Processing Grammatical and Notional Number Information in English and French

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Abstract

Number is a grammatical category found in nearly every language around the world (Corbett, 2000). The syntactic expression of number is referred to as *grammatical number*. In English and French, two number categories are in use: singular and plural. Nouns that are written more frequently in their singular form are called *singular-dominant*, while those that are written more frequently in their plural form are called *plural-dominant*. Several lexical decision and picture naming studies have found that grammatical number and noun dominance interact, resulting in a surface frequency effect for singular-dominant nouns only. Singular-dominant nouns are recognized/named significantly faster in their singular form than in their plural form, while plural-dominant nouns are recognized/named equally fast in both forms (e.g., Baayen, Burani, & Schreuder, 1997; Biedermann, Beyersmann, Mason, & Nickels, 2013; Domínguez, Cuetos, & Segui, 1999; New, Brysbaert, Segui, Ferrand, & Rastle, 2004; Reifegerste, Meyer, & Zwitserlood, 2017). The objective of this thesis is to extend our understanding of the singular-dominant noun surface frequency effect in English and French by adopting three procedures. First, advanced linear mixed modelling techniques were used to improve statistical power and accuracy. Second, the noun dominance ratio technique (Reifegerste et al., 2017) was applied to investigate whether the surface frequency effect remains significant when noun dominance was treated as a continuous variable. Third, a determiner-noun number agreement task was created to determine whether the surface frequency effect could be reproduced in a novel task. Three studies were conducted. In Study 1, two lexical decision tasks (LDTs) were conducted. Results revealed that in both English and French, singular nouns were recognized faster than plural nouns while the noun dominance effect was non-significant. The interaction between grammatical number and noun dominance was significant in French and marginally so in

English. The interaction pattern was identical in both languages, singular-dominant nouns demonstrated a surface frequency effect while plural nouns did not. In Study 2, three determiner-noun number agreement tasks (NATs) were conducted. Results revealed that in both English and French, plural nouns were recognized faster than singular nouns. No other effects were significant. Incorporating irregular singular nouns (e.g., *bonus*) and plural nouns (e.g., *mice*) as foils produced the same results. In Study 3, two LDTs and one NAT were conducted. Lexical decision results revealed that in both English and French, singular nouns were recognized faster than plural nouns. However, the effects of noun collectivity and animacy were significant in English only; non-collective nouns were recognized faster than collective nouns while inanimate nouns were recognized faster than animate nouns. Number agreement results revealed that in English, plural nouns were recognized faster than singular nouns; no other effects reached significance. Taken together, my studies confirm that a strong surface frequency effect exists during visual word recognition for singular-dominant nouns. However, the surface frequency effect does not extend to the formation determiner-noun number agreement decisions, which were influenced nearly exclusively by grammatical number.

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General Introduction

People come into contact with thousands of words every day. These words are construed as physical (i.e., auditory or visual) and symbolic objects. What we know about these objects is commonly assumed to be represented in a hypothetical repository dubbed the *mental lexicon* (Aronoff & Fudeman, 2005). This mental lexicon preserves information about a person's knowledge of words and their various properties, such as the fact that words can be made up of one or more morphemes. *Simple words* are made up of a single morpheme (e.g., *give*), while *complex words* are made up of two or more morphemes (e.g., *giving* → *give* + *ing*; Akmajian, Demers, Farmer, & Harnish, 2001; Aronoff & Fudeman, 2005; Booij, 2007). A *morpheme* is a segmental linguistic unit that is meaningful and cannot be divided into smaller meaningful parts (Akmajian et al., 2001; Aronoff & Fudeman, 2005; Booij, 2007). All morphemes are either free or bound. *Free morphemes* are independent and can stand alone as individual words (e.g., *agree*, *blind*, *give*). In contrast, *bound morphemes* must be attached to another morpheme; they cannot stand alone (e.g., *dis-*, *-ed*, *-ing;* Akmajian et al., 2001). A common type of bound morpheme is an *affix*. There are three kinds of affixes: 1) prefixes added to the beginning of a word, 2) infixes added to the middle of a word, and 3) suffixes added to the end of a word (Akmajian et al., 2001; Aronoff & Fudeman, 2005; Booij, 2007). For example, the complex word *premeditated* is made up of the prefix *pre-*, the free morpheme *meditate*, and the suffix *-ed*. Morphemes are used in many ways to generate different types of complex words.

Bound morphemes can be used to express feature information on a variety of words (Corbett, 2012; Kibort, 2010). Kibort (2010) defined the term *feature* as referring to "a set of values and the available options for their realization on linguistic elements" (p. 80). Features allow linguists to identify common properties across words which are not always immediately apparent based on their written or vocalized forms (Corbett, 2012). There are several different types of features. Feature can be morphological, relating only to morphology (e.g., inflectional class) or syntactic, relating only to syntax (e.g., parts of speech; Corbett, 2012). However, most features are morphosyntactic and relate to both morphology and syntax. Grammatical gender and grammatical number are morphosyntactic features. Gender and number features can be morphologically marked and often influence syntax during the agreement process (Corbett, 2012, Kibort, 2010; see the section on Number Agreement below). Grammatical gender indicates whether a word is feminine, masculine, or neuter (Corbett, 2012; see §4.1.3 and §5.2 for additional gender categories). In some languages, such as Spanish, nouns often carry an identifiable gender marker (Domínguez, Cuetos, & Segui, 1999). Grammatical number is used to indicate whether a word is singular or some variant of plural (e.g., dual, trial, paucal; Acquaviva, 2004; Corbett, 2000; 2012). In many languages, such as Dutch, English, and French, nouns typically carry a plural marker. The absence of this plural marker signals that the noun is singular (Baayen, Dijkstra, & Schreuder, 1997; Corbett, 2000; Reid, 1991; Reifegerste et al., 2017). For my thesis, I focus on how the feature number is processed in French and English in two visual word recognition paradigms.

Number

Number is found in nearly every language around the world (Corbett, 2000). It is used to differentiate between singular (one), dual (two), trial (three), paucal (few), and plural (many; Acquaviva, 2004; Corbett, 2000). In English and French, only two number categories are in use: singular and plural (Booij, 2007; Corbett, 2000; Tallerman, 2011). In both languages, nouns, pronouns, verbs, and some determiners carry number information, as do French adjectives (Corbett, 2000; Mel’čuk & Milićević, 2014a; Reid, 1991). A singular noun refers to a single entity, object or concept. Conversely, a plural noun refers to two or more entities, objects, or concepts (Corbett, 2000; Mel'čuk & Milićević, 2014a; Reid, 1991; Tallerman, 2011).

The syntactic expression of number is inherent and referred to as *grammatical number* (Corbett, 2012; Kibort, 2010). In English and French, a grammatically singular noun is denoted by the absence of a plural marker, while a grammatically plural noun is denoted by the presence of a plural marker (Corbett, 2000; Reid, 1991). The most common plural marker in both languages is the inflectional suffix -*s* (Akmajian et al., 2001; Corbett, 2000; Mel'čuk & Milićević, 2014a; Reid, 1991). The sole purpose of this inflectional suffix is to convey grammatical number information, it does not change the core meaning of the noun in any other respect (Aronoff & Fudeman, 2005; Booij, 2007; Corbett, 2000; Reifegerste, Meyer, & Zwitserlood, 2017). For example, the noun *map* is grammatically singular while *map**s*** is grammatically plural.

Although -*s* is the dominant plural marker in both English and French, less common noun plural markers exist in both languages. In French, there is only one alternative plural marker, the inflectional suffix -*x* (e.g., *hibou**x*** [*owls*]; Corbett, 2000). In English, there are a handful of alternative inflectional suffixes, including -*a*, -*ae*, -*i* , and -*ice* (e.g., *stratum* → *strat**a***, *alga* → *alg**ae***, *cactus* → *cact**i***, *die* → *d**ice***). There are also a small number of plural nouns that do not follow standard plural marking (e.g., *goose* → *geese*, *woman* → *women*; Buck-Gengler, 2003). These exceptions demonstrate that although the inflectional suffix -*s* typically predicts noun plurality, it is not a perfect indicator. Moreover, the plural marker -*s* is often appended to other word classes as a result of the number agreement process, such as pronouns in both languages (e.g., *leur**s*** [*theirs*]) or adjectives in French (e.g., *petit**s*** [*small*]) (discussed further below; Corbett, 2000). Furthermore, it is necessary to mention that in English, the inflectional suffix -*s* has an additional function. It is used to denote third person singular present tense verbs (e.g., *she jumps*; Alegre & Gordon, 1999; Baayen, Feldman, & Schreuder, 2006; Feldman & Basnight-Brown, 2008).

Phonological realization. One important difference between English and French plural markers concerns their phonological realization. In English, the plural marker -*s* is always vocalized. It has three possible pronunciations, /s/ → *books*, /z/ → *boys*, and /əz/ → *boxes* (McGregor, 2009). In French, however, the plural marker -*s* is not vocalized unless it is involved in a phonological liaison (e.g., *les enfants* /lɛ**z**ɑ̃fɑ̃/ [*the children*]; Corbett, 2000; Largy, Cousin, Bryant, & Fayol, 2007; Moeschler & Auchlin, 2009; Totereau, Thevenin, & Fayol, 1997). Consequently, there is normally no audible difference between singular and plural French nouns (Corbett, 2000). Thus, when French nouns are spoken without an accompanying determiner (*le*/*la* [singular], *des*/*les* [plural]), it is impossible for the listener to determine whether they are singular or plural. In English, however, there is both a visual and auditory representation of noun number. This vocalization discrepancy accounts for methodological differences in the research that explores the acquisition of the singular-plural number distinction in English and French children discussed further below.

Notional number. The semantic expression of number is referred to as *notional number* (Corbett, 2012; Kibort, 2010). Notional number (also known as conceptual number or semantic number) is the number of referents, singular or plural, intended by the communicator (Eberhard, Cutting, & Bock, 2005; Nickels, Biedermann, Fieder, & Schiller, 2015). Grammatical number and notional number often align (Corbett, 2006). For example, the noun *map* is grammatically and notionally singular while the noun *maps* is grammatically and notionally plural. However, a noun's notional number is not entirely dependent on its grammatical number (Brehm & Bock, 2013; Corbett, 2000, 2006; Reid, 1991). In some instances, they can mismatch. One example of this is English singular *collective nouns*. This is because the notional number of English singular collective nouns can be conceptualized at two different levels. At the *group level*, singular collective nouns refer to a group of multiples as a single unit and are notionally singular. At the *member level*, singular collective nouns refer to the individual members making up the group and are notionally plural (Benninger, 2001; Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Corbett, 2000, 2006; Joosten et al., 2007; Lammert, 2015). For example, the grammatically singular collective noun *squad* can refer to either a group of individuals (group level) or to the various people who make up the squad (member level). Therefore, even though *squad* is grammatically singular, it can be perceived as either notionally singular or notionally plural. Given this example, it should be evident that notional number does not always match with grammatical number. However, in the majority of cases, grammatical and notional number are aligned.

Irregular noun number categories. Nouns that can be either grammatically singular or plural, like the majority of nouns discussed so far, are called *count nouns*. They refer to distinct countable entities (e.g., *map*/*map**s***; Iwasaki, Vinson, & Vigliocco, 2010; Middleton, Wisniewski, Trindel, & Imai, 2004; Wisniewski, Lamb, & Middleton, 2003). Yet not all nouns have two alternate forms. There are four types of nouns that cannot alternate between singular and plural forms. *Mass nouns* are grammatically singular nouns that refer to non-distinct uncountable entities in both French and English (e.g., *énergie* [*energy*], *hélium* [*helium*], *maïs* [*corn*]; Iwasaki et al., 2010; Middleton et al., 2004; Wisniewski et al., 2003). *Pluralia tantum nouns* are always grammatically plural yet notionally singular. Many pluralia tantum nouns exist in both languages, however they often do not correspond across languages (e.g., *devoirs* [*homework*], *gens* [*people*], *ciseaux* [*scissors*], *jumelles* [*binoculars*]; Bock, Carreiras, & Meseguer, 2012; Bock et al., 2001; Bock & Miller, 1991; Corbett, 2000). *Nouns ending in non-morphemic -s* are number invariant, they are used to represent both singular and plural in either French or English. These nouns often do not correspond across languages either (e.g. *fils* [*son*], *souris* [*mouse*], *toile* [*canvas*], *serveuse* [*waitress*]), but sometimes they do (e.g., *atlas* [*atlas*]). Finally, *zero plural nouns*, which exist only in English, are always grammatically singular yet their notional number can be singular or plural depending on context (e.g., *fish*, *sheep*; Bock & Miller, 1991; Corbett, 2000).

The Development of Singular-Plural Number Distinction

Several researchers have investigated the emergence of the singular-plural number distinction in children. Due to the fact that the plural marker -*s* is vocalized when it appears at the end of nouns in English, but silent when it appears at the end of nouns in French the experimental approaches taken to study this topic differ between the two languages.

English. At 20 months of age, English children do not comprehend the singular-plural noun distinction (Barner, Thalwitz, Wood, Yang, & Carey, 2007; Kouider, Halberda, Wood, & Carey, 2006; Wood, Kouider, & Carey, 2009). By 24 months of age, they begin to demonstrate knowledge of the singular-plural distinction by searching for either a single toy or two toys based on whether they receive singular or plural cues from phrases such as "*There is/are a/some car/cars in my box*" (Barner et al., 2007; Wood et al., 2009). However, they are unable to make this distinction when the verb and quantifier information is removed from the phrase (e.g., "*The car/cars in my box*") or when familiar nouns are replaced with nonce nouns (e.g., "*There is/are a/some blicket/blickets in my box*"; Barner et al., 2007; Kouider et al., 2006; Wood et al., 2009). Moreover, at 24 months old, children spend more time looking at visual displays of multiple nonce nouns than singular nonce nouns when the plural marker *-s* is vocalized as /s/ (e.g., *books*), but not when it was vocalized as /z/ (e.g., *boys*; Davies et al., 2017; Kouider et al., 2006). Jolly and Plunkett (2008) report that children are only able to comprehend the singular-plural distinction for nonce nouns at 30 months. By 32 to 36 months of age, children's comprehension of the singular-plural distinction becomes more sophisticated. They were able to distinguish between singular and plural familiar and nonce nouns when number information was provided by the noun only in both manual search and visual looking comprehension tasks (Blossom, 2013; Kouider et al., 2006).

The emergence of English children's ability to produce singular and plural nouns overlaps with their comprehension development. At 23 months of age, English children are able to verbally produce the singular or plural forms of familiar nouns when provided with their alternative form (e.g., "*Look, a hat. See the hat.*" [shown a picture of a single hat] *What do you see?*" [shown a picture of several hats]). They are also able to verbally generate the singular or plural forms of nonce nouns when provided with their alternative form (e.g., *wug*/*wugs*; Zapf & Smith, 2007). Overall, children find it easier to produce alternative forms for familiar nouns than nonce nouns. Furthermore, Clark and Nikitina (2009) found that at 24 months, children accurately produced singular nouns 65% of the time in the picture naming task when asked "*What do you see there?*" However, their ability to produce plural nouns was at chance (47%). By 36 months of age, children's ability to produce singular and plural nouns increased to 82% and 74% respectively.

French. The majority of research on the emergence of the singular-plural number distinction in French focuses on the written production of singular and plural nouns, with the exception of two studies. Robertson, Shi, and Melançon (2012) found that at 2 years old, French children are able to comprehend the singular-plural distinction for determiners. When they hear phrases such as "*Regarde le/les chat/chats*" [*Look at the cat/cats*], children spend more time looking at the visual display that matches the number information provided by the determiner. At 6 years old, children are able to comprehend the singular-plural distinction in writing when phrases include determiners (e.g., *les chats*), but not when nouns are presented alone (e.g., *chats*; Totereau et al., 1997). By the ages of 7 and 8, children are able to comprehend the difference between singular and plural nouns without the aid of the determiner.

The emergence of French children's written production of singular and plural nouns lags behind their comprehension abilities. At 6 years old, children's ability to produce singular and plural nouns is still developing. After hearing short sentences, their ability to correctly produce a singular or plural written noun to complete the phrases is considerably below chance (38%; "*Il y a un/deux* ______" [*There is/are one/two* ______]; Totereau et al., 1997). After receiving ten weeks of training, 6-year-olds accurately produce singular nouns (94%), but have a hard time producing written plural nouns (25%) when completing vocalized phrases (Largy et al., 2007). By the age of 7, children's overall written production accuracy increases to 80% without training. If they receive training, their ability to produce singular nouns remains high (96%) and their ability to produce plural nouns increases to 53%, on par with chance performance (Largy et al., 2007; Totereau et al., 1997). In other written production tasks, children have to provide a noun ending, if necessary, for determiner-noun phrases (e.g., *le/les chien_*). Researchers find that at 7 years old, children produce very few singular errors. Yet their ability to accurately produce the plural marker *-s* for plural noun phrases ranges from poor (18% to 40%) to good (76%; Fayol, Totereau, & Barrouillet, 2006; Totereau, Barrouillet, & Fayol, 1998). Once they turn 8, French children's ability to correctly produce plural noun endings finally surpasses chance (69%

to 85%). Plural ending production accuracy is nearly perfect by the time children reach 10 years old (90% to 97%; Fayol et al., 2006; Totereau et al., 1998). Finally, Fayol et al. (2006) tested children's singular-plural distinction ability by having them write entire sentences after hearing them vocalized (e.g., *La fille blonde parle* [*The blond girl talks*]). The authors found that at 7 years old, children's plural noun production is substantially below chance (26%) while at 8 years old their production accuracy improves to above chance (65%). By 9 and 10 years old, children's accuracy becomes almost perfect (91% to 100%).

Summary. Based on the research presented above, it is evident that the emergence of the singular-plural distinction for nouns is not a fast process. In both English and French, the concept of singular develops first, while the understanding of plural emerges more slowly. Children being grasping the singular-plural distinction at around 2 years old. In English, it takes children approximately a year to become proficient at both comprehending and producing singular and plural nouns and nonce nouns. In French, it takes children until the age of 8 years old to be able to express the difference between singular and plural nouns in writing. French chidlren's production of singular and plural nouns only emerges around 6 years old and takes up to four years to perfect[1]. Together, these findings suggest that the singular-plural distinction is a complex concept. It is likely that effects based on singular versus plural nouns will remain present to some degree later in life.

Determining a Noun's Dominant Number

Nouns are often written more frequently in one grammatical number than the other. This is referred to as *noun dominance* (Gimenes, Brysbaert, & New, 2015; New, Brysbaert, Segui,

[1] The reason for the cross-language discrepancies in the development of the singular-plural distinction is likely due to the fact that in English the plural marker -*s* is always vocalized, while in French is is never vocalized unless it is involved in a phonological liaison (McGregor, 2009; Corbett, 2000; Largy, Cousin, Bryant, & Fayol, 2007; Moeschler & Auchlin, 2009; Totereau, Thevenin, & Fayol, 1997).

Ferrand, & Rastle, 2004; Reifegerste et al., 2017). Nouns that are written more frequently in their singular form are called *singular-dominant*, while those that are written more frequently in their plural form are called *plural-dominant*. One of the key attributes often used to determine a noun's dominance is surface frequency. *Surface frequency* is the number of times (per million) that a word appears in one specific inflected or conjugated form in a corpus of continuous texts or spoken dialogues (New et al., 2004). For example, the noun *chance* is singular-dominant since it has a singular surface frequency of 143 and a plural surface frequency of only 33. On the other hand, the noun *miles* is plural-dominant because it has a singular surface frequency of only 36 yet a plural surface frequency of 141.

Researchers have proposed three different techniques for calculating noun dominance. The first technique is to calculate a *noun dominance score*. To do this, a noun's singular surface frequency occurrence is subtracted from its plural surface frequency of occurrence. A positive score indicates that the noun is singular-dominant, while a negative score indicates that it is plural-dominant (New et al., 2004; Sereno & Jongman, 1997). Positive and negative values are then used to create a dichotomous categorical noun dominance variable (i.e., singular-dominant vs. plural-dominant). This technique was commonly used in studies published prior to the late 2000s, which analyzed response latency data via analyses of variance (ANOVAs). More recently, with the adoption of more sophisticated statistical techniques, researchers have argued for the need to treat noun dominance as a continuous variable. The second technique is called *inflectional entropy*. It quantifies the average amount of number information expressed in morphemes (Baayen et al., 2006; Baayen, Levelt, Schreuder, & Ernestus, 2007; Moscoso del Prado Martín, Kostić, & Baayen, 2004). A noun's inflectional entropy is calculated by dividing a singular or plural noun's surface frequency by its summed frequencies (singular + plural); the resulting value ranges from 0 to 1. A score of 0.5 indicates no dominance (i.e., singular and plural surface frequencies are equal). A score below 0.5 indicates plural-dominance, while a score over this value indicates singular-dominance. The third technique is to calculate a *noun dominance ratio* by dividing a noun's singular surface frequency by its plural surface frequency (Reifegerste et al., 2017). A value falling below 1 indicates that a noun is plural-dominant while a value greater than 1 indicates that a noun is singular-dominant. A value of exactly 1 indicates no dominance. Recent studies have thus treated number dominance as a continuous rather than a dichotomous variable. To date, researchers have published several studies on the role of noun dominance in relation to both visual word recognition and picture naming. The results of these studies are presented in detail below.

The Role of Noun Dominance in Visual Word Recognition

Researchers have been investigating the role of noun dominance in visual word recognition using a lexical decision task (LDT) since the late 1990s. In a LDT, participants are shown a series of letter strings, half of which are real singular-dominant or plural-dominant nouns (e.g., *tree*) and half of which are non-words created to mimic the structure of real nouns (e.g., *slee*). Their task is to decide whether each letter string is a real word, yes or no. Researchers measure the impact of noun dominance on word recognition by comparing how quickly participants can recognize singular-dominant and plural-dominant nouns when they were presented in either their singular or plural form. This question has been studied in six languages: Dutch, English, French, German, Italian, and Spanish. The number marking system for English and French has been previously described. The number marking systems for Dutch, German, and Spanish are similar. That is, singular nouns are characterized by the absence of a plural marker, while plural nouns carry a plural marker. In Spanish, there is only one plural marker: *-(e)s*

(Domínguez, Cuetos, & Segui, 1999). In Dutch, researchers have only studied the plural marker -*en* (Baayen, Dijkstra, & Schreuder, 1997; Reifegerste et al., 2017). In German, there are four plural markers that have been studied as a group: -*e*, -*er*, -*(e)n*, and -*s* (Reifegerste et al., 2017). The number marking system in Italian is a bit different. Both singular and plural nouns are marked for grammatical number. Singular nouns end in one of three singular markers (-*a*, -*e*, or -*o*) while plural nouns end in one of two plural markers (-*e* or -*i*; Baayen, Burani, & Schreuder, 1997).

Despite discrepancies in number marking systems, lexical decision results are nearly identical across all six languages (see Table 1). First, singular nouns were recognized faster than plural nouns in all languages except Italian (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017). The lack of a grammatical number main effect in Italian is likely due to the fact that singular nouns also carry a number marker. Second, plural-dominant nouns were recognized faster than singular-dominant nouns in Dutch, Italian, and Spanish (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; Reifegerste et al., 2017). However, a noun dominance effect was not found in English, French, or German (New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Third, a significant two-way interaction between grammatical number and noun dominance was found in all six languages (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Singular-dominant nouns were recognized significantly faster in their singular form than in their plural form (25 – 55 ms singular advantage), while plural-dominant nouns were recognized equally fast in their singular and plural forms (2 – 16 ms plural advantage). In other words, there was an effect of surface frequency for singular-dominant nouns only.

Table 1

Sumary table of previous lexical decision noun dominance research study findings.

Article	Language	# of items/ condition	Dominance main effect	Number main effect	Dominance x Number interaction
Baayen, Burani, & Schreuder (1997)	Italian	17	20 ms plural-dominant advantage	ns	Singular-dominant nouns: 25 ms singular advantage Plural-dominant nouns: ns
Baayen, Dijkstra, & Schreuder (1997)	Dutch	21/24	34 ms plural-dominant advantage	31 ms singular advantage	Singular-dominant nouns: 54 ms singular advantage Plural-dominant nouns: ns
Domínguez, Cuetos, & Segui (1999)	Spanish	30	8 ms singular-dominant advantage	12 ms singular advantage	Singular-dominant nouns: 28 ms singular advantage Plural-dominant nouns: ns
New, Brysbaert, Segui, Ferrand, & Rastle (2004)	French	24	ns	13 ms singular advantage	Singular-dominant nouns: 28 ms singular advantage Plural-dominant nouns: ns
	English	24	ns	14 ms singular advantage	Singular-dominant nouns: 34 ms singular advantage Plural-dominant nouns: ns
Sereno & Jongman (1997)	English	12	ns	26 ms singular advantage	Singular-dominant nouns: 55 ms singular advantage Plural-dominant nouns: ns

In all of these noun dominance studies, during noun selection or through statistical analyses, researchers controlled for additional noun characteristics known to influence word recognition speed. These characteristics are base frequency, noun length, and noun gender. Failing to control for these characteristics would produce inaccurate results regarding the importance of noun dominance for visual word recognition. Below is a brief review of the research documenting the effects of these lexical characteristics.

Base frequency. The most influential noun characteristic for visual word recognition is base frequency (Ferrand et al., 2010). *Base frequency* is the number of times (per million) that a word appears in all its possible forms in a corpus of continuous texts or spoken dialogues (New et al., 2004). In lexical decision experiments, researchers find that readers are faster and more accurate at recognizing nouns with a higher base frequency compared to those with a lower base frequency (e.g., Becker, 1979; Conrad, Grainger, & Jacobs, 2007; Gordon, 1983; Grainger, 1990; Keuleers, Diependaele, & Brysbaert, 2010; Petrova, Gaskell, & Ferrand, 2011; Yap & Balota, 2009). This finding has been coined the *frequency effect*. Moreover, eye movement data show that readers spend less time reading and focusing on nouns with a higher base frequency than nouns with a lower base frequency (Miellet, Sparrow, & Sereno, 2007; Schilling, Rayner, & Chumbley, 1998).

Word length. Noun length has also been well documented as a characteristic that influences visual word recognition. Several researchers have found that shorter words are recognized faster and more accurately than longer words (Forster & Chambers, 1973; Hudson & Bergman, 1985; Keuleers et al., 2010; Whaley, 1978; Yap & Balota, 2009). This result has been labelled the *word length effect*. Alternatively, a few researchers have reported finding a u-shaped quadratic relationship between noun length and lexical decision response latency (Ferrand et al., 2010; New, Ferrand, Pallier, & Brysbaert, 2006; Yap & Balota, 2009). Specifically, response latencies decreased for short words (2 to 5 letters), remained flat for medium length words (6 to 8 letters), and increased for long words (9^+ letters). Although the shape of the word length effect is currently undetermined, it is clear that noun length influences visual word recognition speed (Barton, Hanif, Eklinder Björnström, & Hills, 2014).

Noun gender. The effect of noun gender on visual word recognition has been less thoroughly studied. However, researchers have found that noun gender can impact word recognition speed in languages with a gender system. For instance, in French, Italian, and Spanish, all nouns are assigned one of two possible genders: feminine or masculine (Corbett, 1991). Lexical decision studies have found that in French, masculine words are recognized faster than feminine words (Colé, Pynte, & Andriamamonjy, 2003; Desrochers, Carson, Côté, Lamothe, & Morneau, 2018). On the other hand, null gender effects were found in two studies conducted in Italian and Spanish (De Martino, Bracco, & Laudanna, 2011; Urrutia, Domínguez, & Álvarez, 2009). Yet, Domínguez et al. (1999) found that Spanish feminine words are recognized faster than masculine words. Despite the ambiguity of these results, researchers still control for potential noun gender effects in their experiments.

Noun-verb ratio. This characteristic has not been included in previous experiments. However, New and his colleagues (2004) suggested it should be incorporated in future noun dominance experiments. In French and English, nouns can have verb equivalents. In French, singular nouns can have first and third person singular indicative and subjunctive present tense verb equivalents, while plural nouns can have second person singular indicative and subjunctive present tense verb equivalents (e.g., *Bescherelle 1: L'art de conjuger*, 2012). For example, the word *joue(s)* can be perceived as a noun [*cheek(s)*] or as a verb [*you/he/she play(s)*]. In English, singular nouns can have infinite verb equivalents, while plural nouns can have third person singular present tense verb equivalents (Alegre & Gordon, 1999; Baayen et al., 2006; Feldman & Basnight-Brown, 2008). For example, the word *tear(s)* can be perceived as a noun or as a verb. In both languages, it is impossible to know which meaning a class ambiguous word will evoke, noun or verb, and consequently which word class they will be processed as during an experimental task. Therefore, we incorporated the influence of this ambiguity in all experiments using formula (1) proposed by Baayen et al. (2006):

$$\frac{noun\ written\ base\ frequency}{(noun\ written\ base\ frequency + verb\ written\ base\ frequency)} \tag{1}$$

The noun-verb ratio ranges from 0 to 1. A lower noun-verb ratio score indicates that a word occurs more often as a verb while a higher noun-verb ratio score indicates word occurs more often as a noun. Nouns with no verb equivalent receive a score of 1.

Models of Visual Word Recognition

Three classes of theoretical models are directly relevant to the visual recognition of morphologically complex nouns. Each model class makes a different prediction regarding how base frequency and/or surface frequency (i.e., noun dominance) affect visual word recognition speed.

Full-storage models. Advocates for full-storage models argue that all words are independently stored in our mental lexicons and that they are recognized as whole units, irrespective of whether they contain multiple morpheme units (e.g., Butterworth, 1983; Bybee, 1995). According to these models, words are recognized when a reader matches the observed word with its exact cognitive representation in their mental lexicon (Chialant & Caramazza, 1995). Therefore, surface frequency is expected to determine word recognition speed, while base frequency should have no influence. Specifically, full-storage models predict that singular

singular-dominant nouns should be recognized faster than plural singular-dominant nouns while plural plural-dominant nouns should be recognized faster than singular plural-dominant nouns (see Figure 1A). A handful of researchers have argued that their results support a full-storage model of visual word recognition (e.g., Cole, Beauvillain, & Segui, 1989; Giraudo & Grainger, 2000; Manelis & Tharp, 1977). However, this prediction does not align with the noun dominance results presented above.

Full-decomposition models. Promoters of full-decomposition models argue that regular and transparent complex words made up of two or more morphemes are decomposed into their constituent units and then recognized based on these units (e.g., *lips* → *lip* + *-s*). Simple words made up of a single morpheme do not undergo the decomposition process prior to recognition (e.g., *lip* → *lip*; Chialant & Caramazza, 1995; Clahsen, 1999; Rastle et al., 2004). Full-decomposition model supporters affirm that stem frequency is what determines word recognition speed; base frequency and surface frequency have no impact (Rastle et al., 2004; Taft, 2004). *Stem frequency* is the surface frequency for the stem of a morphologically complex word (e.g., *lip* is the stem of the word *lips*; Rastle et al., 2004; Taft, 2004). Based on this logic, full-decomposition models predict that singular nouns should be recognized faster than plural nouns, regardless of their noun dominance ratio since decomposition is unnecessary and their stem frequency is equivalent (see Figure 1B). A few of researchers have claimed that their results support a full-decomposition model of visual word recognition (e.g., Rastle et al., 2004; Taft, 2004). Yet, again, this prediction does not match the noun dominance results presented above.

Dual-route models. Supporters of dual-route models believe that both a full-storage route (sometimes called a direct route) and a full-decomposition route (sometimes called a parsing route) work in tandem. One of the first dual-route models proposed was the Augmented

Addressed Morphology (AAM) model (Caramazza, Laudanna, & Romani, 1988; Caramazza, Miceli, Silveri, & Laudanna, 1985; Chialant & Caramazza, 1995). Caramazza and his colleagues posited that the full-storage route was faster than the full-decomposition route. Furthermore, they asserted that the full-storage route was predominantly used to recognize known words while the full-decomposition route was more effective at recognizing novel words. Currently, the most prominent dual-route model is the parallel dual-route model proposed by Baayen and colleagues (Baayen, Dijkstra, et al., 1997; Baayen, McQueen, Dijkstra, & Schreuder, 2003; Baayen, Schreuder, & Sproat, 2000; Schreuder & Baayen, 1995). Originally, the parallel dual-route model creators theorized that the full-storage and full-decomposition routes worked independently (Baayen, Dijkstra, et al., 1997; Schreuder & Baayen, 1995). More recently, however, they claim that the two routes work in parallel, competing with one another (Baayen et al., 2003, 2000). The parallel dual-route model asserts that both base frequency and surface frequency impact word recognition under different circumstances. More precisely, singular nouns are processed by the full-storage route. Their recognition speed is determined by their base frequency. Alternatively, plural nouns can be processed in one of two ways depending on their dominance ratio. First, plural-dominant plural nouns are processed by the full-storage route. Their recognition speed is determined by their surface frequency, which is often similar to their base frequency (e.g., *kilometres*, 26 vs. 29). Second, singular-dominant plural nouns are processed in a series of stages by the full-decomposition route (Baayen et al., 2000). Their recognition speed is determined by their base frequency plus the decomposition time required to break the noun down into its singular stem and plural marker (e.g., *designs* → *design* + -*s*). Therefore, the parallel dual-route model predicts that singular nouns should be recognized at similar speed, regardless of their noun dominance ratio, while singular-dominant plural nouns

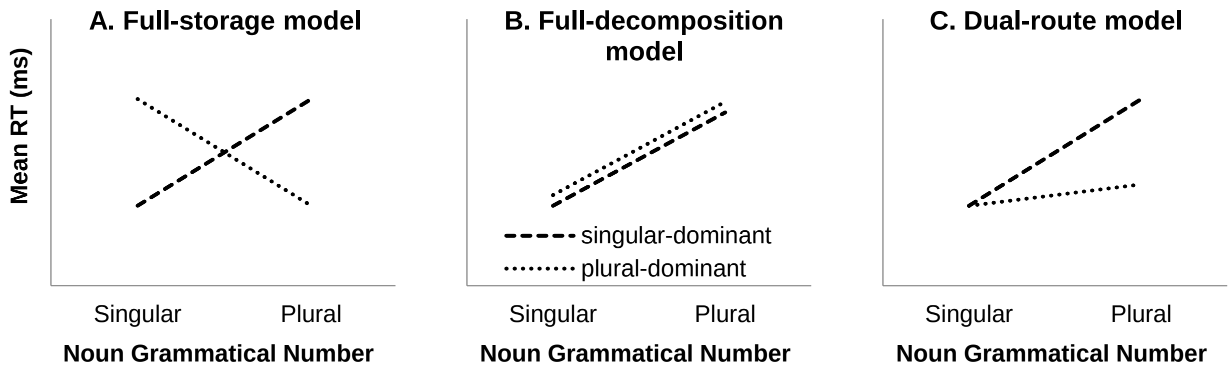

Figure 1. Response time (RT) predictions for singular-dominant and plural-dominant nouns made by the three models of visual word recognition.

should be recognized slower than plural-dominant plural nouns (see Figure 1C). This prediction is consistent with the noun dominance results presented above. The majority of the noun dominance researchers cited above claim that their findings support the parallel dual-route model (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; New et al., 2004; Reifegerste et al., 2017).

The Role of Noun Dominance in Picture Naming

In 2007, researchers began to investigate whether the noun dominance and grammatical number effects found in lexical decision experiments could be replicated in picture naming tasks. Baayen and his colleagues (Baayen et al., 2007) were the first to tackle this question. They conducted three experiments where they asked Dutch participants to name what they saw in pictures containing either one (singular), two (dual/plural), or many (plural) exemplars of singular-dominant and plural-dominant nouns. In all three experiments, participants were faster at naming pictures with one exemplar, regardless of noun dominance. In other words, participants were faster at producing singular nouns than plural nouns. When noun dominance was treated as a dichotomous categorical variable (Experiment 1) there was a main effect of noun dominance; singular-dominant nouns were named 28 ms faster than plural-dominant nouns. The interaction between grammatical number and noun dominance was not significant in any of the experiments. The only LDT empirical result the above findings replicate is that singular nouns have faster response latencies than plural nouns.

More recently, Beyersmann and her colleagues (Beyersmann, Dutton, Amer, Schiller, & Biedermann, 2015; Biedermann, Beyersmann, Mason, & Nickels, 2013) had English and Dutch participants name photographs containing one (singular) or multiple (plural) exemplars of singular-dominant and plural-dominant nouns. The researchers found a grammatical number × noun dominance interaction in both languages. Participants were faster at naming pictures of singular-dominant nouns when they contained one exemplar versus multiple exemplars (62 – 117 ms advantage). Meanwhile, no dominance naming advantage was present for pictures of plural-dominant nouns (0 – 1 ms difference). In Dutch only, there was a significant interaction between grammatical number and inflectional entropy. Nouns with a high inflectional entropy (i.e., singular-dominant nouns) had faster naming latencies in their singular form compared to their plural form. Alternatively, naming latencies were similar for nouns with a low inflectional entropy (i.e., plural-dominant nouns). The main effects of grammatical number and noun dominance were not significant in either study. The interaction results reproduce what has been found in the LDT experiments and demonstrate that surface frequency matters when naming singular-dominant nouns, but not plural-dominant nouns.

A Representational Framework of Number

Based on the picture naming research cited above, Nickels and her colleagues (Nickels et al., 2015) proposed a representational framework for noun number production in speech. The authors theorize that when a person conceptualizes a noun, all of its grammatical forms are automatically activated. In English and French, this translates to an automatic activation of a noun's grammatically singular and plural forms. For example, if a person thinks of the concept *map*, both the singular form *map* and the plural form *map**s*** become active. Whether a person vocalizes the singular or plural grammatical form of the concept depends on notional number. If the intended notional number is singular, the concept of single will be activated and lead to the production of the singular grammatical form of the concept (i.e., *map*). Alternatively, if the intended notional number is plural, the concept multiple will be activated and lead to the production of the plural grammatical form of the concept (i.e., *map**s***). The stronger the activation connection between the concept and a grammatical word form (*map* or *map**s***), the faster noun production occurs. In the visual representations of the framework, the bolder the arrow representing the activation connection, the stronger the connection.

Nickels et al. (2015) propose that singular is the default number value (see also Corbett, 2000). Thus, noun concepts should have a stronger activation connection to their singular grammatical form than their plural grammatical form (see Figure 2A). As a result, singular noun production is faster than plural noun production for the majority of noun concepts. There are some exceptions, of course. For instance, the authors propose that plural-dominant noun concepts have a stronger activation connection to their plural grammatical form than their singular grammatical form (see Figure 2B). This stronger plural connection competes with the singular as the default number expectation. Consequently, singular and plural plural-dominant nouns should be produced at a similar speed. The expected response pattern for singular-dominant and plural-dominant nouns in the representational framework for noun number production matches the parallel dual-route model prediction displayed in Figure 1C.

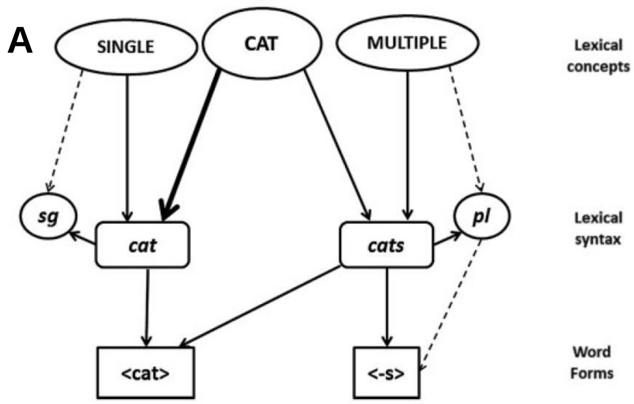

Figure 2. Examples of the representational framework for typical nouns (A) and plural-dominant nouns (B). Taken from Nickels et al. (2015, p. 290, Figure 3c & p. 292, Figure 4). The lexical concepts single and multiple represent notional number. The lexical syntax concepts singular (sg) and plural (pl) represent grammatical number. Finally, the word forms represent the morpheme(s) used to produce the noun.

Number Agreement

Noun number information is used for the important process of number agreement (Corbett, 2000, 2006). When a noun is the subject of a sentence it is called a *subject noun* (Tallerman, 2011). The number information expressed by the subject noun dictates the number information expressed by target words within the sentence or paragraph; this is the number agreement process (Bock & Miller, 1991; Corbett, 2000, 2006; Mel'čuk & Milićević, 2014b; Wechsler, 2009). In French and English, determiners, verbs, and pronouns can all be target words for number agreement (Corbett, 2006; Kim, 2004; Mel'čuk & Milićević, 2014b; Tallerman, 2011).

The likelihood that number agreement will be formed based on a noun's grammatical number versus its notional number is captured in Corbett's (1979, 2006) *agreement hierarchy*. He argues that "[t]he further left an element on the hierarchy, the more likely [grammatical] agreement is to occur, the further right, the more likely [notional] agreement” (Corbett, 1979, p. 204). The agreement hierarchy has the following structure:

attributive > predicate > relative pronoun > personal pronoun

The pertinence of the agreement hierarchy is best illustrated using an example where grammatical and notional number mismatch (see Levin, 2001, for further evidence supporting the agreement hierarchy configuration). First, attributives, such as determiners, almost invariably form grammatical number agreement. This can be exemplified by the following noun phrase: *Cette* *<u>foule</u>* [*This* *<u>crowd</u>*]. In this example, the determiner (*Cette* [*This*]) is singular as is the subject noun (*foule* [*crowd*]). Their grammatical numbers agree. Second, predicates, often verb phrases, behave differently in French and English. In French, they must form grammatical number agreement. In English, they may form grammatical or notional number agreement, although they have a greater tendency towards grammatical number agreement. For example, *Cette* *<u>foule</u>* ***est*** *agitée* [*This* *<u>crowd</u>* ***is*** *restless*]. Third, relative pronouns are number invariant in French and English (e.g., *qui* [*who*], *que* [*that]*). However, this is not the case for all languages (see Corbett, 2006, § 7.2.1). Finally, personal pronouns (e.g., *il*/*elle* [*he*/*she*]) are the most likely to form notional number agreement.

Noun animacy also plays a role in number agreement. *Animacy* is a semantic feature condition that has been defined in many different ways which range from broad to highly specific (see Popp & Serra, 2016; Radanović, Westbury, & Milin, 2016). Exactly how animacy impacts number agreement is represented in the animacy hierarchy below.

1st person > 2nd person > 3rd person > kin > human > animate > inanimate

As you move along the hierarchy from left to right, the expression on number information in noun phrases decreases. That is, nouns relating to humans (e.g., *participant(s)*) are more likey to contain number information and dictate number agreement than nouns relating to inanimate objects (e.g., *oreiller(s)* [*pillow(s)*]) or constructs (e.g., *santé* [*health*]).

Subject-Verb Agreement

The topic of subject-verb number agreement has been widely studied for over two decades. Researchers use a sentence completion paradigm to determine what circumstances encourage or bolster subject-verb number agreement errors. Participants verbally complete sentence beginnings made up of a noun phrase followed by a prepositional phrase containing a secondary local noun, such as "*The debate(s) about the drug(s)*". Researchers alter whether the subject noun and local noun match in grammatical number (singular-singular or plural-plural) or mismatch in grammatical number (singular-plural or plural-singular; Bock & Miller, 1991). Participants often produce a verb when completing these sentence beginnings. If the subject is singular they should produce a third person singular verb (e.g., *est* [*is*]). If the subject is plural they should produce a third person plural verb (e.g., *sont* [*are*]). Numerous researchers have found that agreement errors often occur when the subject noun and local noun mismatch in grammatical number. Labelled *attraction errors,* these errors predominantly occur when the subject noun is singular and the local noun is plural. Thus, participants are much more likely to make the error "*The debate about the drug**s** …**are** ongoing*" than "*The debate**s** about the drug…**is** ongoing*" (e.g., Bock et al., 2012; Bock, Eberhard, & Cutting, 2004; Hartsuiker & Barkhuysen, 2006; Vigliocco, Butterworth, & Garrett, 1996; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996).

Determiner-Noun Agreement

Conversely, the topic of determiner-noun number agreement has received minimal research attention. The term *determiner* refers to words classes that appear before a noun in a sentence, such as definite or indefinite articles (*le*/*la/les* [*the*, ø], *un/une/des* [a, ø], demonstratives (*ce*/*cette* [*this*], *ces* [*these*]), posessives (*leur(s)* [*their(s)*], *notre*/*nos* [*our(s)*]), and quantifiers (*chaque* [*each*], *quelque(s)* [*some*]; Tallerman, 2011). When determiners have alternate singular and plural forms (e.g., *this* vs. *these*), they always form grammatical number agreement with the subject noun in line with Corbett's agreement hierarchy presented above (Bock & Middleton, 2011; Corbett, 1979, 2006; Kim, 2004; Tallerman, 2011). Within the context of subject-verb agreement, a handful of researchers have found that people make fewer subject-verb number agreement errors when sentence beginnings contain a determiner that conveys number information (e.g., *each*, *many*) than when a determiner is number ambiguous (e.g., *the*) in Dutch, English, and German (Antón-Méndez & Hartsuiker, 2010; Eberhard, 1997; Hartsuiker, Schriefers, Bock, & Kikstra, 2003).

The realization of determiner-noun number agreement has only been investigated in one published study to date. Fieder and her colleagues (Fieder, Wang, Biedermann, & Nickels, 2017) presented English participants with coloured pictures depicting either single (one) or multiple (two or three) exemplars of mass nouns (e.g., *garlic*) or singular-dominant count nouns (e.g., *apple(s)*). Each noun exemplar was presented twice, once as a singular depiction and once as a multiple depiction, in two counterbalanced blocks. Participants were tasked with choosing whether a singular determiner (*a*/*this*) or a plural determiner (*some*/*these*) was the correct grammatical choice for the picture displayed. Pictures remained on a computer screen until participans made a determiner decision or 3000 ms passed. The results presented below focus on the singular-dominant count noun data. The authors found that participants were 3% to 8% more accurate and 15- 75 ms faster at providing determiner responses for pictures depicting singular exemplar than multiple exemplars. Stated in another way, participants were more accurate and faster at forming determiner-noun agreement for pictures containing a singular singular-dominant count nouns than pictures containing multiple (i.e., plural) singular-dominant count nouns. These findings mimic the surface frequency effect found in the noun dominance LDT experiments presented above.

Marking and Morphing Model of Number Agreement

Currently, the most conceptually advanced model on how speakers generate subject-verb number agreement is the *marking and morphing model* (Eberhard et al., 2005). According to this model, speakers follow three main stages to form number agreement within a noun phrase. First, *notional number valuation* takes place. At this stage, the speaker determines whether the notional number of the subject (i.e., subject noun) of the intended message is singular or plural. The model presumes that the default value is singular. Second, *marking* occurs. During this stage, the grammatical number for the subject noun is selected to reflect the notional number identified in the previous stage (singular or plural). Third, *morphing* ensues. In this final stage, three interrelated operations take place. One, morphological information, such as plural markers, is structurally bound to the appropriate position based on syntax rules (e.g., *map* + plural → *map* + plural marker -*s* → *map**s***). Two, any discrepancies in notional and grammatical number are reconciled. And three, number agreement is formed with target words within the phrase.

The authors extended the marking and morphing model to account for the finding that determiners conveying clear number information facilitate subject-verb number agreement concord (see equations 9 and 10 on pg. 550). Simulation results demonstrate that the model is adept at reproducing a pattern that closely aligns with the results reported by Eberhard (1997). Antón-Méndez and Hartsuiker (2010) conducted additional simulations of the determiner inclusive marking and morphing model. They found that simulation predictions aligned extremely well with their observed data. In both simulation studies, fewer subject-verb number agreement errors were produced when sentence beginnings contained a determiner that conveyed number information (e.g., *each*, *many*) compared to a determiner that was number ambiguous (e.g., *the*). A version of the model incorporating the number agreement process between determiners and the subject noun specifically has yet to be proposed.

Plan of Study

This thesis examines the influence of noun dominance and noun grammatical number in visual word recognition and determiner-noun number agreement in a series of three studies containing eight experiments. Its objective is to extend our overall understanding of the singular-dominant noun surface frequency effect in French and English. In order to gain insight into the surface frequency effect, the following three procedures were adopted. First, advanced linear mixed modelling techniques were used to improve result statistical power and accuracy. Generalized linear mixed modelling was used to analyze response accuracy data while cross-classified linear mixed effects modelling was used to analyze response latency data. This allowed us to account for the two random samples in my experimental design (i.e., participants and items; Baayen, 2008; Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013). Second, we tested whether the surface frequency effect remained significant when noun dominance was treated as a continuous variable by applying the noun dominance ratio technique described above (Reifegerste et al., 2017). Third, we investigated whether the surface frequency effect could be reproduced in a novel experimental task: a simple determiner-noun number agreement task.

The aim of Study 1 was to extend our understanding of the surface frequency effect using a lexical decision task (LDT). Two experiments were conducted, one in French (Experiment 1) and one in English (Experiment 2). Participants indicated whether or not individual strings of letters represented a real word by selecting *OUI* [*YES*] or *NON* [*NO*]. Results revealed that in both languages, singular nouns were recognized faster than plural nouns while the noun dominance effect was non-significant. The interaction between noun grammatical number and noun dominance was significant in French and marginally so in English. The interaction pattern was identical in both languages, singular-dominant nouns demonstrated a surface frequency effect while plural nouns did not.

Study 2 was designed to investigate whether the findings of Study 1 could be reproduced in a simple determiner-noun number agreement task. Three experiments were conducted, one in French (Experiment 3) and two in English (Experiments 4 and 5). Participants decided whether individual singular and plural nouns were best preceded by a singular determiner *Ce*/*Cette* [*This*] or a plural determiner *Ces* [*These*]. A post-task self-report questionnaire was added to Experiment 5 in order to capture participant response strategies. Results revealed that in all three experiments, plural nouns were recognized faster than singular nouns. Neither the main effect of noun dominance nor the two-way interaction between grammatical number and noun dominance were found to be significant.

Study 3 was intended to determine whether the surface frequency effect found for singular-dominant nouns is influenced by the noun characteristics collectivity and animacy. Three experiments were conducted following the procedures outlined above, a French LDT (Experiment 6), an English LDT (Experiment 7), and an English determiner-noun number agreement task (Experiment 8). Results revealed that in Experiments 6 and 7 singular nouns were recognized faster than plural nouns. The effects of noun collectivity and animacy were significant in Experiment 7 only. In English, non-collective nouns were recognized faster than collective nouns while inanimate nouns were recognized faster than animate nouns. In

Experiment 8, plural nouns were recognized faster than singular nouns and no other effects reached significance. The convergence and discrepancies in this set of results are addressed in the general discussion of the dissertation.

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Study 1: The Processing of Noun Grammatical Number in French and English

The Processing of Noun Grammatical Number in French and English

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Abstract

Several researchers have documented an interplay between noun grammatical number (singular vs. plural) and surface frequency in noun recognition experiments. They find that singular-dominant nouns are recognized faster in their singular form, while plural-dominant nouns demonstrate no form advantage. The aim of this paper is to extend our knowledge of this relationship in French and English. Two lexical decision experiments were conducted. Cross-classified linear mixed modelling results revealed that in both languages, singular nouns were recognized faster than plural nouns. In French, the interaction between noun dominance and grammatical number was significant: singular-dominant nouns were recognized faster in their singular form, while singular and plural plural-dominant nouns were recognized at a similar speed. A similar pattern was observed in English. Our results partially replicate and qualify those found in previous studies. The data patterns align with dual-route models of visual word recognition.

Keywords: number, noun dominance, inflectional morphology, visual word recognition, lexical decision

The Processing of Noun Grammatical Number in French and English

Repeated exposure to printed words influences the accuracy and latency of their visual recognition (Norris, 2006). Estimates of printed word frequency are commonly used as a proxy for past exposures in psycholinguistic research. These estimates can be calculated in two different ways. *Base frequency* is the number of times (per million) that a word appears in all its possible forms in a corpus of continuous texts or spoken dialogues. *Surface frequency* is the number of times (per million) that a word appears in one specific inflected or conjugated form in a corpus of continuous texts or spoken dialogues (New, Brysbaert, Segui, Ferrand, & Rastle, 2004). Both base and surface frequency have been investigated in order to determine which frequency measure best captures the familiarity that results from repeated word exposures.

Researchers have found that responses to printed words are influenced by both base and surface frequency information in lexical decision tasks (LDT). The frequency effect, henceforth *base frequency effect* for clarity, refers to the finding that readers are more accurate and faster at recognizing words with a higher base frequency of occurrence (e.g., Becker, 1979; Conrad, Grainger, & Jacobs, 2007; Gordon, 1983; Grainger, 1990; Petrova, Gaskell, & Ferrand, 2011; Segui, Mehler, Frauenfelder, & Morton, 1982). Meanwhile, the *surface frequency effect* refers to the finding that readers are faster at recognizing words with a higher surface frequency of occurrence when their base frequency is held constant (e.g., Baayen, Burani, & Schreuder, 1997; Baayen, Dijkstra, & Schreuder, 1997; Bertram, Schreuder, & Baayen, 2000; Domínguez, Cuetos, & Segui, 1999; Meunier & Segui, 1999; New et al., 2004; Sereno & Jongman, 1997; Taft, 1979). The main objective of the present research is to pursue the analysis of the surface frequency effect by investigating the responses of French- and English-speaking readers to singular and plural nouns in two lexical decision experiments.

Noun Number in French and English

In both languages, communicators must express noun number by choosing between two options: singular or plural (Booij, 2007; Corbett, 2000; Tallerman, 2011)[2]. A singular noun refers to a single entity, object or concept. Conversely, a plural noun refers to two or more entities, objects, or concepts (Corbett, 2000; Mel'čuk & Milićević, 2014; Reid, 1991; Tallerman, 2011). The written expression of noun number is referred to as *grammatical number*. A singular noun is denoted by the absence of a plural marker, while a plural noun is denoted by the presence of a plural marker (Corbett, 2000; Reid, 1991). The most common plural marker in both French and English is the inflectional suffix -*s*, which is added to the end of the noun being pluralized (Akmajian, Demers, Farmer, & Harnish, 2001; Corbett, 2000; Mel'čuk & Milićević, 2014; Reid, 1991). The sole purpose of this inflectional suffix is to convey noun grammatical number information, it does not change the core meaning of the noun in any other respects (Aronoff & Fudeman, 2005; Booij, 2007; Corbett, 2000; Reifegerste, Meyer, & Zwitserlood, 2017). It should be noted that the inflectional suffix -*s* can be used as a plural marker for other words classes in French (e.g., adjectives, determiners, pronouns; Corbett, 2000) as well as an ending for third person singular present tense verbs in English (e.g., *she jump**s***; Alegre & Gordon, 1999; Baayen, Feldman, & Schreuder, 2006; Feldman & Basnight-Brown, 2008). Additionally, less common noun plural markers exist in both languages. In French, the inflectional suffix -× is an alternate, though less common, noun plural marker (e.g., *hibou**x*** [*owl**s***]; Corbett, 2000). In English, the

[2] There are three types of nouns that cannot alternate between two grammatical number forms. *Pluralia tantum nouns* represent individual items made up of two symmetrical parts. They are always grammatically plural (e.g., *scissors, binoculars*; Bock, Carreiras, & Meseguer, 2012; Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Bock & Miller, 1991; Corbett, 2000). Alternatively, *zero plural nouns* are always grammatically singular (e.g., *fish, sheep*; Bock & Miller, 1991; Corbett, 2000). Finally, *mass nouns* are grammatically singular and refer to non-distinct uncountable entities (e.g., *water, corn, millet*; Iwasaki et al., 2010; Middleton et al., 2004; Wisniewski et al., 2003).

inflectional suffixes -*a*, -*ae*, and -*i* can all be used as noun plural markers (e.g., *strat**a***, *alg**ae***, *cact**i***; Corbett, 2000).

One important difference between French and English concerns the phonological realization of number information. In English, the plural marker -*s* is always vocalized. It has three possible pronunciations, /s/ → *books*, /z/ → *boys*, and /əz/ → *boxes* (McGregor, 2009). In French, however, the plural marker -*s* is not vocalized unless it is involved in a phonological liaison (e.g., *les enfants* /lɛ**z**ɑ̃fɑ̃/ [*the children*]; Corbett, 2000; Largy, Cousin, Bryant, & Fayol, 2007; Moeschler & Auchlin, 2009). Having no audible difference between singular and plural nouns in French makes it impossible for a listener to determine whether the noun is singular or plural without additional information such as the choice of determiner. Therefore, when presented with a written noun in isolation, English speakers have access to both a visual and auditory representation of noun number, while French speakers only have access to a visual representation of noun number.

Word Class Ambiguity

In both French and English, several words can be treated as either a noun or a verb. In French, singular nouns can have first and third person singular indicative and subjunctive present tense verb equivalents, while plural nouns can have second person singular indicative and subjunctive present tense verb equivalents (*Bescherelle 1: L'art de conjuger*, 2012). One example is the word *joue(s)*. When presented to a reader in isolation, it is impossible to know whether its noun meaning [*cheek(s)*] or its verb meaning [*to play*] will be evoked and consequently which word class the word will be allotted to. Similarly, in English, singular nouns can have infinite verb equivalents, while plural nouns can have third person singular present tense verb equivalents (Alegre & Gordon, 1999; Baayen et al., 2006; Feldman & Basnight-

Brown, 2008). One example is the word *tear(s)*. One study has investigated this word class ambiguity in English. Alegre and Gordon (1999) found that readers processed nouns and verbs at a similar speed during a LDT. This suggests that the word class ambiguity has no influence on visual word recognition. However, while some of their items were clearly nouns (e.g., *seas*) or clearly verbs (e.g., *listens*), the word class for other items was equivocal (e.g., *councils*, *trips*). Therefore, it is difficult to determine whether these words were perceived as nouns or verbs during the task. Consequently, the authors' results are less elucidative than they initially appear.

In order to measure whether readers may be processing a word with an ambiguous word class as a noun or a verb it is possible to calculate a noun-verb ratio value using a formula proposed by Baayen et al. (2006):

$$\frac{noun\ written\ base\ frequency}{(noun\ written\ base\ frequency + verb\ written\ base\ frequency)} \quad (1)$$

The noun-verb ratio can range from 0 to 1. A word that occurs more frequently as a verb has a score below 0.5 while a word that occurs more frequently as a noun has a score above 0.5. Nouns with no verb equivalent receive a score of 1. New et al. (2004) suggested that the existence of word class ambiguity may have impacted their English noun dominance results reported below, producing slightly different results in English compared to those found in other languages. To account for the potential influence of verb frequency, the noun-verb ratio score was tested as a possible control variable in all analyses reported below.

Surface Frequency and Noun Dominance

The importance of surface frequency was first investigated by Taft (1979). He used a LDT to compare a series of uninflected and inflected English adjectives, nouns, and verbs. He found that words were responded to 38 ms faster when they had a higher surface frequency, regardless of whether they carried an inflectional suffix or not. Burani, Salmasa and Caramazza

(1984) found the same pattern when comparing high and low surface frequency Italian verbs. During a LDT, verbs with a higher surface frequency had response latencies 55 ms faster than verbs with lower surface frequencies. These two studies set the stage for a series of surface frequency experiments centred around noun dominance.

Nouns may be written more frequently in one grammatical number than the other. This is referred to as *noun dominance* (Gimenes, Brysbaert, & New, 2015; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Nouns that are written more frequently in their singular form are called *singular-dominant*, while those that are written more frequently in their plural form are called *plural-dominant*. A noun's dominance score is obtained by subtracting its singular surface frequency occurrence from its plural surface frequency of occurrence. A positive value indicates that the noun is singular-dominant, while a negative score indicates that it is plural-dominant (New, Brysbaert, et al., 2004; Sereno & Jongman, 1997). Positive and negative values have been used to create a dichotomous categorical noun dominance variable (i.e., singular-dominant vs. plural-dominant).

Since the late 1990s, several articles have been published on the noun surface frequency effect in a number of languages. Researchers have used LDTs to compare how quickly readers recognized singular-dominant and plural-dominant nouns when they were presented in either their singular or plural form. Results are nearly identical across six languages: Dutch, English, French, German, Italian, and Spanish. First, singular nouns were recognized faster than plural nouns in all languages except Italian (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Second, plural-dominant nouns were recognized faster than singular-dominant nouns in Dutch, Italian, and Spanish (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; Reifegerste et al., 2017). No dominance effect has been observed in English, French, or German (New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Finally, there was a significant two-way interaction between noun dominance and grammatical number in all languages studied (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Singular-dominant nouns were recognized significantly faster in their singular form than in their plural form (25 – 55 ms advantage), while the plural form advantage was not statistically significant for plural-dominant nouns (2 – 16 ms advantage). These findings have been used to test and inform models of visual word recognition.

Visual Word Recognition Models

Three classes of models have been proposed to account for the visual recognition of morphologically complex words: 1) full-storage models (e.g., Butterworth, 1983; Bybee, 1995; Manelis & Tharp, 1977); 2) full-decomposition models (e.g., Clahsen, 1999; Giraudo & Grainger, 2000; Rastle, Davis, & New, 2004; Taft, 1979, 2004); and 3) dual-route (race) models (e.g., Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen, Schreuder, & Sproat, 2000; Bertram, Schreuder, & Baayen, 2000; Schreuder & Baayen, 1995). Each model class makes distinct predictions about how base frequency and surface frequency should impact word recognition. A brief summary of each model class and its predictions are presented below.

Full-storage models maintain that all words are stored as whole words, irrespective of the reader's lexical knowledge that complex words can be broken down into smaller meaningful units (i.e., morphemes; Baayen, Dijkstra, et al., 1997). These models assert that surface frequency is the determining factor in word recognition speed, discounting any possible effect of base frequency (Bybee, 1995). Based on this logic, full-storage models predict that singular singular-dominant nouns should be recognized faster than plural singular-dominant nouns and that plural plural-dominant nouns should be recognized faster than singular plural-dominant nouns. This prediction is not supported by the noun dominance results presented above.

Full-decomposition models claim that regular and transparent words with multiple morphemes are first decomposed into their various components and are then recognized based on these components (Giraudo & Grainger, 2000; Rastle et al., 2004; Taft, 2004). Words made up of a single morpheme do not undergo the decomposition process. It follows then, that regular plural nouns are automatically decomposed into their stem and plural marker (e.g., *lip**s*** → *lip* + *-s*). Meanwhile, singular nouns are not decomposed (e.g., *lip* → *lip*). These models affirm that stem frequency is what determines word recognition speed and that neither base nor surface frequency should have an impact on word recognition (Rastle et al., 2004). In the case of singular versus plural nouns, strem frequency is equivalent to the surface frequency value of singular nouns which are the stem (or root) of plural nouns. Based on this logic, full-decomposition models predict that singular nouns should be recognized faster than plural nouns, regardless of noun dominance, since there is no need to strip the plural marker from the word stem of a singular noun. Again, this prediction is not supported by the noun dominance results presented above.

Dual-route (race) models reason that both a full-storage route (also called the direct route) and a full-decomposition route (also called the parsing route) work in tandem. The original version of the parallel dual-route model conceptualized this co-existence as a race between the two routes (Schreuder & Baayen, 1995), while more a recent version suggests that both routes are activated and operate concurrently (Baayen et al., 2000). This model asserts that both base frequency and surface frequency impact word recognition under different circumstances. All singular nouns are believed to be processed by the full-storage route. Therefore, their recognition speed is determined by their base frequency. Plural nouns however, are processed in one of two ways. Plural plural -dominant nouns are processed by the full-storage route. Their recognition speed is determined by their surface frequency, which is often similar to their base frequency (e.g., *kilometres*, 26 vs. 29). Alternatively, plural singular-dominant nouns are processed by the decomposition route (Baayen et al., 2000). Their recognition speed is determined by their base frequency plus the time required to decompose the noun into its singular stem and plural marker. Therefore, the parallel dual-route model predicts that singular nouns should be recognized at similar speed, regardless of their noun dominance, while plural singular-dominant nouns would be recognized slower than plural plural-dominant nouns. This prediction is supported by the noun dominance results presented above. Most of the researchers have indeed argued that their results support the parallel dual-route model and not full-storage or full-decomposition models (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; New, Brysbaert, et al., 2004; Reifegerste et al., 2017).

Noun Dominance as a Continuous Variable

Nearly all of the research on the surface frequency effect cited above treated noun dominance as a dichotomous categorical variable (with one exception: Reifegerste et al., 2017). More recently, with the adoption of more sophisticated statistical techniques, researchers have argued for the need to treat noun dominance as a continuous variable. Baayen and his colleagues suggest using a measure called *inflectional entropy* (Baayen et al., 2006; Baayen, Levelt, Schreuder, & Ernestus, 2007; Moscoso del Prado Martín, Kostić, & Baayen, 2004). Inflectional entropy quantifies the average amount of number information expressed in morphemes. A noun's inflectional entropy is calculated by dividing a singular or plural noun's surface frequency by its base frequency (singular + plural); the resulting value ranges from 0 to 1. A score of 0.5 indicates no dominance (i.e., singular and plural surface frequencies are equal). A score below 0.5 indicates plural-dominance, while a score above 0.5 indicates singular-dominance. The *noun dominance ratio* measure used by Reifegerste et al. (2017), is calculated by dividing a noun's singular surface frequency by its plural surface frequency. A value falling below 1 indicates that a noun is plural-dominant, while a value greater than 1 indicates that a noun is singular-dominant. A value of exactly 1 indicates no dominance. This is the continuous measure used to represent noun dominance in the present research unless otherwise stated.

Study Overview

This paper has two goals. The first goal is to extend our understanding of the surface frequency effect, specifically in French and English. Relative to previous studies, a larger number of items and a larger participant sample were tested. In addition, more sophisticated statistical analyses were used. Response accuracy data were analyzed using generalized linear mixed modelling. Response latency data were analyzed using cross-classified linear mixed effects modelling in place of $F_1 \times F_2$ ANOVAs to account for the existence of two random samples (i.e., participants and items; Baayen, 2008; Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013). The second goal is to determine whether treating noun dominance as a continuous variable impacts statistical outcomes.

On the basis of previous studies, we expected the following results in both French and English: 1) a significant speed advantage of singular nouns over plural nouns; 2) no significant main effect of noun dominance; and 3) a significant interaction whereby singular singular-dominant nouns are recognized faster than plural singular-dominant nouns, while singular and plural plural-dominant nouns are recognized at similar speeds.

Experiment 1: French Lexical Decision Task

Method

Participants. Participants were undergraduate students attending the University of Ottawa. They chose to participate by signing-up through an online Integrated System for Participating in Research and selecting a date and time that was convenient for them. Inclusion criteria were: strong knowledge of French, normal or corrected-to-normal vision, and no diagnosed language disabilities. Participants were credited 1% towards a course of their choice as compensation for their participation.

A total of 75 students participated in this study. Data from 10 participants was lost due to computer error. Three additional participants were removed from the sample due to a high percentage of errors (≥ 10%) or a high percentage of response latency outliers (> 10%). The final sample contains 62 participants (49 female) with a mean age of 20.2 years old (*SD* = 2.89). Fifty-five participants identified French as their native language while the remaining seven fluently spoke French as a second language.

Stimuli. One hundred French nouns (50 singular-dominant, 50 plural-dominant) were selected from the *Lexique 3* database (see Appendix A for a complete list; New, Brysbaert, Veronis, & Pallier, 2007; New, Pallier, Brysbaert, & Ferrand, 2004). The following noun characteristics were controlled for across experimental conditions as closely as possible: noun length, number of phonemes, number of syllables, noun gender, surface frequency, base frequency, and mean noun dominance score (see Table 1). The noun-verb ratio values ranged from 0.25 to 1 with a mean of 0.95 (SD = 0.13). One hundred non-words were created by manipulating 2 to 4 letters of each real noun. This was done to maintain the original number of letters and syllabic structures.

Equipment. Data was collected using Dell PC computers with 64-bit processors. Stimuli were presented in size 18 Courier New boldface font on IBM Think Vision computer screens with a 1280 × 1024 resolution. E-Prime Professional 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) was used to present task instructions, randomly display stimuli, and record participant response accuracy and latency data. An E-Prime serial response box (Model 200A) was used to collect participants' responses.

Experimental design. Dominance is treated as a continuous within-subjects variable while Number (singular vs. plural) and Block (1 vs. 2) are treated as dichotomous within-items variables.

Two lists were created that contained all 100 real nouns, in either their singular or plural form, and 100 non-words. Noun grammatical number was interchanged across lists; a noun that appeared in its singular form on List 1 (e.g., *fleur* [*flower*]) appeared in its plural form on List 2 (e.g., *fleur**s*** [*flower**s***]), and vice versa. Each list contained 25 real nouns belonging to each of the following experimental conditions: 1) singular singular-dominant; 2) plural singular-dominant; 3) singular plural-dominant; and 4) plural plural-dominant.

Every participant was presented with both lists as two equal blocks of items. Consequently, each participant saw every noun twice, once per grammatical number. List order was counterbalanced so that half of participants saw List 1 first followed by List 2, while the other half saw List 2 first followed by List 1. Block 1 replicates the approach used by researchers in the noun dominance studies discussed above. The inclusion of Block 2 allows us to test the robustness of Block 1 effects.

Procedure. Upon their arrival, participants completed an informed consent form and a demographics questionnaire. They sat in a sound-proof testing room with a computer screen and E-Prime response box in front of them while they completed the LDT. Real nouns and non-words were randomly presented one at a time in the center of the screen. They were asked to indicate whether each string of letters represented a real word, *OUI* [*YES*] or *NON* [*NO*], by pressing the response box button with the corresponding label. Label placement was counterbalanced between participants to control for the influence of hand dominance (57 participants were right handed and 5 were left handed). Half of the participants pressed the far left button to respond *OUI* and the far right button to respond *NON*, while the other half pressed the far left button to respond *NON* and the far right button to respond *OUI*. Participants were instructed to read each item and to make their decisions as quickly as possible while maintaining an error rate below 10%. After completing 32 practice trials (16 real nouns and 16 non-words) with the experimenter present, participants were left alone to complete 400 experimental trials. The task took 30 to 45 minutes to complete. Participants were debriefed after they finished the experiment.

All trials followed the same sequence: 1) a message appeared in the center of the screen asking participants if they were ready to start the trial [Ready?]; 2) participants pushed either button to indicate they were ready; 3) a 500 ms delay followed; 4) a fixation point (+) appeared in the centre of the screen for 531 ms; 5) a stimulus appeared in the centre of the screen; 6) participants provided their response, causing the simultaneous disappearance of the stimulus from the screen; 7) there was a 500 ms delay before the sequence recommenced.

Results

Data cleaning. All reaction time (RT) data was cleaned by participant and experimental condition using the following steps: 1) RTs for inaccurate responses were removed, 2) RTs below 250 ms were removed, 3) RTs that were 3.29 standard deviations above or below the mean were removed (Ratcliff, 1993), and 4) RTs that fell between 2.58 to 3.29 standard deviations above or below the mean were winsorized (Tukey, 1962). Implementing this procedure resulted in the removal of 5.5% of the RT data, 2.4% due to inaccurate responses and 3.1% from outliers. Following this procedure, an inverse transformation (-1/RT) was applied to the cleaned RT data to reduce positive skew.

Statistical analysis. Prior to analysis, the linearity of all continuous fixed effects and control variables was verified and the appropriate transformations were applied when necessary. Following this, all fixed effects, with the exception of trial number, were grand mean centred (gmc) or contrast coded (cc) to reduce multicollinearity (Linck & Cunnings, 2015).

Analyses were conducted in R (v. 3.3.2; R Core Team, 2016) using the RStudio user interface (v. 1.0.136, RStudio Team, 2015) and the lme4 package (v. 1.1-12; Bates, Mächler, Bolker, & Walker, 2015). A maximal model was always sought (Barr et al., 2013). In all models presented in this paper, two random effects were specified: participants and items. Their random intercepts were always included. Random slopes were included whenever possible. They were excluded if they correlated too highly ($r \geq 0.90$) with their random intercept or other random slopes. Dominance was entered as a potential random participant slope. Likewise, Number was entered as a potential random noun slope (each singular and plural noun pair represents a single lexical unit). In response accuracy models, Block was entered as a potential random noun slope.

All models included the following fixed effects: 1) Dominance; 2) Number; and 3) Dominance × Number interaction. Several control variables were also added to the models: 1) noun written base frequency; 2) mean noun length (i.e., noun length averaged over the singular and plural forms); 3) noun-verb ratio; 4) participant native language; 5) trial number as a practice indicator; and 6) noun gender. Control variables that did not contribute significantly to the goodness of the model fit based on chi-squared goodness of fit tests were removed from the final models presented below.

Response accuracy data were analyzed using generalized linear mixed modelling (GLMM) for binary data. The `glmer` function was used with the family criterion set to binomial. The maximum likelihood estimator used was Laplace approximation. The `bobyqa` optimizer was used to increase the number of iterations and improve model convergence.

Response latency data were analyzed using cross-classified linear mixed effects (LME) modelling using the `lmer` function. The maximum likelihood estimator was set to restricted maximum likelihood (REML). T-test significance was calculated using the formula proposed by Baayen (2008):

$$2\{1 - pt\ [abs\ (t - value), \#of\ observations - \#of\ fixed\ effects]\} \tag{2}$$

Finally, two model effect size estimates were calculated for all models using the `r.squaredGLM` function from the MuMIn package (v. 1.15.6; Bartoń, 2016). The marginal effect size estimates the amount of variance accounted for by all the fixed effects included in the model (i.e., fixed effects, control variables, and interactions). The conditional effect size estimates the amount of variance accounted for by all the random effects and fixed effects included in the model (Johnson, 2014; Nakagawa & Schielzeth, 2013).

Response accuracy results. Participants' overall accuracy rate was very high (M = 98%; SD = 2%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.02, SE = 0.13, z = 0.12, p = 0.901) and did not improve model fit (p = .901). All final model fixed effect correlations were weak, $r \leq |0.23|$. The final GLMM code is below; results are presented in Table 2.

```
FR.ACC.model <- glmer(ACC ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenSqrt_gmc + (1 + DomRatioLog_gmc|PartID) + (1 + Gramm_cc|NounID), data =
FR_LDT_ACC, family = binomial)
```

Control variables. There was a significant main effect of noun written base frequency; response accuracy increased as written frequency of occurrence increased. In addition, there was a significant main effect of mean noun length; response accuracy increased as mean noun length increased.

Fixed effects and interaction. There was a significant main effect of Dominance. Response accuracy decreased as the noun dominance ratio increased. In other words, response accuracy was lower for singular-dominant nouns than plural-dominant nouns (97% vs. 99%). The main effect of Number was not significant (p = .612). Neither was the interaction between Dominance and Number (p = .072; see Table 3 for descriptive statistics).

Effect size. The final model marginal effect size estimate was 15.44%. The fixed effects and control variables did not account for much of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 53.21%. Adding the variance accounted for by participant and item random effects explained half of the observed variability.

Response latency results. There was a significant main effect of Block ($b = 83.53 \times 10^{-6}$, $SE = 5.86 \times 10^{-6}$, t = 14.25, p < .001), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to previous lexical decision study results. All final model fixed effect correlations were weak ($r \leq |0.30|$). The final cross-classified LME codes are below; results are presented in Tables 4 and 5.

```
FR.RT.B1.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenSqrt_gmc*Gramm_cc + Trial + (1 + DomRatioLog_gmc|PartID) + (1|NounID),
data = FR_LDT_B1)
FR.RT.B2.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenSqrt_gmc*Gramm_cc + Trial + (1|PartID) + (1 + Gramm_cc|NounID), data =
FR_LDT_B2)
```

Control variables. There was a significant main effect of noun written base frequency. In both blocks, response latencies increased as written frequency of occurrence decreased. The main effect of mean noun length was nonsignificant in both blocks ($p \geq .119$). In addition, there was a trend towards a main effect of trial number in Block 1 that diminished in Block 2 ($p \geq .063$). In Block 1, response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number in Blocks 1 and 2. In both blocks, response latencies were faster for singular nouns than plural nouns (Block 1: 584 ms vs. 598 ms; Block 2: 561 ms vs. 567 ms). There was a non-significant main effect of Dominance in Block 1 that became significant in Block 2. In Block 2, response latencies increased as the noun dominance ratio increased. In other words, response latencies were larger for singular-dominant nouns than plural-dominant nouns (570 ms vs. 558 ms).

Interactions. The Dominance × Number interaction was significant in Blocks 1 and 2 (see Figure 1; see Table 6 for descriptive statistics). These interactions were decomposed by creating two sub-datasets per Block, one for singular-dominant nouns and one for plural-dominant nouns. Cross-classified LME models were run for each of these datasets. Models included both random intercepts, Number as a random noun slope (Block 2 models only), Number as a fixed effect, and the three control variables included in the original models. In both blocks, there was a significant main effect of Number for singular-dominant nouns (Block 1: $b = 63.41 \times 10^{-6}$, $SE = 11.69 \times 10^{-6}$, $t = 5.42$, $p < .001$; Block 2: $b = 43.48 \times 10^{-6}$, $SE = 12.50 \times 10^{-6}$, $t = 3.48$, $p < .001$), but not for plural-dominant nouns ($p \geq .503$; see Table C1 for complete results). Specifically, singular singular-dominant nouns were recognized faster than plural singular-dominant nouns (Block 1: 31 ms difference; Block 2: 13 ms difference), while singular and plural plural-dominant nouns were recognized at similar speeds (Block 1: 3 ms difference; Block 2: 1 ms difference).

There was also a significant Number × Length interaction in Block 1 only. This interaction was decomposed by creating two sub-datasets, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. Both models included: both random intercepts, no random slope, Number as a fixed effect, and the three control variables included in the original Block 1 model. There was a significant main effect of Length for plural nouns ($b = 96.73 \times 10^{-6}$, $SE = 29.88 \times 10^{-6}$, $t = 3.24$, $p = .001$), but not for singular nouns ($p = .968$; see Table C2 for complete results). More explicitly, the longer plural nouns were the faster they were recognized.

Effect size. The final model marginal effect size estimates were 2.58% (Block 1) and 2.43% (Block 2). The marginal effect sizes are extremely low, indicating that the fixed effects and control variables were not very effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates were 43.71% (Block 1) and 40.21% (Block 2). Adding the variance accounted for by participant and item random effects increased the variance account for, but over half of the observed variability remains unexplained by the model.

Discussion

In the present experiment, response accuracy was very high (98%), yet it was influenced by noun dominance. Plural-dominant nouns had a 2% accuracy advantage over singular-dominant nouns. This result is not due to a speed-accuracy trade-off; overall plural-dominant nouns had a 10 ms speed advantage across blocks. Meanwhile, response latency was influenced by grammatical number in Blocks 1 and 2. In both blocks, singular nouns had faster response latencies than plural nouns. Moreover, there was a significant main effect of noun dominance in Block 2 only. Response latencies were 12 ms slower for singular-dominant nouns than plural-dominant nouns. Finally, there was a significant Dominance × Number interaction in both blocks. Singular singular-dominant nouns were recognized faster than plural singular-dominant nouns (13 – 31 ms difference), while singular and plural plural-dominant nouns were recognized at similar speeds (1 – 3 ms difference).

Our Block 1 findings align with previous LDT results. Specifically, singular nouns have been found to have faster response latencies than plural nouns in several languages (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Additionally, a non-significant main effect of noun dominance has been reported in English, French, and German (New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Finally, a significant interaction between noun dominance and grammatical number has been found in all previous LDT noun dominance studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). In the present experiment, the typical response pattern was reproduced.

Our Block 2 results indicate that most Block 1 effects persist when the same nouns are seen for a second time. All fixed effects of interest were significant, but diminished in magnitude (Number: 6 ms difference; Dominance 12 ms difference; singular-dominant nouns: 13 ms difference).

In order to determine whether comparable results would be obtained in another language with the same grammatical number marking system, an equivalent experiment was carried out in English.

Experiment 2: English Lexical Decision Task

Method

Participants. Participants were recruited from the same source using the same procedure as Experiment 1. A total of 57 students participated in this study. One participant was removed from the sample due to their high percentage of response latency outliers (> 10%). The final sample included 56 participants (43 female) with a mean age of 19.4 years old (*SD* = 2.39). Forty-three participants identified English as their native language while the remaining 13 participants fluently spoke English as a second language.

Stimuli. Ninety-two English nouns (46 singular-dominant and 46 plural-dominant) were selected from the *CELEX 2* database following the procedure described in Experiment 1 (see Table 1 for noun characteristics; see Appendix B for a complete list; Baayen, Piepenbrock, & Gulikers, 1995). The noun-verb ratio values ranged from 0.29 to 1 with a mean of 0.95 (SD = 0.14). Ninety-two non-words were created using the method described in Experiment 1.

Equipment. Identical to Experiment 1.

Experimental design. Identical to Experiment 1 with the exception that 23 real nouns were presented in each experimental condition.

Procedure. Identical to Experiment 1 with two exceptions: 1) LDT response options were translated into English (*YES*/*NO*), and 2) there were 368 experimental trials instead of 400.

Results

Data cleaning. The data cleaning procedure was identical to Experiment 1. Implementing this procedure resulted in the removal of 4.6% of the RT data, 1.7% due to inaccurate responses and 2.9% from outliers. Once again, an inverse transformation (-1/RT) was applied to the cleaned RT data to reduce positive skew.

Statistical analysis. Identical to Experiment 1.

Response accuracy results. Participants' overall accuracy rate was very high (M = 98%; SD = 2%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.19, SE = 0.16, z = 1.20, p = 0.230) and did not improve model fit (p = .229). All final model fixed effect correlations were weak, $r \leq |0.24|$. The final GLMM code is below; results are presented in Table D1.

```
EN.ACC.model <- glmer(ACC ~ DomRatioLog_gmc*Num_cc + (1|PartID) + (1|NounID),
data = EN_LDT_ACC, family = binomial)
```

Fixed effects and interaction. Neither of the two fixed effects nor the Dominance × Number interaction reached significance ($p \geq .103$; see Table 3 for descriptive statistics).

Effect size. The final model marginal effect size estimate was 1.33%. The fixed effects and control variables account for almost none of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 33.91%. Adding the variance accounted for by participant and item random effects explained only a third of the observed variability.

Response latency results. There was a significant main effect of Block ($b = 39.37 \times 10^{-6}$, $SE = 6.69 \times 10^{-6}$, t = 5.89, p < .001), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to previous lexical decision study results. All final model fixed effect correlations were weak ($r \leq |0.35|$). The final cross-classified LME codes are below; results are presented in Tables 7 and 8.

```
EN.RT.B1.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Trial + (1 + DomRatioLog_gmc|PartID) + (1 +
Num_cc|NounID), data = EN_LDT_B1)
EN.RT.B2.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Trial + (1|PartID) + (1|NounID), data =
EN_LDT_B2)
```

Control variables. There was a significant main effect of noun written base frequency. In both blocks, response latencies increased as written frequency of occurrence decreased. There was also a significant main effect of mean noun length. In both blocks, response latencies increased as mean noun length increased. No significant effect of noun-verb ratio was detected in either block ($p \geq .052$), but there was a trend for response latencies to increase as the noun-verb ratio increased. Finally, there was a significant main effect of trial number in both blocks. In Block 1, response latencies decreased as trial number increased. In Block 2 the pattern reversed, response latencies increased as trial number increased.

Fixed effects. There was a significant main effect of Number in Block 1 which became nonsignificant in Block 2. In Block 1, response latencies were faster for singular nouns than plural nouns (574 ms vs. 588 ms). The main effect of Dominance was not significant in either block ($p \geq .749$; see Table 6 for descriptive statistics).

Interaction. There was a trend toward a significant Dominance × Number interaction in Block 1 that became nonsignificant in Block 2 (see Figure 1). The Block 1 interaction was decomposed by creating two sub-datasets, one for singular-dominant nouns and one for plural-dominant nouns. A cross-classified LME model was run for each of these datasets. These models included both random intercepts, Number as a random noun slope, Number as a fixed effect, and the four control variables included in the Block 1 model. There is a significant main effect of Number for singular-dominant nouns ($b = 52.14 \times 10^{-6}$, $SE = 13.65 \times 10^{-6}$, $t = 3.82$, $p < .001$), but not for plural-dominant nouns ($p = .303$; see Table E1 for complete results). Specifically, singular singular-dominant nouns were recognized 23 ms faster than plural singular-dominant nouns, while singular and plural plural-dominant nouns were recognized at a similar speed (5 ms difference).

Effect size. The final model marginal effect size estimates are 4.52% (Block 1) and 2.38% (Block 2). The marginal effect size is extremely low for both models, indicating that the fixed effects and control variables were not very effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates are 50.78% (Block 1) and 42.00% (Block 2). Adding the variance accounted for by participant and item random effects increases the variance account for, but at least half of the observed variability is still left unexplained by the model.

Discussion

In the present experiment, response accuracy was very high (98%) and not influenced by any of the fixed effects tested. However, response latency was influenced by grammatical number in Block 1 only. Specifically, singular nouns had faster response latencies than plural nouns. There was no main effect of noun dominance. In addition, there was a trend toward a significant Dominance × Number interaction in Block 1 (p = .075). Singular singular-dominant nouns were responded to 23 ms faster than plural singular-dominant nouns while singular plural-dominant nouns were responded to 5 ms faster than plural plural-dominant nouns.

Our Block 1 findings largely align with previous LDT results. Specifically, singular nouns have been found to have faster response latencies than plural nouns in several languages (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Additionally, a non-significant main effect of noun dominance has been reported in English, French, and German (New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Finally, a significant interaction between noun dominance and grammatical number has been found in all previous LDT noun dominance studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Although the interaction did not reach significance in the present experiment, the typical response pattern was reproduced. It is important to note that including the noun-verb ratio as a control variable did not directly change the observed results even though this variable could have explained the absence of a significant Dominance × Number interaction.

Our Block 2 results indicate that Block 1 effects do not persist when the same nouns are seen for a second time. All fixed effects diminished in magnitude (Number: 9 ms difference; Dominance 1 ms difference; singular-dominant nouns: 18 ms difference) and became nonsignificant.

General Discussion

The current experiments examined how singular-dominant and plural-dominant nouns are recognized in French and English. In all response accuracy and response latency models, a series of control variables were tested in order to determine whether they modified our fixed effects of interest. These variables were written base frequency, mean noun length, noun-verb ratio, trial number, noun gender (in French only), and participant native language. Four of these control variables influenced response accuracy and/or latency: Frequency, Length, Noun-verb ratio, and Trial number. None of these variables modified or nullified the fixed effects of interest discussed below.

In both experiments, there was a significant main effect of Number in Block 1. Singular nouns had faster response latencies than plural nouns. Moreover, in Block 1, the Dominance × Number interaction was significant in French and marginally significant in English. Decomposing these interactions revealed that in both languages singular-dominant nouns presented in their singular form had faster response latencies than singular-dominant nouns presented in their plural form. Conversely, response latencies were nearly identical for singular and plural plural-dominant nouns.

Our Block 1 results from both experiments replicate what has been previously reported in the noun dominance LDT literature. Singular nouns have been recognized faster than plural nouns in all languages studied except Italian (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). In addition, a non-significant Dominance effect has been reported in English, French, and German (New, Brysbaert, et al., 2004; Reifegerste et al., 2017), which is consistent with the results of the present research. However, a main effect of Dominance has been reported in Dutch, Italian, and Spanish (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; Reifegerste et al., 2017). In these experiments, plural-dominant nouns were recognized faster than singular-dominant nouns. All published noun dominance studies report a significant interaction effect (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). The response pattern observed in these studies aligns with our results. Specifically, researchers report that singular-dominant nouns are recognized faster in their singular form than in their plural form and that plural-dominant nouns have no form advantage.

There are two possible explanations for why the English Dominance × Number interaction is only marginally significant in Experiment 2. The first explanation is that treating noun dominance as a continuous variable reduced the interaction effect. In all previous experiments, with the exception of those conducted by Reifegerste and her colleagues (2017), noun dominance was treated as a dichotomous categorical variable. As noted in the introduction, an argument for treating noun dominance as a continuous variable has been presented by several researchers. However, the absence of the expected interaction effect raises the question of whether this shift is warranted. Our English results suggest that readers may not be sensitive to subtle differences in the noun dominance ratio and may instead form categorical distinctions. To determine whether this explanation holds merit, the Block 1 response latency model was re-run treating noun dominance as a dichotomous categorical variable based on noun dominance score (i.e., singular-dominant vs. plural-dominant). The final cross-classified LME model fixed effect results are presented in Table F1. Chi-squared model fit comparison tests indicate that treating noun dominance as a categorical variable fits the data significantly better than treating noun dominance as a continuous variable ($p < .001$). All fixed effect and control variable results are similar across models with one notable exception, the Dominance × Number interaction becomes significant when noun dominance is treated as categorical. This result replicates what has been reported in all other noun dominance studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

The second explanation is that the noun-verb ratio influenced singular-dominant noun response latencies. The majority of word class ambiguous items were singular-dominant nouns (e.g., *balance*, *plant*, *view*). In a lexical decision experiment focused on singular-dominant words, Baayen and his colleagues (1997) found a significant Number × Word Class interaction; singular nouns were processed 58 ms faster than singular verbs while plural nouns and verbs were processed at an identical speed. Alternately, Feldman and Basnight-Brown (2008) found that participants were faster at recognizing English class ambiguous words ending in *-ing* if they occurred more frequently as a verb than as a noun (i.e., had a low noun-verb ratio). Extending these results to our English experiment findings, it is possible that singular singular-dominant nouns with a lower noun-verb ratio were perceived as verbs; leading to an overall increase in response latency for singular singular-dominant nouns. As a consequence, the strength of Number main effect for singular-dominant nouns diminished, effectively reducing the interaction effect. Although this explanation is plausible, in the present research the main effect of the noun-verb ratio was not significant and did not significantly interact with either noun dominance or grammatical number ($p \geq .263$).

The present experiments contained a unique element not previously investigated. Participants were presented with each noun a second time in its alternative grammatical form in Block 2 of each experiment. As would be expected, encountering nouns a second time facilitated recognition speed. In both languages, nouns were recognized faster in Block 2 than in Block 1 (French: 28 ms difference; English: 14 ms difference). With regards to the fixed effects of interest, in French, both the Number and interaction pattern effects remained significant and the main effect of Dominance became significant. In English, none of the Block 2 results were significant ($p \geq .121$). The lack of significant Block 2 results in English could be a result of statistical power. There were fewer English participants than French participants (56 vs. 62) and fewer English experimental items than French experimental items (92 vs. 100). The greater the sample size(s), the larger the statistical power (Huta, 2014; Maas & Hox, 2005; Paccagnella, 2011). Alternatively, it is possible that a true language discrepancy exists.

Overall, our French and English Block 1 findings and French Block 2 findings support the parallel dual-route model prediction (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2000; Bertram et al., 2000; Schreuder & Baayen, 1995). There was a significant surface frequency effect for singular-dominant nouns, with singular nouns being recognized faster than plural nouns. No surface frequency effect was found for plural-dominant nouns. These results do not match the predictions of either the full-storage models or the full-decomposition models (Butterworth, 1983; Bybee, 1995; Clahsen, 1999; Giraudo & Grainger, 2000; Manelis & Tharp, 1977; Rastle et al., 2004; Taft, 1979, 2004).

Limitations and Future Directions

The main limitation in the experiments presented in this paper is the number of experimental items tested. In both English and French, there is a limited number of plural-dominant nouns. As a result, there is a built-in maximum on the number of plural-dominant nouns, and hence singular-dominant nouns, that can be selected for noun dominance experiments.

A potential confound in our experiments is that many participants spoke at least two languages, often French and English. Native language did not statistically impact response latency or accuracy in the current experiments ($p \geq .478$). However, participants' ability to speak both languages may have impacted how they processed words that were equivalent across languages, either orthographically (e.g., *minute*) or semantically (e.g., *shoe* vs. *soulier*). Researchers have demonstrated that bilingual readers are faster at processing words that are equivalent across languages compared to words that are dissimilar across languages (Bultena, Dijkstra, & van Hell, 2014; Emulder, Edijkstra, & Ebaayen, 2015; Peeters, Dijkstra, & Grainger, 2013; Temnikova & Nagel, 2015). Therefore, when participants encountered a word that has the same orthographic or semantic form in both French and English it is likely bilingual participants were more familiar with the word than accounted for by our frequency estimates. Moreover, some cognates differed in terms of their dominance ratio across the two langauges. For instance, the noun *relation* is plural-dominant in French, yet singular dominant in English (0.52 vs. 18.5). This is also the case with the nouns *branche* [*branch*] (0.51 vs. 1.3).

Future studies might attempt to extend the present results and those reported by Reifegerste et al. (2017) to additional languages, treating noun dominance as a continuous variable and using linear mixed modelling statistical techniques. It would also be useful to gain insight into the effects of noun dominance and grammatical number within a more complex language structure, such as sentences. A single study has studied these effects in relation to sentence subject-verb agreement (Barker & Nicol, 2000). The authors found that sentences containing singular singular-dominant local nouns were processed 32 ms faster than those containing plural singular-dominant local nouns. This aligns with the surface frequency effect observed in our experiments and the LDT literature. Expanding the sentence processing literature would increase our understanding of when and how the surface frequency effect materializes within a more complex language structure that is more in line with everyday language usage than single word processing.

Conclusion

In conclusion, the present experiments extend our understanding of the surface frequency effect using more sophisticated statistical techniques that account for two random samples (i.e., participants and items). When noun dominance is treated as a continuous variable, there is a significant main effect of Number in both French and English. In addition, the Dominance × Number interaction was significant in French and marginally so in English. A secondary analysis revealed that treating noun dominance as a categorical variable produces a significant Dominance × Number interaction in English. Effects were more robust in French, they remained statistically significant in the Block 2 analyses. In English, effects disappeared in Block 2. The observed interaction patterns match those predicted by the parallel dual-route model of visual word recognition (Baayen et al., 2000). Specifically, singular singular-dominant nouns were recognized faster than plural singular-dominant nouns while no form advantage was observed for plural-dominant nouns.

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Table 1

French and English Noun Characteristics

	French		English	
	Singular-dominant nouns (n = 50)	Plural-dominant nouns (n = 50)	Singular-dominant nouns (n = 46)	Plural-dominant nouns (n = 46)
Noun length	6.14	6.20	6.24	6.28
Number of phonemes	4.52	4.44	5.09	5.15
Number of syllables	1.58	1.62	1.93	1.96
Number of masculine nouns	22	25		
Singular surface frequency	61.92	22.22	74.76	35.96
Plural surface frequency	20.12	62.84	30.48	79.89
Base frequency	82.08	89.82	105.20	115.87
Noun dominance score	41.81	-41.51	44.28	-43.93
Noun dominance ratio	13.57	0.29	3.85	0.43

Note. Means for noun length, number of phonemes, and number of syllables are based on the singular form of the nouns.

Table 2

Experiment 1 French LDT Response Accuracy Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	1.31	1.15	
	Number	0.16	0.40	-0.52
PartID	(Intercept)	1.47	1.21	
	Dominance	0.19	0.43	-0.50
		Number of observations: 12400; Groups: NounID, 100; PartID, 62		

Fixed effects			
	b	*SE*	*z*
(Intercept)	5.61	0.27	20.94^{***}
Control variables			
Frequency	2.65	0.59	4.53^{***}
Length	1.86	0.50	3.75^{***}
Fixed effects			
Dominance	-0.70	0.22	-3.20^{**}
Number	-0.12	0.23	-0.51
Interaction			
Dominance × Number	-0.29	0.16	-1.80^{T}

Note. Frequency = noun written base frequency; Length = mean noun length.

^{T} $p < .10$. ** $p < .01$. *** $p < .001$.

Table 3

French and English Response Accuracy Descriptive Statistics

Number	Singular-dominant nouns		Plural-dominant nouns	
	M	*SD*	*M*	*SD*
French				
Singular	96.87%	3.50%	98.48%	2.47%
Plural	96.32%	3.32%	98.84%	2.10%
English				
Singular	97.79%	2.05%	98.64%	2.01%
Plural	97.87%	2.98%	98.99%	1.90%

Table 4

Experiment 1 French LDT Response Latency Random Effect Results

		Block 1			Block 2		
Group	Name	Variance	*SD*	*r*	Variance	*SD*	*r*
NounID	(Intercept)	70.55^{-10}	8.40^{-5}		66.79^{-10}	8.17^{-5}	
	Number				11.67^{-10}	3.42^{-5}	0.14
PartID	(Intercept)	624.20^{-10}	24.98^{-5}		579.90^{-10}	24.08^{-5}	
	Dominance	0.75^{-10}	0.86^{-5}	-0.35			
Residual		951.90^{-10}	30.85^{-5}		1028.00^{-10}	32.06^{-5}	
		Number of observations: 5810			Number of observations: 5913		
		Groups: NounID, 100; PartID, 62			Groups: NounID, 100; PartID, 62		

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 5

Experiment 1 French LDT Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1777^{-6}	33.84^{-6}	-52.51***			-1872^{-6}	32.73^{-6}	-57.20***		
Control variables										
Frequency	-173.70^{-6}	31.05^{-6}	-5.60***	-234.25^{-6}	-113.29^{-6}	-182.10^{-6}	30.50^{-6}	-5.97***	-241.57^{-6}	-122.72^{-6}
Length	45.83^{-6}	29.38^{-6}	1.56	-11.42^{-6}	103.03^{-6}	3.77^{-6}	28.87^{-6}	0.13	-52.49^{-6}	59.98^{-6}
Trial	-0.13^{-6}	0.07^{-6}	-1.86^{T}	-0.27^{-6}	-0.01^{-6}	-0.02^{-6}	0.07^{-6}	-0.32	-0.17^{-6}	0.12^{-6}
Fixed effects										
Dominance	18.66^{-6}	12.30^{-6}	1.52	-5.30^{-6}	42.66^{-6}	27.59^{-6}	12.04^{-6}	2.29*	4.16^{-6}	51.07^{-6}
Number	30.78^{-6}	8.12^{-6}	3.79***	14.86^{-6}	46.70^{-6}	26.95^{-6}	9.04 e^{-6}	2.98**	9.32^{-6}	44.60^{-6}
Interactions										
Dominance × Number	42.90^{-6}	10.85^{-6}	3.95***	21.63^{-6}	64.18^{-6}	35.86^{-6}	11.98^{-6}	2.99**	12.47^{-6}	59.53^{-6}
Number × Length	90.84^{-6}	25.48^{-6}	3.57***	40.89^{-6}	140.75^{-6}	36.15^{-6}	28.21^{-6}	1.28	-18.84^{-6}	91.19^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .1$. * $p < .05$. ** $p < .01$. *** $p < .001$.

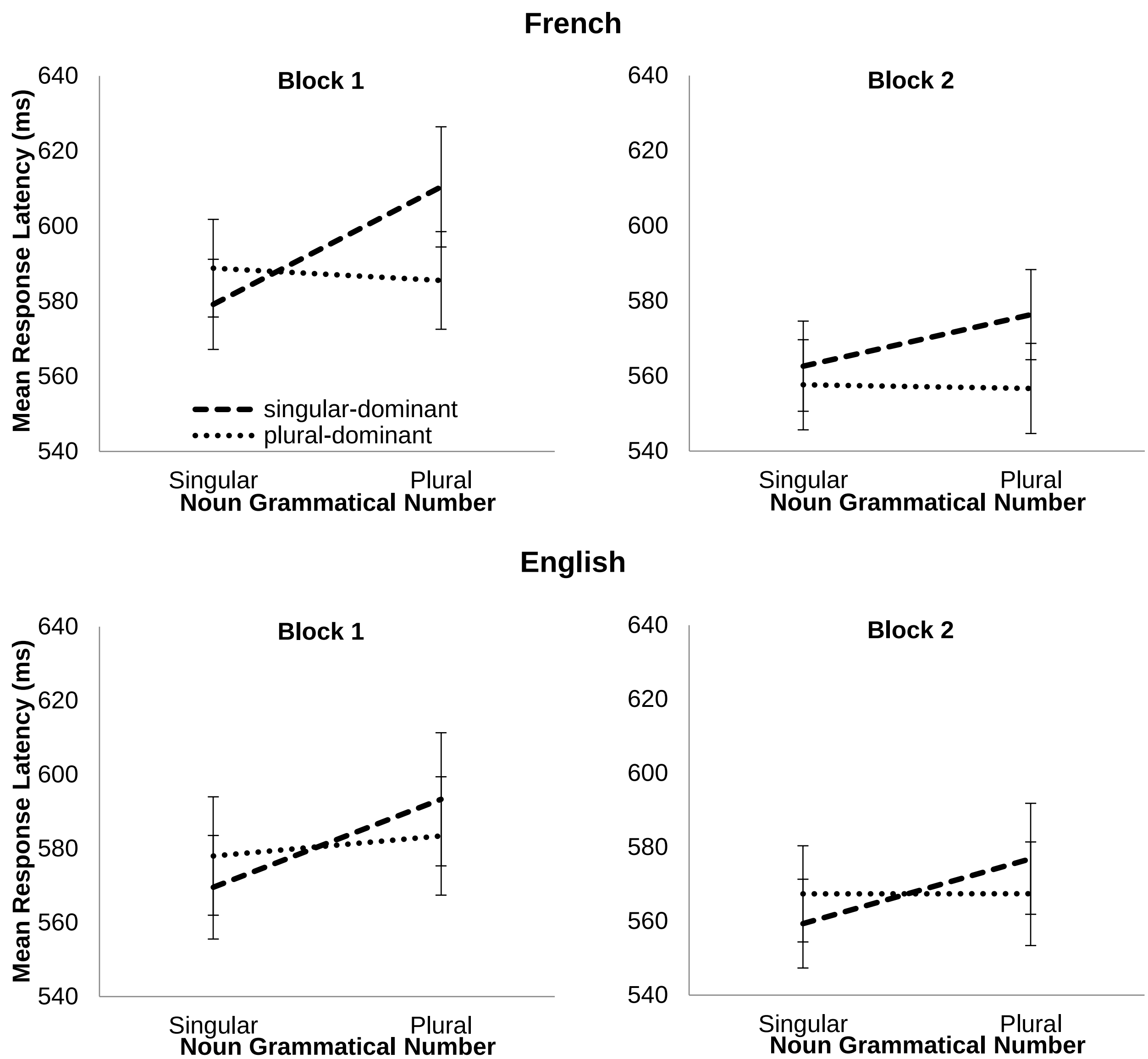

Figure 1. French and English mean response latencies as a function of language, block number, grammatical number, and noun dominance category. Error bars represent standard error of the means.

Table 6

French and English Response Latency Descriptive Statistics

Number	Block 1				Block 2			
	Singular-dominant nouns		Plural-dominant nouns		Singular-dominant nouns		Plural-dominant nouns	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
French								
Singular	579	91	589	105	563	92	558	91
Plural	611	127	586	103	576	92	557	94
English								
Singular	570	106	578	119	559	87	567	99
Plural	593	132	583	121	577	116	567	106

Table 7

Experiment 2 English LDT Response Latency Random Effect Results

		Block 1			Block 2	
Group	Name	Variance	*SD*	*r*	Variance	*SD*
NounID	(Intercept)	60.03^{-10}	7.75^{-5}		36.84^{-10}	6.07^{-5}
	Number	9.34^{-10}	3.06^{-5}	0.05		
PartID	(Intercept)	833.90^{-10}	28.88^{-5}		753.60^{-10}	27.45^{-5}
	Dominance	6.14^{-10}	2.48^{-5}	-0.03		
Residual		955.50^{-10}	30.91^{-5}		1157.00^{-10}	34.01^{-5}
		Number of observations: 4916			Number of observations: 4911	
		Groups: NounID, 92; PartID, 56			Groups: NounID, 92; PartID, 56	

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 8

Experiment 2 English LDT Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1803^{-6}	40.45^{-6}	-44.58^{***}			-1896^{-6}	38.52^{-6}	-49.22^{***}		
Control variables										
Frequency	-81.62^{-6}	28.06^{-6}	-2.91^{**}	-136.43^{-6}	-26.83^{-6}	-67.59^{-6}	24.35^{-6}	-2.78^{**}	-114.73^{-6}	-20.46^{-6}
Length	462.40^{-6}	60.90^{-6}	7.59^{***}	341.21^{-6}	583.40^{-6}	325.10^{-6}	52.82^{-6}	6.15^{***}	222.81^{-6}	427.27^{-6}
N-V ratio	115.60^{-6}	69.65^{-6}	1.66^{T}	-20.85^{-6}	252.23^{-6}	116.80^{-6}	60.37^{-6}	1.94^{T}	0.01^{-6}	233.68^{-6}
Trial	-0.34^{-6}	0.08^{-6}	-4.07^{***}	-0.51^{-6}	-0.18^{-6}	0.21^{-6}	0.09^{-6}	2.25^{*}	0.02^{-6}	0.39^{-6}
Fixed effects										
Dominance	5.90^{-6}	18.36^{-6}	0.32	-29.68^{-6}	41.48^{-6}	-3.22^{-6}	15.63^{-6}	-0.21	-33.47^{-6}	27.02^{-6}
Number	32.50^{-6}	9.38^{-6}	3.46^{***}	14.12^{-6}	50.91^{-6}	15.10^{-6}	$9.71\ e^{-6}$	1.55	-3.93^{-6}	34.14^{-6}
Interaction										
Dominance × Number	32.31^{-6}	18.13^{-6}	1.78^{T}	-3.22^{-6}	67.82^{-6}	19.68^{-6}	18.69^{-6}	1.05	-16.95^{-6}	56.29^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix A

French Experimental Stimuli [Gender] (Dominance Score)

Singular-dominant nouns: bassin [m] (17.23), bière* [f] (32.57), bloc [m] (17.84), boîte* [f] (52.59), bouquet [m] (14.93), carré [m] (17.91), cave [f] (27.83), cercle[v] [m] (30.61), charge[v] [f] (30.88), collège [m] (23.18), comptoir* [m] (37.50), couverture [f] (20), crise [f] (26.21), défaite[v] [f] (17.10), don [m] (20.68), faiblesse* [f] (19.06), fauteuil* [m] (51.35), fenêtre [f] (118.58), figure[v] [f] (60.13), force[v] [f] (92.03), fric [m] (26.28), grange [f] (35.47), grille[v] [f] (29.46), journée [f] (102.09), lenteur [f] (21.42), masque[v] [m] (18.25), moteur [m] (31.48), neige[v] [f] (68.98), nuque [f] (46.08), paire [f] (20.94), papier [m] (86.08), pierre [f] (48.92), plafond* [m] (42.36), plancher [m] (27.63), poing [m] (19.86), promenade [f] (26.75), rapport [m] (43.51), réponse [f] (67.50), réussite* [f] (15.61), rive[v] [f] (24.13), rivière [f] (29.26), salle* [f] (179.46), semaine [f] (26.28), sentier [m] (20.27), soin [m] (22.57), solution [f] (30.27), source* [f] (21.63), sucre[v] [m] (28.31), verre* [m] (120.34), voyage[v] [m] (81.01)

Plural-dominant nouns: botte [f] (35.27), branche[v] [f] (37.37), camarade [m] (21.29), centaine [f] (20.74), centimètre [m] (15.94), chaussure [f] (38.92), circonstance [f] (26.22), cuisse [f] (27.29), dent [f] (103.38), doigt [m] (95.47), fesse[v] [f] (32.30), feuille [f] (45.34), fleur [f] (78.45), fruit [m] (20.13), gant [m] (20.07), joue[v] [f] (29.06), kilomètre [m] (49.67), larme [f] (111.89), légume [m] (19.26), lèvre [f] (180.54), limite[v] [f] (21.89), lunette [f] (60.41), membre [m] (34.46), mètre[v] [m] (86.42), meuble[v] [m] (30.47), millier [m] (37.71), million [m] (38.38), minute[v] [f] (79.94), mot [m] (32.84), muscle[v] [m] (26.69), narine [f] (15.54), nerf [m] (22.63), nouvelle [f] (29.32), nuage [m] (23.85), patte [f] (42.57), paupière [f] (49.39), prisonnier [m] (26.42), rein [m] (30.54), relation [f] (31.96), reprise[v] [f] (19.66), ride[v] [f] (17.23), sein [m]

(19.59), son [m] (18.51), soulier [m] (26.08), sourcil [m] (30.34), talon [m] (24.53), trait[v] [m] (21.48), vacance [f] (80.81), vêtement [m] (59.46), volet [m] (27.77)

Note. * Items also included in the New et al. (2004) experiment; [v] Items that have a verb equivalent in French.

Appendix B

English Experimental Stimuli (Dominance Score)

Singular-dominant nouns: application (19), area (53), balance[v] (76), bell (12), benefit[v] (15), bicycle[v] (14), boat[v] (34), chance[v] (110), club[v] (59), condition[v] (29), design[v] (55), example (186), exception (14), expenditure (23), expression (67), field[v] (62), gun (30), habit (16), hat* (40), image (44), incident (16), job (149), journal* (12), mortgage (13), moustache* (14), operation (15), pattern (27), perspective (19), plant[v] (18), programme[v] (54), record[v] (25), region (14), school[v] (258), second (12), share[v] (14), ship[v] (17), snow[v] (55), stick[v] (13), sum* (15), survey[v] (22), talent* (13), threat (48), value (56), view[v] (152), vitamin (16), wheel[v] (12)

Plural-dominant nouns: affair (16), bean (14), bone (17), boot (22), characteristic (13), chemical (19), circumstance (73), consequence (14), dollar* (40), egg (12), event (19), eye[v] (289), finger[v] (28), flower[v] (44), hour (60), implication (16), institution (33), instruction (13), kilometre (23), knee (25), leg (52), lip* (48), mile (105), minute (143), month (142), muscle (27), pound[v] (179), regulation (16), requirement (19), resource (66), rule[v] (15), shoe*[v] (54), sock[v]* (13), standard (32), statistic* (12), symptom* (13), tear[v] (55), technique (12), toe[v] (12), ton (13), tool* (15), tree (49), vegetable (14), weapon* (58), word (51), yard (16)

Note. * Items also included in the New et al. (2004) experiment; [v] Items that have a verb equivalent in English.

Appendix C

Table C1

Experiment 1 French LDT Response Latency Dominance × Number Interaction Fixed Effect Results

	Block 1						Block 2					
	Singular-dominant nouns			Plural-dominant nouns			Singular-dominant nouns			Plural-dominant nouns		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1772^{-6}	36.33^{-6}	-48.79^{***}	-1782^{-6}	35.57^{-6}	-50.09^{***}	-1867^{-6}	35.48^{-6}	-52.62^{***}	-1877^{-6}	34.28^{-6}	-54.77^{***}
Control variables												
Frequency	-175.10^{-6}	44.53^{-6}	-3.93^{***}	-178.50^{-6}	43.93^{-6}	-4.06^{***}	-204.50^{-6}	44.05^{-6}	-4.64^{***}	-164.40^{-6}	43.67^{-6}	-3.76^{***}
Length	6.77^{-6}	49.82^{-6}	0.14	64.84^{-6}	36.31^{-6}	1.79^{T}	-36.91^{-6}	49.48^{-6}	-0.75	26.55^{-6}	36.12^{-6}	0.74
Trial	-0.12^{-6}	0.10^{-6}	-1.20	$-.15^{-6}$	0.10^{-6}	-1.48	0.06^{-6}	0.11^{-6}	0.58	-0.11^{-6}	0.10^{-6}	-1.11
Fixed effect												
Number	63.41^{-6}	11.69^{-6}	5.42^{***}	-4.28^{-6}	11.27^{-6}	-0.38	43.48^{-6}	12.50^{-6}	3.48^{***}	8.78^{-6}	13.15^{-6}	0.67
Interaction												
Number × Length	177.40^{-6}	42.08^{-6}	4.21^{***}	34.93^{-6}	31.85^{-6}	1.10	99.97^{-6}	44.69^{-6}	2.24^{*}	-4.41^{-6}	37.02^{-6}	-0.12

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. * $p < .05$. *** $p < .001$.

Table C2

Experiment 1 French LDT Block 1 Response Latency Number × Length Interaction Fixed Effect Results

	Singular nouns			Plural nouns		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1792^{-6}	34.03^{-6}	-52.65^{***}	-1764^{-6}	35.66^{-6}	-49.48^{***}
Control variables						
Frequency	-188.50^{-6}	33.87^{-6}	-5.57^{***}	-151.40^{-6}	31.41^{-6}	-4.82^{***}
Length	1.44^{-6}	32.11^{-6}	0.04	96.73^{-6}	29.88^{-6}	3.24^{**}
Trial	-0.15^{-6}	0.10^{-6}	-1.46	-0.13^{-6}	0.10^{-6}	-1.27
Fixed effect						
Dominance	-4.27^{-6}	13.44^{-6}	-0.32	36.82^{-6}	12.54^{-6}	2.94^{**}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

** $p < .01$. *** $p < .001$.

Appendix D

Table D1

Experiment 2 English LDT Response Accuracy Results

Random effects			
Group	Name	Variance	*SD*
NounID	(Intercept)	1.06	1.03
PartID	(Intercept)	0.57	0.75
		Number of observations: 10304; Groups: NounID, 92; PartID, 56	
Fixed effects			
	b	*SE*	*z*
(Intercept)	4.92	0.21	23.99***
Fixed effects			
Dominance	-0.46	0.28	-1.63
Number	0.17	0.16	0.32
Interaction			
Dominance × Number	-0.21	0.32	-0.67

*** $p < .001$.

Appendix E

Table E1

Experiment 2 English LDT Block 1 Response Latency Dominance × Number Interaction Fixed Effect Results

	Singular-dominant			Plural-dominant		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1799^{-6}	42.78^{-6}	-42.06***	-1816^{-6}	42.26^{-6}	-42.97***
Control variables						
Frequency	-77.76^{-6}	47.00^{-6}	-1.65^{T}	-88.57^{-6}	33.16^{-6}	-2.67**
Length	533.60^{-6}	109.50^{-6}	4.87***	390.60^{-6}	69.52^{-6}	5.62***
N-V ratio	78.92^{-6}	87.74^{-6}	0.90	285.70^{-6}	144.40^{-6}	1.98*
Trial	-0.37^{-6}	0.12^{-6}	-3.12**	-0.30^{-6}	0.12^{-6}	-2.51*
Fixed effect						
Number	52.14^{-6}	13.65^{-6}	3.82***	13.27^{-6}	12.88^{-6}	1.03

Note. $^{-6}$ is shorthand for × 10^{-6} scientific notation. Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

^{T} $p < .1$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix F

Table F1

English Response Latency Fixed Effect Results when Dominance is Treated as Categorical

				95% *CI*	
	b	*SE*	*t*	Lower	Upper
(Intercept)	-1803^{-6}	40.44^{-6}	-44.59^{***}	---	---
Control variables					
Frequency	-81.19^{-6}	27.97^{-6}	-2.90^{**}	-135.93^{-6}	-26.48^{-6}
Length	462.90^{-6}	60.85^{-6}	7.61^{***}	341.72^{-6}	583.85^{-6}
N-V ratio	116.90^{-6}	70.82^{-6}	1.65^{T}	-21.48^{-6}	255.32^{-6}
Trial	-0.34^{-6}	0.08^{-6}	-4.05^{***}	-0.51^{-6}	-0.18^{-6}
Fixed effects					
Dominance	-5.44^{-6}	19.82^{-6}	-0.27	-43.86^{-6}	32.98^{-6}
Number	32.60^{-6}	9.32^{-6}	3.50^{***}	14.35^{-6}	50.87^{-6}
Interaction					
Dominance × Number	-39.39^{-6}	18.63^{-6}	-2.11^{*}	-75.89^{-6}	-2.89^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

^{T} $p < .1$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Study 2: Determiner-Noun Number Agreement in French and English

Determiner-Noun Number Agreement in French and English

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Abstract

To date, a single study has been published on determiner-noun number agreement. The authors found participants were more accurate and faster at forming agreement for pictures containing a single exemplar versus multiple exemplars of singular-dominant nouns (Fieder, Wang, Biedermann, & Nickels, 2017). The objective of this paper is to further our understanding of determiner-noun number agreement in French and English by investigating the effects of grammatical number and noun dominance in three number agreement experiments. In all three experiments, number agreement was formed faster with plural nouns than singular nouns; noun dominance had no effect. In French only, a surface frequency effect was observed for plural-dominant nouns. These findings are not consistent with the results reported in the lexical decision and picture naming literature. This suggests that grammatical number and surface frequency are accessed differently when individuals make determiner-noun number agreement decisions then when they make lexical or picture naming decisions.

Keywords: number, noun dominance, inflectional morphology, number agreement

Determiner-Noun Number Agreement in French and English

Agreement has been defined as the "systematic covariance between a semantic or formal property of one element and a formal property of another [element]" (Steele, 1978, p. 610). Number agreement is the grammatical agreement of number information expressed by a subject and a target word (Bock & Miller, 1991). It is a common phenomenon which transpires nearly every time a phrase or sentence is formed. In many languages, the subject that dictates the number information expressed by target words is a noun (Bock & Miller, 1991; Corbett, 2000, 2006; Mel'čuk & Milićević, 2014b; Wechsler, 2009). When a noun is the subject it is called a *subject noun* (Tallerman, 2011). In French and English, determiners, verbs, and pronouns can all be target words for number agreement (Corbett, 2006; Kim, 2004; Mel'čuk & Milićević, 2014b; Tallerman, 2011). To date, the majority of number agreement research has focused on subject-verb agreement (e.g., Bock, Carreiras, & Meseguer, 2012; Bock & Miller, 1991; Hartsuiker & Barkhuysen, 2006; Staub, 2009, 2010; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). To our knowledge, only a single article has been published on the topic of determiner-noun agreement (Fieder et al., 2017). The main objective of this paper is to further our knowledge surrounding determiner-noun number agreement. Specifically, we examine whether grammatical number and/or surface frequency impact determiner-noun number agreement by investigating the responses of French- and English-speaking readers in three number agreement experiments.

Grammatical Number in French and English

Grammatical number is the written expression of noun number. A singular noun is denoted by the absence of a plural marker and refers to a single entity, object or concept. A plural noun is often denoted by the presence of a plural marker and refers to two or more entities, objects, or concepts (Corbett, 2000; Mel'čuk & Milićević, 2014a; Reid, 1991; Tallerman, 2011). The most common plural marker in both French and English is the inflectional suffix -*s*, which is added to the end of the noun being pluralized (Akmajian, Demers, Farmer, & Harnish, 2001; Corbett, 2000; Mel'čuk & Milićević, 2014a; Reid, 1991). For example, the French noun *carte* [*map*] is grammatically singular while the noun *carte**<u>s</u>*** [*map**<u>s</u>***] is grammatically plural. Nouns that can alternate between singular and plural are called *count nouns*. They refer to distinct countable entities (Iwasaki, Vinson, & Vigliocco, 2010; Middleton, Wisniewski, Trindel, & Imai, 2004; Wisniewski, Lamb, & Middleton, 2003).

There are some exceptions to the plural marker "rule" in both languages. For instance, in both French and English, a small subset of singular nouns end in -*s* (e.g., French: *souris* [*mouse*], *dos* [*backside*], English: *bonus*, *fortress*. In these cases, the final -*s* is not morphemic. Moreover, less common noun plural markers exist in both languages. In French, there is only one alternative plural marker, the inflectional suffix -*x* (e.g., *hibou**<u>x</u>*** [*owls*]; Corbett, 2000). In English, there are a handful of alternative inflectional suffixes, including -*a*, -*ae*, -*i* , and -*ice* (e.g., *stratum* → *strat**<u>a</u>***, *alga* → *alg**<u>ae</u>***, *cactus* → *cact**<u>i</u>***, *die* → *d**<u>ice</u>***). There are also a small number of English plural nouns that do not follow standard grammatical rules (e.g., *goose* → *geese*, *woman* → *women*; Buck-Gengler, 2003). Finally, final -*s* can serve another morphological function in English, namely, to mark present tense verbs as third person singular (e.g., *s/he plays*, *s/he runs*). These cases demonstrate that although final -*s* typically predicts plurality in French and English, it is not always a reliable indicator of grammatical number.

Determiner-Noun Number Agreement

The term *determiner* encompasses a set of words classes that always appear immediately before a noun, such as definite or indefinite articles (*le*/*la* [*the*], *les* [*the*, plur.]; *un/une* [*a*], *des* [ø, plur.]), demonstratives (*ce*/*cette* [*this*], *ces* [*these*]), and quantifiers (*chaque* [*each*], *quelque(s)* [*some*]; Tallerman, 2011). Some determiners are number invariant (e.g., *the*). However, many determiners have alternative singular and plural forms (e.g., *this* vs. *these*). Despite the fact that they often precede the subject, determiners with alternating forms must form grammatical number agreement with the subject noun of a phrase or sentence (Bock & Middleton, 2011; Corbett, 1979, 2006; Kim, 2004; Tallerman, 2011). For example, the sentence ***Ce*** *magasin est ouvert* [***This*** *store is open*] contains proper determiner-noun number agreement. Both the determiner (*Ce* [*This*]) and noun (*magasin* [*store*]) are grammatically singular. Meanwhile, the sentence ***Ces*** *magasin est ouvert* [***These*** *store is open*] contains improper determiner-noun agreement. The grammatically plural determiner (*Ces* [*These*]) misaligns in number with the grammatically singular subject noun.

The act of forming determiner-noun number agreement has only been investigated in one published study to date. Fieder and her colleagues (Fieder et al., 2017) presented English participants with coloured pictures depicting single (one) or multiple (two or three) exemplars of mass nouns or singular-dominant count nouns.[3] Each noun exemplar was presented twice, once as a singular depiction and once as a multiple depiction, in two counterbalanced blocks. Participants were tasked with choosing whether a singular determiner (*a*/*this*) or a plural determiner (*some*/*these*) was the correct grammatical choice for the picture displayed. Pictures remained on a computer screen until participans made a determiner decision or 3000 ms passed. The results presented below focus on the singular-dominant count noun data. The authors found that participants were 3% to 8% more accurate and 15 – 75 ms faster at providing determiner responses for pictures containing a single exemplar than multiple exemplars. Expressly,

[3] *Mass nouns* cannot alternate between singular and plural forms. They are non-distinct uncountable entities and are typically singular (e.g., *hélium* [*helium*]; Iwasaki et al., 2010; Middleton et al., 2004; Wisniewski et al., 2003).

participants were more accurate and faster at forming determiner-noun number agreement for pictures containing a singular singular-dominant count noun than pictures containing multipe (i.e., plural) singular-dominant count nouns. These findings align with the surface frequency effect found within the noun dominance literature presented below.

Noun Dominance Literature

Nouns may be written more frequently in one grammatical number than the other. This is referred to as *noun dominance* (Gimenes, Brysbaert, & New, 2015; New, Brysbaert, Segui, Ferrand, & Rastle, 2004; Reifegerste, Meyer, & Zwitserlood, 2017). Nouns that are written more frequently in their singular form are called *singular-dominant*, while those that are written more frequently in their plural form are called *plural-dominant*. Noun dominance is determined by surface frequency information. *Surface frequency* is the number of times (per million) that a word appears in one specific inflected or conjugated form in a corpus of continuous texts or spoken dialogues (New, Brysbaert, et al., 2004). A noun's dominance score is obtained by subtracting its singular surface frequency from its plural surface frequency. A positive value indicates that the noun is singular-dominant, while a negative score indicates that it is plural-dominant (New, Brysbaert, et al., 2004; Sereno & Jongman, 1997). This is the noun dominance measure used in the majority of studies presented below. Alternatively, a *noun dominance ratio*, a continuous measure of noun dominance suggested by Reifegerste et al. (2017), can be calculated by dividing a noun's singular surface frequency by its plural surface frequency. A value falling below 1 indicates that a noun is plural-dominant while a value greater than 1 indicates that a noun is singular-dominant. A value of exactly 1 indicates no dominance. This is the noun dominance measure used in the experiments presented in this paper.

Several lexical decision studies have been published which examine how quickly readers recognize singular-dominant and plural-dominant nouns when they are presented in either their singular or plural form. Study results are nearly identical across six languages: Dutch, English, French, German, Italian, and Spanish. Singular nouns were recognized faster than plural nouns in all languages except Italian, irrespective of noun dominance (Baayen, Dijkstra, & Schreuder, 1997; Domínguez, Cuetos, & Segui, 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). An effect of noun dominance was observed in a few studies such that plural-dominant nouns have a speed advantage over singular-dominant nouns (Baayen, Burani, & Schreuder, 1997; Baayen, Dijkstra, et al., 1997; Baayen, Levelt, Schreuder, & Ernestus, 2007; Reifegerste et al., 2017). However, the majority of researchers reported that noun dominance did not impact response latency speed (Baayen et al., 2007; Beyersmann, Dutton, Amer, Schiller, & Biedermann, 2015; Biedermann, Beyersmann, Mason, & Nickels, 2013; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Moreover, there was a significant two-way interaction between noun dominance and grammatical number in all languages (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Decomposing these interactions revealed that singular-dominant nouns were recognized significantly faster in their singular form than in their plural form (25 – 55 ms advantage), while no form advantage was found for plural-dominant nouns (2 – 16 ms advantage). The effect observed for singular-dominant nouns is referred to as the *surface frequency effect*; readers are faster at recognizing words if they have a higher surface frequency when base frequency is held constant.

A surface frequency effect has also been observed for singular-dominant nouns in two picture naming studies. Beyersmann and her colleagues (Beyersmann et al., 2015; Biedermann et al., 2013) asked English or Dutch participants to name what they saw in pictures out loud. Pictures contained either one (singular) or multiple (plural) exemplars of singular-dominant and plural-dominant nouns. The researchers found a significant interaction between noun dominance and grammatical number in both languages. Participants were 62 to 117 ms faster at naming pictures of singular-dominant nouns when they contained one exemplar versus multiple exemplars. Meanwhile, no dominance advantage was found for pictures of plural-dominant nouns (0 – 1 ms difference). In the first picture naming study to focus on noun dominance, Baayen et al. (Baayen, Levelt, Schreuder, & Ernestus, 2007) found that Dutch participants were faster at naming pictures containing one exemplar in three separate experiments, regardless of noun dominance. The authors failed to find a significant interaction between noun dominance and grammatical number.

Together, the lexical decision and picture naming experiment results suggest that singular nouns are easier to process than plural nouns and that the surface frequency effect often persists across experimental paradigms for singular-dominant nouns. We were interested in testing whether these effects extend to determiner-noun number agreement decisions as suggested by the results of Fieder et al. (2017).

Study Overview

The goal of this paper is to increase our understanding of determiner-noun number agreement by testing whether surface frequency and/or noun dominance have an effect on number agreement decisions in French and English. In order to achieve our goal, we designed a simple determiner-noun number agreement task (NAT). A large number of items and participants were tested in three experiments. Sophisticated statistical analyses were used. Response accuracy data were analyzed using generalized linear mixed modelling. Response latency data were analyzed using cross-classified linear mixed effects modelling in place of $F_1 \times F_2$ ANOVAs to account for the two random samples (i.e., participants and items; Baayen, 2008; Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013).

On the basis of previous studies, we expected the following results in all three experiments: 1) a significant speed advantage of singular nouns over plural nouns; 2) no main effect of noun dominance; and 3) a significant interaction whereby singular singular-dominant nouns are recognized faster than plural singular-dominant nouns and singular and plural plural-dominant nouns are recognized at similar speeds.

Experiment 1: French Number Agreement Task

Method

Participants. Participants were undergraduate students attending the University of Ottawa. They chose to participate by signing-up through an online Integrated System for Participating in Research and selecting a date and time that was convenient for them. Inclusion criteria were: strong knowledge of French, normal or corrected-to-normal vision, and no diagnosed language disabilities. Participants were credited 1% towards a course of their choice as compensation for their participation.

A total of 56 students (51 female) with a mean age of 19.7 years old (SD = 3.07) participated in this study. The majority of participants identified French as their native language (n = 49), while the remaining participants fluently spoke French as a second language (n = 7).

Stimuli. One hundred French nouns (50 singular-dominant, 50 plural-dominant) were selected from the *Lexique 3* database (see Appendix B for a complete list; (New, Brysbaert, Veronis, & Pallier, 2007; New, Pallier, Brysbaert, & Ferrand, 2004). The following noun characteristics were controlled for across experimental conditions as closely as possible: noun length, number of phonemes, number of syllables, noun gender, surface frequency, base frequency, and mean noun dominance score (see Table 1). Each noun's dominance score was calculated by subtracting its singular surface frequency from its plural surface frequency. The noun-verb ratio values ranged from 0.25 to 1 with a mean of 0.95 (SD = 0.13).

Equipment. Data was collected using Dell PC computers with 64-bit processors. Stimuli were presented in size 18 Courier New boldface font on IBM Think Vision computer screens with a 1280 × 1024 resolution. E-Prime Professional 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) was used to present task instructions, randomly display stimuli, and record participant response accuracy and latency. An E-Prime serial response box (Model 200A) was used to collect participants' responses.

Experimental design. Dominance is treated as a continuous within-subjects variable while Number (singular vs. plural) and Block (1 vs. 2) are treated as dichotomous within-items variables.

Two lists were created that contained all 100 nouns in either their singular or plural form. Noun grammatical number was interchanged across lists; a noun that appeared in its singular form on List 1 (e.g., *fleur* [*flower*]) appeared in its plural form on List 2 (e.g., *fleur**s*** [*flower**s***]), and vice versa. Each list contained 25 nouns belonging to each of the following experimental conditions: 1) singular singular-dominant; 2) plural singular-dominant; 3) singular plural-dominant; and 4) plural plural-dominant.

Every participant was presented with both lists as two equal blocks of items. Consequently, each participant saw each noun twice, once per grammatical number. List order was counterbalanced so that half of participants saw List 1 first followed by List 2, while the other half saw List 2 first followed by List 1. Block 1 replicates the approach used by researchers in the noun dominance studies discussed above. The inclusion of Block 2 allows us to test the robustness of Block 1 effects.

Procedure. Upon their arrival, participants completed an informed consent form and a demographics questionnaire. They sat in a soundproofed testing room with a computer screen and E-Prime response box in front of them while they completed the determiner-noun number agreement task (NAT). Nouns were randomly presented one at a time in the center of the screen. Participants were asked to indicate whether they would place *Ce/Cette* [*This*] (representing singular grammatical number) or *Ces* [*These*] (representing plural grammatical number) in front of each noun by pressing the response box button with the corresponding label. Label placement was counterbalanced between participants to control for the influence of hand dominance (48 participants were right handed and 8 were left handed). Half of the participants pressed the far left button to respond *Ce/Cette* and the far right button to respond *Ces*, while the other half pressed the far left button to respond *Ces* and the far right button to respond *Ce/Cette*. Participants were instructed to read each item and to make their decisions as quickly as possible while maintaining an error rate below 10%. After completing 32 practice trials (16 singular-dominant nouns and 16 plural-dominant nouns) with the experimenter present, participants were left alone to complete 200 experimental trials. The task took 10 to 20 minutes to complete. Participants were debriefed after they finished the study.

All trials followed the same sequence: 1) a message appeared in the center of the screen asking participants if they were ready to start the trial [Ready?]; 2) participants pushed either button to indicate they were ready; 3) a 500 ms delay followed; 4) a fixation point (+) appeared in the centre of the screen for 531 ms; 5) a stimulus appeared in the centre of the screen; 6) participants provided their response, causing the simultaneous disappearance of the stimulus; 7) there was a 500 ms delay before the sequence recommenced.

Results

Data cleaning. All reaction time (RT) data was cleaned by participant and experimental condition using the following steps: 1) RTs for inaccurate responses were removed, 2) RTs below 250 ms were removed, 3) RTs that were 3.29 standard deviations above or below the mean were removed (Ratcliff, 1993), and 4) RTs that fell between 2.58 to 3.29 standard deviations above or below the mean were winsorized (Tukey, 1962). Implementing this procedure resulted in the removal of 5.4% of the RT data, 3.0% due to inaccurate responses and 2.4% from outliers. Following this procedure, an inverse transformation (-1/RT) was applied to the cleaned data to reduce positive skew.

Statistical analysis. Prior to analysis, the linearity of all continuous fixed effects and control variables was verified and the appropriate transformations were applied when necessary. Following this, all fixed effects, with the exception of trial number, were grand mean centred (gmc) or contrast coded (cc) to reduce multicollinearity (Linck & Cunnings, 2015).

Analyses were conducted in R (v. 3.3.2; R Core Team, 2016) using the RStudio user interface (v. 1.0.136, RStudio Team, 2015) and the lme4 package (v. 1.1-12; Bates, Mächler, Bolker, & Walker, 2015). A maximal model was always sought (Barr et al., 2013). In all models presented in this paper, two random effects were specified: participants and items. Their random intercepts were always included. Random slopes were included whenever possible. They were excluded if they correlated too highly ($r \geq 0.90$) with their random intercept or other random slopes. Dominance was entered as a potential random participant slope. Likewise, Number was entered as a potential random noun slope (each singular and plural noun pair represents a single lexical unit). In response accuracy models, Block was entered as a potential random noun slope.

All models included the following fixed effects: 1) Dominance; 2) Number; and 3) Dominance × Number interaction. Several control variables were also added to the models: 1) noun written base frequency; 2) mean noun length (i.e., noun length averaged over the singular and plural forms); 3) noun-verb ratio; 4) participant native language; 5) trial number as a practice indicator; and 6) noun gender. Control variables that did not contribute significantly to the goodness of the model fit based on chi-square goodness of fit tests were removed from the final model.

Response accuracy data were analyzed using generalized linear mixed modelling (GLMM) for binary data. The `glmer` function was used with the family criterion set to binomial. The maximum likelihood estimator used was Laplace approximation. The `bobyqa` optimizer was used to increase the number of iterations and improve model convergence.

Response latency data were analyzed using cross-classified linear mixed effects (LME) modelling using the `lmer` function. The maximum likelihood estimator was set to restricted maximum likelihood (REML). T-test significance was calculated using the formula proposed by Baayen (2008):

$$2\{1 - pt\ [abs\ (t - value), \#of\ observations - \#of\ fixed\ effects]\} \tag{2}$$

Finally, two model effect size estimates were calculated for all models using the `r.squaredGLM` function from the MuMIn package (v. 1.15.6; Bartoń, 2016). The marginal effect size estimates the amount of variance accounted for by all the fixed effects included in the model (i.e., fixed effects, control variables, and interactions). The conditional effect size estimates the amount of variance accounted for by all the random effects and fixed effects included in the model (Johnson, 2014; Nakagawa & Schielzeth, 2013).

Response accuracy results. Participants' overall accuracy rate was very high (M = 97%; SD = 2%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = -0.12, SE = 0.11, z = -1.07, p = 0.285) and did not improve model fit (p = .293). All final model fixed effect correlations were weak, $r \leq |0.18|$. The final GLMM code is below; results are presented in Table 2.

```
FR.ACC.model <- glmer(ACC ~ DomRatioLog_gmc*Num_cc + (1+
DomRatioLog_gmc|PartID) + (1|NounID), data = FR_NAT_ACC, family = binomial)
```

Fixed effects and interaction. There was a significant main effect of Dominance. Response accuracy increased as the noun dominance ratio increased. In other words, response accuracy was 1% higher for singular-dominant nouns than plural-dominant nouns. There was also a significant effect of Number. Response accuracy was 1% higher for singular nouns than plural nouns (98% vs. 96%; see Table 3 for descriptive statistics). The Dominance × Number interaction was not significant (p = .530).

Effect size. The final model marginal effect size estimate was 0.02%. The fixed effects did not account for any of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 0.21%. Adding the variance accounted for by participant and item random effects did not help explain the observed variability.

Response latency results. There was a significant main effect of Block (b = 26.97 × 10^{-6}, SE = 7.35 × 10^{-6}, t = -3.67, p < .001), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to the research studies presented in the introduction. All final model fixed effect correlations were moderately weak ($r \leq |0.41|$). The final cross-classified LME codes are below; results are presented in Tables 4 and 5.

```
FR.RT.B1.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Gender_cc + Trial + DomRatio_gmc:BFreqLog_gmc +
DomRatio_gmc: MLenLog_gmc + Num_cc:MLenLog_gmc + (1 + DomRatioLog_gmc|PartID)
+ (1|NounID), data = FR_NAT_B1)
FR.RT.B2.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Gender_cc + Trial + DomRatio_gmc:BFreqLog_gmc +
DomRatio_gmc: MLenLog_gmc + Num_cc:MLenLog_gmc + (1|PartID) + (1|NounID),
data = FR_NAT_B2)
```

Control variables. There was a significant main effect of noun written base frequency in Block 2 only. Nouns with a higher written frequency of occurrence were responded to faster than those with a lower written frequency of occurrence. There was a significant effect of noun-verb ratio in Block 1 that became non-significant in Block 2. In Block 1, response latencies increased as the noun-verb ratio increased. There was also a significant main effect of noun gender in Block 1 only. Feminine nouns were responded to faster than masculine nouns (595 ms vs. 599 ms). Additionally, there was a significant main effect of mean noun length in Block 1 only. Response latencies increased as mean noun length increased. Finally, there was a significant main effect of trial number in both blocks. In Block 1, response latencies increased as trial number increased. In Block 2 the pattern reversed, response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number in Blocks 1 and 2. Response latencies were slower for singular nouns than plural nouns in both blocks (Block 1:

601 ms vs. 599 ms; Block 2: 587 ms vs. 592 ms)[4]. The main effect of Dominance was not significant in either block ($p \geq .159$).

Interactions. The interaction between Dominance and Number did not reach significance in Block 1, but became significant in Block 2 (see Figure 1; see Table 6 for descriptive statistics). The Block 2 interaction was decomposed by creating two sub-datasets, one for singular-dominant nouns and one for plural-dominant nouns. Cross-classified LME models were run for each of these datasets. These models included both random intercepts, Number as a random noun slope in the plural-dominant noun model, Number as a fixed effect, the five control variables included in the original model, and the Number × Length interaction. There was a significant main effect of Number for plural-dominant nouns ($b = 65.39 \times 10^{-6}$, $SE = 15.54 \times 10^{-6}$, $t = -4.21$, $p < .001$), but not for singular-dominant nouns ($p = .638$; see Table C1 for complete results). Specifically, plural-dominant nouns were recognized 8 ms faster in their plural form than in their singular form. Meanwhile, singular-dominant nouns were recognized 17 ms faster in their singular form than their plural form, but this difference was not significant.

There was also a significant Number × Length interaction in both blocks. This interaction was decomposed by creating two sub-datasets per block, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Dominance as a random slope for the Block 1 models only, Dominance as a fixed effect, the five control variables included in the original models, and the two interactions, Dominance × Frequency and Dominance × Length. There is a significant main effect of Length for singular nouns in both blocks (Block 1: $b = 14.46 \times 10^{-6}$, $SE = 27.01 \times 10^{-6}$, t

[4] The cross-classified LME model produces estimates based on the observed response latency data. Model estimates do not always correspond with the observed data. This is evident here where there is an observed singular noun speed advantage in Block 2 yet an estimated plural noun speed advantage.

= 5.35, $p < .001$; Block 2: $b = 73.05 \times 10^{-6}$, $SE = 24.80 \times 10^{-6}$, $t = 2.95$, $p = .003$), and a trending effect for plural nouns in Block 1 that reversed and became significant in Block 2 (Block 1: $b = 42.60 \times 10^{-6}$, $SE = 24.97 \times 10^{-6}$, $t = 1.71$, $p = .087$; Block 2: -55.48×10^{-6}, $SE = 26.15 \times 10^{-6}$, $t = -2.12$, $p = .034$; see Table C2 for complete results). More explicitly, the longer singular nouns were the faster they were recognized. Meanwhile, the longer plural nouns were the faster they were recognized in Block 1 and the slower they were recognized in Block 2.

Effect size. The final model marginal effect size estimates were 0.92% (Block 1) and 0.82% (Block 2). The marginal effect sizes are extremely low, indicating that the fixed effects and control variables were not effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates were 48.41% (Block 1) and 44.42% (Block 2). Adding the variance accounted for by participant and item random effects increased the variance accounted for, but over half of the observed variability remains unexplained by the model.

Discussion

In the present experiment, response accuracy was very high (97%), yet it was influenced by both noun dominance and grammatical number. Singular-dominant nouns had a 1% accuracy advantage over plural-dominant nouns. In addition, singular nouns had a 1% accuracy advantage over plural nouns. Meanwhile, response latency was influenced by grammatical number in Blocks 1 and 2. In both blocks, plural nouns had faster response latencies than singular nouns. Moreover, there was a significant Dominance × Number interaction in Block 2 only. Plural plural-dominant nouns were recognized significantly faster than singular plural-dominant nouns (8 ms advantage). Additionally, singular singular-dominant nouns were recognized faster than plural singular-dominant nouns (17 ms advantage), however this difference was not significant.

Our Block 1 findings align with previous research in only one way, the main effect of Dominance was not significant (Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Otherwise, our results contradict previous findings. First, the plural noun advantage observed in our experiment contradicts the results of Fieder and her colleagues (2017), who found that participants were faster at providing determiner-noun number agreement decisions for pictures depicting single exemplars than multiple exemplars. Moreover, it runs counter to noun dominance studies, which report that singular nouns are recognized or named faster than plural nouns or find no grammatical number effect at all (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Second, we failed to replicate the Dominance × Number interaction which has been observed in nearly all published noun dominance studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

Our Block 2 results indicate that Block 1 results persist when the same nouns are seen for a second time. The main effect of Number remained significant while the main effect of Dominance remained non-significant. Moreover, the Dominance × Number interaction became significant. The pattern observed in our experiment differs notably from that reported in published noun dominance studies which find a surface frequency effect for singular-dominant nouns only, not plural-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

In order to determine whether comparable results would be obtained in another language with the same grammatical number marking system, an equivalent determiner-noun number agreement experiment was carried out in English.

Experiment 2: English Number Agreement Task

Method

Participants. Participants were recruited from the same source using the same procedure as Experiment 1. A total of 55 students participated in this study. Two participants were removed from the sample due to their high error rate (> 10%). The final sample contains 53 participants (47 female) with a mean age of 19.3 years old (*SD* = 2.60). Thirty-two participants identified English as their native language while the remaining 21 participants fluently spoke English as a second language.

Stimuli. Ninety-two English nouns (46 singular-dominant and 46 plural-dominant) were selected from the *CELEX 2* database following the procedure described in Experiment 1 (see Table 1 for noun characteristics; see Appendix B for a complete list; Baayen, Piepenbrock, & Gulikers, 1995). The noun-verb ratio values ranged from 0.29 to 1 with a mean of 0.95 (SD = 0.14).

Equipment. Identical to Experiment 1.

Experimental design. Identical to Experiment 1 with the exception that 23 real nouns were presented in each experimental condition.

Procedure. Identical to Experiment 1 with two exceptions: 1) response options were translated into English (*This*/*These*), and 2) there were 184 experimental trials instead of 200.

Results

Data cleaning. The data cleaning procedure was identical to Experiment 1. Implementing this procedure resulted in the removal of 5.0% of the RT data, 2.5% due to inaccurate responses and 2.5% from outliers. Once again, an inverse transformation (-1/RT) was applied to the cleaned RT data to reduce positive skew.

Statistical analysis. Identical to Experiment 1.

Response accuracy results. Participants' overall accuracy rate was very high (M = 98%; SD = 2%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.06, SE = 0.15, z = 0.36, p = 0.716) and did not improve model fit (p = .717). All final model fixed effect correlations were weak, $r \leq |0.18|$. The final GLMM code is below; results are presented in Table D1.

```
EN.ACC.model <- glmer(ACC ~ DomRatioLog_gmc*Num_cc + (1+ DomRatioLog_gmc|
PartID) + (1 + Num_cc + Block_cc|NounID), data = EN_NAT_ACC, family =
binomial)
```

***Fixed effects and interaction*.** There was a trend toward a significant effect of Number. Response accuracy was 1% higher for singular nouns than plural nouns (98% vs. 97%). Neither the main effect of Dominance nor the Dominance × Number interaction reached significance ($p \geq .157$; see Table 3 for descriptive statistics).

***Effect size*.** The final model marginal effect size estimate was 0.01%. The fixed effects did not account for any of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 2.06%. Adding the variance accounted for by participant and item random effects did not help explain the observed variability.

Response latency results. There was a significant main effect of Block ($b = 66.72 \times 10^{-6}$, $SE = 7.66 \times 10^{-6}$, $t = 8.71$, $p < .001$), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to the research studies presented in the introduction. All final model fixed effect correlations were weak ($r \leq |0.20|$). The final cross-classified LME model code is below; results are presented in Tables 7 and 8.

```
EN.RT.B1.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + MLenLog_gmc + Trial +
Num_cc:MLenLog_gmc + (1|PartID) + (1 + Num_cc|NounID), data = EN_NAT_B1)
EN.RT.B2.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + MLenLog_gmc + Trial +
Num_cc:MLenLog_gmc + (1 + DomRatioLog_gmc |PartID) + (1 + Num_cc |NounID),
data = EN_NAT_B2)
```

Control variables. There was a significant main effect of mean noun length. In both blocks, response latencies increased as mean noun length increased. There was also a significant main effect of trial number in both blocks. In both blocks, response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number in Blocks 1 and 2. Response latencies were slower for singular nouns than plural nouns in both blocks (Block 1: 640 ms vs. 627 ms; Block 2: 612 ms vs. 601 ms). The main effect of Dominance was not significant in either block ($p \geq .267$).

Interactions. The interaction between Dominance and Number did not reach significance in Block 1 or Block 2 ($p \geq .250$; see Figure 1; see Table 6 for descriptive statistics). However, there was a significant Number × Length interaction in both blocks. This interaction was decomposed by creating two sub-datasets per block, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Dominance as a random slope for singular noun models only, Dominance as a fixed effect, and the two control variables included in the original models. There is a significant main effect of Length for singular nouns in both blocks (Block 1: $b = 427.80 \times 10^{-6}$, $SE = 56.63 \times 10^{-6}$, $t = 7.56$, $p < .001$; Block 2: $b = 339.20 \times 10^{-6}$, $SE = 61.68 \times 10^{-6}$, $t = 5.06$, $p < .001$), but not for plural nouns ($p \geq .535$; see Table D2 for complete results). Specifically, the longer singular nouns were, the slower they were recognized.

Effect size. The final model marginal effect size estimates were 1.17% (Block 1) and 0.88% (Block 2). The marginal effect sizes are extremely low, indicating that the fixed effects and control variables were not effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates were 53.04% (Block 1) and 46.38% (Block 2). Adding the variance accounted for by participant and item random effects increased the variance account for, but approximately half of the observed variability remains unexplained by the model.

Discussion

In the current experiment, response accuracy was very high (98%), yet there was a trend towards it being influenced by grammatical number. Singular nouns had a 1% accuracy advantage over plural nouns. Meanwhile, response latency was influenced by grammatical number in Blocks 1 and 2. In both blocks, plural nouns had faster response latencies than singular nouns. Neither the Dominance main effect nor the Dominance × Number interaction were significant in either block. Our Experiment 2 findings virtually replicate what was observed in Experiment 1, contradicting the majority of previously published research (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; Fieder et al., 2017; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

Given that the majority of our Experiment 1 and Experiment 2 results are not in line with what was predicted, a third experiment was designed to test whether our findings were an artifact of the reliability of the plural marker -*s*. This experiment was designed in English, where singular nouns can end in -*s* (e.g., *bonus*, *fortress*) and plural nouns can have alternative plural markers (e.g., *statra*, *cacti*). We hypothesized that integrating these types of nouns as foils among experimental items should reduce participants' reliance on the inflectional suffix -*s* as the main indicator of plural grammatical number.

Experiment 3: English Follow-Up Number Agreement Task

Method

Participants. Participants were recruited from the same source using the same procedure as Experiments 1 and 2. A total of 98 students (88 female) with a mean age of 18.7 years old (*SD* = 2.29) participated in this study. Ninety-two participants identified English as their native language while the six remaining participants fluently spoke English as a second language. A post-experimental questionnaire was completed by 84 participants, two of which did not answer all the questions. The final questionnaire dataset contains 82 participants (72 female) with a mean age of 18.8 years old (*SD* = 2.45).

Stimuli. Experimental items were identical to Experiment 2. In addition, 46 foils were introduced to reduce the reliability of the plural marker -*s*. Half of the foils were singular nouns ending in -*s* (e.g., *bonus*). The other half were plural nouns that do not end in the plural marker -*s* (e.g., *statra*, *cacti*; see Appendix B for a complete list, for noun characteristics see Table 1). The noun-verb ratio values for the foils ranged from 0.23 to 1 with a mean of 0.93 (SD = 0.17).

Equipment. Identical to Experiment 1.

Experimental design. For foil analyses, Dominance (singular-dominant vs. plural-dominant vs. equal-dominance) is treated as a categorical within-subjects variable[5] and Number (singular vs. plural) is treated as dichotomous within-items variables. For experimental item analyses, Dominance is treated as a continuous within-subjects variable while Number (singular vs. plural) is treated as dichotomous within-items variable.

Procedure. The procedure was identical to Experiment 2 with three exceptions. First, participants saw all foils once in their predetermined form. Accordingly, experimental items were presented only once, in either their singular or plural form. This was done to increase the salience of the foils due to their limited number. Therefore, there are no Block 2 analyses. Second, there were 230 experimental trials instead of 184. And third, a short post-experiment questionnaire was given to the participants after they completed the NAT. It contained a combination of open- and close-ended questions to assess response strategies and perceived performance.

Results

Data cleaning. The data cleaning procedure was identical to Experiment 1. Implementing this procedure resulted in the removal of 11.9% of the RT data, 10.4% due to inaccurate responses and 1.5% from outliers. Once again, an inverse transformation (-1/RT) was applied to the cleaned data to reduce positive skew.

Statistical analysis. Identical to Experiments 1 and 2 with two exceptions. First, foils were analyzed separately from experimental items to determine whether or not they were processed as expected. And second, plural foil accuracy was added as a control variable in the experimental item analyses.

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[5] For foil analyses, Dominance was treated as a categorical variable instead of a continuous variable because two items had an equal surface frequency in their singular and plural forms (i.e., were equal-dominance).

Foil analyses.

Response accuracy. Participants' overall accuracy rate was quite variable, yet relatively high (M = 72%; SD = 12%). All final model fixed effect correlations were moderate to weak, $r \leq |0.62|$. The final GLMM code is below; results are presented in Table 9.

```
EN.foil.ACC.model <- glmer(ACC ~ Dom_cc + Num_cc + Len_gmc (1|PartID) +
(1|NounID), data = EN_NAT2, family = binomial)
```

Control variable. There was a significant effect of noun length. Response accuracy decreased by 24% for each additional letter a noun contained.

Fixed effects. There was a significant main effect of Number. Response accuracy was 44% higher for singular nouns than plural nouns (94% vs. 50%). The main effect of Dominance was not significant (p = .980; see Table 3 for descriptive statistics).

Effect size. The final model marginal effect size estimate was 38.47%. The fixed effects and control variable account for a moderate amount of the observed variability in response accuracy. The final model conditional effect size estimate was 60.67%. Adding the variance accounted for by participant and item random effects increased the variance account for, but approximately one-third of the observed variability remains unexplained by the model.

Response latency. All final model fixed effect correlations were moderate to weak ($r \leq |0.66|$). The final cross-classified LME model code is below; results are presented in Table 10.

```
EN.foil.RT.model <- lmer(InvRT ~ Dom_cc + Num_cc + SFreqLog_gmc + Len_gmc +
NVRatio_gmc + Num_cc:Len_gmc + (1 + Dom_cc|PartID) + (1|NounID), data =
EN_NAT2)
```

Control variables. There was a significant main effect of noun written surface frequency. Response latencies for foils decreased as written surface frequency of occurrence increased. There was also a significant main effect of noun length. Response latencies increased as noun length increased. Finally, there was a significant main effect of noun-verb ratio. Response latencies increased as the noun-verb ratio increased.

Fixed effects. There was a significant main effect of Number. Response latencies were faster for singular nouns than plural nouns (937 ms vs. 1384 ms). The main effect of Dominance was not significant (p = .697; see Figure 2A; see Table 6 for descriptive statistics).

Interaction. There was a significant Number × Length interaction. This interaction was decomposed by creating two sub-datasets, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Dominance as a fixed effect, and the three control variables included in the original model. There is a significant main effect of Length for singular nouns ($b = 69.01 \times 10^{-6}$, $SE = 12.03 \times 10^{-6}$, $t = 5.74$, $p < .001$) and plural nouns ($b = 31.54 \times 10^{-6}$, $SE = 10.77 \times 10^{-6}$, $t = 2.93$, $p = .004$; see Table E1 for complete results). The slope differential shows that the length effect was 2.19 times larger for singular nouns than plural nouns.

Effect size. The final model marginal effect size estimate was 16.82%. The fixed effects and control variables account for a small amount for the observed variability in response latencies. The final model conditional effect size estimate was 52.46%. Adding the variance accounted for by participant and item random effects increased the variance account for, but approximately half of the observed variability remains unexplained by the model.

Experimental item analyses.

Response accuracy. Participants' overall accuracy rate was very high (M = 98%; SD = 2%). All final model fixed effect correlations were weak, $r \leq |0.22|$, with the exceptions of the correlations between the Intercept and Plural Foil Accuracy (r = -0.97) and between Number and the Number × Plural Foil Accuracy interaction (r = -0.99). Plural Foil Accuracy and its associated interaction were retained in the model despite these high correlations based on the strength of the effects. The final GLMM code is below; results are presented in Table 11.

```
EN.exp.ACC.model <- glmer(ACC ~ DomRatioLog_gmc*Num_cc + Pfoil_ACC +
Pfoil_ACC:Num_cc (1+ DomRatioLog_gmc|PartID) + (1|NounID), data =
EN_NAT2_ACC, family = binomial)
```

Control variable. There was a significant effect of plural foil accuracy. Response accuracy increased by 3% for every 1% increase in plural foil accuracy.

Fixed effects. There was a significant effect of Number. Response accuracy was 1% higher for singular nouns than plural nouns (99% vs. 98%). The main effect of Dominance was not significant (p = .381; see Table 3 for descriptive statistics).

Interactions. The Dominance × Number interaction was not significant (p = .506). However, there was a trend toward a significant Number × Plural Foil Accuracy interaction. This interaction was decomposed by creating two sub-datasets, one for singular nouns and one for plural nouns. A GLMM was run for each of these datasets. These models included: both random intercepts, Dominance as a random slope, Dominance as a fixed effect, and Plural Foil Accuracy as a control variable. There is a significant main effect of Plural Foil Accuracy for plural nouns (b = 0.04, SE = 0.01, z = 3.55, p < .001), but not for singular nouns (p = .228; see Table E2 for complete results). Response accuracy for plural experimental items increased as plural foil accuracy increased.

Effect size. The final model marginal effect size estimate was 1.51%. The fixed effects and control variable did not account for nearly any of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 3.59%. Adding the variance accounted for by participant and item random effects did not help explain the observed variability.

Response latency. All final model fixed effect correlations were moderately weak ($r \leq |0.34|$). The final cross-classified LME model code is below; results are presented in Table 12.

```
EN.exp.RT.model <- lmer(InvRT ~ DomRatioLog_gmc*Num_cc + BFreqLog_gmc +
MLenLog_gmc + Trial + Num_cc:MLenLog_gmc + (1 + DomRatioLog_gmc|PartID) +
(1|NounID), data = EN_NAT2_RT)
```

Control variables. There was a trend towards a significant main effect of noun written base frequency. Response latencies decreased as written frequency of occurrence increased. There was a significant main effect of mean noun length. Response latencies increased as mean noun length increased. In addition, there was a significant main effect of trial number. Response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number. Response latencies were considerably slower for singular nouns than plural nouns (774 ms vs. 709 ms). The main effect of Dominance was not significant (p = .772; see Figure 2B; see Table 6 for descriptive statistics).

Interactions. The Dominance × Number interaction was not significant (p = .503). There was, however, a significant Number × Length interaction. This interaction was decomposed by creating two sub-datasets, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Dominance as a random slope, Dominance as a fixed effect, and the three control variables included in the original model. There is a significant main effect of Length for singular nouns ($b = 345.50 \times 10^{-6}$, $SE = 59.08 \times 10^{-6}$, $t = 5.85$, $p < .001$), and plural nouns ($b = 92.47 \times 10^{-6}$, $SE = 41.35 \times 10^{-6}$, $t = 2.24$, $p = .025$; see Table E3 for complete results). The slope differential shows that the length effect was 3.74 times larger for singular nouns than plural nouns.

Effect size. The final model marginal effect size estimate was 2.06%. The fixed effects and control variables did not account for nearly any of the observed variability in response latencies. The final model conditional effect size estimate was 43.77%. Adding the variance accounted for by participant and item random effects increased the variance account for, but over half of the observed variability remains unexplained by the model.

Post-experimental questionnaire analyses. The post-experimental questionnaire was made up of a mixture of open- and closed-ended questions. The questionnaire responses provide insight into how 82 participants approached the NAT. Prior to analyses, results from the open-ended questions were qualitatively coded to identify self-report response strategies.

The majority of participants reported that they read the entire noun before making an agreement decision (n = 67). In spite of explicit instructions to read the entire noun prior to making a number agreement decision, some participants admitted to reading the entire noun only sometimes (n = 13) or never (n = 2). Most participants reported using a combination of two response strategies (n = 64) to complete the NAT, while a smaller number used a single strategy (n = 7) or three or more strategies (n = 11). The most prominent strategy used was to look at the ending of the noun being presented (n = 80). Of the 80 participants who used this strategy, 63 reported that their initial focus was on noun endings. Other strategies involved mentally or verbally sounding out nouns either alone (n = 22) or preceded by the response options *This* or *These* (n = 54). A small number of participants placed nouns in a sentence (n = 7) or identified their alternative form (n = 7). Interestingly, a handful of participants reported that they mentally altered the response options with alternatives such as *One/More than one* (n = 5), *Singular/ Plural* (n = 2), and *A/Many* or *Some* (n = 2).

Participants were explicitly asked which type of nouns they found easier to identify, singular, plural, or equally easy. On average, participants considered singular nouns the easiest and plural nouns the hardest (equally easy was in the middle; see Figure 3). This pattern appears to reflect overall response accuracy (collapsed across foils and experimental items), which indicates that determiner-noun number agreement was formed more accurately for singular nouns (97%) than plural nouns (74%). To evaluate whether participants' perceptions aligned with their response behaviour we calculated a response latency mean difference score for all items. Singular mean response latencies were subtracted from plural mean response latencies. Mean differences of -20 ms or lower were classified as singular easier, mean differences of 20 ms or higher were classified as plural easier, and mean differences ranging between ±19 ms were classified as equally easy. As can be seen in Figure 3, participants overestimated how easy it was to identify singular nouns and underestimated how easy it was to identify plural nouns. Self-reported perception and response behaviour for all items aligned for only 34 participants.

Discussion

In the current experiment, foil response accuracy was moderately high (72%). It was influenced by grammatical number only. Singular nouns had a 44% accuracy advantage over plural nouns. Surprisingly, participants' response accuracy was not impacted by an *-s* at the end of singular nouns, yet was significantly hindered by the absence of an *-s* at the end of plural nouns. Foil response latency was also influenced by grammatical number; singular nouns had a 442 ms speed advantage over plural nouns.

Our foil findings replicate previous research. In a previous study, determiner-noun number agreement was more accurate and faster for singular nouns than plural nouns (Fieder et al., 2017). Moreover, the singular noun advantage replicates what has been found in several noun dominance studies (Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). It is important to note that the effects observed in our experiment may be a consequence of the foils used. All singular foils were singular-dominant nouns. In contrast, plural foils were a mixture of plural-dominant (n = 12), singular-dominant (n = 9), and equal dominance (n = 2) nouns.

In the present experiment, response accuracy for experimental items was extremely high (98%) and impacted by grammatical number and plural foil accuracy. Singular nouns had a 1% accuracy advantage over plural nouns. Additionally, as plural foil accuracy increased so did experimental item response accuracy. Experimental item response latency was also impacted by grammatical number. However, plural nouns had a 65 ms speed advantage over singular nouns. Neither the main effect of Dominance nor the Dominance × Number interaction were significant. Post-task questionnaire responses revealed that participants used the reliability of the plural marker *-s* to develop efficient response strategies, despite the presence of foils (e.g., *bonu**s***, *cact**i***). Furthermore, participants reported that they found singular words easier to identify and plural words harder to identify than their response latency behaviour suggests.

Our experimental item findings align with what was observed in Experiments 1 and 2 despite the inclusion of noun foils. Our results primarily contradict previously published noun dominance research. Several researchers found that in lexical decision experiments, singular nouns were recognized faster than plural nouns as well as a surface frequency effect for singular-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; Fieder et al., 2017; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

General Discussion

The current experiments examined how determiner-noun number agreement is formed in French and English. In all response accuracy and response latency models, a series of control variables were tested in order to determine whether they modified our fixed effects of interest.

These variables were written base frequency, mean noun length, noun-verb ratio, trial number, noun gender (in French only), participant native language, and plural foil response accuracy (Experiment 3 only). Six of these control variables influenced response accuracy and/or latency: Frequency, Length, Noun-verb ratio, Trial number, Gender, and Plural foil accuracy. However, none of these variables modified or nullified the fixed effects of interest discussed below.

In all three experiments, singular nouns had a 1% response accuracy advantage over plural nouns. This finding aligns with what was observed by Fieder and her colleagues (2017). They reported that participants were 3% to 5% faster at providing a determiner decision for pictures containing single exemplars than multiple (i.e., plural) exemplars of singular-dominant nouns. This implies that forming determiner-noun number agreement is easier with singular nouns than plural nouns, regardless of their noun dominance characteristics.

Yet counter to this implication, in all three of our experiments we found a significant main effect of Number such that determiner-noun number agreement was faster for plural nouns than singular nouns (2 – 65 ms advantage). This result indicates that, under the present conditions, determiner-noun number agreement was in fact easier to achieve with plural nouns. Our observed plural noun advantage does not align with previous research. Specifically, Fieder et al. (2017) found that participants were 15 to 75 ms faster at making determiner decisions for pictures depicting singular exemplars of singular-dominant nouns than pictures depicting multiple exemplars of singular-dominant nouns. However, they presented participants with coloured pictures, not written words. In the noun dominance literature, researchers reported finding that singular nouns were recognized or named faster than plural nouns or found no grammatical number effect at all using lexical decision tasks (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997).

One potential explanation for the plural speed advantage observed in all three of our experiments is that the plural response options (*Ces* and *These*) could have a higher written frequency of occurrence than the singular response options (*Ce*/*Cette* and *This*), facilitating plural responses. According to *Lexique 3*, *Ce* and *Cette* have written frequencies of 2436.55 and 2320.68 respectively, while *Ces* has a written frequency of 1547.50 (New et al., 2007; New, Pallier, et al., 2004). The 831 average discrepancy favours the singular response options. Likewise, according to *CELEX 2*, *This* has a written frequency of 4548 while *These* has a written frequency of 1235 (Baayen et al., 1995). The 3313 discrepancy favours the singular response option. Therefore, response option frequency does not explain the plural noun advantage. Moreover, participants did not favour one response option over the other during the NAT. In all three experiments, participants selected response options equally for experimental items (*This*: 50% – 51%, *These*: 49% – 50%). Introducing foils resulted in a slight shift toward favouring the singular response option *This* (57%) over the plural response option *These* (43%).

A more plausible explanation for the plural noun advantage is the reliability of the plural marker -*s* as an indicator of plural grammatical number. We speculated that having a perfect predictor (i.e., the plural marker -*s*) in Experiments 1 and 2 encouraged participants to develop response strategies based on this salient noun feature. Experiment 3 was conducted to test this hypothesis. Singular and plural foils were added to the Experiment 2 experimental noun list to reduce the reliability of the plural marker -*s* and a post-experimental questionnaire was introduced to measure participant response strategies. Questionnaire responses revealed that nearly all participants were implementing a noun ending response strategy (98%) despite the inclusion of foils. Over three-quarters (77%) reported that they looked at noun endings prior to reading the word. This aligns with our speculations and highlights the saliency of plural marker predictability. That being said, incorporating singular and plural foils did decrease overall response latency speed. It took participants 108 ms longer to provide a number agreement decision for regular nouns in Experiment 3 than in Experiment 2. Unexpectedly however, the strength of the Number effect increased. In Experiment 2, plural nouns had a 13 ms advantage over singular nouns in Block 1 (627 ms vs. 640 ms). In Experiment 3, this plural advantage jumped to 65 ms (709 ms vs. 774 ms). This suggests that including singular and plural foils increased the demands of the task, yet somehow also increased the saliency of *-s* as a plural marker. The later half of this statement is surprising. Without further research, it is difficult to determine the reason for this increased saliency.

In all three of our experiments, the main effect of Dominance was non-significant. This suggests that Dominance does not impact determiner-noun number agreement speed. In their experiments, Fieder et al. (2017) presented participants with pictures and only tested singular-dominant nouns so we cannot directly compare our results to theirs. Yet, our observed null Dominance effect does replicate what has been found in Dutch, English, French, and German noun dominance experiments (Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Alternatively, in a few studies a significant effect of Dominance has been found where plural-dominant nouns had a speed advantage over singular-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Domínguez et al., 1999; Reifegerste et al., 2017).

The only significant Dominance × Number interaction observed in our experiments was found in Experiment 1. In Block 2, there was a significant surface frequency effect for French plural-dominant nouns; response latencies were 8 ms faster for plural plural-dominant nouns than singular plural-dominant nouns. This pattern is in opposition with nearly all noun dominance studies which find a surface frequency advantage for singular-dominant nouns only, not plural-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). One potential explanation for why we observed a surface frequency effect for French plural-dominant nouns, but not French singular-dominant nouns is the regularity of the plural marker *-s*. Participants likely used this cue to determine plural agreement, thus shifting from a singular as default stratefy to a plural as default. This shift may have increased the strength of the surface effect for French plural-dominant nouns.

Finally, our most thought provoking finding is that in Experiment 3 participants were highly capable at forming determiner-noun number agreement correctly for singular foils (accuracy: 94%,) yet they performed at chance when making number agreement decisions for plural foils (accuracy: 50%). This discrepancy in response accuracy was not anticipated. To date, no research has been published on how readers process irregular English nouns. Therefore, it is only possible to speculate as to why plural foils were so much more difficult to process than singular foils. We offer two potential explanations. First, although written surface and base frequency information was balanced as closely as possible during foil selection, the median surface and base frequency values for singular foils are much higher than those for plural foils (median surface frequency: 42 vs. 4; median base frequency: 50 vs. 11). This may explain the accuracy and speed advantages seen for singular foils over plural foils. Second, all singular foils were singular-dominant nouns. In comparison, plural foils were a mixture of singular-dominant, plural-dominant, and equal-dominance nouns. Based on the surface frequency effect found in previous noun dominance studies, singular foils should have a speed advantage because they are singular-dominant (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Baayen et al., 2007; Beyersmann et al., 2015; Biedermann et al., 2013; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). This is exactly what was observed. Singular foils had a 442 ms advantage over plural foils (937 ms vs. 1379 ms). It is likely a combination of these two explanations culminated to produce the notable discrepancies in how singular and plural foils were processed by participants during the determiner-noun NAT.

Limitations and Future Directions

The main limitation in the experiments presented in this paper is that there is only one highly regular plural marker in both languages, the inflectional suffix *-s*. Consequently, it acts as a facilitating feature that prompts participants to adopt an ending based response strategy. When an attempt was made to reduce the reliability of the plural marker *-s* in English, the disparity in response latencies for regular singular and plural nouns grew larger instead of smaller. In order to counteract this limitation, it would be beneficial to conduct determiner-noun number agreement decision studies in languages with multiple plural markers such as Dutch or German in order to determine whether the results presented in this paper are language specific.

Additionally, future studies may benefit from incorporating an eye-tracking element to collect objective evidence to supplement self-report response strategy measures. Several researchers have devised eye-tracking methods that encourage participants to produce fixation movements when reading a single word (Calvo & Nummenmaa, 2009; Colé, Pynte, & Andriamamonjy, 2003; Liu & Li, 2013; Paterson, Jordan, & Kurtev, 2009; Vergilino-Perez et al., 2012). One or more of these techniques could be incorporated into the determiner-noun NAT paradigm.

Finally, manipulating the ratio of regular experimental items to noun foils in future experiments would provide a way to test the robustness of the plural noun speed advantage and identify at what point (if any) response strategies change. In Experiment 3, we adopted a 2:1 ratio based on the limits of the language (92 experimental items to 46 foils). Although foil selection is limited by language constraints, it may be possible to adjust this ratio in languages other than English with more plural noun exceptions.

Conclusion

In conclusion, the present experiments demonstrate that determiner-noun number agreement response accuracy is higher for singular nouns while agreement response latency is faster for plural nouns when forming number agreement decisions. Adding singular and plural foils only increased the strength of the response latency Number effect. This effect was robust in all experiments, remaining statistically significant in Block 2 analyses. Noun dominance had no impact on determiner-noun number agreement in any of our experiments. Finally, the Dominance × Number interaction was only significant in French in Block 2. A surface frequency effect was observed for plural-dominant nouns, but not singular-dominant nouns. Post-experimental questionnaire results indicate that participants developed a response strategy focused primarily on noun endings to help them make number agreement decisions. The application of this strategy prevailed even when foils were encountered.

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Table 1

English and French Noun Characteristic Means

	French		English			
	Singular-dominant nouns (n = 50)	Plural-dominant nouns (n = 50)	Singular-dominant nouns (n = 46)	Plural-dominant nouns (n = 46)	Singular foils (n = 23)	Plural foils (n = 23)
Noun length	6.14	6.20	6.24	6.28	5.78	6.43
Number of phonemes	4.52	4.44	5.09	5.15	4.91	5.70
Number of syllables	1.58	1.62	1.93	1.96	1.70	2.39
Number of masculine nouns	22	25				
Singular surface frequency	61.92	22.22	74.76	35.96	67.30	
Plural surface frequency	20.12	62.84	30.48	79.89		66.87
Base frequency	82.08	89.82	105.20	115.87	77.70	110.74
Noun dominance score	41.81	-41.51	44.28	-43.93	57.04	-22.83
Noun dominance ratio	13.57	0.29	3.85	0.43	11.00	1.84

Note. Means for noun length, number of phonemes, and number of syllables are based on the singular form of the nouns.

Table 2

Experiment 1 French: Response Accuracy Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	0.01	0.11	
PartID	(Intercept)	0.33	0.57	
	Dominance	0.01	0.10	0.71
		Number of observations: 11400; Groups: NounID, 100; PartID, 56		

Fixed effects			
	b	*SE*	*z*
(Intercept)	3.64	0.10	35.25^{***}
Fixed effects			
Dominance	0.18	0.09	2.06^{*}
Number	-0.40	0.11	-3.64^{***}
Interaction			
Dominance × Number	-0.09	0.14	-0.63

* $p < .05$. *** $p < .001$.

Table 3

Response Accuracy Descriptive Statistics

Number	Singular-dominant nouns		Plural-dominant nouns		Equal-dominance nouns	
	M	*SD*	*M*	*SD*	*M*	*SD*
French						
Singular	97.61%	2.33%	97.36%	3.08%		
Plural	96.93%	3.26%	95.79%	3.87%		
English						
Singular	98.32%	1.98%	97.46%	3.40%		
Plural	97.33%	3.24%	96.92%	3.68%		
English Follow-up						
Foils						
Singular	94.37%	7.01%				
Plural	48.53%	27.79%	50.77%	22.26%	50.51%	36.96%
Experimental items						
Singular	98.80%	2.56%	98.76%	2.57%		
Plural	98.09%	3.54%	97.56%	4.10%		

Table 4

Experiment 1 French: Response Latency Random Effect Results

		Block 1			Block 2	
Group	Name	Variance	*SD*	*r*	Variance	*SD*
NounID	(Intercept)	6.23^{-10}	2.50^{-5}		9.67^{-10}	3.11^{-5}
PartID	(Intercept)	1258^{-10}	35.47^{-5}		1132^{-10}	33.64^{-5}
	Dominance	11.62^{-10}	3.41^{-5}	0.33		
Residual		1381^{-10}	37.16^{-5}		1455^{-10}	38.14^{-5}
		Number of observations: 5387			Number of observations: 5391	
		Groups: NounID, 100; PartID, 56			Groups: NounID, 100; PartID, 56	

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 5

Experiment 1 French: Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1882^{-6}	48.57^{-6}	-38.74^{***}			-1842^{-6}	46.28^{-6}	-39.80^{***}		
Control variables										
Frequency	-32.44^{-6}	19.37^{-6}	-1.67^{T}	-69.46^{-6}	4.54^{-6}	-63.28^{-6}	20.74^{-6}	-3.05^{**}	-102.81^{-6}	-23.70^{-6}
Gender	-24.38^{-6}	11.96^{-6}	-2.04^{*}	-47.22^{-6}	-1.54^{-6}	7.52^{-6}	12.82^{-6}	0.59	-16.93^{-6}	31.97^{-6}
Length	91.73^{-6}	18.30^{-6}	5.01^{***}	56.78^{-6}	126.69^{-6}	9.02^{-6}	19.59^{-6}	0.46	-28.33^{-6}	46.42^{-6}
N-V ratio	89.12^{-6}	43.80^{-6}	2.03^{*}	5.52^{-6}	172.82^{-6}	5.85^{-6}	47.29^{-6}	0.12	-27.64^{-6}	46.39^{-6}
Trial	0.43^{-6}	0.18^{-6}	2.43^{*}	0.08^{-6}	0.77^{-6}	-0.81^{-6}	0.18^{-6}	-4.47^{***}	-1.16^{-6}	-0.45^{-6}
Fixed effects										
Dominance	-7.77^{-6}	9.34^{-6}	-0.83	-25.76^{-6}	10.23^{-6}	-12.28^{-6}	8.70^{-6}	-1.41	-28.86^{-6}	4.30^{-6}
Number	-25.69^{-6}	10.14^{-6}	-2.53^{*}	-45.53^{-6}	-5.78^{-6}	-35.64^{-6}	10.40^{-6}	-3.43^{***}	-56.01^{-6}	-15.26^{-6}
Interactions										
Dominance × Number	4.40^{-6}	13.12^{-6}	0.34	-21.32^{-6}	30.10^{-6}	36.10^{-6}	13.39^{-6}	2.69^{**}	9.81^{-6}	62.31^{-6}
Dominance × Frequency	-69.33^{-6}	28.26^{-6}	-2.45^{*}	-123.29^{-6}	-15.33^{-6}	12.58^{-6}	30.10^{-6}	0.42	-44.84^{-6}	69.99^{-6}

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
Dominance × Length	-59.40^{-6}	24.54^{-6}	-2.42^{*}	-106.30^{-6}	-12.54^{-6}	-35.06^{-6}	26.25^{-6}	-1.34	-85.16^{-6}	15.00^{-6}
Number × Length	-104.10^{-6}	31.72^{-6}	-3.28^{**}	-166.04^{-6}	-41.71^{-6}	-145.80^{-6}	32.39^{-6}	-4.50^{***}	-209.02^{-6}	-82.06^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Gender = noun gender; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

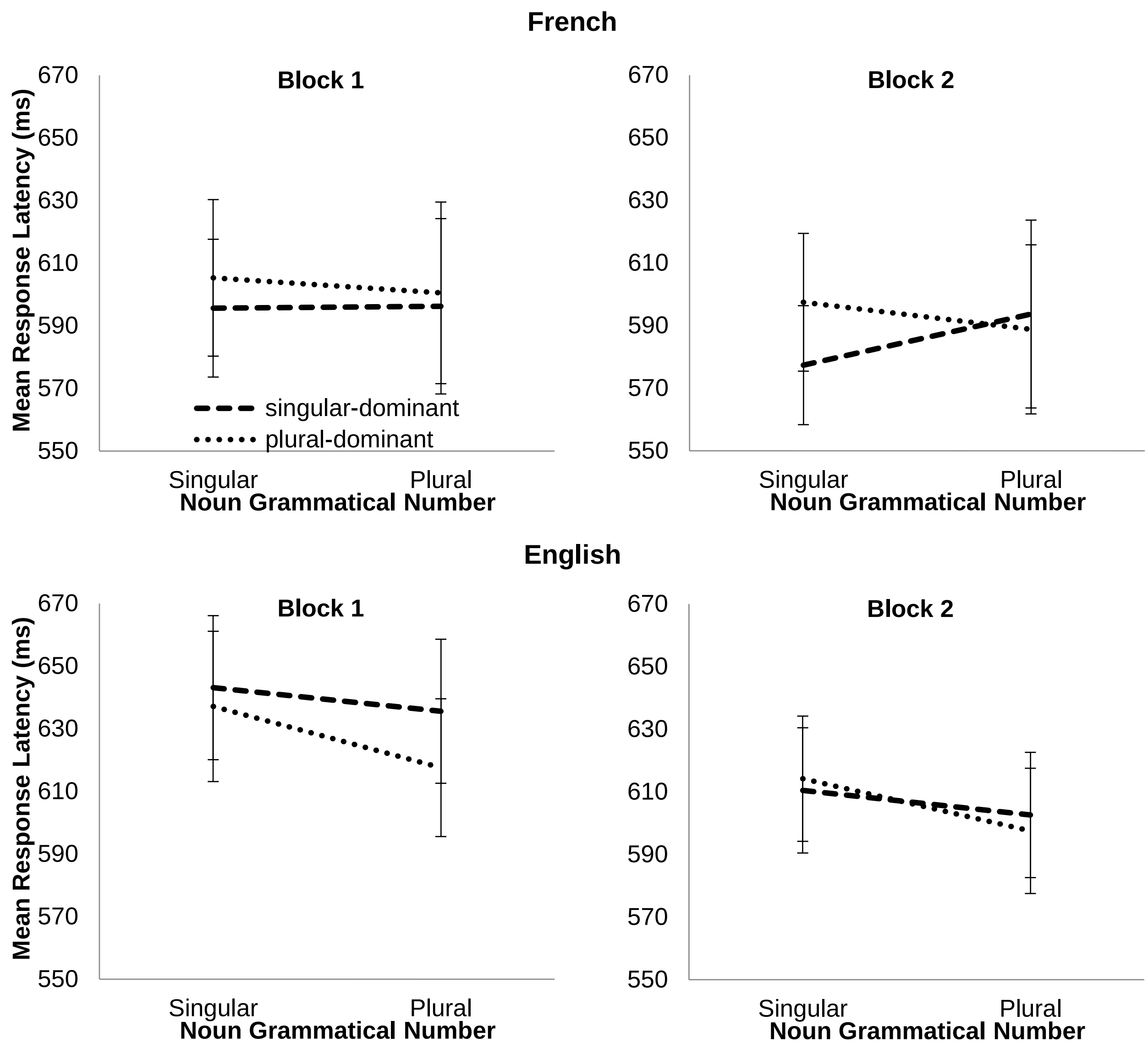

Figure 1. French (Experiment 1) and English (Experiment 2) mean response latencies as a function of language, block number, grammatical number, and noun dominance category. Error bars represent standard error of the means.

Table 6

Response Latency Descriptive Statistics

	Block 1						Block 2			
	Singular-dominant nouns		Plural-dominant nouns		Equal-dominance nouns		Singular-dominant nouns		Plural-dominant nouns	
Number	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
French										
Singular	596	167	605	187			577	142	597	166
Plural	596	209	601	213			594	228	589	203
English										
Singular	643	169	637	173			610	146	614	148
Plural	636	170	618	159			603	146	598	144
English Follow-up										
Foils										
Singular	937	327								
Plural	1547	810	1356	591	1248	895				
Experimental items										
Singular	777	226	771	198						

Plural	710	186	707	172

Table 7

Experiment 2 English: Response Latency Random Effect Results

		Block 1			Block 2		
Group	Name	Variance	*SD*	*r*	Variance	*SD*	*r*
NounID	(Intercept)	28.53^{-10}	5.34^{-5}		15.70^{-10}	3.96^{-5}	
	Number	2.50^{-10}	1.58^{-5}	0.00	38.84^{-10}	6.23^{-5}	-0.48
PartID	(Intercept)	1320^{-10}	36.33^{-5}		1137^{-10}	33.73^{-5}	
	Dominance				5.12^{-10}	2.26^{-5}	-0.38
Residual		1222^{-10}	34.95^{-5}		1372^{-10}	37.04^{-5}	
		Number of observations: 4623			Number of observations: 4638		
		Groups: NounID, 92; PartID, 53			Groups: NounID, 92; PartID, 53		

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 8

Experiment 2 English: Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1714^{-6}	51.29^{-6}	-33.42***			-1773^{-6}	47.80^{-6}	-37.09***		
Control variables										
Length	219.20^{-6}	46.80^{-6}	4.68***	127.46^{-6}	310.77^{-6}	146.20^{-6}	42.25^{-6}	3.46***	63.41^{-6}	228.94^{-6}
Trial	-0.63^{-6}	0.20^{-6}	-3.26**	-1.02^{-6}	-0.25^{-6}	-0.80^{-6}	0.21^{-6}	-3.86***	-1.20^{-6}	-0.39^{-6}
Fixed effects										
Dominance	16.27^{-6}	14.68^{-6}	1.11	-12.46^{-6}	45.04^{-6}	7.07^{-6}	13.61^{-6}	0.52	-19.64^{-6}	33.82^{-6}
Number	-27.80^{-6}	10.42^{-6}	-2.67**	-48.10^{-6}	-7.48^{-6}	-36.91^{-6}	12.68^{-6}	-2.91**	-61.61^{-6}	-12.22^{-6}
Interactions										
Dominance × Number	0.82^{-6}	20.24^{-6}	0.04	-38.63^{-6}	40.25^{-6}	28.19^{-6}	24.61^{-6}	1.15	-19.75^{-6}	76.11^{-6}
Number × Length	-429.10^{-6}	64.57^{-6}	-6.65***	-554.93^{-6}	-303.33^{-6}	-367.10^{-6}	78.69^{-6}	-4.67***	-520.21^{-6}	-213.62^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Length = mean noun length; Trial = trial number.

** $p < .01$. *** $p < .001$.

Table 9

Experiment 3 English Follow-up: Foil Response Accuracy Results

Random effects				
Group	Name	Variance		*SD*
NounID	(Intercept)	0.82		0.91
PartID	(Intercept)	1.03		1.02
			Number of observations: 4508; Groups: NounID, 46; PartID, 98	
Fixed effects				
	b		*SE*	*z*
(Intercept)	1.75		0.20	8.68^{***}
Control variables				
Length	-0.24		0.09	-2.71^{**}
Fixed effects				
Dominance	-0.01		0.42	-0.03
Number	-3.34		0.38	-8.72^{***}

Note. Length = noun length. Dominance is treated as a categorical variable.

** $p < .01$. *** $p < .001$.

Table 10

Experiment 3 English Follow-up: Foil Response Latency Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	46.89^{-10}	6.85^{-5}	
PartID	(Intercept)	655.80^{-10}	25.61^{-5}	
	Dominance	129.90^{-10}	11.40^{-5}	-0.09
Residual		1001^{-10}	31.64^{-5}	
		Number of observations: 3227; Groups: NounID, 46; PartID, 98		

Fixed effects					
				95% *CI*	
	b	*SE*	*t*	Lower	Upper
(Intercept)	-1075^{-6}	29.99^{-6}	-35.86^{***}		
Control variables					
Frequency	-114.00^{-6}	21.41^{-6}	-5.33^{***}	-154.01^{-6}	-74.11^{-6}
Length	50.35^{-6}	7.67^{-6}	6.56^{***}	36.05^{-6}	64.62^{-6}
N-V ratio	222.10^{-6}	73.54^{-6}	3.02^{**}	85.28^{-6}	358.59^{-6}
Fixed effects					
Dominance	16.56^{-6}	42.07^{-6}	0.39	-62.61^{-6}	95.61^{-6}
Number	168.00^{-6}	43.19^{-6}	3.89^{***}	86.93^{-6}	248.27^{-6}
Interaction					
Number × Length	-37.16^{-6}	15.25^{-6}	-2.44^{*}	-65.60^{-6}	-8.81^{-6}

Note. $^{-5}$, $^{-6}$, and $^{-10}$ are shorthand for $\times 10^{-5}$ $\times 10^{-6}$, and $\times 10^{-10}$ scientific notations. CI = confidence interval; Frequency = noun written surface frequency; Length = noun length; N-V ratio = noun-verb ratio. Dominance is treated as a categorical variable.

$^{*} p < .05$. $^{**} p < .01$. $^{***} p < .001$.

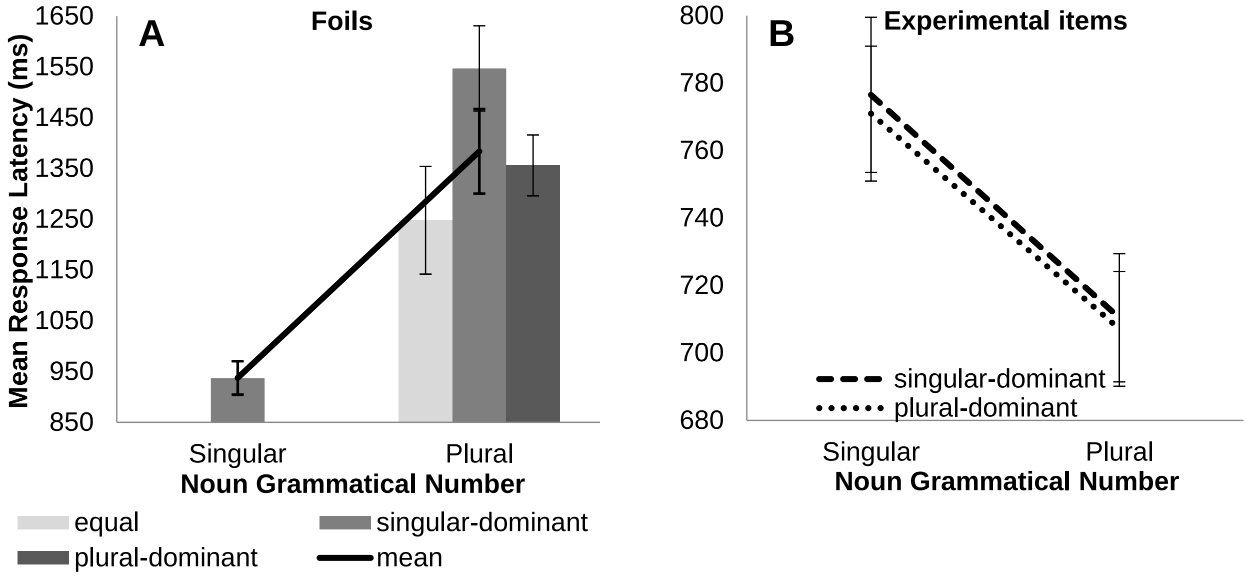

Figure 2. English follow-up mean response latencies as a function of grammatical number and noun dominance category. Error bars represent standard error of the means.

Table 11

Experiment 3 English Follow-up: Experimental Item Response Accuracy Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	0.40	0.63	
PartID	(Intercept)	0.38	0.61	
	Dominance	0.57	0.75	0.13
		Number of observations: 9016; Groups: NounID, 92; PartID, 98		

Fixed effects			
	b	*SE*	*z*
(Intercept)	2.58	0.66	3.93^{***}
Control variable			
Filler accuracy	0.03	0.01	3.07^{**}
Fixed effects			
Dominance	0.24	0.27	0.88
Number	-2.50	1.01	-2.47^{*}
Interactions			
Dominance × Number	0.21	0.32	0.67
Number × Plural foil accuracy	0.03	0.01	1.92^{T}

Note. Plural foil accuracy = plural foil accuracy rate.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 12

Experiment 3 English Follow-up: Experimental Item Response Latency Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	27.77^{-10}	5.27^{-5}	
PartID	(Intercept)	778.80^{-10}	27.91^{-5}	
	Dominance	3.24^{-10}	1.80^{-5}	-0.32
Residual		1089^{-10}	33.00^{-5}	
		Number of observations: 8680; Groups: NounID, 92; PartID, 98		

Fixed effects					
				95% *CI*	
	b	*SE*	*t*	Lower	Upper
(Intercept)	-1483^{-6}	29.59^{-6}	-50.13^{***}		
Control variables					
Frequency	-37.47^{-6}	19.82^{-6}	-1.89^{T}	-76.08^{-6}	1.13^{-6}
Length	216.50^{-6}	42.84^{-6}	5.05^{***}	133.11^{-6}	299.98^{-6}
Trial	-0.34^{-6}	0.09^{-6}	-3.84^{***}	-0.52^{-6}	-0.17^{-6}
Fixed effects					
Dominance	-2.27^{-6}	12.78^{-6}	-0.18	-27.17^{-6}	22.64^{-6}
Number	-80.00^{-6}	7.09^{-6}	-11.29^{***}	-93.89^{-6}	-66.11^{-6}
Interactions					
Dominance × Number	9.19^{-6}	13.72^{-6}	0.67	-17.70^{-6}	36.08^{-6}
Number × Length	-277.10^{-6}	43.87^{-6}	-6.32^{***}	-363.00^{-6}	-191.06^{-6}

Note. $^{-5}$, $^{-6}$, and $^{-10}$ are shorthand for $\times 10^{-5}$ $\times 10^{-6}$, and $\times 10^{-10}$ scientific notations. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. *** $p < .001$.

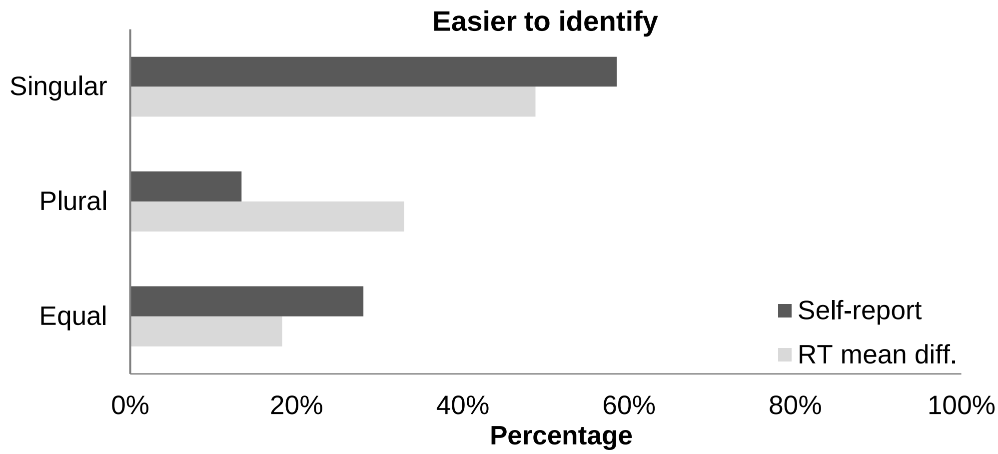

Figure 3. Percentages for whether participants found it easier to identify singular or plural nouns or whether they were equally easy based on mean response latency mean differences and self-report post-experimental questionnaire responses for the English follow-up experiment.

Appendix A

French Experimental Stimuli [Gender] (Dominance Score)

Singular-dominant nouns: bassin [m] (17.23), bière* [f] (32.57), bloc [m] (17.84), boîte* [f] (52.59), bouquet [m] (14.93), carré [m] (17.91), cave [f] (27.83), cercle[v] [m] (30.61), charge[v] [f] (30.88), collège [m] (23.18), comptoir* [m] (37.50), couverture [f] (20), crise [f] (26.21), défaite[v] [f] (17.10), don [m] (20.68), faiblesse* [f] (19.06), fauteuil* [m] (51.35), fenêtre [f] (118.58), figure[v] [f] (60.13), force[v] [f] (92.03), fric [m] (26.28), grange [f] (35.47), grille[v] [f] (29.46), journée [f] (102.09), lenteur [f] (21.42), masque[v] [m] (18.25), moteur [m] (31.48), neige[v] [f] (68.98), nuque [f] (46.08), paire [f] (20.94), papier [m] (86.08), pierre [f] (48.92), plafond* [m] (42.36), plancher [m] (27.63), poing [m] (19.86), promenade [f] (26.75), rapport [m] (43.51), réponse [f] (67.50), réussite* [f] (15.61), rive[v] [f] (24.13), rivière [f] (29.26), salle* [f] (179.46), semaine [f] (26.28), sentier [m] (20.27), soin [m] (22.57), solution [f] (30.27), source* [f] (21.63), sucre[v] [m] (28.31), verre* [m] (120.34), voyage[v] [m] (81.01)

Plural-dominant nouns: botte [f] (35.27), branche[v] [f] (37.37), camarade [m] (21.29), centaine [f] (20.74), centimètre [m] (15.94), chaussure [f] (38.92), circonstance [f] (26.22), cuisse [f] (27.29), dent [f] (103.38), doigt [m] (95.47), fesse[v] [f] (32.30), feuille [f] (45.34), fleur [f] (78.45), fruit [m] (20.13), gant [m] (20.07), joue[v] [f] (29.06), kilomètre [m] (49.67), larme [f] (111.89), légume [m] (19.26), lèvre [f] (180.54), limite[v] [f] (21.89), lunette [f] (60.41), membre [m] (34.46), mètre[v] [m] (86.42), meuble[v] [m] (30.47), millier [m] (37.71), million [m] (38.38), minute[v] [f] (79.94), mot [m] (32.84), muscle[v] [m] (26.69), narine [f] (15.54), nerf [m] (22.63), nouvelle [f] (29.32), nuage [m] (23.85), patte [f] (42.57), paupière [f] (49.39), prisonnier [m] (26.42), rein [m] (30.54), relation [f] (31.96), reprise[v] [f] (19.66), ride[v] [f] (17.23), sein [m]

(19.59), son [m] (18.51), soulier [m] (26.08), sourcil [m] (30.34), talon [m] (24.53), trait[v] [m] (21.48), vacance [f] (80.81), vêtement [m] (59.46), volet [m] (27.77)

Note. [v] Items that have a verb equivalent in French.

Appendix B

English Experimental Stimuli (Dominance Score)

Singular-dominant nouns: application (19), area (53), balance[v] (76), bell (12), benefit[v] (15), bicycle[v] (14), boat[v] (34), chance[v] (110), club[v] (59), condition[v] (29), design[v] (55), example (186), exception (14), expenditure (23), expression (67), field[v] (62), gun (30), habit (16), hat* (40), image (44), incident (16), job (149), journal* (12), mortgage (13), moustache* (14), operation (15), pattern (27), perspective (19), plant[v] (18), programme[v] (54), record[v] (25), region (14), school[v] (258), second (12), share[v] (14), ship[v] (17), snow[v] (55), stick[v] (13), sum* (15), survey[v] (22), talent* (13), threat (48), value (56), view[v] (152), vitamin (16), wheel[v] (12)

Plural-dominant nouns: affair (16), bean (14), bone (17), boot (22), characteristic (13), chemical (19), circumstance (73), consequence (14), dollar* (40), egg (12), event (19), eye[v] (289), finger[v] (28), flower[v] (44), hour (60), implication (16), institution (33), instruction (13), kilometre (23), knee (25), leg (52), lip* (48), mile (105), minute (143), month (142), muscle (27), pound[v] (179), regulation (16), requirement (19), resource (66), rule[v] (15), shoe*[v] (54), sock*[v] (13), standard (32), statistic* (12), symptom* (13), tear[v] (55), technique (12), toe[v] (12), ton (13), tool* (15), tree (49), vegetable (14), weapon* (58), word (51), yard (16)

Singular foil nouns: address[v], analysis, basis, boss[v], bus[v], business, canvas[v], circus, class[v], crisis, cross[v], dress[v], emphasis, genius, glass, grass, illness, loss, mess[v], process[v], stress[v], thesis, witness[v]

Plural foil nouns: algae, alumni, antennae, children, criteria, curricula, data, dice[v], feet, formulae, fungi, geese, larvae, mice, millennia, nuclei, oxen, phenomena, referenda, stimuli, strata, vertebrae, women

Note. [v] Items that have a verb equivalent in English.

Appendix C

Table C1

Experiment 1 French: Response Latency Block 2 Dominance × Number Interaction Fixed Effect Results

	Singular-dominant nouns			Plural-dominant nouns		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1853^{-6}	47.50^{-6}	-39.01^{***}	-1830^{-6}	47.95^{-6}	-38.16^{***}
Control variables						
Frequency	-37.97^{-6}	28.84^{-6}	-1.32	-85.42^{-6}	30.57^{-6}	-2.79^{**}
Gender	12.18^{-6}	18.65^{-6}	0.65	2.55^{-6}	18.32^{-6}	0.14
Length	19.41^{-6}	31.90^{-6}	0.61	5.56^{-6}	25.75^{-6}	0.22
N-V ratio	25.54^{-6}	60.86^{-6}	0.42	-13.24^{-6}	79.97^{-6}	-0.17
Trial	-0.75^{-6}	0.25^{-6}	-2.97^{**}	-0.87^{-6}	0.26^{-6}	-3.33^{***}
Fixed effect						
Number	-6.75^{-6}	14.44^{-6}	-0.47	-65.39^{-6}	15.54^{-6}	-4.21^{***}
Interaction						
Number × Length	115.30^{-6}	51.41^{-6}	-2.24^{*}	-17.62^{-6}	43.50^{-6}	-4.05^{***}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written base frequency; Gender = noun gender; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table C2

Experiment 1 French: Response Latency Number × Length Interaction Fixed Effect Results

	Block 1						Block 2					
	Singular nouns			Plural nouns			Singular nouns			Plural nouns		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1876^{-6}	49.18^{-6}	-38.14^{***}	-1885^{-6}	51.08^{-6}	-36.91^{***}	-1804^{-6}	45.13^{-6}	-39.96^{***}	-1874^{-6}	50.75^{-6}	-36.93^{***}
Control variables												
Frequency	-46.59^{-6}	28.44^{-6}	-1.64	-20.02^{-6}	26.54^{-6}	-0.75	-76.36^{-6}	26.25^{-6}	-2.91^{**}	-50.38^{-6}	27.67^{-6}	-1.82^{T}
Gender	-18.94^{-6}	17.95^{-6}	-1.06	-18.53^{-6}	16.64^{-6}	-1.11	19.20^{-6}	16.53^{-6}	1.16	-5.77^{-6}	17.42^{-6}	-0.33
Length	144.60^{-6}	27.01^{-6}	5.35^{***}	42.60^{-6}	24.97^{-6}	1.71^{T}	73.05^{-6}	24.80^{-6}	2.95^{**}	-55.48^{-6}	26.15^{-6}	-2.12^{*}
N-V ratio	65.98^{-6}	64.92^{-6}	1.02	111.10^{-6}	59.32^{-6}	1.87^{T}	74.49^{-6}	59.93^{-6}	1.24	-68.48^{-6}	63.13^{-6}	-1.08
Trial	0.59^{-6}	0.25^{-6}	2.36^{*}	0.23^{-6}	0.25^{-6}	0.92	-1.22^{-6}	0.25^{-6}	-4.96^{***}	-0.49^{-6}	0.26^{-6}	-1.87^{T}
Fixed effect												
Dominance	-10.55^{-6}	14.28^{-6}	-0.74	-3.69^{-6}	11.34^{-6}	-0.33	-34.95^{-6}	11.01^{-6}	-3.17^{**}	9.45^{-6}	11.59^{-6}	0.82
Interactions												
Dominance × Frequency	-61.35^{-6}	41.86^{-6}	-1.47	-58.05^{-6}	38.67^{-6}	-1.50	-17.86^{-6}	38.21^{-6}	-0.47	41.87^{-6}	40.37^{-6}	1.04
Dominance × Length	-57.73^{-6}	36.52^{-6}	-1.58	-50.02^{-6}	33.77^{-6}	-1.48	-63.66^{-6}	33.24^{-6}	-1.92^{T}	-10.85^{-6}	35.40^{-6}	-0.31

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Gender = noun gender; Length = mean noun length; N-V ratio = noun-verb ratio; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix D

Table D1

Experiment 2 English: Response Accuracy Results

Random effects					
Group	Name	Variance	*SD*	*r*	
NounID	(Intercept)	0.06	0.24		
	Number	1.31	1.14	-0.19	
	Block	0.10	0.32	-0.75	0.80
PartID	(Intercept)	0.64	0.80		
	Dominance	0.08	0.29	0.33	
		Number of observations: 9752; Groups: NounID, 92; PartID, 53			

Fixed effects			
	b	*SE*	*z*
(Intercept)	4.18	0.16	26.55^{***}
Fixed effects			
Dominance	0.28	0.20	1.41
Number	-0.41	0.21	-1.94^{T}
Interaction			
Dominance × Number	-0.35	0.35	-1.00

^{T} $p < .10$. *** $p < .001$.

Table D2

Experiment 2 English: Response Latency Number × Length Interaction Fixed Effect Results

	Block 1						Block 2					
	Singular nouns			Plural nouns			Singular nouns			Plural nouns		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1697^{-6}	52.58^{-6}	-32.27^{***}	-1734^{-6}	53.37^{-6}	-32.48^{***}	-1759^{-6}	50.39^{-6}	-34.90^{***}	-1790^{-6}	49.02^{-6}	-36.51^{***}
Control variables												
Length	427.80^{-6}	56.63^{-6}	7.56^{***}	-1.64^{-6}	56.85^{-6}	-0.03	339.20^{-6}	61.68^{-6}	5.50^{***}	-32.80^{-6}	52.55^{-6}	-0.62
Trial	-0.72^{-6}	0.27^{-6}	-2.64^{**}	-0.52^{-6}	0.27^{-6}	-1.91^{T}	-0.70^{-6}	0.28^{-6}	-2.50^{*}	-0.83^{-6}	0.30^{-6}	-2.77^{**}
Fixed effect												
Dominance	15.45^{-6}	19.10^{-6}	0.81	15.81^{-6}	17.83^{-6}	0.89	-6.11^{-6}	21.39^{-6}	-0.29	21.01^{-6}	16.56^{-6}	1.27

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix E

Table E1

Experiment 3 English Follow-up: Foil Response Latency Number × Length Interaction Fixed Effects Results

	Singular			Plural		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1154^{-6}	39.89^{-6}	-28.94^{***}	-984.40^{-6}	39.91^{-6}	-24.67^{***}
Control variables						
Frequency	-140.80^{-6}	47.81^{-6}	-2.95^{**}	-116.40^{-6}	25.96^{-6}	-4.49^{***}
Length	69.01^{-6}	12.03^{-6}	5.74^{***}	31.54^{-6}	10.77^{-6}	2.93^{**}
N-V ratio	220.10^{-6}	80.67^{-6}	2.73^{**}	451.80^{-6}	282.10^{-6}	1.60
Fixed effect						
Dominance				8.73^{-6}	42.46^{-6}	0.21

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written surface frequency; Length = noun length; N-V ratio = noun-verb ration. Dominance is treated as a categorical variable. Dominance was not included in the singular nouns model because all singular nouns were singular-dominant.

** $p < .01$. *** $p < .001$.

Table E2

Experiment 3 English Follow-up: Experimental Item Response Accuracy Number × Plural Foil Accuracy Interaction Fixed Effect Results

	Singular			Plural		
	b	*SE*	*z*	*b*	*SE*	*z*
(Intercept)	4.06	1.03	3.94^{***}	1.46	0.82	1.78^{T}
Control variable						
Plural foil accuracy	0.02	0.01	1.21	0.04	0.01	3.55^{***}
Fixed effect						
Dominance	0.16	0.47	0.74	0.22	0.34	0.64

Note. Plural foil accuracy = plural foil accuracy rate.

^{T} $p < .10$. *** $p < .001$.

Table E3

Experiment 3 English Follow-up: Experimental Item Response Latency Number × Length Interaction Fixed Effect Results

	Singular			Plural		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1445^{-6}	33.03^{-6}	-43.75^{***}	-1523^{-6}	29.67^{-6}	-51.35^{***}
Control variables						
Frequency	-51.48^{-6}	27.28^{-6}	-1.89^{T}	-21.25^{-6}	19.10^{-6}	-1.11
Length	345.50^{-6}	59.08^{-6}	5.85^{***}	92.47^{-6}	41.35^{-6}	2.24^{*}
Trial	-0.31^{-6}	0.13^{-6}	-2.40^{*}	-0.34^{-6}	0.12^{-6}	-2.92^{**}
Fixed effect						
Dominance	-5.27^{-6}	17.82^{-6}	-0.30	1.34^{-6}	12.98^{-6}	0.10

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written surface frequency; Length = noun length; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Study 3: Does the Surface Frequency Effect Extend to French and English Collective Nouns?

Does the Surface Frequency Effect Extend to French and English Collective Nouns?

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Abstract

To date, only a single study has studied the visual processing of individual collective nouns. Nenonen and Niemi (2010) found that Finnish singular non-collective nouns had a 271 ms advantage over collective nouns and that 23% of singular collective nouns were classified as notionally plural. The current paper attempts to extend our knowledge of noun collectivity, grammatical number, and animacy in a series of three experiments, involving two lexical decision tasks (LDTs) and one determiner-noun number agreement task (NAT). The non-collective noun speed advantage was replicated in the English LDT only. Meanwhile, singular nouns had a speed advantage in both LDTs, while plural nouns had a speed advantage in the NAT. Finally, inanimate nouns had a speed advantage in the English LDT; no other animacy effects were found. Together, these results suggest that whether individuals make use of noun collectivity and animacy information depends on the language studied and the requirements of the experimental task.

Keywords: number, inflectional morphology, collective nouns; animacy; word recognition, lexical decision, number agreement

Does the Surface Frequency Effect Extend to French and English Collective Nouns?

Over the past two decades, researchers have been studying the importance of surface frequency on visual word recognition. *Surface frequency* is the number of times (per million) that a word appears in one specific form in a corpus of continuous texts or spoken dialogues (New, Brysbaert, Segui, Ferrand, & Rastle, 2004). The *surface frequency effect* refers to the finding that readers are faster at recognizing words with a higher surface frequency of occurrence when their base frequency is held constant (e.g., Bertram, Schreuder, & Baayen, 2000; Meunier & Segui, 1999; New, Brysbaert, et al., 2004; Taft, 1979). In order to investigate this question, researchers compare *singular-dominant* nouns that are written more frequently in their singular form to *plural-dominant* nouns that are written more frequently in their plural form.

In lexical decision task (LDT) experiments, researchers have reported three main findings. First, singular nouns were recognized faster than plural nouns (Baayen, Dijkstra, & Schreuder, 1997; Domínguez, Cuetos, & Segui, 1999; New, Brysbaert, et al., 2004; Reifegerste, Meyer, & Zwitserlood, 2017). Second, in some studies, plural-dominant nouns were recognized faster than singular-dominant nouns (Baayen, Burani, & Schreuder, 1997; Baayen, Dijkstra, et al., 1997; Reifegerste et al., 2017), while in others there was no main effect of noun dominance (New, Brysbaert, et al., 2004; Reifegerste et al., 2017). Finally, in all lexical decision experiments, singular-dominant nouns were recognized significantly faster in their singular form than in their plural form (25 – 55 ms advantage), while a plural form advantage was not statistically significant for plural-dominant nouns (2 – 16 ms advantage; (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). In other words, a surface frequency effect was observed for singular-dominant nouns only.

The pervasiveness of the surface frequency effect for singular-dominant nouns found in lexical decision studies raises the question of whether all singular-dominant nouns demonstrate a surface frequency effect. In an attempt to begin answering this question, we contrasted collective nouns which are primarily singular-dominant to a matched sample of non-collective nouns in two LDT experiments. In addition, we conducted a number agreement experiment to examine whether the surface frequency effect would extend to an agreement situation. Thus, the core objective of this paper is to expand our understanding of the surface frequency effect by comparing collective and non-collective singular-dominant nouns.

In order to understand how collective nouns differ from non-collective nouns it is important to define two key concepts: grammatical number and notional number. *Grammatical number* is the written expression of noun number. A singular noun is denoted by the absence of a plural marker, while a plural noun is denoted by the presence of a plural marker (Corbett, 2000; Reid, 1991). The most common plural marker in French and English is the inflectional suffix -*s*, which is added to the end of the noun being pluralized (Akmajian, Demers, Farmer, & Harnish, 2001; Corbett, 2000; Mel'čuk & Milićević, 2014; Reid, 1991). *Notional number* (also known as conceptual number or semantic number) is the number of referents, singular or plural, intended by the communicator (Eberhard, Cutting, & Bock, 2005; Nickels, Biedermann, Fieder, & Schiller, 2015). Grammatical number and notional number often align (Corbett, 2006). For example, the noun *map* is grammatically and notionally singular while the noun *map**s*** is grammatically and notionally plural. However, a noun's notional number is not dependent on its grammatical number (Brehm & Bock, 2013; Corbett, 2000, 2006; Reid, 1991). In some instances, they can mismatch.

Collective Nouns

Collective nouns are defined by Jespersen (1924) as:

[…] words which denote a unit made up of several things or beings which may be counted separately; a collective, then, is logically from one point of view “one” and from another point of view “more than one”, and this accounts for the linguistic properties of such words which take sometimes a singular and sometimes a plural construction. (p. 195)

In accordance with this definition, Joosten et al. (2007) describe collective nouns as having two conceptual levels. At the *group level*, they refer to a group of multiple entities as a single unit and are considered notionally singular. At the *member level*, they refer to the individual members making up the group and are considered notionally plural. As a result, grammatically singular collective nouns can be notionally singular or notionally plural (Benninger, 2001; Corbett, 2000, 2006; Joosten et al., 2007; Lammert, 2015). For example, the grammatically singular noun *squad* can refer to either a group of individuals (group level) or to the various people who make up the squad (member level). Therefore, even though *squad* is grammatically singular, it can be perceived as either notionally singular or notionally plural.

However, not all singular collective nouns can be perceived as either notionally singular or notionally plural. In French, all singular collective nouns are perceived at the group level only and are thus always notionally singular (Joosten et al., 2007; Lammert, 2015). For example, the collective nouns *communauté* [*community*] and *archipel* [*archipelago*] are grammatically singular and notionally singular. There is one community made up of a group of individuals and one archipelago made up of a group of islands. In English, only animate singular collective nouns can be notionally singular or notionally plural (Joosten et al., 2007; Levin, 2001). According to Gelman and Spelke (1981, p. 45), animate nouns represent entities that can: 1) act on their own; 2) grow and reproduce; 3) know, perceive, emote, learn, and think; and 4) maintain life, foster growth, and allow reproduction. Thus, *family*, *jury*, and *mob* are all considered animate collective nouns. Nouns that represent entities which cannot do all of these things are considered inanimate. English inanimate singular collective nouns can only be perceived at the group level and thus are always conceptualized as notionally singular (Joosten et al., 2007). Their notional number always matches their grammatical number. Nevertheless, Levin (2001) affirms that inanimate collective nouns meet the requirements of Jespersen's (1924) definition and are true collectives. For example, the noun *forest* denotes a group several things (i.e., trees) that can be counted separately. Further examples include *bouquet*, *garden*, and *stack* which are all considered inanimate collective nouns.

To date, only a single study has been published that examines how readers perceive the notional number of individual singular collective nouns. The study was conducted in Finnish, a language which marks noun collectivity by using one of two inflectional suffixes, -*sto* or -*stö*. For example, the word *karta* [*map*] is a non-collective noun while the word *karta**sto*** [*atlas*] is a collective noun. In their study, Nenonen and Niemi (2010) asked participants to indicate whether collective and non-collective nouns had *one* or *many* referents by pressing one of two buttons in a number decision task. They found that participants classified 77% of singular collective nouns as having a single referent (i.e., notionally singular). The remaining 23% were classified as having many referents (i.e., notionally plural). In comparison, participants classified 99% of singular non-collective nouns as notionally singular and 92% of plural non-collective nouns as notionally plural. Response latency results indicated that participants were 271 ms slower at classifying collective nouns than non-collective nouns. Moreover, when classifying singular collective nouns, participants were 141 ms faster at providing *one* responses than *many* responses. These findings suggest that grammatically singular collective nouns can be perceived as notionally plural and that arriving at this decision requires additional processing time.

All other research investigating singular collective noun notional number has been conducted using subject-verb number agreement paradigms. Researchers have predominantly focused on how English participants complete noun phrases containing an animate singular collective subject noun. A *subject noun* controls the number information expressed by other target words, such as verbs, within a sentence (Corbett, 2000, 2006; Tallerman, 2011). The number information expressed by these target words should agree with the number information provided by the subject noun. In English, number agreement for animate singular collective nouns can be formed based on the subject noun's grammatical number or notional number. Therefore, both singular and plural number agreement are possible (e.g., "*The jury for the trial* ***is/are****...*"; Corbett, 2006).

In order to investigate whether English speakers produce notional number agreement, researchers have them complete noun phrases containing either an animate singular collective subject noun or a singular non-collective subject noun followed by a second singular noun (e.g., *The herd/house behind the fence*…). The production of a plural verb following animate singular collective subject noun phrases is viewed as an indicator that the collective noun was perceived as notionally plural and notional number agreement was produced (e.g., *The herd behind the fence* ***are****…*; Bock, Eberhard, & Cutting, 2004). A number of studies report that participants produced significantly more plural verbs (3% - 28%) when completing animate singular collective noun phrases compared to singular non-collective noun phrases (2% - 4%, Bock et al., 2004; Bock, Nicol, & Cutting, 1999; Haskell & MacDonald, 2003; Humphreys & Bock, 2005; Staub, 2009). In addition, researchers have suggested that plural verb production can be promoted in two ways: a) by highlighting the collective noun's member level instead of its group level (Brehm & Bock, 2013; Humphreys & Bock, 2005) and b) by having participants read short texts where animate singular collective nouns are followed by plural verb agreement prior to completing noun phrases (Haskell, Thornton, & MacDonald, 2010).

One major limitation among the number agreement studies is the exclusion of inanimate singular collective nouns. This omission is noteworthy given the argument presented above that animate and inanimate singular collective nouns differ in English. No research has been published to examine whether these two types of collective nouns are processed differently even though a number of studies have reported finding an animacy effect in both French and English.

Noun Animacy

While the definition of animacy varies somewhat among the research studies presented in this section, most authors stipulate that a word must refer to an entity that is able to move on its own to be considered animate, otherwise it is considered inanimate (for alternative animacy definitions see Popp & Serra, 2016; Radanović, Westbury, & Milin, 2016).

Memory researchers have established the existence of a strong *animacy effect* during free memory recall experiments in both French and English. Participants correctly recall significantly more animate nouns that inanimate nouns. An animacy effect is observed both when participants are and are not informed that they will be tested for recall (Bonin, Gelin, & Bugaiska, 2014; Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013; Popp & Serra, 2016; VanArsdall, Nairne, Pandeirada, & Cogdill, 2017). An animacy effect is even found when initial word exposure coincides with an unrelated memory task (Bonin, Gelin, Laroche, Mélot, & Bugaiska, 2015). Further, an animacy effect is sometimes found in cued memory recall experiments, although not consistently (Popp & Serra, 2016; VanArsdall, Nairne, Pandeirada, & Cogdill, 2015). Finally, VanArsdall and his colleagues (VanArsdall, Nairne, Pandeirada, & Blunt, 2013) found that participants recalled more non-words in memory recognition and free memory recall tasks when they were associated with animate qualities (e.g., dreams at night) as opposed to inanimate qualities (e.g., sinks in water).

An animacy effect has also been found in visual word recognition tasks. In French, several studies have found an animacy effect in both LDTs and gender decision tasks where participants are asked to designate a noun's gender by choosing between the articles "Un" [masculine] or "Une" [feminine] (Desrochers, Carson, Côté, Lamothe, & Morneau, 2018). Conversely, Radanović, Westbury, and Milin (2016) had English and Serbian participants complete a LDT with a list of nouns previously rated on an animacy continuum. The authors found that noun animacy had no impact on response latency in either language when noun base frequency was controlled.

Study Overview

The goal of this paper is to expand our understanding of the surface frequency effect by determining whether collective nouns, which are predominantly singular-dominant, differ from singular-dominant non-collective nouns. In addition, the influence of noun animacy was examined. Two languages were studied: French and English. In French, all singular collective nouns are notionally singular. In English however, singular animate collective nouns can be notionally singular or notionally plural, while singular inanimate collective nouns can only be notionally singular. Two experimental tasks were used: a lexical decision task (French and English) and a determiner-noun number agreement task (English only).

We expect to find the following results in all tasks based on previous research findings: 1) non-collective nouns will be recognized faster than collective nouns; 2) singular nouns will be recognized faster than plural nouns; 3) in French, animate nouns will be recognized faster than inanimate nouns; 4) in English, animate and inanimate nouns will be recognized at a similar speed; 5) in English, there will be a 3-way interaction between noun collectivity, grammatical number, and animacy such that animate collective nouns will not demonstrate a surface frequency effect while inanimate collective nouns and all non-collective nouns will display a surface frequency effect. Furthermore, based on the research by Nenonen and Niemi (2010), we expected to find the following result in the determiner-noun number agreement task only: 6) plural agreement will be higher for singular collective nouns than singular non-collective nouns.

Experiment 1: French Lexical Decision Task

Method

Participants. Participants were undergraduate students attending the University of Ottawa. They chose to participate by signing-up through an online Integrated System for Participating in Research and selecting a date and time that was convenient for them. Inclusion criteria were: strong knowledge of French, normal or corrected-to-normal vision, and no diagnosed language disabilities. Participants were credited 1% towards a course of their choice as compensation for their participation.

A total of 92 students participated in this study. Thirty participants were removed from the sample due to a high percentage of errors (> 20%). The final sample contains 62 participants (57 female) with a mean age of 20.3 years old (*SD* = 4.56). Sixty participants identified French as their native language while the remaining two participants spoke French as a second language.

Stimuli. Two hundred and twenty-four French nouns (112 collective and 112 non-collective) were selected from the *Lexique 3* database (see Appendix A for a complete list; (New, Brysbaert, Veronis, & Pallier, 2007; New, Pallier, Brysbaert, & Ferrand, 2004). The following noun characteristics were controlled for across experimental conditions as closely as possible: noun length, number of phonemes, number of syllables, noun gender, noun-verb ratio, and surface frequency (see Table 1). The noun-verb ratio values ranged from 0.30 to 1 with a mean of 0.99 (SD = 0.07). Two hundred and twenty-four non-words were created by manipulating 2 – 4 letters of each real noun. This was done to maintain the original number of letters and syllables and syllabic structures.

Equipment. Data was collected using Dell PC computers with 64-bit processors. Stimuli were presented in size 18 Courier New boldface font on IBM Think Vision computer screens with a 1280 × 1024 resolution. E-Prime Professional 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) was used to present task instructions, randomly display stimuli, and record participant response accuracy and latency. An E-Prime serial response box (Model 200A) was used to collect participants' responses.

Experimental design. Collectivity (collective vs. non-collective) and Animacy (animate vs. inanimate) are treated as dichotomous within-subjects variables while Number (singular vs. plural) and Block (1 vs. 2) are treated as dichotomous within-items variables.

Two lists were created that contained all 224 real nouns and 224 non-words, in either their singular or plural form. Noun grammatical number was interchanged across lists; a noun that appeared in its singular form on List 1 (e.g., *colonie* [*colony*]) appeared in its plural form on List 2 (e.g., *colonie**s***), and vice versa. Each list contained 56 real nouns belonging to each of the following experimental conditions: 1) singular animate collective; 2) singular inanimate collective; 3) singular animate non-collective; 4) singular inanimate non-collective; 5) plural animate collective; 6) plural inanimate collective; 7) plural animate non-collective; and 8) plural inanimate non-collective.

Every participant was presented with both lists as two equal blocks of items. Consequently, each participant saw each noun twice, once per grammatical number. List order was counterbalanced so that half of participants saw List 1 first followed by List 2, while the other half saw List 2 first followed by List 1. Block 1 aligns with the approach used by researchers in the noun dominance lexical decision studies discussed above. The inclusion of Block 2 allows us to test the robustness of Block 1 effects.

Procedure. Upon their arrival, participants completed an informed consent form and a demographics questionnaire. They sat in a sound-proof testing room with a computer screen and E-Prime response box in front of them while they completed the LDT. Real nouns and non-words were randomly presented one at a time in the center of the screen. They were asked to indicate whether each string of letters represented a real word, *OUI* [*YES*] or *NON* [*NO*], by pressing the response box button with the corresponding label. Label placement was counterbalanced between participants to control for the influence of hand dominance (57 participants were right handed and 5 were left handed). Half of the participants pressed the far left button to respond *OUI* and the far right button to respond *NON*, while the other half pressed the far left button to respond *NON* and the far right button to respond *OUI*. Participants were instructed to read each item and to make their decisions as quickly as possible while maintaining an error rate below 10%. After completing 32 practice trials (16 real nouns and 16 non-words) with the experimenter present, participants were left alone to complete 896 experimental trials. The task took 60 to 80 minutes to complete. Participants were debriefed after they finished the experiment.

All trials followed the same sequence: 1) a message appeared in the center of the screen asking participants if they were ready to start the trial [Prêt?/Ready?]; 2) participants pushed either button to indicate they were ready; 3) a 500 ms delay followed; 4) a fixation point (+) appeared in the centre of the screen for 531 ms; 5) a stimulus appeared in the centre of the screen; 6) participants provided their response, causing the simultaneous disappearance of the stimulus; 7) there was a 500 ms delay before the sequence recommenced.

Results

Data cleaning. All reaction time (RT) data was cleaned by participant and experimental condition using the following steps: 1) RTs for inaccurate responses were removed, 2) RTs below 250 ms were removed, 3) RTs that were 3.29 standard deviations above or below the mean were removed (Ratcliff, 1993), and 4) RTs that fell between 2.58 to 3.29 standard deviations above or below the mean were winsorized (Tukey, 1962). Implementing this procedure resulted in the removal of 14.9% of the RT data, 11.7% due to inaccurate responses and 3.2% from outliers. Following this procedure, an inverse transformation (-1/RT) was applied to the cleaned RT data to reduce positive skew.

Statistical analysis. Prior to analysis, the linearity of all continuous fixed effects and control variables was verified and the appropriate transformations were applied when necessary. Following this, all fixed effects, with the exception of trial number, were grand mean centred (gmc) or contrast coded (cc) to reduce multicollinearity (Linck & Cunnings, 2015).

Analyses were conducted in R (v. 3.3.2; R Core Team, 2016) using the RStudio user interface (v. 1.0.136, RStudio Team, 2015) and the lme4 package (v. 1.1-12; Bates, Mächler, Bolker, & Walker, 2015). A maximal model was always sought (Barr, Levy, Scheepers, & Tily, 2013). In all models presented in this paper, two random effects were specified: participants and items. Their random intercepts were always included. Random slopes were included whenever possible. They were excluded if they correlated too highly ($r \geq 0.90$) with their random intercept or other random slopes. Collectivity and Animacy were entered as potential random participant slope. Likewise, Number was entered as a potential random noun slope (each singular and plural noun pair represents a single lexical unit). In response accuracy models, Block was entered as a potential random noun slope.

All models included the following fixed effects: 1) Collectivity; 2) Number; and 3) Animacy. Several control variables were also added to the models: 1) noun written base frequency; 2) mean noun length; 3) noun-verb ratio; 4) trial number as a practice indicator; 5) noun gender (in French only); and 6) participant native language (in English only). Control variables that did not contribute significantly to the goodness of the model fit based on chi-squared goodness of fit tests were removed from the final model.

Response accuracy data were analyzed using generalized linear mixed modelling (GLMM) for binary data. The `glmer` function was used with the family criterion set to binomial. The maximum likelihood estimator used was Laplace approximation. The `bobyqa` optimizer was used to increase the number of iterations and improve model convergence.

Response latency data were analyzed using cross-classified linear mixed effects (LME) modelling using the `lmer` function. The maximum likelihood estimator was set to restricted maximum likelihood (REML). T-test significance was calculated using the formula proposed by Baayen (2008):

$$2\{1 - pt\ [abs\ (t - value), \#of\ observations - \#of\ fixed\ effects]\}$$

Finally, two model effect size estimates were calculated for all models using the `r.squaredGLM` function from the MuMIn package (v. 1.15.6; Bartoń, 2016). The marginal effect size estimates the amount of variance accounted for by all the fixed effects included in the model (i.e., fixed effects, control variables, and interactions). The conditional effect size estimates the amount of variance accounted for by all the random effects and fixed effects included in the model (Johnson, 2014; Nakagawa & Schielzeth, 2013).

For Experiment 1 only, two animate non-collective nouns were removed from the dataset prior to analyses because they were presented twice in their singular form instead of once in their singular form and once in their plural form (*fripouille* and *patriarche*).

Response accuracy results. Participants' overall accuracy rate was high (M = 88%; SD = 5%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.01, SE = 0.05, z = 0.23, p = .820) and did not improve model fit (p = .820). All final model fixed effect correlations were weak, $r \leq |0.31|$. The final GLMM code is below; results are presented in Table 2.

```
FR.ACC.model <- glmer(ACC ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLen_gmc + BFreqLog_gmc:MLen_gmc + (1 + Coll_cc*Anim_cc|PartID) + (1|NounID),
data = FR_LDT_ACC, family = binomial)
```

***Control variables*.** There was a significant main effect of noun written base frequency; response accuracy increased as written frequency of occurrence increased. There was also a significant main effect of mean noun length; response accuracy increased as mean noun length increased.

***Fixed effects and interaction*.** There was a trend towards a significant main effect of Collectivity. Response accuracy was slightly higher for non-collective nouns than collective nouns (90% vs. 87%). Neither the Number nor Animacy main effects were significant ($p \geq .145$; see Table 3 for descriptive statistics). There was a significant Frequency × Length interaction. The effect of Frequency increased response accuracy by 3% for each additional letter a noun contained.

Effect size. The final model marginal effect size estimate was 29.09%. The fixed effects and control variables account for approximately a quarter of the observed variability in response accuracy. The final model conditional effect size estimate was 66.25%. Adding the variance accounted for by participant and item random effects explained two-thirds of the observed variability.

Response latency results. There was a significant main effect of Block ($b = 103.10 \times 10^{-6}$, $SE = 3.94 \times 10^{-6}$, $t = 26.14$, $p < .001$), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to the research studies presented in the introduction. All final model fixed effect correlations were weak ($r \leq |0.28|$). The final cross-classified LME code is below; results are presented in Tables 4 and 5.

```
FR.RT.B1.model <- lmer(InvRT ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLen_gmc + Trial + Coll_cc:Gramm_cc + (1 + Coll_cc*Anim_cc|PartID) + (1 +
Num_cc|NounID), data = FR_LDT_B1)
FR.RT.B2.model <- lmer(InvRT ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLen_gmc + Trial + Coll_cc:Gramm_cc + (1 + Coll_cc*Anim_cc |PartID) + (1 +
Num_cc|NounID), data = FR_LDT_B2)
```

Control variables. There was a significant main effect of noun written base frequency. In both blocks, response latencies increased as written frequency of occurrence decreased. There was also a significant main effect of mean noun length. In both blocks, response latencies increased as mean noun length increased. Finally, there was significant main effect of trial number in both blocks; response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number in Blocks 1 and 2. In both blocks, singular nouns had faster response latencies than plural nouns (Block 1: 731 ms vs. 765 ms; Block 2: 677 ms vs. 710 ms). Neither the Collectivity nor Animacy main effects were significant ($p \geq .168$; see Figure 1; see Table 6 for descriptive statistics).

Interaction. There was a significant Collectivity × Number interaction in Block 2 only. The interaction was decomposed by creating two sub-datasets, one for collective nouns and one for non-collective nouns. A cross-classified LME model was run for each of these datasets. These models included both random intercepts, Animacy as a random participant slope, Number as a random noun slope (non-collective model only), Animacy and Number as fixed effects, and the three control variables included in the original models. There was a significant main effect of Number for both collective nouns ($b = 44.31 \times 10^{-6}$, $SE = 7.83 \times 10^{-6}$, $t = 5.66$, $p < .001$) and non-collective nouns ($b = 68.11 \times 10^{-6}$, $SE = 8.22 \times 10^{-6}$, $t = 8.28$, $p < .001$; see Table C1 for complete results). The slope differential shows that the discrepancy between singular and plural noun response latencies was 1.54 times greater for non-collective nouns than collective nouns.

Effect size. The final model marginal effect size estimates were 9.88% (Block 1 and Block 2). The marginal effect sizes are extremely low, indicating that the fixed effects and control variables were not very effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates were 50.93% (Block 1) and 49.51% (Block 2). Adding the variance accounted for by participant and item random effects increased the variance account for, but half of the observed variability remains unexplained by the model.

Discussion

In the present experiment, response accuracy was high (88%). There was a trend towards accuracy being influenced by noun collectivity; it was 3% higher for non-collective nouns than collective nouns. Meanwhile, response latency was influence by grammatical number in Blocks 1 and 2. In both blocks, singular nouns had faster response latencies than plural nouns (Block 1: 34 ms advantage; Block 2: 33 ms advantage). Moreover, there was a significant Collectivity × Number interaction in Block 2 only. Both collective and non-collective nouns demonstrated a surface frequency effect. The strength of this effect was 1.54 time stronger for non-collective nouns than collective nouns.

Our findings only partially align with previous research. A surface frequency effect has been found for singular-dominant nouns in several languages (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). The significant Collectivity × Number interaction we observed in Block 2 indicates that the surface frequency effect extends to collective nouns, although its strength is diminished. The absence of a significant Collectivity effect in the current experiment counters our expectation. Nenonen and Niemi (2010) found that participants were 271 ms slower at classifying collective nouns compared to non-collective nouns in a number decision task. However, it is likely that the null Collectivity effect seen in our experiment is an artifact of the language studied. In French, the grammatical number and notional number of collective nouns align, eliminating any notional number ambiguity that may interfere with noun recognition (Joosten et al., 2007; Lammert, 2015). Therefore, French collective nouns are identical to French non-collective nouns in this respect. The more surprising result was that despite animate nouns having a 29 ms advantage across blocks, the Animacy effect was not significant in the present experiment. This finding contradicts what has been observed in several French lexical and gender decision studies. Typically, animate nouns have faster response latencies than inanimate nouns (Desrochers et al., 2018). The null Animacy effect does, however, correspond with English and Serbian LDT results (Radanović et al., 2016). In order to determine whether comparable results would be obtained in another language with the same grammatical number marking system, an equivalent experiment was carried out in English.

Experiment 2: English Lexical Decision Task

Method

Participants. Participants were recruited using the same procedure as Experiment 1. A total of 86 students participated in this study. Data from six participants was lost due to computer error. Twelve additional participants were removed from the sample due to a high percentage of errors (≥ 20%) or a high percentage of response latency outliers (> 10%). The final sample contains 68 participants (59 female) with a mean age of 18.7 years old (*SD* = 1.38). Forty-five participants identified English as their native language while the remaining 23 participants spoke English as a second language.

Stimuli. One hundred and seventy-two English nouns (86 collective and 86 non-collective) were selected from the *CELEX 2* database (see Table 1 for noun characteristics; see Appendix B for a complete list; Baayen, Piepenbrock, & Gulikers, 1995). The noun-verb ratio values ranged from 0.01 to 1 with a mean of 0.95 (SD = 0.15). One hundred and seventy-two non-words were created using the method described in Experiment 1.

Equipment. Identical to Experiment 1.

Experimental design. Identical to Experiment 1 with the exception that 43 real nouns were presented in each experimental condition.

Procedure. All elements of the procedure were identical to Experiment 1 with two exceptions: 1) LDT response options were translated into English (*YES*/*NO*) and 2) there were 688 experimental trials instead of 896. The task took 45 to 60 minutes to complete.

Results

Data cleaning. The data cleaning procedure was identical to Experiment 1. Implementing this procedure resulted in the removal of 11.6% of the RT data, 8.1% due to inaccurate responses and 3.5% from outliers. Once again, an inverse transformation (-1/RT) was applied to the cleaned data to reduce positive skew.

Statistical analysis. Identical to Experiment 1.

Response accuracy results. Participants' overall accuracy rate was very high (M = 92%; SD = 5%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.01, SE = 0.06, z = 0.23, p = .817) and did not improve model fit (p = .408). All final model fixed effect correlations were weak, $r \leq |0.17|$. The final GLMM code is below; results are presented in Table 7.

```
EN.ACC.model <- glmer(ACC ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLenLog_gmc + Coll_cc:BFreqLog_gmc (1 + Coll_cc*Anim_cc |PartID) + (1 +
Num_cc |NounID), data = EN_LDT_ACC, family = binomial)
```

***Control variables*.** There was a significant main effect of noun written base frequency; response accuracy increased as written frequency of occurrence increased. There was also a significant main effect of mean noun length; response accuracy increased as mean noun length increased.

***Fixed effects*.** There was a significant main effect of Collectivity. Response accuracy was higher for non-collective nouns than collective nouns (96% vs. 88%). There was also a significant main effect of Number. Singular nouns were recognized slightly more accurately than plural nouns (92% vs. 91%). Finally, there was a significant main effect of Animacy. Inanimate nouns were recognized more accurately than animate nouns (93% vs. 90%; see Table 3 for complete descriptive statistics).

Interaction. There was a significant Collectivity × Frequency interaction. The interaction was decomposed by creating two sub-datasets, one for collective nouns and one for non-collective nouns. A cross-classified LME model was run for each of these datasets. These models included both random intercepts, Animacy as a random participant slope, Number as a random noun slope, Animacy and Number as fixed effects, and the two control variables included in the original model. There was a significant main effect of Frequency for both collective nouns (b = 3.35, SE = 0.40, z = 8.48, p < .001) and non-collective nouns (b = 2.19, SE = 0.42, z = 5.25, p < .001; see Table D1 for complete results). The slope differential shows that the base frequency effect was 1.53 times larger for collective nouns than non-collective nouns.

Effect size. The final model marginal effect size estimate was 24.97%. The fixed effects and control variables account for a quarter of the observed variability in response accuracy. The final model conditional effect size estimate was 58.48%. Adding the variance accounted for by participant and item random effects explained over half of the observed variability.

Response latency results. There was a significant main effect of Block ($b = 91.39 \times 10^{-6}$, $SE = 4.42 \times 10^{-6}$, t = 20.67, p < .001), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to the research studies presented in the introduction. All final model fixed effect correlations were weak ($r \leq |0.28|$). The final cross-classified LME code is below; results are presented in Tables 8 and 9.

```
EN.RT.B1.model <- lmer(InvRT ~ Coll_cc*Num_cc*Anim_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Coll_cc:BFreqLog_gmc + Anim_cc:MLenLog_gmc + (1 +
Coll_cc|PartID) + (1 + Num_cc|NounID), data = EN_LDT_B1)
EN.RT.B2.model <- lmer(InvRT ~ Coll_cc*Num_cc*Anim_cc + BFreqLog_gmc +
MLenLog_gmc + NVRatio_gmc + Coll_cc:BFreqLog_gmc + Anim_cc:MLenLog_gmc + (1 +
Anim_cc|PartID) + (1 + Num_cc|NounID), data = EN_LDT_B2)
```

Control variables. There was a significant main effect of noun written base frequency. In both blocks, response latencies decreased as written frequency of occurrence increased. There was also a significant main effect of mean noun length. In both blocks, response latencies increased as mean noun length increased. Finally, there was significant main effect of noun-verb ratio in Block 1 that became a non-significant trend in Block 2. In Block 1, response latencies increased as the noun-verb ratio increased.

Fixed effects. There was a significant main effect of Collectivity. In both blocks, non-collective nouns had faster response latencies than collective nouns (Block 1: 673 ms vs. 725 ms; Block 2: 635 ms vs. 683 ms). There was also a significant main effect of Number. In both blocks, singular nouns had faster response latencies than plural nouns (Block 1: 681 ms vs. 716 ms; Block 2: 643 ms vs. 674 ms). Finally, there was a significant main effect of Animacy. In both blocks, inanimate nouns had faster response latencies than animate nouns (Block 1: 683 ms vs. 714 ms; Block 2: 649 ms vs. 668 ms).

***Interactions*.** There was a significant Animacy × Length interaction in both blocks. This interaction was decomposed by creating two sub-datasets per block, one for animate nouns and one for inanimate nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Number as a random noun slope, Collectivity as a random participant slope (inanimate noun models only), Collectivity and Number as fixed effects, and the three control variables included in the original models. The main effect of Length was a significant for animate nouns in both blocks (Block 1: $b = 433.00 \times 10^{-6}$, $SE = 112.90 \times 10^{-6}$, $t = 3.84$, $p < .001$; Block 2: $b = 374.90 \times 10^{-6}$, $SE = 98.93 \times 10^{-6}$, $t = 3.79$, $p < .001$), but not for inanimate nouns ($p \geq .271$; see Table D2 for complete results). More explicitly, the longer animate nouns were, the faster they were recognized in both blocks.

There was also a significant Collectivity × Frequency interaction in Block 1 that became a non-significant trend in Block 2. The Block 1 interaction was decomposed by creating two sub-datasets, one for collective nouns and one for non-collective nouns. A cross-classified LME model was run for each of these datasets. These models included both random intercepts, Number as a random noun slope, Animacy and Number as fixed effects, and the three control variables included in the original models. There was a significant main effect of Frequency for both collective nouns (b = -267.80 × 10^{-6}, SE = 29.02 × 10^{-6}, t = -9.23, p < .001) and non-collective nouns (b = -182.40 × 10^{-6}, SE = 30.93 × 10^{-6}, t = -5.90, p < .001; see Table D3 for complete results). The slope differential shows that the base frequency effect was 1.47 times larger for collective nouns than non-collective nouns.

Finally, there was a significant Animacy × Collectivity × Number interaction in Block 2 only (see Figure 2; see Table 6 for descriptive statistics). However, none of the two-way interactions between the three fixed effects reached significance ($p \geq .332$). Therefore, the 3-way interaction was not decomposed statistically. Conclusions drawn in the discussion are based on the response latency patterns presented in Figure 2.

Effect size. The final model marginal effect size estimates are 10.16% (Block 1) and 7.44% (Block 2). The marginal effect size is quite low for both models, indicating that the fixed effects and control variables were not very effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates are 42.87% (Block 1) and 40.83% (Block 2). Adding the variance accounted for by participant and item random effects increases the variance account for, but over half of the observed variability is still left unexplained by the model.

Discussion

In the present experiment, response accuracy was high (92%), yet it was influenced by noun collectivity, animacy, and grammatical number. Response accuracy was 8% higher for non-collective nouns than collective nouns. In addition, accuracy was 3% higher for inanimate nouns than animate nouns and 1% higher for singular nouns than plural nouns. Meanwhile, response latency was influenced by Collectivity in Blocks 1 and 2. Non-collective nouns had faster response latencies than collective nouns (Block 1: 52 ms advantage; Block 2: 48 ms advantage). Response latency was also influenced by Number in both blocks. Singular nouns had faster response latencies than plural nouns (Block 1: 35 ms advantage; Block 2: 31 ms advantage). In addition, there was a main effect of Animacy in both blocks. Inanimate nouns had faster response latencies than animate nouns (Block 1: 31 ms advantage; Block 2: 19 ms advantage). Finally, there was a significant Animacy × Collectivity × Number interaction in Block 2 that was not decomposed statistically since none of the underlying two-way interactions were significant. However, based on the pattern portrayed in Figure 3, the observed pattern does do not match our prediction. We expected to find a surface frequency effect for all noun types except animate collective nouns. Instead, we found that animate collective nouns demonstrated the strongest surface frequency effect (52 ms advantage for singular nouns) compared to all other noun types (18 – 36 ms advantage).

Our findings predominantly align with previous research. A Collectivity effect was reported by Nenonen and Niemi (2010). They found that participants were 271 ms faster at classifying non-collective nouns compared to collective nouns in a number decision task. Although the size of our effect is smaller (50 ms averaged across blocks), the direction is the same. Furthermore, the surface frequency effect observed in the present experiment has been found for singular-dominant nouns in several languages (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). The one unexpected result was that in the current experiment inanimate nouns had faster response latencies than animate nouns in both blocks (25 ms advantage across blocks). This finding contradicts all previous animacy studies, which report finding either faster response latencies for animate nouns, or no animacy effect at all in several lexical and gender decision studies (Desrochers et al., 2018; Radanović et al., 2016).

In order to determine whether similar effects would be seen in an experimental task requiring explicit noun number processing, the same nouns were tested in a simple determiner-noun number agreement task. This task measures participants' perception of noun notional number using the mechanism of number agreement. This differs from the paradigm used by Nenonen and Niemi (2010) which required participants to make explicit notional number decisions.

Experiment 3: English Number Agreement Task

Method

Participants. Participants were recruited using the same procedure as Experiment 1. A total of 57 students participated in this study. One participant was removed from the sample due to their high percentage of errors (> 10%). The final sample contains 56 participants (48 female) with a mean age of 18.8 years old (*SD* = 1.65). Forty-three participants identified English as their native language while the remaining 13 participants spoke English as a second language.

Stimuli. The 172 real nouns used in Experiment 2.

Equipment. Identical to Experiment 1.

Experimental design. Identical to Experiment 2 except that each list contained 43 real nouns only.

Procedure. All elements of the procedure were identical to Experiment 1 except for the experimental task used. Participants completed a determiner-noun number agreement task (NAT). Real nouns were randomly presented one at a time in the center of the screen. Participants were asked to indicate whether they would place *This* (representing singular grammatical/notional number) or *These* (representing plural grammatical/notional number) in front of each noun by pressing the response box button with the corresponding label. After completing 32 practice trials (16 singular nouns and 16 plural nouns) with the experimenter present, participants were left alone to complete 344 experimental trials. The task took 20 to 30 minutes to complete.

Results

Data cleaning. The data cleaning procedure was identical to Experiment 1. Implementing this procedure resulted in the removal of 5.5% of the RT data, 3.1% due to inaccurate responses and 2.4% from outliers. Once again, an inverse transformation (-1/RT) was applied to the cleaned RT data to reduce positive skew.

Statistical analysis. Identical to Experiment 1.

Response accuracy results. Participants' overall accuracy rate was very high (M = 97%; SD = 2%). Block 1 and Block 2 data were analyzed together since the main effect of block was not significant (b = 0.16, SE = 0.08, z = 1.89, p = 0.058) and did not improve model fit (p = .062). This main effect was, however, retained in the model since it approached significance. All final model fixed effect correlations were weak, $r \leq |0.08|$. The final GLMM code is below; results are presented in Table E1.

```
EN.ACC.model <- glmer(ACC ~ Coll_cc + Num_cc + Anim_cc + Block_cc (1 +
Anim_cc |PartID) + (1|NounID), data = EN_NDT_ACC, family = binomial)
```

Fixed effects. There was a trend towards a significant main effect of Collectivity. Response accuracy was minimally higher for non-collective nouns than collective nouns (97.2% vs. 96.8%). The Number and Animacy main fixed effects did not approach significance ($p \geq$ .168; see Table 3 for descriptive statistics).

Effect size. The final model marginal effect size estimate was 0.54%. The fixed effects and control variable account for a virtually none of the observed variability in response accuracy. This is not surprising given there is little variability to be explained. The final model conditional effect size estimate was 14.54%. Adding the variance accounted for by participant and item random effects increased the variance account for, but over three-quarters of the observed variability remains unexplained by the model.

Response latency results. There was a significant main effect of Block ($b = 95.01 \times 10^{-6}$, $SE = 6.08 \times 10^{-6}$, $t = 15.62$, $p < .001$), therefore two datasets were created and analyzed separately. The Block 1 dataset analyses are comparable to the research studies presented in the introduction. All final model fixed effect correlations were weak ($r \leq |0.19|$). The final cross-classified LME code is below.

```
EN.RT.model.B1 <- lmer(InvRT ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLenLog_gmc + Trial + Num_cc:BFreqLog_gmc + Num_cc:MLenLog_gmc +
Anim_cc:MLenLog_gmc + (1|PartID) + (1 + Num_cc |NounID), data = EN_NDT_B1)
EN.RT.model.B2 <- lmer(InvRT ~ Coll_cc + Num_cc + Anim_cc + BFreqLog_gmc +
MLenLog_gmc + Trial + Num_cc:BFreqLog_gmc + Num_cc:MLenLog_gmc +
Anim_cc:MLenLog_gmc + (1 + Coll_cc |PartID) + (1|NounID), data = EN_NDT_B2)
```

Control variables. There was a significant main effect of noun written base frequency. In both blocks, response latencies decreased as written frequency of occurrence increased. In addition, there was a significant main effect of mean noun length. In both blocks, response latencies increased as mean noun length increased. Finally, there was a significant main effect of trial number. In both blocks, response latencies decreased as trial number increased.

Fixed effects. There was a significant main effect of Number in Blocks 1 and 2. Response latencies were slower for singular nouns than plural nouns in both blocks (Block 1:

672 ms vs. 658 ms; Block 2: 640 ms vs. 618 ms). Neither the Collectivity nor Animacy main effects reached significance ($p \geq .091$; see Figure 3; see Table 6 for descriptive statistics).

***Interactions*.** There was a significant Number × Length interaction in Blocks 1 and 2. These interactions were decomposed by creating 2 sub-datasets per block, one for singular nouns and one for plural nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Collectivity as a random participant slope (Block 2 models only), Collectivity and Animacy as fixed effects, and the three control variables included in the original models. In both blocks, there was a significant main effect of Length for singular nouns (Block 1: $b = 461.80 \times 10^{-6}$, $SE = 52.00 \times 10^{-6}$, $t = 8.88$, $p < .001$; Block 2: $b = 426.20 \times 10^{-6}$, $SE = 47.24 \times 10^{-6}$, $t = 9.02$, $p < .001$), but not for plural nouns ($p \geq .064$; see Table E2 for complete results). More explicitly number agreement decision response latencies decreased as mean noun length decreased for singular nouns only. In addition, there was a significant Number × Frequency interaction in Block 2 only. There was a significant main effect of Frequency for singular nouns ($b = -46.99 \times 10^{-6}$, $SE = 13.10 \times 10^{-6}$, $t = -3.59$, $p < .001$), but not for plural nouns ($p = .860$; see Table E2 for complete results). For singular nouns only, agreement response latencies decreased as written frequency of occurrence increased.

Finally, there was a significant Animacy × Length interaction in Block 2 only. This interaction was decomposed by creating two sub-datasets, one for Block 2 animate nouns and one for Block 2 for inanimate nouns. A cross-classified LME model was run for each of these datasets. These models included: both random intercepts, Collectivity as a random participant slope, Collectivity and Number as fixed effects, the three control variables included in the original models, and the Number × Length interaction. There was a significant main effect of Length for inanimate nouns ($b = 279.30 \times 10^{-6}$, $SE = 52.22 \times 10^{-6}$, $t = 5.35$, $p < .001$), but not for animate nouns (*p* = .688; see Table E3 for complete results). More precisely, for inanimate nouns only, number agreement response latencies increased as mean noun length increased.

Effect size. The final model marginal effect size estimates were 10.67% (Block 1) and 10.87% (Block 2). The marginal effect sizes are low, indicating that the fixed effects and control variables were not very effective at accounting for the observed variability in response latencies. The final model conditional effect size estimates were 56.89% (Block 1) and 51.17% (Block 2). Adding the variance accounted for by participant and item random effects increased the variance account for, but half of the observed variability remains unexplained by the model.

Discussion

In the present experiment, response accuracy was very high (97%) and not influenced by any of the fixed effects investigated. Meanwhile, number agreement response latency was influenced by Number in Blocks 1 and 2. Plural nouns had faster agreement response latencies than singular nouns (Block 1: 14 ms advantage; Block 2: 22 ms advantage). No other effects were significant in either block.

Our findings primarily contradict previously published research. A notable Collectivity effect has been observed for both response accuracy and response latency. Specifically, in a number decision experiment, Finnish participants classified 23% of singular collective nouns they saw as notionally plural (Nenonen & Niemi, 2010). Moreover, it took participants an additional 271 ms to make number decisions for collective nouns than non-collective nouns. In several number agreement studies, researchers have reported finding a higher prevalence of plural notional subject-verb agreement following singular animate collective subject nouns than singular non-collective subject nouns (Bock et al., 2004, 1999; Haskell & MacDonald, 2003; Humphreys & Bock, 2005; Staub, 2009). Furthermore, some of these studies found that participants were significantly slower at producing number agreement following singular collective subject nouns compared to singular non-collective subject nouns (Haskell & MacDonald, 2003; Staub, 2009). The direction of the Number effect in the current experiment disagrees with all noun dominance lexical decision experiments, which find a surface frequency effect for singular-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Instead, we find that determiner-noun number agreement was faster for plural nouns than singular nouns, despite the majority of items being singular-dominant. Finally, our observed null Animacy effect replicates what was found by Radanovíc and her colleagues (2016) in English and Serbian LDT experiments.

General Discussion

The current experiments expand our understanding of the surface frequency effect by examining the strength of this effect for singular-dominant collective and non-collective nouns in French and English. We had two goals: 1) to verify whether a surface frequency effect would be observed for collective nouns; and 2) to determine whether this effect would be found in a simple determiner-noun NAT.

In all response accuracy and response latency models, a series of control variables were tested in order to determine whether they modified our fixed effects of interest. These variables were written base frequency, mean noun length, noun-verb ratio, trial number, noun gender (in French only), and participant mother tongue (in English only). Four of these control variables influenced response accuracy and/or latency: Frequency, Length, Noun-verb ratio, and Trial number. However, none of these variables modified or nullified the fixed effects of interest discussed below.

In all three experiments there was a significant main effect of Number in Block 1 that persisted in Block 2. In Experiments 1 and 2, singular nouns were recognized faster than plural nouns (French: 34 ms advantage; English: 33 ms advantage). This finding replicates what has been reported for singular-dominant nouns in previous lexical decision studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). Effectively, there is a surface frequency effect for singular-dominant nouns; they are recognized faster when presented in their dominant form. In Experiment 3, the opposite pattern was observed. Participants were faster at producing determiner-noun number agreement for plural nouns than singular nouns (18 ms advantage). This finding was unexpected and contradicts the results of all the noun dominance LDT studies cited above. One possible explanation for this finding is the nature of the stimuli. All plural nouns ended in the plural marker *-s*, making it a perfect indicator of plural grammatical number. This may have led participants to devise response strategies based on grammatical number alone, ignoring all other noun characteristics. The most plausible response strategy is that participants focused solely on the end of a noun to determine grammatical number and then provided a number agreement response (*This* or *These*). Participants knew *-s* meant plural but may have taken longer to read singular nouns in full to verify their singular grammatical number before making a decision. It is important to add that in Experiment 3, there were significant two-way interactions between Number and the control variables Frequency and Length. In both blocks, singular nouns had faster response latencies the higher their written base frequency or the shorter their mean length. Frequency and Length had no impact on plural noun response latencies, lending further support to our proposed response strategy approach.

The Collectivity main effect was only significant in Experiment 2. In both blocks, English non-collective nouns were recognized faster than collective nouns (50 ms advantage averaged across block). There was also a significant and unexpected 8% response accuracy advantage for non-collective nouns over collective nouns. Together, these results imply that in English, collective nouns are harder to recognize than non-collective nouns. Our response latency pattern replicates what was found in a Finnish number decision experiment (Nenonen & Niemi, 2010). More precisely, the authors found that participants were 271 ms slower at making a notional number decision for collective nouns than non-collective nouns. In Experiment 3, the same nouns produced a null Collectivity effect for both response accuracy and response latency in a determiner-noun number agreement task. We failed to replicate the findings of subject-verb number agreement studies which report greater plural notional agreement and longer agreement response latencies following singular collective subject nouns than singular non-collective subject nouns (Bock et al., 2004, 1999; Haskell & MacDonald, 2003; Humphreys & Bock, 2005; Staub, 2009). Further, our null results also contradict the findings of Nenonen and Niemi (2010) who reported an increased incidence of plural notional number decisions for singular collective nouns and longer number decision response latencies. The null Collectivity effects found in Experiment 1 are not surprising given the fact that in French the grammatical and notional number of collective nouns always align (Joosten et al., 2007; Lammert, 2015). Our result suggests that French readers do not actively distinguish between collective and non-collective nouns during visual word recognition.

Similarly, the Animacy main effect was only significant in Experiment 2. In the English LDT, inanimate nouns were recognized faster than animate nouns in both blocks (25 ms advantage averaged across block). In addition, response accuracy was 3% higher for inanimate nouns than animate nouns. Therefore, the response latency advantage for inanimate nouns is not due to a speed-accuracy trade-off. This finding contradicts all previous animacy studies, which document either an animate noun advantage or a null animacy effect (Bonin et al., 2014, 2015; Desrochers et al., 2018; Nairne et al., 2013; Popp & Serra, 2016; VanArsdall et al., 2013, 2015, 2017). In Experiment 3, we found a non-significant Animacy effect in a determiner-noun number agreement paradigm, replicating what has been observed in English and Serbian LDT experiments (Radanović et al., 2016). Finally, the null Animacy effect observed in Experiment 1 conflicts with several French lexical and gender decision studies which find a speed advantage for animate nouns (Desrochers et al., 2018).

Lastly, we hypothesized that we would find a significant Animacy × Collectivity × Number three-way interaction in Experiments 2 and 3. We expected that all nouns except animate collective nouns would display a surface frequency effect. A significant three-way interaction was found in Experiment 2 in Block 2 only. However, the observed pattern did not match our expectation. Animate collective nouns had a stronger surface frequency effect than all other noun types (52 ms advantage vs. 18 – 36 ms advantage). This finding indicates that although English animate collective nouns have a stronger surface frequency effect than English inanimate collective nouns they do not dramatically differ from one another, despite the notional number ambiguity associated with singular animate collective nouns. In Experiment 3, the three-way interaction was not significant.

Limitations and Future Directions

The main limitation in the present experiments is that there is only one highly regular plural marker in both languages, the inflectional suffix *-s*. Consequently, it likely acted as a faciliatory feature to inspire participants to adopt an ending specific response strategy when completing Experiment 3. In addition, as a consequence of the limited number of collective nouns that exist in both French and English, a small number of nouns used in our experiments were not singular-dominant (see Appendices A and B).

To deal with the plural marker limitation, future studies may benefit from incorporating nouns that have less common plural markers (e.g., -× in French or -*a* or -*i* in English). Adding an eye tracking element (e.g., Colé, Pynte, & Andriamamonjy, 2003) may help identify readers' response strategies. In order to gain further insight into the role of collectivity and surface frequency in noun recognition and determiner-noun agreement, it would be useful to conduct English and French replication studies as well as extend these experiments to other languages.

Conclusion

Together, these three experiments provide some initial insight into how individual collective nouns are processed. Our results from Experiments 1 and 2 indicate that readers attend to noun collectivity information during visual word recognition in English, but not in French. They also replicate previous lexical decision research, which finds a surface frequency effect for singular-dominant nouns; singular nouns are recognized faster than plural nouns. Finally, they reveal that the importance of noun animacy in visual word recognition is not as strong as it is in memory recall tasks. In Experiment 3, we find that neither noun collectivity or animacy influence determiner-noun number agreement when grammatical number is easily identifiable through a reliable plural marker. Given the limited breadth of research surrounding noun collectivity and animacy, much more research is needed to gain a proper understanding of how these types of nouns are processed by readers.

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Table 1

English and French Noun Characteristics

	English				French			
	Collective nouns		Non-collective nouns		Collective nouns		Non-collective nouns	
	Animate (n = 43)	Inanimate (n = 43)	Animate (n = 43)	Inanimate (n = 43)	Animate (n = 56)	Inanimate (n = 56)	Animate (n = 56)	Inanimate (n = 56)
Noun length	6.28	6.33	6.30	6.30	7.64	7.73	7.63	7.63
Number of phonemes	5.16	5.12	5.09	5.21	6.05	5.84	5.89	5.79
Number of syllables	2.00	1.95	2.00	2.00	2.55	2.48	2.34	2.38
Number of masculine nouns					27	27	27	27
Singular surface frequency	15.23	14.49	15.21	14.56	18.28	18.21	18.15	18.14
Plural surface frequency	4.19	4.95	4.47	5.00	4.08	4.18	3.97	4.08
Noun dominance ratio	4.62	4.10	5.06	3.53	10.94	5.37	8.13	5.83

Note. Means for noun length, number of phonemes, and number of syllables are based on the singular form of the nouns.

Table 2

Experiment 1 French LDT: Response Accuracy Results

Random effects						
Group	Name	Variance	*SD*	*r*		
NounID	(Intercept)	3.02	1.74			
PartID	(Intercept)	0.53	0.73			
	Collectivity	0.05	0.22	-0.36		
	Animacy	0.16	0.41	-0.24	-0.07	
	Collectivity × Animacy	0.30	0.54	0.04	-0.67	-0.48
		Number of observations: 27528; Groups: NounID, 222; PartID, 62				

Fixed effects			
	b	*SE*	*z*
(Intercept)	3.83	0.17	22.19^{***}
Control variables			
Frequency	2.94	0.25	11.58^{***}
Length	0.28	0.07	4.16^{***}
Fixed effects			
Animacy	0.02	0.27	0.93
Collectivity	-0.47	0.26	0.08^{T}
Number	-0.07	0.05	0.15
Interaction			
Frequency × Length	0.26	0.11	2.27^{*}

Note. Frequency = noun written base frequency; Length = mean noun length.

^{T} $p < .10$. * $p < .05$. *** $p < .001$.

Table 3

Response Accuracy Descriptive Statistics

Number	Collective nouns				Non-collective nouns			
	Singular		Plural		Singular		Plural	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
French LDT								
Animate	87.15%	6.00%	86.35%	6.11%	91.25%	4.60%	90.92%	5.35%
Inanimate	86.69%	5.60%	86.87%	5.08%	89.11%	5.83%	88.31%	5.56%
English LDT								
Animate	87.04%	7.71%	85.91%	8.28%	95.11%	4.55%	93.78%	4.97%
Inanimate	90.53%	6.31%	89.26%	6.60%	96.75%	3.39%	96.58%	3.25%
English Number Agreement Task								
Animate	96.63%	3.66%	96.93%	3.58%	97.26%	3.08%	96.47%	3.26%
Inanimate	96.89%	3.24%	96.55%	3.68%	97.78%	3.05%	97.30%	2.80%

Table 4

Experiment 1 French LDT: Response Latency Random Effect Results

		Block 1					Block 2				
Group	Name	Variance	*SD*	*r*			Variance	*SD*	*r*		
NounID	(Intercept)	173.70^{-10}	13.18^{-5}				173.50^{-10}	13.17^{-5}			
	Number	11.85^{-10}	3.44^{-5}	-0.06			1.21^{-10}	1.10^{-5}	0.20		
PartID	(Intercept)	537.10^{-10}	23.18^{-5}				512.40^{-10}	22.64^{-5}			
	Collectivity	12.57^{-10}	3.55^{-5}	-0.03			11.85^{-10}	3.44^{-5}	-0.39		
	Animacy	20.78^{-10}	4.56^{-5}	-0.17	0.19		8.91^{-10}	2.99^{-5}	-0.36	0.29	
	Animacy × Collectivity	8.89^{-10}	2.98^{-5}	0.75	-0.22	0.44	9.78^{-10}	3.13^{-5}	0.10	0.00	-0.66
Residual		863.70^{-10}	29.39^{-5}				882.00^{-10}	29.70^{-5}			
		Number of observations: 11616					Number of observations: 11801				
		Groups: NounID, 222; PartID, 62					Groups: NounID, 222; PartID, 62				

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 5

Experiment 1 French LDT: Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1428^{-6}	31.15^{-6}	-45.85^{***}	---	---	-1532^{-6}	30.59^{-6}	-50.06^{***}	---	---
Control variables										
Frequency	-206.90^{-6}	16.62^{-6}	-12.45^{***}	-239.38^{-6}	-174.49^{-6}	-205.10^{-6}	16.60^{-6}	-12.35^{***}	-232.81^{-6}	-161.72^{-6}
Length	11.34^{-6}	4.66^{-6}	2.44^{*}	2.24^{-6}	20.44^{-6}	11.15^{-6}	4.65^{-6}	2.40^{*}	105.82^{-6}	366.38^{-6}
Trial	-0.05^{-6}	0.02^{-6}	-2.24^{*}	-0.09^{-6}	-0.01^{-6}	-0.05^{-6}	0.02^{-6}	-2.38^{*}	-7.15^{-6}	214.99^{-6}
Fixed effects										
Animacy	14.48^{-6}	19.64^{-6}	0.74	-23.86^{-6}	-52.81^{-6}	26.31^{-6}	19.13^{-6}	1.38	-80.51^{-6}	-14.66^{-6}
Collectivity	12.24^{-6}	19.17^{-6}	0.64	-25.15^{-6}	49.65^{-6}	13.96^{-6}	19.12^{-6}	0.73	68.29^{-6}	133.84^{-6}
Number	61.71^{-6}	6.01^{-6}	10.28^{***}	49.84^{-6}	73.55^{-6}	56.14^{-6}	5.58^{-6}	10.06^{***}	44.38^{-6}	72.86^{-6}
Interactions										
Collectivity × Number	-2.45^{-6}	12.00^{-6}	-0.20	-25.97^{-6}	21.09^{-6}	-23.44^{-6}	11.16^{-6}	-2.10^{*}	-42.62^{-6}	14.22^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

* $p < .05$. *** $p < .001$.

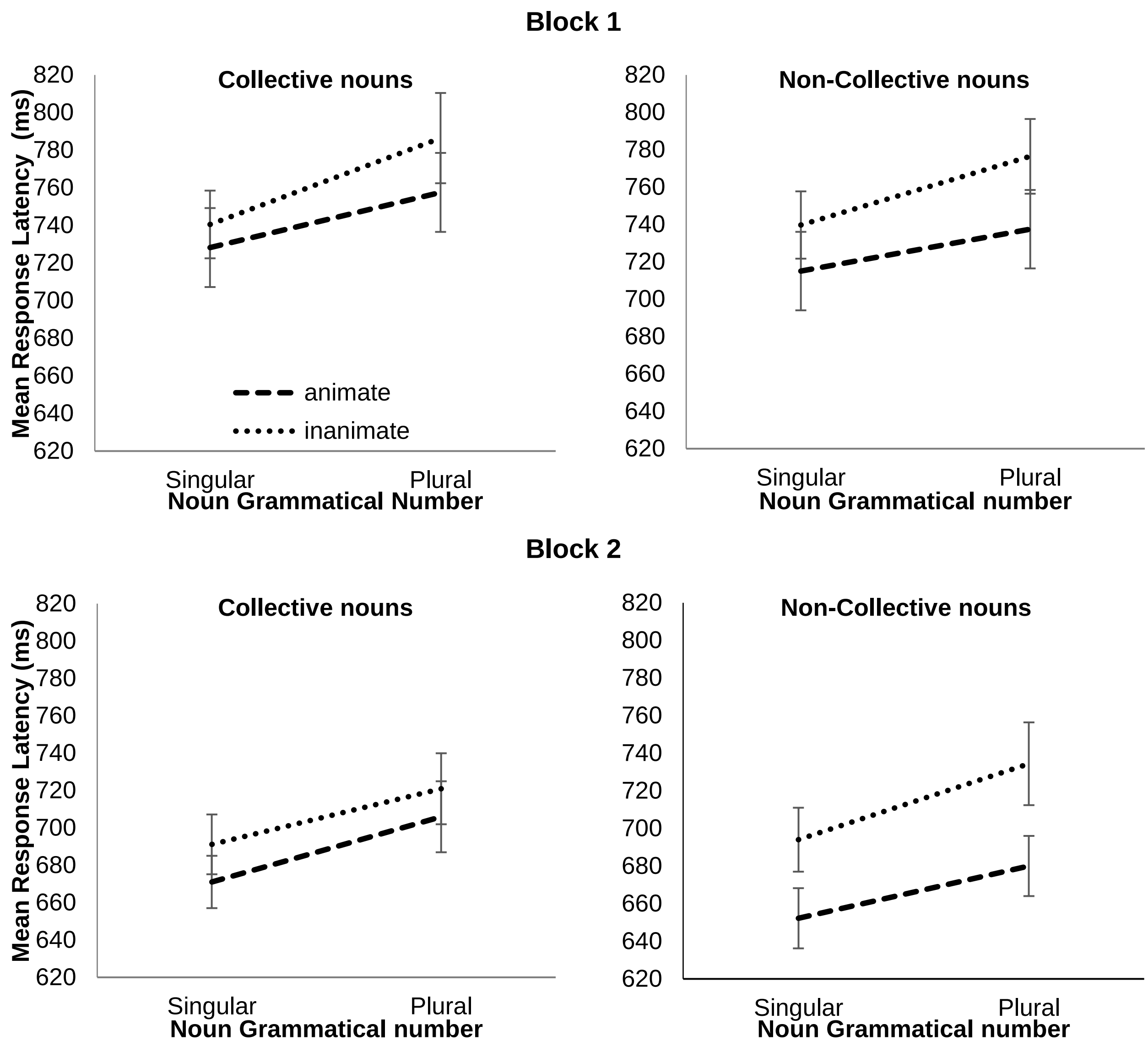

Figure 1. French LDT mean response latencies as a function of block number, noun collectivity, grammatical number, and noun animacy. Error bars represent standard error of the means.

Table 6

Response Latency Descriptive Statistics

Number	Block 1								Block 2							
	Collective nouns				Non-collective nouns				Collective nouns				Non-collective nouns			
	Singular		Plural		Singular		Plural		Singular		Plural		Singular		Plural	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
French LDT																
Animate	728	168	758	162	715	169	738	165	671	112	706	147	652	123	680	124
Inanimate	741	138	786	189	740	138	776	159	691	128	721	147	694	131	734	171
English LDT																
Animate	720	126	771	163	672	114	693	123	669	101	721	180	631	99	651	113
Inanimate	691	114	716	120	640	97	685	130	661	114	679	123	610	103	646	100
English Number Agreement Task																
Animate	685	267	683	293	649	175	652	222	645	226	632	217	625	174	612	204
Inanimate	688	260	649	234	666	211	647	221	635	180	620	247	627	179	608	196

Table 7

Experiment 2 English LDT: Response Accuracy Results

Random effects						
Group	Name	Variance	*SD*	*r*		
NounID	(Intercept)	1.99	1.41			
	Number	0.23	0.48	-0.32		
PartID	(Intercept)	0.67	0.82			
	Collectivity	0.10	0.31	0.44		
	Animacy	0.16	0.40	-0.08	-0.43	
	Animacy × Collectivity	0.44	0.66	0.26	-0.07	-0.34
		Number of observations: 23392; Groups: NounID, 172; PartID, 68				

Fixed effects			
	b	*SE*	*z*
(Intercept)	3.98	0.16	24.31***
Control variables			
Frequency	2.84	0.30	9.58***
Length	2.13	0.96	2.22*
Fixed effects			
Animacy	0.64	0.25	2.57*
Collectivity	-1.05	0.25	-4.23***
Number	-0.31	0.10	3.17**

Note. Frequency = noun written base frequency; Length = mean noun length.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 8

Experiment 2 English LDT: Response Latency Random Effect Results

		Block 1			Block 2		
Group	Name	Variance	*SD*	*r*	Variance	*SD*	*r*
NounID	(Intercept)	130.70^{-10}	11.43^{-5}		105.90^{-10}	10.29^{-5}	
	Number	40.86^{-10}	6.39^{-5}	0.11	23.59^{-10}	4.86^{-5}	0.61
PartID	(Intercept)	396.80^{-10}	19.92^{-5}		460.90^{-10}	21.47^{-5}	
	Collectivity	8.95^{-10}	2.99^{-5}	-0.13			
	Animacy				4.65^{-10}	2.16^{-5}	-0.29
Residual		943.50^{-10}	30.72^{-5}		1017^{-10}	31.89^{-5}	
		Number of observations: 10255			Number of observations: 10424		
		Groups: NounID, 172; PartID, 68			Groups: NounID, 172; PartID, 68		

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 9

Experiment 2 English LDT: Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1531^{-6}	25.87^{-6}	-59.19***			-1627^{-6}	27.38^{-6}	-59.44***		
Control variables										
Frequency	-22.70^{-6}	21.02^{-6}	-10.80***	-267.41^{-6}	-186.46^{-6}	-197.40^{-6}	18.48^{-6}	-10.68***	-232.81^{-6}	-161.72^{-6}
Length	272.70^{-6}	76.96^{-6}	3.54***	124.51^{-6}	421.05^{-6}	235.60^{-6}	67.53^{-6}	3.49***	105.82^{-6}	366.38^{-6}
N-V ratio	172.30^{-6}	65.45^{-6}	2.63***	45.86^{-6}	298.64^{-6}	104.30^{-6}	57.39^{-6}	1.82^{T}	-7.15^{-6}	214.99^{-6}
Fixed effects										
Animacy	-64.98^{-6}	18.71^{-6}	-3.47***	-100.97^{-6}	-28.98^{-6}	-47.79^{-6}	17.30^{-6}	-2.76**	-80.51^{-6}	-14.66^{-6}
Collectivity	11.07^{-6}	18.97^{-6}	5.84***	74.13^{-6}	147.16^{-6}	101.10^{-6}	17.02^{-6}	5.94***	68.29^{-6}	133.84^{-6}
Number	63.79^{-6}	7.84^{-6}	8.14***	48.51^{-6}	79.10^{-6}	58.51^{-6}	7.29^{-6}	8.03***	44.38^{-6}	72.86^{-6}
Interactions										
Animacy × Length	-311.10^{-6}	15.00^{-6}	-2.07*	-599.96^{-6}	-22.76^{-6}	-296.90^{-6}	131.50^{-6}	-2.26*	-553.77^{-6}	-40.62^{-6}
Animacy × Number	9.17^{-6}	15.67^{-6}	0.59	-21.36^{-6}	39.70^{-6}	2.47^{-6}	14.58^{-6}	0.17	-25.89^{-6}	30.93^{-6}
Collectivity × Animacy	-45.77^{-6}	37.54^{-6}	-1.22	-117.99^{-6}	26.43^{-6}	-11.70^{-6}	34.30^{-6}	-0.34	-77.45^{-6}	54.62^{-6}

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
Collectivity × Frequency	-83.31^{-6}	41.76^{-6}	-2.00^{*}	-163.64^{-6}	-2.83^{-6}	-60.58^{-6}	36.70^{-6}	-1.65^{T}	-131.94^{-6}	10.42^{-6}
Collectivity × Number	-4.71^{-6}	15.67^{-6}	-0.30	-35.22^{-6}	25.83^{-6}	-14.19^{-6}	14.58^{-6}	-0.97	-42.62^{-6}	14.22^{-6}
Animacy × Collectivity × Number	-48.66^{-6}	31.34^{-6}	-1.55	-109.73^{-6}	12.38^{-6}	-77.97^{-6}	29.16^{-6}	-2.67^{**}	-134.63^{-6}	-20.97^{-6}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

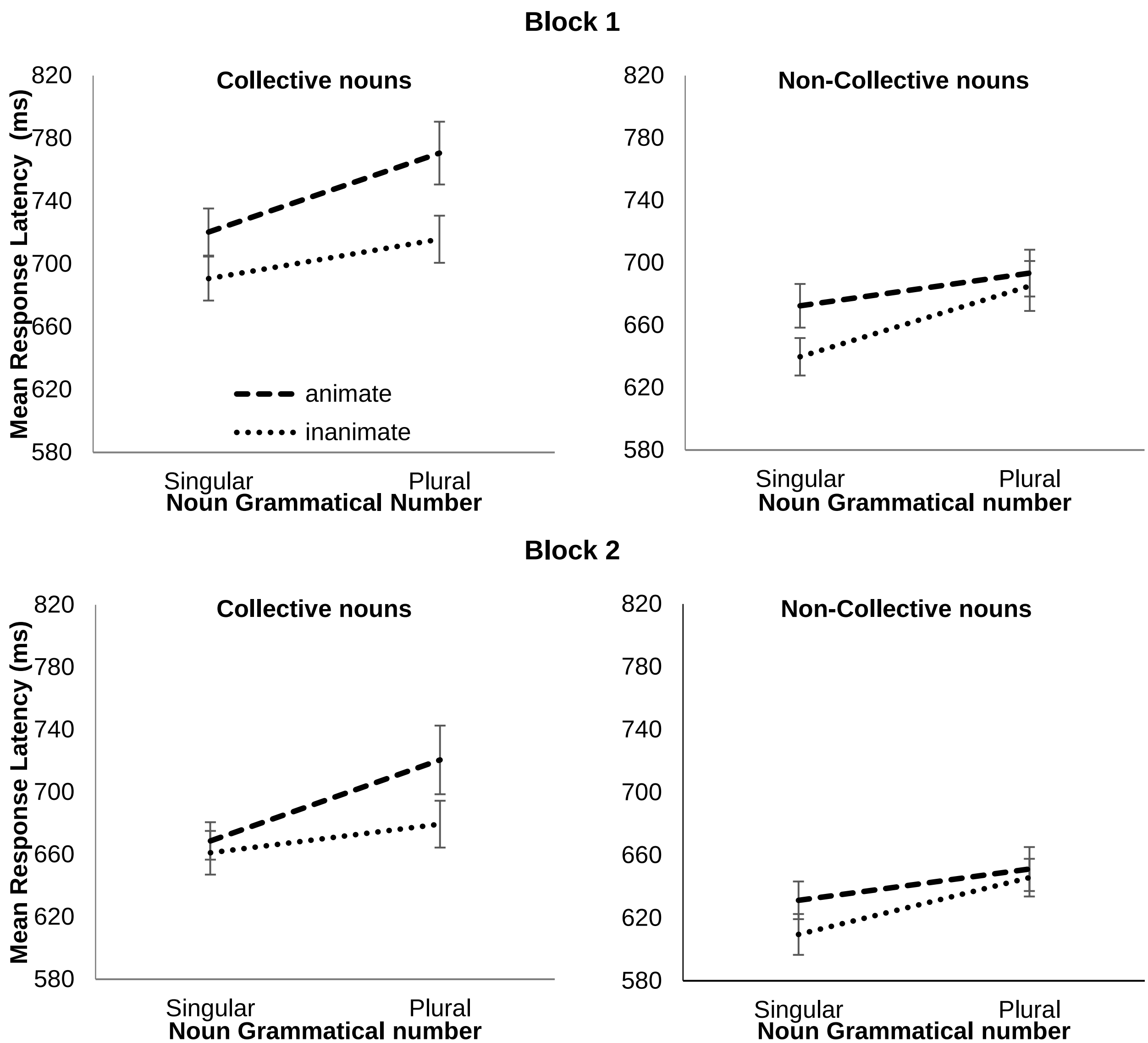

Figure 2. English LDT mean response latencies as a function of block number, noun collectivity, grammatical number, and noun animacy. Error bars represent standard error of the means.

Table 10

Experiment 3 English Number Agreement Task: Response Latency Random Effect Results

		Block 1			Block 2		
Group	Name	Variance	*SD*	*r*	Variance	*SD*	*r*
NounID	(Intercept)	9.81^{-10}	3.13^{-5}		3.13^{-10}	1.77^{-5}	
	Number	12.72^{-10}	3.57^{-5}	-0.16			
PartID	(Intercept)	1835^{-10}	42.83^{-5}		1864^{-10}	43.17^{-5}	
	Collectivity				3.64^{-10}	1.91^{-5}	0.20
Residual		1427^{-10}	37.77^{-5}		1821^{-10}	42.68^{-5}	
		Number of observations: 9119			Number of observations: 9122		
		Groups: NounID, 172; PartID, 56			Groups: NounID, 172; PartID, 56		

Note. $^{-5}$ and $^{-10}$ are shorthand for $\times 10^{-5}$ and $\times 10^{-10}$ scientific notations.

Table 11

Experiment 3 English Number Agreement Task: Response Latency Fixed Effect Results

	Block 1					Block 2				
				95% *CI*					95% *CI*	
	b	*SE*	*t*	Lower	Upper	*b*	*SE*	*t*	Lower	Upper
(Intercept)	-1688^{-6}	57.84^{-6}	-29.18^{***}			-1790^{-6}	58.41^{-6}	-30.65^{***}		
Control variables										
Frequency	-37.94^{-6}	10.47^{-6}	-3.62^{***}	-58.26^{-6}	-17.60^{-6}	-20.96^{-6}	10.60^{-6}	-1.98^{*}	-41.55^{-6}	-0.37^{-6}
Length	256.20^{-6}	37.51^{-6}	6.83^{***}	183.42^{-6}	329.09^{-6}	151.60^{-6}	37.85^{-6}	4.01^{***}	78.09^{-6}	225.12^{-6}
Trial	-0.56^{-6}	0.08^{-6}	-7.00^{***}	-0.72^{-6}	-0.40^{-6}	-0.48^{-6}	0.09^{-6}	-5.26^{***}	-0.65^{-6}	-0.30^{-6}
Fixed effects										
Animacy	-13.58^{-6}	9.27^{-6}	-1.47	-31.63^{-6}	4.47^{-6}	-9.45^{-6}	9.37^{-6}	-1.01	-27.65^{-6}	8.76^{-6}
Collectivity	10.78^{-6}	9.24^{-6}	1.17	-7.17^{-6}	28.72^{-6}	16.34^{-6}	9.68^{-6}	1.69^{T}	-2.60^{-6}	35.29^{-6}
Number	-52.92^{-6}	8.37^{-6}	-6.32^{***}	-69.27^{-6}	-36.73^{-6}	-74.26^{-6}	8.94^{-6}	-8.31^{***}	-91.77^{-6}	-56.73^{-6}
Interactions										
Animacy × Length	1.27^{-6}	74.66^{-6}	0.02	-143.80^{-6}	146.28^{-6}	256.70^{-6}	75.40^{-6}	3.41^{***}	1100.25^{-6}	403.11^{-6}
Number × Frequency	25.81^{-6}	18.89^{-6}	1.37	-11.08^{-6}	62.74^{-6}	52.15^{-6}	20.22^{-6}	2.58^{**}	12.53^{-6}	91.78^{-6}

Number × Length	-39.84^{-6}	68.37^{-6}	-5.83***	-531.88^{-6}	-264.74^{-6}	-539.80^{-6}	72.92^{-6}	-7.40***	-682.66^{-6}	-396.85^{-6}

Note. $^{-6}$ is shorthand for × 10^{-6} scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

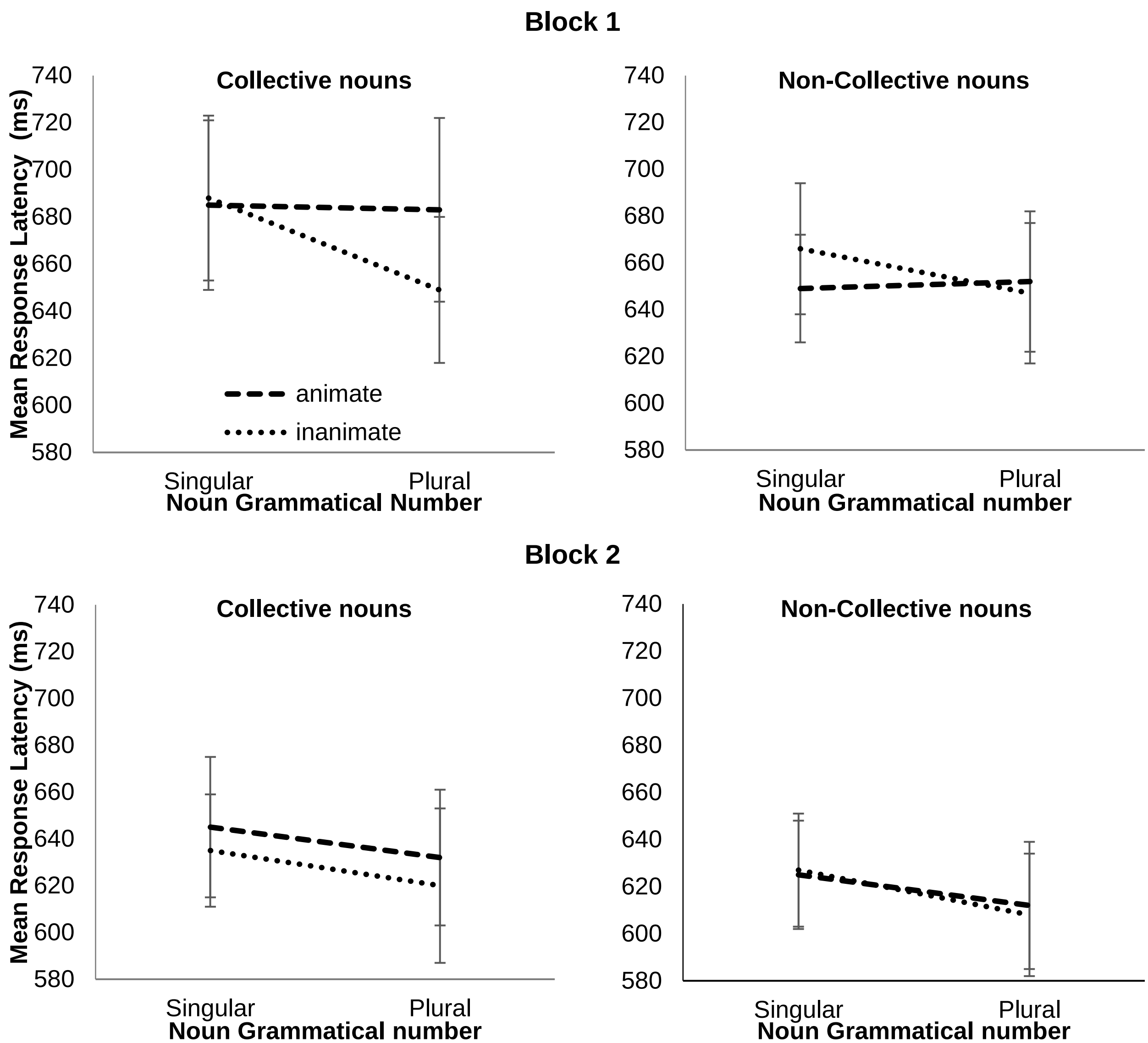

Figure 3. English Number agreement task mean response latencies as a function of block number, noun collectivity, grammatical number, and noun animacy. Error bars represent standard error of the means.

Appendix A

French Experimental Stimuli (Gender)

Collective animate nouns: agglomération (f), armée[v] (f), association (f), attroupement (m), audience (f), auditoire (m), bataillon[v] (m), brigade (f), caravane (f), cavalcade (f), chœur (m), clan (m), clergé (m), cohorte (f), colonie (f), communauté (f), commune (f), congrégation (f), cortège (m), coterie (f), couple[v] (m), défilé (m), délégation (f), duo (m), élite (f), entourage (m), équipage (m), escadrille[!] (f), escadron (m), escouade (f), essaim (m), famille (f), gang (m), garnison (f), gouvernement (m), harde[!] (f), harem (m), horde (f), jury (m), légion (f), ménagerie (f), milice (f), minorité (f), orchestre[v] (m), patrouille[v] (f), peloton (m), personnel (m), peuple[v] (m), population (f), prolétariat (m), quatuor (m), quintette (m), régiment (m), royauté (f), ruche (f), troupeau (m)

Collective inanimate nouns: accumulation (f), album (m), amalgame[v] (m), amoncellement (m), anthologie (f), archipel (m), arsenal (m), assemblage (m), assiettée[!] (f), assortiment (m), bosquet[!] (m), bottin (m), bouquet (m), brassée[v] (f), cargaison (f), catalogue[v] (m), chaîne (f), collage (m), collection (f), conglomérat (m), constellation (f), convoi (m), enchaînement (m), enfilade (f), flopée (f), flottille (f), flotte[v] (f), forêt (f), fortune (f), fournée (f), galaxie (f), gerbe[!v] (f), grappe[!] (f), gréement (m), groupement (m), inventaire (m), jardin (m), lexique (m), liasse (f), lot (m), magot (m), mosaïque (f), myriade[–] (f), neuvaine[!] (f), panoplie (f), pelletée[!] (f), plantation (f), pluie (f), rassemblement (m), série (f), syndicat (m), touffe[!] (f), train (m), trésor (m), variété (f), verger (m)

Non-collective animate nouns: amant (m), ambassadeur (m), araignée (f), baron (m), biquette (f), boulanger[v] (m), canaille (f), caniche (m), cantatrice (f), cardinal (m), civière (f), commère[!] (f), comtesse (f), conducteur (m), crapule (f), écureuil (m), étudiante (f), fauvette (f), fiancée[v] (f), forestier (m), forgeron (m), fripouille (f), gamine (f), garçon (m), gardienne (f), gazelle (f), géante (f), gouverneur (m), idiote (f), idole (f), infirmière (f), inspecteur (m), instituteur (m), institutrice (f), jardinier (m), lézard (m), maire (m), maman (f), marraine (f), matrone (f), mulot (m), musaraigne (f), oncle (m), organisme (m), pasteur (m), patriarche (m), pépé (m), poète (m), princesse (f), proviseur (m), roi (m), servante (f), starlette[!] (f), tonton (m), vierge (f), voisine[v] (f)

Non-collective inanimate nouns: ascenseur (m), auberge (f), babiole[!] (f), banquet (m), barricade[!v] (f), bibliothèque (f), bistouri (m), braise[!v] (f), cabochon (m), cachette[v] (f), caméra (f), canonnière (f), capot (m), carrée[v] (f), catapulte[!v] (f), ceinturon (m), chaudron (m), chaufferette (f), chemisette (f), clarine[!] (f), coin (m), côte (f), couteau (m), décoration (f), démarreur (m), emballage (m), émeraude (f), encrier (m), exemplaire[!] (m), gravelle (f), guichet (m), hélice (f), landau (m), lisière (f), literie (f), lumière (f), maillon[v] (m), mallette (f), manchon (m), matériel (m), matière (f), menuet (m), mirage (m), mosquée (f), mousseline (f), muselière (f), nid (m), ouvrage[v] (m), parloir (m), passerelle (f), pelure (f), perchoir (m), quartier (m), sermon (m), serviette (f), tisonnier (m)

Note: [!] designates nouns that are not singular-dominant; [v] Items that have a verb equivalent in French.

Appendix B

English Experimental Stimuli

Collective animate nouns: alliance, assemblage, battalion, bloc, brigade, caravan, choir, clan, clique, coalition, cohort[!], colony, congregation, council, crew[v], crowd[v], delegation, drove[!v], elite, faction, federation, flock[v], folk, gang, garrison, herd[v], horde[!], jury, league, minority, mob[v], orchestra, parade[v], platoon, quartet, queue[v], regiment[v], sect, shoal[v], squadron, swarm[!v], team, tribe

Collective inanimate nouns: accumulation, album, alloy[!], array[v], bale[!], barrage, batch, blob, bouquet, bunch[v], bundle[v], bushel[!], cargo, chain[v], cloud[v], clump[v], cluster[v], collection, conglomerate[!], constellation, convoy, fleet, forest, formation, galaxy, garden[v], grove, heap[v], inventory, jungle, mosaic, multitude, myriad[!], orchard, pile[v], plantation[!], rain[v], rash, stack[v], thicket, treasure[v], tuft[!], wad

Non-collective animate nouns: ambassador, archer, architect, assistant, attorney, aunt, author, barber, beast, bishop, bride, bull, butterfly[!], canary, chancellor, chief, colonel, constable, cop[v], cynic[!], donkey, dreamer, earl, heir, host[v], listener, lunatic, mare, matron, monarch, nanny, novice, nymph, photographer, robin, sergeant, shrew, sister, squirrel, suitor[!], toad, traitor, winner

Non-collective inanimate nouns: affinity, anchor[v], award[v], boulevard, brochure, calendar, cemetery, chair[v], chant[v], college, concert, correction, crease[v], dome, echo[v], emerald[!], enchantment, fence[v], guitar, hurricane, knob, lawn, melody, mirror[v], paradox, parlour, pencil[v], porch, prison, receipt, robe[v], safe, sash, secret, signal[v], signature, slogan, steamer, steeple, triangle, wand, wicket[!], yolk

Note: [!] designates nouns that are not singular-dominant; [v] Items that have a verb equivalent in English.

Appendix C

Table C1

Experiment 1 French LDT: Response Latency Collectivity × Number Block 2 Interaction Fixed Effect Results

	Collective nouns			Non-collective nouns		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1531^{-6}	32.16^{-6}	-47.62^{***}	-1532^{-6}	32.70^{-6}	-46.85^{***}
Control variables						
Frequency	-200.60^{-6}	25.68^{-6}	-7.81^{***}	-210.20^{-6}	21.10^{-6}	-9.96^{***}
Length	10.56^{-6}	6.59^{-6}	1.60	11.97^{-6}	6.58^{-6}	1.82^{T}
Trial	-0.02^{-6}	0.03^{-6}	-0.60	-0.09^{-6}	0.03^{-6}	-2.82^{**}
Fixed effects						
Animacy	4.34^{-6}	29.14^{-6}	0.15	48.88^{-6}	24.38^{-6}	2.01^{*}
Number	44.31^{-6}	7.83^{-6}	5.66^{***}	68.11^{-6}	8.22^{-6}	8.28^{***}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix D

Table D1

Experiment 2 English LDT: Response Accuracy Collectivity × Frequency Interaction Fixed Effect Results

	Collective nouns			Non-collective nouns		
	b	*SE*	*z*	*b*	*SE*	*z*
(Intercept)	3.49	0.20	17.11^{***}	4.42	0.21	21.18^{***}
Control variables						
Frequency	3.35	0.40	8.48^{***}	2.19	0.42	5.25^{***}
Length	2.34	1.22	1.92^{T}	1.96	1.46	1.35
Fixed effects						
Animacy	0.75	0.33	2.26^{*}	0.47	0.36	1.32
Number	-0.29	0.12	-2.53^{*}	-0.33	0.16	-2.00^{*}

Note. Frequency = noun written base frequency; Length = mean noun length.

^{T} $p < .10$. * $p < .05$. *** $p < .001$.

Table D2

Experiment 2 English LDT: Response Latency Animacy × Length Interaction Fixed Effect Results

	Block 1						Block 2					
	Animate nouns			Inanimate nouns			Animate nouns			Inanimate nouns		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1499^{-6}	28.83^{-6}	-52.01***	-1566^{-6}	26.43^{-6}	-59.25***	-1604^{-6}	29.34^{-6}	-54.69***	-1653^{-6}	28.16^{-6}	-58.68***
Control variables												
Frequency	-226.50^{-6}	34.02^{-6}	-6.66***	-231.00^{-6}	26.80^{-6}	-8.62***	-20.15^{-6}	29.90^{-6}	-6.74***	-197.70^{-6}	23.62^{-6}	-8.37***
Length	433.00^{-6}	112.90^{-6}	3.84***	116.10^{-6}	105.60^{-6}	1.10	374.90^{-6}	98.93^{-6}	3.79***	95.76^{-6}	92.80^{-6}	1.03
N-V ratio	246.50^{-6}	109.40^{-6}	2.25*	104.70^{-6}	81.56^{-6}	1.28	17.58^{-6}	95.61^{-6}	1.84^{T}	53.55^{-6}	71.62^{-6}	0.75
Fixed effects												
Collectivity	137.00^{-6}	28.87^{-6}	4.75***	96.35^{-6}	24.97^{-6}	3.86***	10.23^{-6}	25.34^{-6}	4.04***	114.80^{-6}	22.43^{-6}	5.12***
Number	58.22^{-6}	11.38^{-6}	5.12***	69.35^{-6}	10.93^{-6}	6.35***	56.34^{-6}	9.51^{-6}	5.93***	60.79^{-6}	11.44^{-6}	5.32***

Note. $^{-6}$ is shorthand for × 10^{-6} scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio.

^{T} $p < .10$. * $p < .05$. *** $p < .001$.

Table D3

Experiment 2 English LDT: Response Latency Collectivity × Frequency Block 1 Interaction Fixed Effect Results

	Collective nouns			Non-collective nouns		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1476^{-6}	27.17^{-6}	-54.32^{***}	-1586^{-6}	28.06^{-6}	-56.52^{***}
Control variables						
Frequency	-267.80^{-6}	29.02^{-6}	-9.23^{***}	-182.40^{-6}	30.93^{-6}	-5.90^{***}
Length	342.60^{-6}	101.00^{-6}	3.39^{***}	199.50^{-6}	119.60^{-6}	1.67^{T}
N-V ratio	201.20^{-6}	82.43^{-6}	2.44^{*}	104.00^{-6}	107.20^{-6}	0.97
Fixed effect						
Animacy	-85.24^{-6}	25.57^{-6}	-3.33^{***}	-49.04^{-6}	28.48^{-6}	-1.72^{T}
Number	61.61^{-6}	11.19^{-6}	5.51^{***}	66.00^{-6}	10.98^{-6}	6.01^{***}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written base frequency; Length = mean noun length; N-V ratio = noun-verb ratio.

^{T} $p < .10$. * $p < .05$. *** $p < .001$.

Appendix E

Table E1

Experiment 3 English Number Agreement Task: Response Accuracy Results

Random effects				
Group	Name	Variance	*SD*	*r*
NounID	(Intercept)	0.01	0.09	---
PartID	(Intercept)	0.53	0.73	---
	Animacy	0.02	0.14	0.32
		Number of observations: 19264; Groups: NounID, 172; PartID, 56		

Fixed effects			
	b	*SE*	*z*
(Intercept)	3.72	0.11	33.22^{***}
Animacy	0.14	1.29	1.29
Block	0.16	0.08	1.89^{T}
Collectivity	-0.16	0.09	-1.87^{T}
Number	-0.12	0.08	-1.38

^{T} $p < .10$. *** $p < .001$.

Table E2

Experiment 3 English Number Agreement Task: Response Latency Number × Frequency and Number × Length Interaction Fixed Effect Results

	Block 1						Block 2					
	Singular nouns			Plural nouns			Singular nouns			Plural nouns		
	b	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1668^{-6}	55.80^{-6}	-29.90^{***}	-1706^{-6}	61.83^{-6}	-27.58^{***}	-1756^{-6}	55.56^{-6}	-31.61^{***}	-1821^{-6}	63.41^{-6}	-28.71^{***}
Control variables												
Frequency	-50.16^{-6}	14.34^{-6}	-3.50^{***}	-25.51^{-6}	13.95^{-6}	-1.83^{T}	-46.99^{-6}	13.10^{-6}	-3.59^{***}	3.01^{-6}	16.94^{-6}	0.18
Length	461.80^{-6}	52.00^{-6}	8.88^{***}	61.07^{-6}	50.05^{-6}	1.22	426.20^{-6}	47.24^{-6}	9.02^{***}	-112.40^{-6}	60.75^{-6}	-1.85^{T}
Trial	-0.47^{-6}	0.11^{-6}	-4.19^{***}	-0.66^{-6}	0.11^{-6}	-5.83^{***}	-0.43^{-6}	0.12^{-6}	-3.64^{***}	-0.55^{-6}	0.14^{-6}	-4.02^{***}
Fixed effect												
Animacy	-5.12^{-6}	12.73^{-6}	-0.40	-21.59^{-6}	12.34^{-6}	-1.75^{T}	-3.14^{-6}	11.61^{-6}	-0.27	-17.00^{-6}	14.96^{-6}	-1.14
Collectivity	11.84^{-6}	12.69^{-6}	0.93	9.48^{-6}	12.30^{-6}	0.77	14.20^{-6}	13.92^{-6}	1.02	18.05^{-6}	16.05^{-6}	1.12

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. CI = confidence interval; Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

^{T} $p < .10$. *** $p < .001$.

Table E3

Experiment 3 English Number Agreement Task: Response Latency Animacy × Length Block 2 Interaction Fixed Effect Results

	Animate nouns			Inanimate nouns		
	b	*SE*	*t*	*b*	*SE*	*t*
(Intercept)	-1776^{-6}	59.82^{-6}	-29.69^{***}	-1805^{-6}	58.52^{-6}	-30.84^{***}
Control variables						
Frequency	-22.43^{-6}	16.60^{-6}	-1.35	-20.11^{-6}	13.79^{-6}	-1.46
Length	22.37^{-6}	55.68^{-6}	0.40	279.30^{-6}	52.22^{-6}	5.35^{***}
Trial	-0.58^{-6}	0.14^{-6}	-4.32^{***}	-0.36^{-6}	0.12^{-6}	-2.98^{**}
Fixed effect						
Collectivity	18.14^{-6}	13.99^{-6}	1.30	14.87^{-6}	12.80^{-6}	1.16
Number	-66.00^{-6}	13.37^{-6}	-4.94^{***}	83.14^{-6}	11.89^{-6}	-6.99^{***}
Interaction						
Number × Length	-693.00^{-6}	106.50^{-6}	-6.51^{***}	-41.57^{-6}	98.63^{-6}	-4.21^{***}

Note. $^{-6}$ is shorthand for $\times 10^{-6}$ scientific notation. Frequency = noun written base frequency; Length = mean noun length; Trial = trial number.

** $p < .01$. *** $p < .001$.

General Discussion

The primary objective of this doctoral thesis is to expand our understanding of the surface frequency effect on lexical and morpho-syntactic processing in French and English. Several researchers have used noun number dominance to investigate how different parameters of word frequency impact word recognition and naming. In lexical decision studies, they have found that singular-dominant nouns display a surface frequency effect while plural-dominant nouns do not (Baayen, Burani, & Schreuder, 1997; Baayen, Dijkstra, & Schreuder, 1997; Domínguez, Cuetos, & Segui, 1999; New, Brysbaert, Segui, Ferrand, & Rastle, 2004; Reifegerste, Meyer, & Zwitserlood, 2017; Sereno & Jongman, 1997). More precisely, singular-dominant nouns are recognized faster in their singular form (i.e., their more frequent form) than in their plural form. Meanwhile, plural-dominant nouns display no such discrepancy. Recently, the singular-dominant noun surface frequency effect has been replicated in a series of picture naming studies (Beyersmann, Dutton, Amer, Schiller, & Biedermann, 2015; Biedermann, Beyersmann, Mason, & Nickels, 2013; although see Baayen, Levelt, Schreuder, & Ernestus, 2007). This suggests that the surface frequency effect for singular-dominant nouns may be pervasive and generalize across experimental tasks. To gain additional insight into the surface frequency effect, I conducted eight experiments presented in three studies. I did this by: 1) applying advanced linear mixed modelling techniques to improve result outcomes and statistical power; 2) testing whether the surface frequency effect remained significant in a lexical decision task (LDT) when noun dominance was treated as a continuous variable (Baayen, Feldman, & Schreuder, 2006; Reifegerste et al., 2017); and 3) testing whether the surface frequency effect could be reproduced in a simple determiner-noun number agreement task.

In Study 1, I examined the effects of noun dominance and grammatical number on the visual recognition of French (Experiment 1) and English (Experiment 2) nouns. In Study 2, I investigated the effects of noun dominance and grammatical number on determiner-noun number agreement in three number agreement tasks, one in French (Experiment 3) and two in English (Experiments 4 and 5). In Study 3, I explored the effects of noun collectivity and noun animacy on the visual recognition of singular-dominant nouns in French (Experiment 6) and English (Experiment 7), as well as the effects of these two noun characteristics on the determiner-noun number agreement in English (Experiment 8).

Applying Linear Mixed Modelling Techniques

As mentioned above, I conducted linear mixed modelling analyzes for all my experiments. I used generalized linear mixed modelling (GLMM) to analyze my response accuracy data and cross-classified linear mixed effects (LME) modelling to analyze my response latency data. Given my experimental designs, these techniques provided me with several advantages over the more traditional approach of conducting two separate analyses of variance (ANOVAs), one ANOVA treating participants as a random sample, averaging over items (F_1) and one ANOVA treating items as a random sample, averaging over participants (F_2).

The main advantage of linear mixed modelling techniques is that both participants and items can be treated as random samples within a single statistical analysis. Otherwise stated, in all of my experiments, participants are treated as being randomly selected from a larger population and so are the experimental items (i.e., nouns). This allows for all sources of systematic variance to be captured within the model, which directly increases statistical power (Locker, Hoffman, & Bovaird, 2007; Quené & van den Bergh, 2004, 2008). Moreover, including both random samples allows for both participant and item fixed effect variables to be entered into a single statistical model. These effects can be either categorical (e.g., participant native language) or continuous (e.g., noun frequency of occurrence; Cunnings, 2012). As a result, it becomes possible to directly test interactions between participant and item effects without prior averaging (e.g., native language × frequency; Cunnings, 2012; Hoffman & Rovine, 2007). Finally, incorporating both samples into a single statistical model allows researchers to generalize to both participant and item populations simultaneously (Baayen, Davidson, & Bates, 2008; Janssen, 2012; Locker et al., 2007; Quené & van den Bergh, 2008).

I used GLMM to analyze my response accuracy data. This enabled me to analyze a binary dependent variable in its raw state without applying any prior averaging to create a proportion or percentage value (Linck & Cunnings, 2015; Quené & van den Bergh, 2008). I used cross-classified LME modelling to analyze my response latency data. This enabled me to analyze a continuous dependent variable without any prior averaging across items (F_1 ANOVA) or across participants (F_2 ANOVA; Field, 2009; Linck & Cunnings, 2015; Quené & van den Bergh, 2008). In addition to gaining the benefits listed above, by applying the same statistical techniques across experiments I was able to create a more coherent picture of the surface frequency effect based on my results across experiments and studies.

Experimental Tasks

I used two experimental tasks to investigate the surface frequency effect: a lexical decision task and a determiner-noun noun agreement task. Using two experimental tasks provided additional insight into the generalizability of the surface frequency effect.

Lexical decision task. In a lexical decision task (LDT) experiment, participants are presented with a series of real words and non-words created to mimic real words on a computer screen. Their task is to decide whether each item is a real word, "*YES*" or "*NO*". The LDT does not require participants to explicitly process any word characteristics. They simply need to search their mental lexicon for a matching sequence of letters to identify real words. However, several researchers have found that participants are sensitive to word characteristics, such as base frequency and word length (e.g., Becker, 1979; Conrad, Grainger, & Jacobs, 2007; Forster & Chambers, 1973; Gordon, 1983; Keuleers, Diependaele, & Brysbaert, 2010; Yap & Balota, 2009). The LDT has been the predominant task used to investigate the effect of surface frequency. A surface frequency effect has been found for singular-dominant nouns in six separate LDT studies (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New, Brysbaert, et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). I chose to use the LDT in order to expand our understanding of the surface frequency effect when noun dominance is treated as a continuous variable.

Determiner-noun number agreement task. We wanted to examine whether the surface frequency effect remained significant when participants had to explicitly attend to noun number information. Noun number information must be processed when forming agreement. Therefore, we created a determiner-noun number agreement task. Participants saw real words on a computer screen the same as in the LDT. However, their task was to decide whether they would place a single determiner ("*This*") or a plural determiner ("*These*") in front of each word. A similar task was used by Nenonen and Niemi (2010) who adopted the choices "*One*" or "*Many*" to compare responses to different types of words.

Lexical Decision Task Results

I conducted four LDT experiments to examine the persistence of the singular-dominant noun surface frequency effect when noun dominance was treated as a continuous variable. In Study 1, I compared regular French and English singular-dominant and plural-dominant nouns (Experiments 1 and 2). In Study 3, I compared collective and non-collective French and English nouns that were predominantly singular-dominant (Experiments 6 and 7). Below I discuss the result similarities and differences across these experiments. Next, I summarize how my results fit within the relevant literature. I conclude by providing an overview of the three classes of visual word recognition models and their predictions regarding the effects of base and/or surface frequency on word recognition.

Similarities. In all four experiments, singular nouns were recognized faster than plural nouns (6 – 35 ms advantage). For Experiments 1 and 2, this finding indicates that singular nouns were recognized faster than plural nouns regardless of their noun dominance ratio. However, for Experiments 6 and 7 this finding indicates that the surface frequency effect was significant for both collective and non-collective singular-dominant nouns in French and English. Support for the singular-dominant noun surface frequency effect was also found in Experiments 1 and 2 in the form of significant and marginally significant noun dominance × grammatical number interactions. Decomposing the interactions revealed that in both languages, singular-dominant nouns displayed a surface frequency effect (13 – 31 ms advantage) while plural-dominant nouns did not (1 – 3 ms difference).

Differences. In Experiment 1, French singular-dominant nouns were recognized 2% less accurately and 12 ms slower (Block 2 only) than plural-dominant nouns. In Experiment 2, no noun dominance effects were significant. In Experiment 7, noun collectivity and animacy had a significant influence on both response accuracy and latency. Specifically, English non-collective nouns were recognized 1% more accurately and 48 – 52 ms faster than collective nouns while animate nouns were recognized 3% less accurately and 19 – 31 ms slower than inanimate nouns. In Experiment 6, no collectivity or animacy effects approached significance.

Relevant literature. My findings align with those reported within the lexical decision noun dominance literature. First, researchers have found that singular nouns were recognized faster than plural nouns in Dutch, English, French, German, and Spanish (Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997), but not in Italian (Baayen, Burani, et al., 1997). I replicated this effect in both French and English (Experiments 1 and 2). Second, researchers have found that the noun dominance effect is not perfectly reliable. Some authors find that singular-dominant nouns are recognized slower than plural-dominant nouns (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; Reifegerste et al., 2017). Meanwhile, others find that the effect of noun dominance is not significant (New et al., 2004; Reifegerste et al., 2017). In my experiments, I found a significant noun dominance effect in French (Experiment 1) in Block 2 only. Singular-dominant nouns were recognized slower than plural-dominant nouns. The noun dominance effect was non-significant in English (Experiment 2). Therefore, even within my two experiments, there is inconsistency in the significance of the noun dominance effect. Finally, in all previous lexical decision studies researchers have reported finding a surface frequency effect for singular-dominant nouns only (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017; Sereno & Jongman, 1997). I replicated this finding in all four of my lexical decision experiments. Moreover, I expanded our knowledge of the singular-dominant noun surface frequency effect by demonstrating that the surface frequency effect exists for singular-dominant collective nouns as well as singular-dominant non-collective nouns in both French and English (Experiments 6 and 7). In addition, I found that the characteristic of noun animacy did not influence the surface frequency effect in any way. In English only, noun collectivity influenced response latency; collective nouns were recognized slower than non-collective nouns. This finding aligns with the collectivity effect reported by

Nenonen and Niemi (2010). In their study, participants were 271 ms slower at identifying the notional number of collective nouns compared to non-collective nouns in a number decision task.

Models of visual word recognition. There are three model classes of visual word recognition: 1) full-storage models, 2) full-decomposition models, and 3) dual-route models. Each model class makes a different prediction regarding how base frequency and/or surface frequency impact visual word recognition. Of the three model classes, only the dual-route model predictions are confirmed by my results and the majority of the lexical decision noun dominance literature (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; Domínguez et al., 1999; New et al., 2004; Reifegerste et al., 2017).

***Full-storage models*.** These models maintain that surface frequency determines word recognition speed; base frequency has no influence (e.g., Butterworth, 1983; Bybee, 1995). They predict that singular-dominant nouns should be recognized faster in their singular form than in their plural form while plural-dominant nouns should be recognized faster in their plural form than in their singular form. A small number of researchers have argued that their visual word recognition results support the full-storage model (e.g., Cole, Beauvillain, & Segui, 1989; Giraudo & Grainger, 2000; Manelis & Tharp, 1977). However, this pattern is not what was observed in my experiments.

***Full-decomposition models*.** These models argue that stem frequency determines word recognition speed; base frequency and surface frequency have no impact (e.g., Chialant & Caramazza, 1995; Clahsen, 1999; Rastle, Davis, & New, 2004; Taft, 2004). *Stem frequency* is the surface frequency for the stem of a morphologically complex word (e.g., *lip* is the stem of the word *lips*; Rastle et al., 2004; Taft, 2004). These models predict that singular nouns should be recognized faster than plural nouns, regardless of their noun dominance ratio. Another modest subset researchers have claimed that their visual word recognition results support a full-decomposition model (e.g., Rastle et al., 2004; Taft, 2004). Yet, this pattern is not supported by the results of my experiments.

***Dual-route models*.** These models assert that both base frequency and surface frequency impact word recognition under different circumstances (e.g., Baayen, Dijkstra, et al., 1997; Baayen, McQueen, Dijkstra, & Schreuder, 2003; Baayen, Schreuder, & Sproat, 2000; Schreuder & Baayen, 1995). They posit that base frequency always determines recognition speed for singular nouns, yet plural nouns can be recognized in one of two ways. For most plural nouns, recognition speed is determined by surface frequency. However, the recognition speed of singular-dominant plural nouns is determined by their base frequency plus the time required to decompose the noun down into its singular stem and plural marker (e.g., *designs* → *design* + -*s*). The parallel dual-route model predicts that singular nouns should be recognized at similar speeds, regardless of their noun dominance ratio, while singular-dominant plural nouns should be recognized slower than plural-dominant plural nouns due to the decomposition time required to distinguish the stem from the plural marker. This is the pattern observed in and supported by all four of my lexical decision experiments.

Determiner-Noun Number Agreement Task Results

I conducted four determiner-noun number agreement experiments to examine the pervasiveness of the singular-dominant noun surface frequency effect. In Study 2, I examined number agreement decisions for regular French and English singular-dominant and plural-dominant nouns (Experiments 3 through 5). In Study 3, I compared collective and non-collective English nouns that were predominantly singular-dominant (Experiment 8). Below I discuss the result similarities and differences across these experiments. This is followed by a summary of how my results fit within the relevant literature.

Similarities. In all four experiments, noun dominance had no impact on determiner-noun number agreement speed ($p \geq .159$). Meanwhile, number agreement was faster for plural nouns than singular nouns in Experiments 3 through 5 (exception: English foils in Experiment 5). The potential impact of noun gender was controlled for during statistical analyses in French (Experiment 3). In Block 1, number agreement was 5 ms faster for feminine nouns than masculine nouns. In Block 2, there was no effect of noun gender. Post-experimental questionnaire results imply that this is due to the fact that participants were using noun endings to facilitate their agreement decisions. Notably, over three quarters (77%) of participants reported that their first focal point was noun endings. Neither noun collectivity nor animacy influenced this result or had any impact on determiner-noun number agreement. This suggests that form-oriented strategic processing can neutralize the effects of semantic variables.

Differences. In Experiments 3 through 5, number agreement accuracy was 1% higher for regular singular nouns than regular plural nouns. In Experiment 5, accuracy was 44% higher for singular foils (e.g., *bonus*) than plural foils (e.g., *mice*). However, in Experiment 8, grammatical number had no impact on number agreement accuracy, nor did noun collectivity or animacy. Furthermore, there was a significant noun dominance × grammatical number interaction in Experiment 3 in Block 2 only. Agreement was significantly faster for French plural-dominant nouns when they were presented in their plural form (i.e., their dominant form) than their singular form. A surface frequency effect was not observed for French singular-dominant nouns. In English, the noun dominance × grammatical number interaction was not significant in

Experiments 4 or 5 (*p* > .250). In Experiment 8 however, determiner-noun number agreement was faster for singular-dominant plural nouns than singular-dominant singular nouns.

Relevant literature. Researchers maintain that determiner-noun number agreement is purely grammatical in nature; it is not influenced by noun notional number (Bock & Middleton, 2011; Kim, 2004; Tallerman, 2011). In other words, a grammatically singular noun should be preceded by a singular determiner regardless of its notional number (e.g., *this family*), while a grammatically plural noun should be preceded by a plural determiner (e.g., *these families*). My finding that noun collectivity had no influence on determiner-noun number agreement accuracy or speed is consistent with this claim. If notional number impacted agreement, an effect of collectivity should have been observed. Furthermore, although no studies have been published on the importance of surface frequency in number agreement, my results suggest that noun dominance alone has no impact on determiner-noun number agreement decisions. Noun dominance does appear to interact with grammatical number however. The nature of this interaction appears to differ across languages. In French (Experiment 3), plural plural-dominant nouns formed faster number agreement than singular plural-dominant nouns. In English, no interaction was observed at all in Experiments 4 and 5. Yet in Experiment 8, plural singular-dominant nouns formed faster number agreement than singular singular-dominant nouns. My inconsistent results suggest that this interaction is volatile and difficult to predict. Further research into possible interactive processes is needed to understand my findings.

A single article has been published on how healthy individuals select determiners when provided with noun number information. Fieder and her colleagues (Fieder, Wang, Biedermann, & Nickels, 2017) presented English participants with pictures depicting single (i.e., one) or multiple (i.e., three) images of mass nouns or singular-dominant count nouns. In this discussion I focus on their count noun results. The authors found that participants were 3% to 8% more accurate when providing determiner responses for singular nouns than plural nouns. I partially replicated this finding in my experiments. Determiner-noun number agreement accuracy was 1% higher for French and English singular nouns than their plural counterparts in Experiments 3 through 5, which included both singular- and plural-dominant nouns. Yet, in Experiment 8, which investigated English singular-dominant nouns only, no main effect of grammatical number was observed. Given the small size of the effect seen in Experiments 3 through 5, the null effect found in Experiment 8 is not remarkable. What is remarkable is the accuracy difference between singular and plural foils in Experiment 5. Participants were 44% more accurate at forming determiner-noun number agreement decisions with singular foils (e.g., *bonus*) than plural foils (e.g., *mice*). One possible explanation for this finding is that all singular foils were singular-dominant while plural foils were a mixture of singular-dominant, plural-dominant and equal dominance nouns. Thus, my result may in fact be a surface frequency effect materializing as a consequence of the foils selected. However, since no research has been published on how readers process irregular English nouns to date, it is only possible to speculate.

Fieder et al. (2017) also reported that participants demonstrated a speed advantage when choosing a determiner for images depicting a singular entity versus multiple entities (15 – 75 ms). In all four of my experiments, I observed the opposite response latency pattern. In both French and English, determiner-noun number agreement decisions were faster for plural nouns than singular nouns (2 – 65 ms advantage), regardless of noun dominance, collectivity, or animacy. The post-experimental questionnaire results from Experiment 5 suggest that this finding is the result of participants making use of the reliability of the plural marker -*s* to form response strategies centred around noun endings.

Conclusions and Future Directions

My lexical decision experiments contribute evidence that the singular-dominant noun surface frequency effect is robust in French and English visual word recognition when noun dominance is treated as a continuous variable. The strength of this effect may wane slightly for English collective singular-dominant nouns, but it does not cease to exist. However, this effect was not reproduced in several French and English determiner-noun number agreement experiments. Grammatical number, not noun dominance, influenced number agreement speed. Surprisingly, determiner-noun agreement was formed faster with regular plural nouns than regular singular nouns in all four experiments. This is likely a consequence of the saliency and reliability of the plural marker -*s*. In the lexical decision experiments, singular nouns had a speed advantage over plural nouns.

Taken together, my results confirm that a strong surface frequency effect exists during visual word recognition for singular-dominant nouns. However, the surface frequency effect does not extend to the formation determiner-noun number agreement decisions, which are influenced nearly exclusively by grammatical number. In future studies, it would be beneficial to expand the determiner-noun number agreement experiments to other languages which contain more than one regular plural marker (e.g., Dutch or German). Further, it would be beneficial to conduct number decision experiments where participants are asked to identify the notional number of written singular- and plural-dominant nouns (e.g., Nenonen & Niemi, 2010). This could help answer the question of whether the singular-dominant noun surface frequency effect disappears as soon as noun grammatical number becomes the focus of the task or only once number agreement decisions are required.

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