to being restricted to a definite NP as in relative clauses, where the head noun is modified to be uniquely identified (Gordon et al. 2001). This flexibility allows for the testing of interferences involving the same NP type of an intervenor with the filler by probing various NP types. With this advantage in mind, the current study aims to address the tension between two main memory-based accounts: similarity-based interferences and the GH under the DLT. Returning to Gordon et al (2001)'s finding, they tested three NP types of an intervenor: pronouns, first names, and definite NPs, while maintaining fillers to be definite NPs. The difficulty of definite intervenors, compared to other NP types, was attributed to the same NP type of the intervenor to the filler (i.e., definite NP). The GH has an alternative account for their finding; intervening pronouns and names are easier to process than intervening definite NPs because both pronouns and names are more central in discourse than definite descriptions on the GH. As illustrated in (5), both pronouns and proper names are higher than definite NPs on the GH. Gordon et al (2001)'s experiment, therefore, does not allow for teasing apart the givenness effects from similarity-based effects.

To address this, the paper investigates whether the interference effect of an intervenor primarily results from similarity interference, a more nuanced discourse-level effect based on the semantic hierarchy, or a combination of both. To properly assess the contribution of the GH of an intervenor to integration costs (at the verb), this study introduces tests using *indefinite* descriptions instead of the name condition, as used in Gordon et al. (2001)'s study, which is critical in terms of the hierarchy. That is, the pronoun is higher than the definite description, whereas the indefinite description is lower than the definite description as presented in (5).

(5) **1st/2nd pronouns** < 3rd-person pronouns < first names < full names < **definite descriptions** < **indefinite descriptions**

(<: harder to process)
(Warren and Gibson 2002)

The indefinite fillers were included to further assess similarity-based effects involving the same indefinite NP types between the filler and intervenor, in addition to definite NPs.

Another factor that this paper addresses is the potential confounding experimental design related to disentangling memory-based integration costs from the spillover effects of expectation-based processing of an intervenor. To the best of my knowledge, only two studies have tested cleft sentences by manipulating the NP types of both the clefted and the embedded NP positions (Gordon et al. 2001, Warren and Gibson 2005). However,

these studies exclusively examined memory-based costs at the verb region without considering expectation-based processing, and their findings remain somewhat inconclusive. Gordon et al. (2001)'s Experiment 4 tested the NP types in both the clefted and the embedded NP positions and used definite descriptions and names as shown in (6).

(6) It was {Patricia/the lawyer} that {Dan/the businessman} avoided at the party.

Their findings supported the similarity-based interference effects, indicating that two NPs of the same type led to increased processing load. Warren and Gibson (2005) extended this experiment by including pronoun conditions to explore both similarity effects and the GH. Reading times at the verb favored the GH effect: pronoun conditions were read fastest, name conditions slower and definite conditions slowest. However, when considering expectation-based processing, it's possible that the reading times at the verb in both studies reflected spillover effects from processing intervenors because the verb immediately follows the intervenor. Additionally, these studies reported raw reading times without accounting for word length variations across NP types. The word length variation across NP types could potentially affect the reading time at the verb, given that pronouns are the shortest, names are longer, and definite NPs are the longest. Given these confounding factors in previous studies, the current study aims to explore expectation-based processes alongside memory-based retrieval while addressing these confounding factors. To mitigate these issues, this paper introduces an adverb between the intervenor and the verb to prevent spillover effects resulting from intervenor processing and reports residual log-transformed reading times, eliminating the influence of word lengths and positions between conditions.

4. Experiment 1

4.1 Method

4.1.1 Participants

Participants were 50 native speakers of English who were recruited from Amazon's Mechanical Turk web service. All participants were self-reported native speakers of English. They were compensated $3.75. Three of the participants were excluded from the analysis because their performance across all comprehension questions was lower than 80%.

4.1.2 Materials

This experiment had a 2 x 3 design, crossing two NP types of the filler in the clefted position and three NP types of an intervenor in the embedded subject position: [definite descriptions, indefinite descriptions] x [definite descriptions, indefinite descriptions, pronouns].

(7) It was {the editor/an editor}$_i$ who {we /the author/an author} highly recommended __$_i$ after
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a new manager was announced.

The filler type was manipulated to test the similarity-based interference hypothesis. At the main verb region

(e.g., *recommended*), the similarity-based interference hypothesis predicts that the same NP type of intervenors with fillers should lead to increased processing difficulty, as reflected in longer reading times than the other conditions. The conditions with matching NPs ("definite filler-definite intervenor" and the "indefinite filler-indefinite intervenor" conditions) are predicted to show the longest reading time, compared to other conditions. Another memory-based account of the GH under the DLT, in contrast, predicts a main effect of intervenor type, but no interaction with the filler type: the fastest reading times when the intervenor is a pronoun (e.g., *we*) condition, longer when it is a definite description (e.g., *the director*), and longest when it is an indefinite description (e.g., *a director).* Importantly, expectation-based accounts predict that the processing difficulty arises at the point of intervenor regions. Given the corpus data on the NP types of the embedded subject, the prediction of expectation-based accounts would be the fastest reading time of a pronoun intervenor (e.g., *we*), longer reading time of a definite intervenor (e.g., *the director*), and longest for the indefinite intervenor (e.g., *a director*) once encountered the intervenor region[1]. Experimental materials consisted of 24 sets of 4 items in each of the 6 conditions. The 24 sets of six conditions were distributed across six lists in a Latin Square design and combined with 26 filler sentences. The predictions of processing theories concerning the processing difficulty of dependency formation are summarized in Table 1.

Table 1. Prediction by each model for the difficulty of processing

Models	Prediction	Region of Difficulty
Memory-based account		The main verb
(i) Similarity-based interference	Definite fillers-Definite intervenors & Indefinite fillers-Indefinite intervenors : the most difficult conditions	
(ii) Givenness Hierarchy under the Dependency Locality Theory	Pronoun < Definite < Indefinite (< : harder to process)	
Expectation-based account	Pronoun << Definite < Indefinite (< : harder to process)	The embedded subject (Intervenor)

4.1.3 Procedure

A self-paced reading task was run on the Ibex Farm platform (Drummond 2018) using a non-cumulative moving-window paradigm (Just et al. 1982). Participants read items like (7), each of which was followed by a comprehension question. The experiment lasted approximately 25 min. To ensure participants did not learn to expect a one-word display, a word or phrase was presented at a time. Each word or phrase was displayed in the middle of the screen. The display pattern was constant across the conditions of each item in the Latin Square design. Participants pressed the spacebar to proceed to the next word or phrase. After the last word or phrase of

[1] This model might predict a main effect of the filler type at the filler position, based on the corpus data of the NP types in the clefted position, but this is beyond the scope of the current paper. The statistical result did not reveal a significant effect of filler NP type (t=.81, p=.41).

each sentence, the full sentence of a comprehension question appeared. Prior to beginning the experiment, three practice trials were given to familiarize participants with the task.

4.1.4 Analysis

Before statistical analysis, raw reading times exceeding 4000ms or less than 100ms were excluded, affecting a total of 0.001% of the data. No additional outlier removal processes were implemented. Trials for which participants provided a correct answer to the comprehension question were analyzed. Reading times were log-transformed to normalize the residuals and then regressed against word length and log list position (Ferreira and Clifton 1986, Hofmeister 2011, Hofmeister and Norcliffe 2014) to avoid the two factors that affect reading times. The residual log reading times, therefore, were analyzed as the dependent variable.

Data were analyzed with linear mixed-effects models with crossed random effects for participants and items (Baayen et al. 2008) using the lme4 package (Bates 2010) in the R software, version 3.4.4.(Bates et al. 2015). The maximal random effect structure that enabled model convergence (Barr et al. 2013) was used. The predictors, namely, the filler type (2 levels) and the intervenor type (3 levels) were contrast-coded utilizing centered Helmert contrasts. For the filler type, definite was coded as -1/2, and indefinite was coded as +1/2. As for the intervenor type, the first coefficient, PRONOUN vs. NP, contrasted pronouns (coefficient: +2/3) with NPs that contained a determiner (coefficient: -1/3 for definite NP; -1/3 for indefinite NP). This contrast sought to investigate the effect of having a pronoun or an NP with a determiner in the intervenor position. The second coefficient, DEFINITENESS, contrasted definite NPs with indefinite NPs (DEFINITENESS coefficients: 0 for Pronoun, -1/2 for definite NP, and +1/2 for indefinite NP). This contrast aimed to examine the effect of definiteness. Finally, similarity-based interference effects were tested by distinguishing between conditions where the filler and intervenor shared the same NP types (i.e., “definite filler-definite intervenor” and “indefinite filler-indefinite intervenor” conditions, with a coefficient of -1/2) and all other conditions (coefficient: +1/2). If deemed necessary based on the results, additional analysis was conducted, which is reported in the following results section.

4.2 Results

A total of 47 participants were included in the analysis, with a mean accuracy rate of 96.2% on the comprehension questions. The mean accuracy rate for comprehension questions by conditions did not reveal significant effects. The study focused on measuring the real-time reading time of three main regions of interest: the "intervenor and adverb" region, the main verb region, and the region following the verb (Spillover region). The “intervenor + adverb” regions were one of the regions that were not presented separately to prevent participants from learning a one-word display. It is presumed that the results were driven by the intervenor region as identical adverbs were shown across conditions.

Region-by-region residual log reading times for the definite and indefinite fillers are presented in Figures 1 and 2, respectively. The results of log-transformed statistical analyses by region are summarized in Table 2. In the “intervenor and adverb” region, a linear mixed-effects model revealed a main effect of the intervenor type, but not a filler type effect or interaction. Specifically, the contrast between definite and indefinite intervenors revealed that indefinite intervenors led to significantly slower reading time than definite intervenors. Given the observed descriptively slower reading times for indefinite intervenors compared to pronoun intervenors, further analyses were conducted to investigate potential differences between these two types of intervenors. The statistical analysis confirmed that it was significant (t=4.18, p <.001). No significant difference was observed when pronoun

intervenors were compared to full NPs pooled. In brief, the indefinite intervenors led to processing difficulty compared to definite and pronoun intervenors. No other contrasts were significant.

The critical verb region did not exhibit any significant main effect of the filler type, such as the verb (e.g., *recommended*), either. However, the model confirmed a significant effect of the intervenor types, with the pronoun condition being read significantly faster than the averaged definite and indefinite conditions. In a separate analysis, the definite filler-definite intervenor and indefinite filler-indefinite intervenor conditions were compared, against the other conditions, with regard to their similarity effects. However, the results of this analysis did not yield any significant findings, indicating a lack of similarity-based interference effects on the formation of dependencies (t=.95, p=.33). Finally, pronouns were read marginally faster than full NPs at the Spillover region (t=-1.79, p=.07).

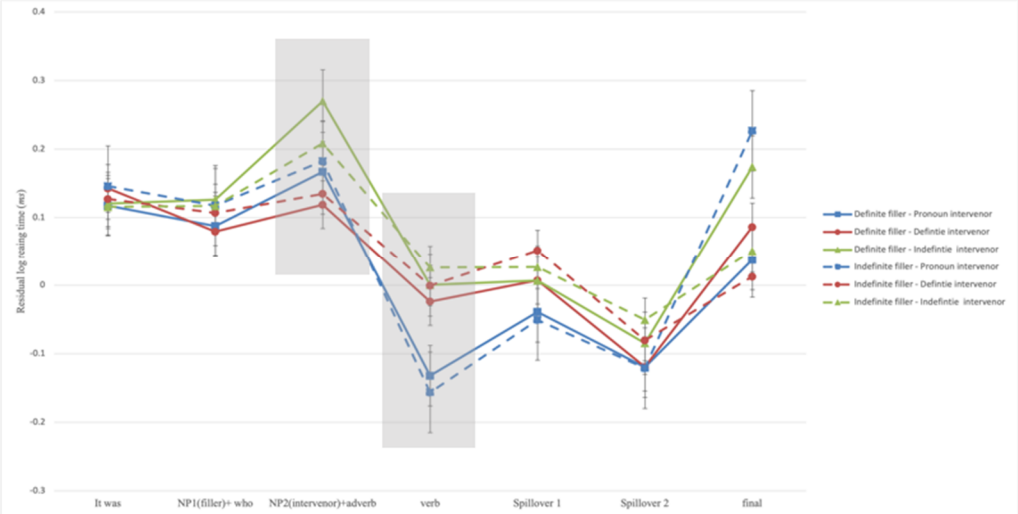

Figure 1. Mean Residual Log-Transformed Reading Time (*ms*) by Region for All Conditions. Boxes Indicate the Regions Where a Main Effect was Observed. Error Bars Indicate Standard Errors.

Table 2. Summary of Log-Transformed Statistical Analyses by Region

	Estimate	SE	*t*	*p*
Intervenor + Adverb region (*we /the author/an author highly*)				
(Intercept)	0.185	0.065	2.842	0.008
The filler type	-0.013	0.020	-0.632	0.527
Pronoun (pronoun vs full NP intervenor)	-0.026	0.030	-0.876	0.381

Definiteness (definite vs indefinite intervenor)	**-0.149**	**0.035**	**-4.183**	**<.00001***
The filler type x Pronoun (intervenor)	0.035	0.043	0.803	0.422
The filler type x Definiteness (intervenor)	0.057	0.050	1.129	0.259
Verb Region (*recommended*)				
(Intercept)	-0.051	0.024	-2.091	0.04
The filler type	0.008	0.018	0.458	0.646
Pronoun (pronoun vs full NP intervenor)	**-0.011**	**0.026**	**-4.377**	**.00001***
Definiteness (definite vs indefinite intervenor)	-0.023	0.031	-0.763	0.445
The filler type x Pronoun (intervenor)	-0.049	0.038	-1.286	0.198
N1 type x Definiteness (intervenor)	-0.002	0.044	-0.053	0.958
Spillover1 Region (*after*)				
(Intercept)	-0.007	0.021	-0.370	0.712
N1 type (the filler)	0.017	0.016	1.063	0.288
Pronoun (pronoun vs full NP intervenor)	**-0.044**	**0.024**	**-1.790**	**0.073**
Definiteness (definite vs indefinite intervenor)	0.001	0.029	0.037	0.970
N1 type x Pronoun (intervenor)	-0.044	0.035	-1.246	0.213
N1 type x Definiteness (intervenor)	0.025	0.041	0.612	0.540

Significant or marginal coefficients are in bold.

According to the GH, one would predict that indefinite intervenors should induce more difficulty at the verb compared to definite intervenors. However, this expected pattern was not observed. Importantly, this findings at the verb region, associated with memory-based accounts, may reflect another confounding factor. One possibility of no sensitivity to different types of full NPs and no similarity effects at the verb region can be a setting without contexts. That is, the absence of contexts may give rise to a higher processing load of definites, but not indefinites because definites (but not indefinites) are generally considered to refer to old or established referents in the discourse (Heim 1982). Since no contexts were given, definites might fail to find the referent, which could be the byproduct of processing difficulty (Kirsten et al, 2014, Löbner 1985, Tiemann et al. 2011). Indefinites, on the other hand, introduce a new referent and thus do not trigger a search for the referent (Heim 1982). Accordingly, no prior contexts could have caused definites difficult as indefinites, which are in fact less central in discourse and lower than definites on the GH. To explore this remaining issue, Experiment 2 focuses on examining definite and indefinite intervenors in contexts. The comparison of these full NPs allows us to test the possibility that the definite description, in particular, was difficult to process in null contexts due to accommodation costs of a referent driven by the absence of contextual support.

5. Experiment 2

Experiment 2 exclusively investigates the integration costs associated with full NPs, including definite and indefinite intervenors. It accomplishes this by providing contextual information to examine the possibility that definite descriptions, in particular, might pose processing challenges in null contexts due to accommodation costs

associated with establishing a referent when contextual support is absent. To clarify, if the presence of an appropriate referent in the provided contexts reduces the integration costs of definite descriptions (at the verb region) compared to indefinite descriptions, then the difficulty observed with definite descriptions in Experiment 1 can be attributed to contextual effects. In contrast, if the integration costs of definite descriptions remain high, similar to those of indefinite descriptions, even when contextual support is provided, it would suggest that the integration costs of definite descriptions observed in Experiment 1 cannot be reduced to contextual effects.

5.1 Method

5.1.1 Participants

32 native speakers of English were recruited from Prolific Academics online platform (http://prolific.co/). Participants were compensated $3. All participants indicated that they were native speakers of English.

5.1.2 Materials

This experiment follows a 2x2 design, crossing NP types for both the filler and intervenor, specifically definites and indefinites. In all provided contexts, two individuals with distinct professions were introduced, such as *a chef* and *a manager* as presented in Table 3. Within the target sentence, these individuals are referenced in the filler and intervenor positions, respectively. Importantly, these supporting contexts are designed to eliminate any potential difficulty associated with the definite intervenor resulting from the absence of a referent in discourse. The experimental materials comprised 16 sets of 4 items in each 4 condition. These sets were arranged into 4 lists using a Latin square design. Additionally, 16 filler items were included, structured similarly to the target items.

Table 3. Sample Item Set for Experiment 2

Filler type (NP1) - Intervenor type (NP2)	**Contexts**
	"Bob, a chef, worked with Sydney, a manager, who unwillingly distrusted Bob after the restaurant closed."
Definite - Definite	It was/ the chef/ who/ the manager/ unwillingly/ distrusted/ after/ the restaurant/ closed.
Definite - Indefinite	It was/ the chef/ who/ a manager/ unwillingly/ distrusted/ after/ the restaurant/ closed.
Indefinite - Indefinite	It was/ a chef/ who/ a manager/ unwillingly/ distrusted/ after/ the restaurant/ closed.
Indefinite - Definite	It was/ a chef/ who/ the manager/ unwillingly/ distrusted/ after/ the restaurant/ closed.

5.1.3 Procedure

A self-paced reading task was conducted using the PCIbex Farm platform (Zehr and Schwarz 2018). In the experiment, a full context was given all at once, followed by region-by-region display of the target sentence (as indicated by slashes '/' in Table 3). A true-false question such as "Is the last statement true or false?" appeared

once the last word or phrase of each sentence was presented. All other procedures were identical to Experiment 1.

5.1.4 Analysis

Data were analyzed with linear mixed-effects regression models, which were conducted with the *lme4* package in the R software. As the approach employed in Experiment 1, parsimonious models were utilized for analysis. For predictor variables, two factors were considered: filler NP type (with 2 levels) and intervenor NP type (also with 2 levels). These factors were contrast-coded as follows: definite NP types were coded as +1/2, while indefinite NP types were coded as -1/2, a coding scheme that applied to both filler and intervenor NP types. To specifically evaluate similarity effects at the verb region, the conditions "definite filler-definite intervenor" and "indefinite filler-indefinite intervenor" were coded as (+1/2), while the conditions "definite filler-indefinite intervenor" and "indefinite filler-definite intervenor" were coded as (-1/2).

5.2 Results

Two out of the 32 participants were excluded from the analysis due to a performance accuracy lower than 80% across all comprehension questions, including the filler questions. Consequently, data from the remaining 30 participants were subjected to analysis. The primary regions of interest remained the same as those in Experiment 1, namely the intervenor region, spillover region, main verb region, and spillover region[2]. The identical methods for outlier removal and the modeling procedure used in Experiment 1 were applied. The participants exhibited a mean accuracy rate of 92.5% on the comprehension questions. The mean accuracy rates for comprehension questions across the various conditions did not reveal any significant effects. Figure 2 presents a plot of the reading times by region for all conditions, and the corresponding statistical results are summarized in Table 4. At the intervenor region, significant main effects were observed for both filler NP type and intervenor NP type (t=2.28, p=0.02; t=2.60, p=0.01). Reading times were faster for definite NP types compared to indefinite NP types for both filler NP types and intervenor NP types. Notably, an interaction between filler and intervenor NP types was also significant (t=-1.99, p=0.04). Planned comparisons showed no effect of intervenor type when the filler was indefinite (t=-0.22, p=0.81), but such an effect was evident when the filler was definite (t=2.60, p=0.01). This result suggests that the faster reading times associated with definite NP types were primarily driven by conditions in which both the filler and intervenor were definite. The advantage in reading times for definite intervenors persisted until the subsequent spillover region (t=1.90, p=0.05). However, reading times for the main verb region and the following region did not show any main effects of either filler NP types or intervenor NP types (all ps > 0.17). Additional analysis of similarity-based effects at the verb region did not reveal any significance (t=-1.42, p=0.17).

[2] In this Experiment, the intervenor and the following spillover regions were presented separately, but the regions of interest are the same as with Experiment 1.

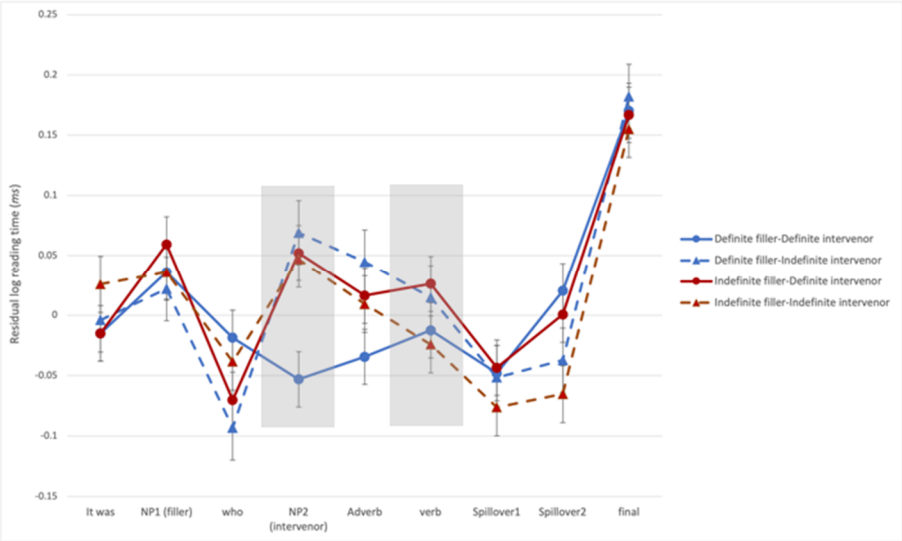

Figure 2. Mean Residual Log-Transformed Reading Time (*ms*) by Region for All Conditions. Boxes Indicate the Critical Regions Where a Main Effect was Observed. Error Bars Indicate Standard Errors.

Table 4. Summary of Log-Transformed Statistical Analyses by Region

	Estimate	SE	*t*	*p*
Intervenor Region (*the manager/a manager*)				
(Intercept)	-0.051	0.043	-1.198	0.236
The filler NP type (NP1)	**0.111**	**0.048**	**2.283**	**0.023***
The intervenor NP type (NP2)	**0.126**	**0.048**	**2.601**	**0.010***
The filler NP type x intervenor NP type	**-0.137**	**0.069**	**-1.991**	**0.047***
Spillover Region (*unwillingly*)				
(Intercept)	-0.032	0.035	-0.930	0.356
The filler NP type (NP1)	0.049	0.041	1.191	0.235
The intervenor NP type (NP2)	**0.076**	**0.040**	**1.903**	**0.058***
The filler NP type x intervenor NP type	-0.084	0.058	-1.444	0.150
Verb Region (*distrusted*)				
(Intercept)	-0.049	0.054	-0.915	0.374
The filler NP type (NP1)	0.072	0.056	1.268	0.218
The intervenor NP type (NP2)	0.068	0.082	0.829	0.419
The filler NP type x intervenor NP type	-0.141	0.098	-1.427	0.176
Spillover Region (*after*)				
(Intercept)	-0.045	0.037	-1.199	0.235
The filler NP type (NP1)	0.001	0.050	0.031	0.975
The intervenor NP type (NP2)	-0.002	0.049	-0.055	0.956
The filler NP type x intervenor NP type	-0.038	0.070	-0.553	0.581

Significant or marginal coefficients are in bold.

6. Discussion

The goal of this study is to investigate the sources of processing difficulty that arise during the incremental processing of dependencies, with a specific focus on the investigation of cleft constructions. To achieve this goal, we evaluated both memory- and expectation-based accounts in Experiment 1. First, memory-based accounts propose that interference of NPs, intervening dependencies, leads to processing loads at the point of integrating dependencies (e.g., *verb regions*). Experiment 1 revealed the significantly faster reading time at the verb region for pronoun conditions, which is the highest on the GH, resulted in faster reading times compared to full NPs (i.e., *definites* and *indefinites*), as per the Givenness Hierarchy (GH), are situated at the highest position, resulting in faster reading times compared to full NPs (i.e., *definites and indefinites*), which occupy lower positions on the hierarchy. However, Experiment 1 did not reveal any differences between definite and indefinite conditions or any evidence of similarity-based interference effects. To further investigate contextual factors that might contribute to the processing difficulty of definite intervenors in null contexts, Experiment 2 exclusively examined definite and indefinite intervenors while providing a unique referent within contexts. The results of Experiment 2 affirmed two key findings: (i) definite and indefinite intervenors impose a similar level of processing burden on integrations, irrespective of contextual support, and (ii) similarity-based interference effects stemming from the same NP types between the filler and intervenor do not influence the integration process.

The distinctive pattern observed between pronouns and full NPs at the verb region suggests that the GH of an intervenor plays a role in the resolution of dependencies in a binary or categorical metric, rather than following a continuous metric, as proposed by Warren and Gibson (2002). Experiment 2, which demonstrated consistent insensitivity to full NPs even in contexts providing an old referent, suggests that the binary metric affecting integration costs is not solely reliant on contextual information indicating whether the NP refers to an old or new referent. Instead, it suggests that what truly matters for integration costs is the inherent lexical property of NP types, namely pronouns vs full NPs. It is plausible that both definite and indefinite NPs can incur processing loads by constructing more conceptual content.

The similarity-based interference effect, another memory-based accounts for integration costs, predicts higher reading times in conditions with the same NP types between the filler and the intervenor (i.e., “definite-definite” and “indefinite-indefinite” conditions), which was not observed in both Experiments 1 and 2. However, a broader perspective of similarity-based interference effects of NP types (Gordon et al. 2004) can be compatible with the findings of the current experiment: similarity interferences of NP types of an intervenor based on the property of common nouns. Gordon et al. (2004) conducted a follow-up study based on Gordon et al. (2001), collecting more data on other NP types of an intervenor such as indefinites (e.g., *an accountant*), generic expressions (e.g., *the accountants*), and quantified expressions (e.g., *everyone*). Putting the result of Gordon et al. (2001) together, they grouped these NP types into the property of common nouns. That is, the NPs that have the property of common nouns (e.g., *definites, indefinites, generics*) and those that do not (e.g., *proper names, pronouns, everyone*) determines the representational similarity affecting processing loads. They found the processing difficulty of the former NPs, which was attributed to their similarity to the filler NP type (i.e., *definites*), sharing common noun features in the memory representation. That is, similarity-based interference effects occur when an intervenor has a property of common nouns, the same as the filler. Therefore, no difference in processing definite and indefinite intervenors in the current study can be accounted for by the property of a common noun. Indefinite and definite intervenors share the property of common nouns with the indefinite filler, unlike pronoun intervenors. Indefinites and definites, as common nouns, required more processing load than pronouns that do not share the features of a common noun.

The distinction between common nouns and other NP types (Gordon et al. 2004) exhibits a similar notion of accessibility to the GH. Gordon et al. (2004) highlight that common nouns, which semantically denote sets of entities sharing a common property (e.g., *definites, indefinites, generics*), tend to refer indirectly, as opposed to pronouns and proper names, which have more direct reference. Due to their indirect reference, common nouns encompass a broader range of possible entities compared to other non-common nouns, as they allow entities that satisfy their own properties. It is noteworthy that common nouns (e.g., *definites, indefinites*) occupy a lower position on the GH, while non-common nouns (e.g., *proper names, pronouns*) hold a higher position on the GH. The distinct characteristic of noun forms aligns with the GH, as it captures more limited interpretations of forms that are higher on the hierarchy (i.e., non-common nouns) and more unrestricted interpretation for those that are lower on the hierarchy (i.e., common nouns); The more central a form is in a discourse, the greater the availability of a restrictive interpretation. This restrictive interpretation incurs minimal processing cost by eliminating the need to consider alternative interpretations without imposing a cognitive burden for exploring other possibilities (Gundel 2010, Gundel et al. 1993, 2012).

The overall findings of experiments suggest the binary metric, or categorical integration costs between high and low forms on the hierarchical ranking, namely, pronoun vs full NPs[3]. The hierarchical ranking of an intervenor plays a crucial role in determining interference effects on the resolution of dependencies. To further enhance our understanding of the precise cut-off point on the hierarchy, other NP types, such as third-person pronouns and proper names, which are assumed to be between the pronoun and full NPs on the hierarchy, need to be further investigated.

Secondly, expectation-based accounts predict earlier processing difficulties at the intervenor region when the NP type of an intervenor is either unpredicted or less common in the embedded subject position. This prediction aligns with the findings from both Experiments 1 and 2, which demonstrated evidence of expectation-based processing related to referential forms. In Experiment 1, it was observed that indefinite intervenors were read significantly slower than both pronoun and definite intervenors. This indicates a higher processing load associated with the low expectations for encountering indefinite NPs in the (embedded) subject position[4]. Prior corpus studies have reported a much higher frequencies of pronouns than full NPs (e.g., *definites* and *indefinites*) in the subject position of both main and embedded clauses (Arnold 2010, Kaiser and Trueswell 2008, Levy 2008), as well as higher frequencies of definite NPs than indefinite NPs in the embedded subject position (Givon 1984, Leonetti 2004). Given the absence of a significant difference in processing between pronoun and definite intervenors, this result suggests that parsers have the capacity to accommodate a range of potentially available NP types in the embedded subject position. The penalty for immediate processing difficulty appears to occur when encountering an uncommon NP type that lies beyond the range of possible NP types, thereby violating the parser's predictions. Experiment 2 presented old referents for both filler and intervenor in a prior context. Overall, indefinite intervenors were read more slowly than definite intervenors, consistent with the results from Experiment 1. Notably, the speed-up in reading definite intervenors was primarily driven by instances where the filler was also definite. This outcome suggests that parsers tended to predict that the upcoming NP would have the same NP type as the filler, specifically

[3] Parsers were not as sensitive to a gradient status of the intervenor, as they were in Warren and Gibson (2002). One possibility is that they measured the combined region of the verb and the spillover region, not separately, because they did not observe a significant difference at the verb region.

[4] Cleft constructions are focus constructions in which the clefted element has the function to focus, while the remnants are backgrounded. On this view, the difficulty of indefinite intervenors is also compatible with a pragmatic explanation because indefinites are known to be pragmatically infelicitous to serve as background constituents. However, several empirical studies on the properties of definite and indefinite NPs have demonstrated that using indefinite NPs to refer to an old referent in discourse is not incompatible as theoretically assumed (Bade and Schwarz 2019, 2021, Masharov 2008). Therefore, we presume that the finding in the current study is not entirely driven by pragmatic factors.

definite, when the filler itself was definite. This prediction might stem from the expectation that if the filler employs a definite NP, which typically refers to an old referent, and is followed by an intervenor that also refers to an existing referent, it would likely be a definite NP. In contrast, when the filler was indefinite, this strong prediction for definites might have been attenuated because indefinites do not carry the same restriction of referring to an old referent. Consequently, this opens up the possibility of various NP types for upcoming NPs.

Overall, the findings of the present study indicate that both interferences in memory and expectation-based processing contribute to the processing of dependencies. These findings align with recent studies such as Staub's (2010) eye-movement experiments on English relative clauses and Price and Witzel (2017)'s self-paced reading task on Russian relative clauses. Furthermore, given that distinct profiles of processing difficulty were observed at each region, it is unlikely that the integration cost found at the verb is solely attributed to spillover effects from the embedded subject (i.e., intervenor). The results support previous research demonstrating that such difficulty cannot be exclusively explained by spillover effects (Gibson and Wu 2011, Grodner et al. 2005, Hofmeister and Vasishth 2014) and that expectation-based accounts do not fully elucidate the mechanisms underlying incremental processing (Fedorenko et al. 2006, 2009, Gordon et al. 2006, Van Dyke and McElree 2006). For instance, Grodner et al. (2005) found that processing difficulty at the embedded verb persisted even when the embedded subject was modified by a prepositional phrase (e.g., *the nurse from the clinic*) in English object relative clauses. Future research could explore structures involving integration, as in (8a), and compare them with those without integration, as in (8b), to disentangle the two sources of difficulty: memory loads and violation of expectation. This comparison could test whether the same pattern of reading times is observed at the verb region even when there is no dependency formation.

(8) a. It was true that {we/the director/a director} graciously thanked...
b. It was Tom that {we/the director/a director} graciously thanked...

There are three potential avenues for enhancing the validity and generalizability of this experiment. Firstly, further investigations with larger sample sizes and enhanced statistical power are necessary to ascertain that the absence of gradient susceptibility to referential forms is not simply due to the lack of statistical power. Secondly, rigorous corpus studies on the noun phrase (NP) types in cleft sentences will serve as a valuable resource to ascertain the distributional properties of NP types within cleft constructions. Despite these potential avenues for improvement, the current study contributes additional data to a growing body of literature on the role of both memory- and expectation-based processes during dependency formations by examining other types of long-distance dependency, cleft sentences.

As pointed out by an anonymous reviewer, Culicover and Winkler's (2022) recent study extends the effect of an intervening NP to encompass the complexity of island structures, illustrating that the presence of an intervening NP, which they refer to as "uninvited guests", can introduce enough complexity to shift a marginally acceptable extraction into the realm of unacceptability (e.g., **War and Peace is a book that$_i$ I always amuse Sandy while reading t_i.*). Importantly, it's worth noting that extractions from islands exhibit greater complexity and lower acceptability compared to other typical filler-gap dependencies, such as relative clauses and cleft sentences. Furthermore, they compared the complexity introduced by an intervening NP to situations without an intervening NP, where the gap was present. Therefore, it is likely that the mere presence of an intervening NP in such structures, regardless of its NP type, can introduce complexity due to the structural complexity, potentially violating an island constraint. As they explored the complexity of comprehension concerning the degree of acceptability, a comprehensive investigation into real-time processing of islands structures with or without discourse would

provide additional context for examining the effect of referential forms across various structural configurations in the incremental process of building structures.

7. Conclusion

This study employs two self-paced reading tasks to investigate the influence of NP types on real-time processing of cleft sentences. The overall findings suggest that both the violation of expectations and interference effects in memory may contribute to the processing difficulty. First, in the intervenor region, Experiment 1 revealed a clear presence of processing difficulty when predictions were significantly violated and Experiment 2 demonstrated processing ease when the NP type of the filler led to a strong prediction of the NP type of the intervenor. The processing difficulty also emerges on the verb, indicating the easier processing of pronoun conditions than full NP conditions during the retrieval of the filler. Experiment 2 confirmed that the similar processing load of full NPs at the verb cannot be attributed to contextual effects. These distinct processing patterns observed in the two regions imply the involvement of different types of processing mechanisms in the comprehension of dependencies. Future studies are needed to explore other potential factors that contribute to processing difficulties in various structures to deepen our understanding of the underlying processing mechanisms in complex sentences.

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Examples in: English
Applicable Languages: English
Applicable Level: Tertiary

