The Effects of Frequency on Pronoun Production

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The present study aims to examine whether pronoun production is influenced by referent frequency. We used a story continuation task and manipulated the frequency of referent nouns in one-entity *(the woman(HF)/ postman(LF) skated to the house)* and two-entity contexts *(HF Subject-LF Object: the girl(HF) calmed the monk(LF) & LF Subject-HF Object: the postman(LF) warned the mother(HF))*. We found that frequency had no effect in one-entity contexts. However, the frequency effect was significant in two-entity contexts. When the subject had a high frequency while the object had a low frequency (HF Subject-LF Object), the rate of pronoun use increased for subject but decreased for object referents, compared to when the subject had a low frequency while the object had a high frequency (LF Subject-HF Object). That is, participants tended to use more pronouns for high frequency referents. This suggests that frequency is a factor that modulates pronoun production in the presence of multiple entities. We discuss the implications of our results in terms of existing theories.

Keywords: *language production, pronouns, reference, accessibility, discourse, frequency*

1. Introduction

When making references, speakers can choose between longer and more specific forms, such as proper names (*Mary*) and noun phrases (*the woman*), and shorter and more general forms such as personal pronouns (*she*). Previous production research suggests that the accessibility of discourse entities plays an important role in the choice of referring expression (e.g., Ariel, 1990; Arnold, 2008, 2015; Arnold & Griffin, 2007; Gernsbacher & Hargreaves, 1988). In particular, Ariel (1990) suggests that the form of reference denotes the relative degree of accessibility, such that the use of a pronoun (*she*) indicates that the referent is highly accessible, while the use of a noun phrase means that the referent is of a relatively low degree of accessibility, i.e., the accessibility theory (see Arnold, Eisenband, Brown-Schmidt & Trueswell, 2000; MacDonald & MacWhinney, 1990 for the effect of accessibility in comprehension).

A referent's accessibility has been linked with various linguistic and non-linguistic factors (see Arnold, 2010 for a review). Examples include syntactic prominence (e.g., subjecthood and topichood, Rhode & Kehler, 2014), givenness (e.g., Bock & Irwin ,1980), thematic prominence (e.g., Arnold, 2001; Brown & Fish, 1983; Kaiser, Li, & Holsinger, 2011), semantic properties (e.g., animacy, Fukumura & van Gompel, 2011; informativity, Karimi, Fukumura, Ferreira & Pickering, 2014), and visual salience (e.g., Fukumura, van Gompel & Pickering, 2010; Vogels, Krahmer & Maes, 2013). Here we review three factors associated with accessibility that are known to have robust effects on pronoun use: subjecthood, competition, and gender.

Previous research suggests that speakers tend to use pronouns more frequently to refer to the subject entity than the non-subject entity. Speakers often assign relatively accessible entities to the subject function and use that function to signal discourse focus (Arnold, 2001, 2008; Grosz, Weinstein & Joshi, 1995; Rohde & Kehler, 2014). As a result, the subject entity is perceived as more accessible and thus is more likely to be pronominalized. That is, speakers are more likely to use pronouns to refer to "Jill" than "Kenny" in (1), i.e., the subjecthood effect.

(1) Jill walked to school with Kenny.

In addition to using more pronouns for the subject, English speakers are more likely to use pronouns in the presence of one discourse entity as opposed to two (Arnold & Griffin, 2007; Fukumura et al., 2010). That is, speakers are more likely to use pronouns to refer to "Jill" in (2) than in (1), i.e., the competition effect.

(2) Jill walked to school.

Arnold and Griffin (2007) account for the competition effect in terms of the speaker's finite cognitive resources for memory and attention. When an additional entity is present in the discourse, it captures a certain amount of the speaker's attention, decreasing the attention allocated to the referent. Consequently, the referent is less accessible to the speaker's representation of the discourse and speakers tend to use fewer pronouns in the presence of two entities compared to one (see also Fukumura et al., 2010; Hwang, 2016).

Although speakers tend to use fewer pronouns in the presence of two entities, they tend to use even fewer pronouns when the entities share the same gender as opposed to when they differ in gender, i.e., the gender effect (e.g., Arnold & Griffin, 2007; Fukumura, Hyönä & Scholfield, 2013; Fukumura et al., 2010). Thus, English speakers are more likely to use "she" to refer to Mary after (3) than (4),

(3) Mary walked to school with John.
(4) Mary walked to school with Jane.

Arnold and Griffin (2007) suggest that this is because the competition is stronger when entities share more features. When speakers prepare for reference production, they have to consider various properties relevant to the reference form (e.g., number, gender, and animacy for English). When an additional discourse entity shares the gender feature in consideration, it would capture the speaker's attention more than when it does not match that feature. Thus, the referent becomes less accessible in the same-gender

context and is less likely to be pronominalized.

In sum, the effects of subjecthood, competition, and gender suggest that the accessibility of referents plays a crucial role in determining referential preferences. In this paper, we examine how referential preferences are influenced by frequency, a factor that is well-known to affect the accessibility of words in sentence production literature.

There is considerable evidence that frequency affects how accessible an entity is in speakers' representation. Balota and Chumbley (1984) suggest that high frequency (HF) words are more easily activated (accessible) than LF words. As a result, they are recognized and produced more quickly and accurately than LF words, i.e., the frequency effect. Results from Jescheniak and Levelt (1994) corroborate this account; speakers named HF objects faster than LF objects in a picture-naming task, even when they were familiar with all items due to repeated exposure. This suggests that frequency has a robust effect on lexical access (see also, Bonin & Fayol, 2002; Bonin, Fayol & Gombert, 1998; Forster & Chambers, 1973, Griffin, 2001; Oldfield & Wingfield, 1965).

In contrast, the frequency effect is not as clear in reference processing. Research on pronoun production suggests that HF antecedents are more accessible (Navarrete, Basagni, Alario & Costa, 2006), whereas research on pronoun comprehension suggests otherwise (Egusquiza, Navarrete & Zawiszewski, 2016; Lago, 2014; van Gompel & Majid, 2004).

In terms of reference production, Navarrete et al. (2006) showed that referent frequency affected how fast Spanish speakers produced pronouns to name pictures of referents. In the study, participants were shown pictures of objects with names of different frequencies and asked to describe them with the structure "pronoun (this/that) + verb + adjective (new/old)". Navarrete et al. found that when the depicted object had a high frequency name (e.g. train), participants were significantly faster in producing the relevant structure than when the object had a low frequency name (e.g. igloo).

Although the results of Navarrete et al. (2006) suggest that HF antecedents are more accessible, the results of pronoun comprehension research provide no conclusive evidence on the frequency effect. For example, van Gompel and Majid (2004) found that reading times for the

region immediately after pronouns were faster when the antecedents were LF than when they were HF. The results are quite surprising given that HF words are easier to produce (e.g., Balota and Chumbley, 1984; Jescheniak & Levelt, 1994). Van Gompel and Majid (2004) suggest that their results can be accounted for by the saliency account of memory; LF referents are more salient in memory because they attract more attention and require more processing effort, and they are thus encoded better in memory. As a result, LF referents are retrieved faster. However, Lago (2014) failed to replicate the findings with common nouns. Similarly, Egusquiza et al. (2016) did not find any frequency effect on reading times of pronouns in Spanish. Thus, the effect of frequency in pronoun comprehension is not clear.

In sum, the effect of frequency on reference processing is inconclusive and calls for more empirical studies. The present study attempts to contribute to a better understanding of how frequency influences reference processing by examining the relationship between frequency and pronoun use. Navarrete et al. (2006) showed that speakers are faster to produce pronouns with HF referents, but the study does not address whether frequency influences the choice of reference form (pronoun vs. NP). As pronoun use closely reflects the accessibility of discourse entities (e.g., Ariel, 1990), our results can help clarify whether frequency increases or decreases accessibility.

Theories of reference processing make different predictions regarding the effect of frequency on pronoun production. This is because theories differ in terms of what makes referents more accessible. We first review theories that predict more pronouns for HF referents, namely the accessibility theory (Ariel, 1990), the expectancy hypothesis (Arnold, 2001) and the informational load hypothesis (Almor, 2004; Almor & Nair, 2007). Then, we discuss theories that predict a null effect (the Bayesian computational model; Kehler, Kertz, Rohde & Elman, 2008) or greater pronoun use for LF referents (the saliency account of memory; van Gompel & Majid, 2004).

The accessibility theory is one of the theories that predict more pronouns for HF referents. It assumes that speakers favor pronouns for highly accessible referents and NPs for less accessible referents (Ariel, 1990). Since HF words are more easily activated than LF words in production, it predicts that speakers would use more pronouns for HF referents but more NPs for

LF referents.

Similar predictions can be made by the expectancy hypothesis. According to the hypothesis, entities that are likely to receive subsequent mention are more accessible and thus tend to be pronominalized (Arnold, 2001, 2008, 2010; Arnold, Fagnano & Tanenhaus, 2003). Although the expectancy hypothesis does not define predictability in terms of frequency, these two factors may be related. High frequency words occur more often in discourse than low frequency words. Hence, if HF words are also more likely to be mentioned again than LF words in the discourse, the expectancy hypothesis predicts that speakers would use more pronouns for HF referents than LF.

In addition, the information load hypothesis also predicts more pronouns for HF referents from a processing cost perspective. It argues that the choice of reference form is a balance between function and cost (Almor, 2004; Almor & Nair, 2007). Detailed expressions (e.g., NPs) activate relatively more semantic information, and this makes it easier for speakers to process referents that are less active in memory. However, active referents take up more space in speakers' finite working memory, resulting in processing difficulties when paired with NP references. Therefore, it is easier to process active referents when they are paired with pronouns (Trenkic, 2009). Although the information load hypothesis is mainly about comprehension, if HF words are more active during production (e.g., Balota and Chumbley, 1984; Jescheniak & Levelt, 1994), speakers are expected to use more pronouns for HF referents.

There are, however, theories suggesting that frequency has no effect or a reverse effect on pronoun use. For example, the Bayesian computational model by Kehler et al. (2008) defines accessibility in terms of syntactic prominence and does not predict frequency to be a factor affecting pronoun use. Rhode and Kehler (2014) replicated the subjecthood effect, showing speakers' preference to use more pronouns for subject than non-subject referents. They further found that speakers use more pronouns for the subject when it is likely to be the topic (e.g., the subject of a passive clause) than not (e.g., the subject of an active clause). This suggests that the subject is not only the relatively prominent grammatical role but also the default topic position in English. The model does not predict frequency to be a factor affecting pronoun use, as frequency is not inherently related to

syntactic position nor topichood.

   Van Gompel and Majid (2004) further suggest that frequency may have a reverse influence on pronoun use and LF referents should be more likely to be pronominalized. Previous research suggests that referents that require more processing effort are better encoded into memory, leading to easier access subsequently. For example, Karimi et al., (2014) showed that speakers use more pronouns for NP antecedents that are modified by relative clauses than those that are not. Since antecedents with relative clauses require more processing effort than those that do not, the results suggest that processing effort contributes to memory encoding and accessibility. Similarly, van Gompel and Majid (2004) suggest that LF words require relatively more processing effort and are better encoded in memory. Consequently, they are retrieved faster and speakers should thus use more pronouns for LF referents.

   We aim to evaluate these different theories by examining the frequency effect on the choice of referential form.

2. Method

2.1 Participants

We recruited 52 participants on Amazon Mechanical Turk in exchange for $3.50. We restricted our recruitment to participants in the US with approval rates greater than 95%. All participants indicated English as their native language.

2.2 Materials and Procedure

Following previous pronoun production studies, we used a written story continuation task (see Arnold, 2001; Arnold & Griffin, 2007; Fukumura et al., 2010). In the task, participants were presented with one sentence at a time. They were instructed to freely add a complete and grammatical sentence that naturally continues the story. For example, they were presented with a sentence ("*the woman begged the postman*") and asked to respond by providing their own sentence (e.g., "*she needed money*"). They

were reminded to keep their continuations relevant to the original stories, but no further instruction was given regarding the choice of reference form or referent.

The questionnaire consisted of 48 target items. To construct target items that differed in frequency, we chose 16 target referent nouns in total, eight high frequency (HF) nouns and eight low frequency (LF) nouns. We determined the frequency of the referent nouns based on their lemma-based frequencies in the WebCelex database (Baayen, Piepenbrock & Gulikers, 2001). The mean counts per million was 555.25 (SD = 481.55, range = 154-1629) for the HF nouns and 5.63 (SD = 3.5, range = 2-10) for the LF nouns. The difference between the two groups was significant ($t_{(14)}$ = 3.23, p < .001). The HF and LF nouns did not differ in terms of numbers of syllables (mean syllable for HF nouns = 1.5; mean syllable for LF nouns = 1.75; range = 1-2; $t_{(14)}$= -1, p > .05).

In order to see how frequency affects pronoun use, we manipulated the frequency of the referent nouns in one- and two-entity conditions. In the one-entity condition, we manipulated the frequency of subject nouns (e.g., *the woman (HF)/ the postman (LF) skated to the house*). There were eight items with HF subjects and eight items with LF subjects.

In the two-entity condition, we manipulated the frequency of both subject and object nouns. In particular, we manipulated the subject and the object nouns to be of contrasting frequencies; when the subject had a high frequency, the object had a low frequency, and vice versa (e.g., *the man (HF) bit the monk (LF)/ the pastor (LF) found the woman (HF)*). We intentionally used the contrasting frequencies design to easily detect the frequency effect. For example, if there is a strong tendency for speakers to use pronouns for the subject, the manipulation of subject frequency with the object frequency controlled may not have any significant effect on pronoun use (i.e., ceiling effect). Thus, rather than manipulating the frequency for the subject and the object individually, we chose to use contrasting frequencies. This maximizes the difference in pronoun use between the grammatical functions in HF Subject-LF Object and minimizes the difference in LF Subject-HF Object. We are interested in how the frequency manipulation affects the difference in the rates of pronoun use for the subject and the object (calculated by % of pronoun use for the subject - % of pronoun use

Table 1. Examples of the 6 experimental conditions

Number of entity	Frequency	Example
One	HF Subject	The girl (HF) ran to the pool.
	LF Subject	The postman (LF) skated to the house.
Two	HF Subject-LF Object (same gender)	The husband (HF) begged the pastor (LF).
	HF Subject-LF Object (different gender)	The husband (HF) encouraged the duchess (LF).
	LF Subject-HF Object (same gender)	The mermaid (LF) rescued the mother (HF).
	LF Subject-HF Object (different gender)	The nun (LF) forgave the boy (HF).

for the object) in the two-entity conditions.

There were 16 items for each frequency condition (16 for HF Subject-LF Object and 16 for LF Subject-HF Object). Within each frequency condition, there were eight items with same-gender entities and eight with different-gender entities. The nouns were not paired with the same noun again to prevent participants from making any associations between entities. The subject and the object nouns were combined with 16 verbs, with each verb occurring twice. Each verb occurred with different pairs of entities, so that participants do not make associations between entities and actions (see Table 1 for examples of the stimuli).

The verbs we selected were not biased towards either entity as the subsequent continuation. Previous research suggests that when there are two entities, speakers are more likely to interpret pronouns as referring to the cause of the action encoded by the verb (e.g., Au, 1986; Brown & Fish, 1983; see Rudolph & Fŏrsterling, 1997 for review). Thus, to eliminate the possible confounding variable of implicit causality, we chose 16 equi-biased verbs based on Hartshorne & Snedeker's (2013) online referent judgment study (% object bias: $M = 51.94$, $SD = 2.49$, range = 46-55).

The 48 target items were combined with 26 fillers. The filler sentences were plural or constructed with non-human entities (e.g., *the children went to the park/ the monkey scratched the hikers*). The sentences were semi-randomized, so that no more than two target items occurred consecutively. Participants were given two practice trials before the experimental items.

2.3 Coding and Analyses

Following previous studies (e.g., Arnold & Griffin, 2007; Fukumura et al., 2013; Fukumura et al., 2010), we analyzed participants' responses based on the form of the first-mentioned entity (pronoun vs. NP). We excluded incomplete or ungrammatical responses (e.g., *with a hearty hello*). We also excluded references other than those referring to the subject or object entities of the stimuli, such as possessives and determiners (e.g., *his mother was oblivious to the fact, this surprised the man very much*). Only responses that started with NPs or pronouns were included in our analyses. This resulted in the removal of 364 trials, leaving 2132 experimental trials for analyses (about 85% of the total number of responses).

In order to see whether our participants behaved similarly to those of previous studies, we first analyzed whether our data replicated the competition, subjecthood and gender effects. To investigate the effect of frequency in reference production in the one-entity condition, we compared the rates of pronoun use in HF Subject and LF Subject conditions. In two-entity conditions, we analyzed both the choice of referent (whether participants continued with the subject or the object) and reference form (whether participants used pronouns or NPs).

The data were analyzed with logit mixed-effects models. The models are well-suited for analyzing categorical data as in our study and are better able to deal with unbalanced data sets than ANOVAs (see Barr, Levy, Scheepers & Tily, 2013; Jaeger, 2008). In the one-entity condition, we ran a model with subject frequency as the fixed effect. For the two-entity condition, we ran models with the number of entities, the grammatical function of the referent, the gender of discourse entities, and the interaction of our frequency manipulation and the referent's grammatical function as the fixed effects. Participant and item were the random effects in all models.

For each model, we performed a stepwise backward reduction to find the best predictors of the choice of reference form (see Appendix A for all logit models). Additionally, for the frequency effect in the two-entity condition, we also report paired t-test results for the subject-object differences of pronoun use.

3. Results

3.1 Replication of Competition, Subjecthood, and Gender Effects

We first report whether our study replicated the competition, subjecthood, and gender effects reported in previous studies. Figure 1a shows the percentages of pronoun responses produced in the one-entity and two-entity conditions. Participants used significantly more pronouns in one-entity conditions (95.6%, 608 out of 636 trials) than two-entity conditions (61.77%, 908 out of 1470 trials)(β = -1.5639, z= -8.298, $p < .001$, SE = 0.1885). This replicates the previous evidence for the competition effect reported by Arnold & Griffin (2007) and Fukumura et al. (2010).
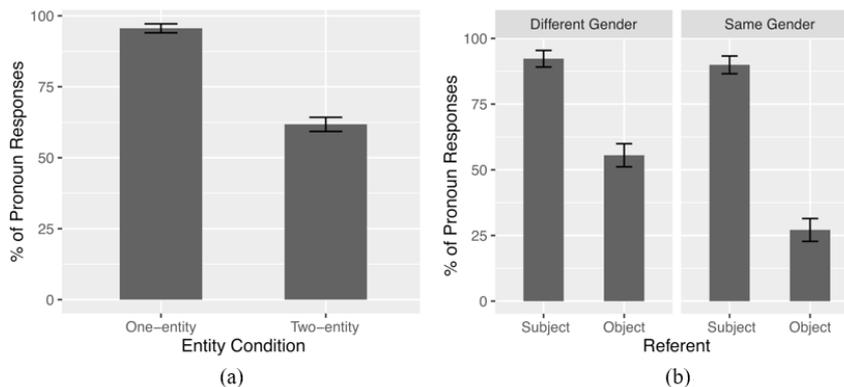

Figure 1. (a) Percentages of pronoun responses produced in the one-entity and two-entity conditions. (b) Percentages of subject/object referent pronouns out of all forms referring to the subject/object in same/different-gender conditions. Error bars represent the 95% confidence intervals from the population proportions.

Figure 1b shows the percentages of pronoun use (out of both pronoun and NP responses) for the subject and the object in same and different gender conditions. As can be seen, participants used pronouns to refer to the subject significantly more often than the object (91% vs. 42.7%; $\beta = 3.7681$, $z = 8.911$, $p < .001$, $SE = 0.4229$). In fact, 33 out of 52 participants used pronouns for subject entities 100% of the time. The results are consistent with existing literature on the subjecthood effect (Grosz et al., 1995; Rohde & Kehler, 2014).

We also found a significant gender effect consistent with previous research (e.g., Arnold & Griffin, 2007; Fukumura et al., 2010; Fukumura et al., 2013); participants used more pronouns to refer to both the subject and the object when the two entities had different genders than when they had the same gender ($\beta = -1.9269$, $z = -5.352$, $p < .001$, $SE = 0.3600$; Subject: 92.3% vs. 89.9%; Object: 55.5% vs. 27.1%).

3.2 Frequency Effect

We conducted separate analyses to examine the effect of frequency in one-entity and two-entity conditions.

3.2.1 One-entity

In one-entity conditions, participants predominantly used pronouns to refer to the referents (95.6%) regardless of frequency. The pronoun use was slightly higher when the subject had a high frequency (96.56%) than a low frequency (94.62%). However, the difference did not reach statistical significance ($\beta = -0.8240$, $z = -1.034$, $p = 0.301$, $SE = 0.7973$).

3.2.2 Two-entity

Figure 2a shows the percentages of pronoun responses. When we compared the choice of reference form in the HF Subject-LF Object condition with LF Subject-HF Object, we found that the rate of pronoun use for the subject function decreased (93.1% vs. 87.7%) while that for the object function increased (35.9% vs. 48.2%). The result of logit analysis suggests that
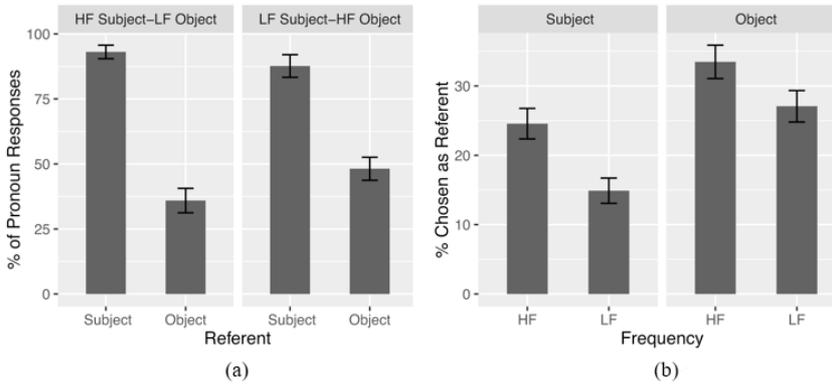
Figure 2. (a) Percentages of pronoun responses for the subject and the object in two-entity conditions (HF Subject-LF Object and LF Subject-HF Object). (b) Percentage distribution of all continuations in two-entity conditions, categorized by grammatical function and referent frequency. Error bars represent the 95% confidence intervals from population proportions.

the interaction between the frequency manipulation and the grammatical function of the referent was significant ($\beta = -0.9973$, $z = -1.974$, $p < .05$, $SE = 0.5053$). The paired t-test confirms that the subject-object difference in pronoun use (calculated by % of pronoun use for the subject - % of pronoun use for the object) was significantly larger in the HF Subject-LF Object condition (44% vs. 26%) than in the LF Subject-HF Object condition ($t_{(51)} = 3.5938$, $p < .001$). Taken together, frequency significantly modulates the subjecthood effect in pronoun use. When grammatical function is not considered, speakers were significantly more likely to use pronouns for HF referents and NPs for LF referents ($\beta = -0.5656$, $z = -3.523$, $p < .001$, $SE = 0.1606$).

Frequency also had a significant influence on the choice of referent. Figure 2b shows referent choice as a function of grammatical functions and frequency in two-entity conditions. In general, participants were more likely to continue with object (60.5% vs. 39.5%; 890 out of 1470 trials were object continuations) over subject entities ($t_{(51)} = 3.18$, $p < .01$; $t_{(31)} = 3.78$, $p < .001$). Crucially, however, when the frequency condition changed from HF Subject-LF Object to LF Subject-HF Object, the likelihood of subject continuation significantly decreased while that of object significantly

increased (β = -0.9603, z = -3.268, p < .01, SE = 0.2938). When grammatical function is not considered, participants were more likely to continue with HF entities (59% vs. 41%) than LF entities ($t_{(51)}$ = 6.42, p < .001; $t_{(31)}$ = 2.56, p < .05).

4. Discussion

Our results replicated previous findings on the competition, subjecthood, and gender effects; we found that speakers used more pronouns when there was one entity in the sentence than when there were two (Arnold & Griffin, 2007; Fukumura et al., 2010). When there was more than one entity, we found that participants used more pronouns for the subject entities (Arnold, 2001, 2010; Rohde & Kehler, 2014) and for the entities that had a different gender from other entities in the discourse (e.g., Arnold et al., 2000; Arnold & Griffin, 2007; MacDonald & MacWhinney, 1990). Thus, the results suggest that our participants behaved like those in other studies.

The main purpose of our study was to examine the effects of frequency on the choice of reference form (repeated NP or pronoun) and the choice of referent (Subject or Object) in one- and two-entity conditions. We did not observe any significant effect of frequency on the subject function in the one-entity condition (96.56% vs. 94.62%). This may be due to the strong subjecthood effect. The subject entity, being the sole entity in the discourse, captures the speaker's attention and is highly accessible in the speaker's representation. As a result, our participants were highly inclined to use pronouns for the subject entity, overshadowing the frequency effect, if any (i.e., ceiling effect).

In two-entity conditions, however, we found a significant interaction effect of referent noun frequency and the grammatical function of the referent in our logit result. In the LF Subject-HF Object condition, compared to the HF Subject-LF Object condition, the rate of pronoun use for the subject decreased, while that for the object increased. The difference in pronoun use for the subject and the object was significantly larger in HF Subject-LF Object than LF Subject-HF Object. That is, participants tended to use more pronouns for high frequency referents.

The significant frequency effect in the two-entity condition is consistent

with the accessibility theory (Ariel, 1990) and the information load hypothesis (Almor 2004; Almor & Nair, 2007), which predict more pronoun use for accessible entities. Our results are also compatible with the expectancy hypothesis (Arnold, 2001). Although speakers tended to use more pronouns to refer to the subject in our study, the rates of pronoun use for both the subject and the object were higher when they had a high frequency than when they had a low frequency. That is, the frequency effect modulated the subjecthood effect. When grammatical functions were collapsed, we found that speakers were more likely to continue with HF referents and pronominalize them. As HF words occur more often than LF words in discourse, they are more predictable and speakers would thus use more pronouns for HF referents. Hence, our results are in line with Arnold's (2001) suggestion that predictability is a contributing factor in pronoun use.

Our results, however, do not fare well with the saliency account of memory (van Gompel & Majid, 2004) and the Bayesian computational model (Rhode & Kehler, 2014), which predict more pronoun use for LF referents and no influence of referent frequency, respectively. However, as discussed in the introduction, the effect of frequency on reference comprehension has not been clearly established. Therefore, we cannot reliably conclude that frequency has reverse effects on reference production and comprehension.

Although we found that frequency significantly affects pronoun use, our results can be accounted for by the informational content of the word rather than frequency. The uniform information density theory (Frank & Jaeger, 2008; Jaeger, 2010; Jaeger & Levy, 2006) suggests that speakers prefer to keep the rate of information transmission regular, by avoiding any sudden acceleration caused by high information load. For instance, Frank and Jaeger (2008) studied the use of contractions (such as "you're", "you've", and "didn't"). They found that speakers used more full forms for high information content, because this strategy distributes the large amount of information over a longer time. The LF words (e.g., "mermaid" and "wizard") in our stimuli are more specific and contain more information than HF words (e.g., "woman" and "man"). Thus, in order to maintain a uniform information density, speakers would use more full forms for LF referents and more pronouns for HF referents. That is, the pattern

of pronoun use we found may reflect the production strategy based on information density rather than the frequency effect. To further clarify the cause of the pronoun use pattern we found, future studies may control frequency but manipulate the informativity of referents.

As our study did not include conditions in which the frequencies of subject and object entities are controlled, we cannot address how frequency influences the subject and the object function separately. However, due to the strong subjecthood effect, we suspect that the frequency effect might be difficult to detect without having contrasting frequencies (as seen in the one-entity condition in our study). Nevertheless, the interaction between frequency and grammatical functions in production merits future research (see Egusquiza et al., 2016 for their interaction in comprehension). Moreover, the current study used written words to manipulate frequency. Future studies may investigate the frequency effect using pictures as in Navarrete et al. (2006) to see if the frequency effect is replicated.

5. Conclusion

The present study replicated previous findings on the competition, subjecthood, and gender effects, which are suggested to be factors affecting accessibility. Crucially, the study showed that the frequency manipulation significantly influenced the choice of referent and reference form. Taken together, the results of our study suggest that frequency is a factor affecting pronoun production in the presence of multiple entities, along with gender and grammatical roles.

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Appendix A: Summaries of the fiexed effects in the logit-mixed effect model

Table 2. Summary of the fixed effects in the model for the competition effect in the two-entity condition
(Form of reference~Number of entity+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	2.2954	0.2648	8.667	<.001
Number of entity = *two*	-1.5639	0.1885	-8.298	<.001

Table 3. Summary of the fixed effects in the model for the subjecthood and gender effects in the two-entity condition
(Form of reference~Grammatical function*Gender+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	0.8157	0.4550	1.793	>.05
Grammatical function = *subject*	3.7681	0.4229	8.911	<.001
Gender = *same*	-1.9269	0.3600	-5.352	<.001
Interaction = *subject & same gender*	0.9831	0.5033	1.953	0.05

Table 4. Summary of the fixed effects in the model for the frequency effect in the one-entity condition
(Form of reference~Frequency+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	9.1380	1.7754	5.147	<.001
Frequency = *low*	-0.824	0.7973	-1.034	>.05

Table 5. Summary of the fixed effects in the model for the frequency effect on the choice of referent in the two-entity condition (Grammatical function~Frequency+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	-1.0562	0.2703	-0.578	.56325
Frequency = *LF Subejct-HF Object*	-0.9603	0.2938	-3.268	<.01

Table 6. Summary of the fixed effects in the model for the interaction effect in the two-entity condition (Form of reference~Frequency*Grammatical function+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	-0.469	0.5085	-0.922	>.05
Grammatical function = *subject*	4.8478	0.4141	11.707	<.001
Frequency = *LF Subject-HF Object*	0.6053	0.4649	1.302	>.05
Grammatical function: Frequency = *Subject:LF Subject-HF Object*	-0.9973	0.5053	-1.974	<.05

Table 7. Summary of the fixed effects in the model for the frequency effect on the choice of reference form in the two-entity condition when grammatical function is not considered (Form of reference~Referent frequency+(1|Item)+(1|Subject))

Predictor	Coefficient	SE	Wald Z	p
Intercept	1.3071	0.3866	3.381	<.001
Frequency = *LF Subject-HF Object*	-0.5656	0.1606	-3.523	<.001

Appendix B: Stimuli used in the experiment classified by conditions

One-entity, HF

The woman skated to the market.
The mother cycled to the nursery.
The girl ran to the pool.
The wife drove to the office.
The father swam to the pier.
The husband walked to the bar.
The man jogged to the forest.
The boy crawled to the playground.

One-entity, LF

The mermaid swam to the shore.
The duchess walked to the ballroom.
The nun ran to the nunnery.
The goddess cycled to the courthouse.
The postman skated to the house.
The pastor drove to the church.
The monk jogged to the temple.
The wizard crawled to the cave.

Two-entity, HF Subject-LF Object
Same gender

The father answered the postman.
The husband begged the pastor.
The man bit the monk.
The boy calmed the wizard.
The woman caught the mermaid.
The mother helped the duchess.
The girl commanded the nun.
The wife found the goddess.

Different gender

    The woman begged the postman.
    The mother answered the pastor.
    The girl calmed the monk.
    The wife thanked the wizard.
    The father warned the mermaid.
    The husband encouraged the duchess.
    The man served the nun.
    The boy obeyed the goddess.

Two-entity, LF Subject-HF Object
Same gender

    The postman forgave the husband.
    The pastor encouraged the father.
    The monk led the boy.
    The wizard obeyed the man.
    The mermaid rescued the mother.
    The duchess served the woman.
    The nun thanked the wife.
    The goddess bit the girl.

Different gender

    The mermaid led the husband.
    The duchess commanded the father.
    The nun forgave the boy.
    The goddess helped the man.
    The postman warned the mother.
    The pastor found the woman.
    The monk caught the wife.
    The wizard rescued the girl.