UiT The Arctic University of Norway

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Discovering gender and inflection

A view from Icelandic

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Contents

Dedication

For all survivors of sexual violence

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Now, on to the wonders of grammatical gender and inflection in Icelandic...

Abstract

In this dissertation, I investigate the nature of generalizations in grammatical gender and inflectional morphology from a learning perspective. Cross-linguistic differences in children's learning trajectories have been at the forefront of research on the acquisition of grammatical gender. Transparency has been argued to be predictive of children's behavior in gender acquisition (Slobin, 1977). Hitherto, however, it has been unclear what it means for a gender system to be either transparent or opaque to the child learner. I argue that in order to get to the root of the cause, a theory of grammatical gender acquisition must explain the conditions under which children generalize in gender assignment – and when these conditions are not met.

In a series of corpus studies that approximate a child's lexical experience in gender acquisition in Icelandic, I formulate predictions for children's behavior using two contrasting models of productivity, Baayen's P and P* metrics (1989; 1991; 1993) and Yang's Tolerance Principle (2005; 2016). These predictions were put to the test in an elicited production task on children and adults with two conditions: Productive and unproductive. I argue that the empirical results demonstrate that children and adults draw a categorical distinction between productive and unproductive processes in gender assignment in Icelandic. I argue that cross-linguistic differences in gender acquisition reflect a learning process that is guided by the search for productive patterns.

In two subsequent studies, using the same corpus-based and experimental methods, I investigate how knowledge of gender facilitates the induction of other inflectional forms or vice versa, using plural formation in Icelandic as a test case. Noun pluralization in Icelandic cross-cuts both gender and inflection classes, which raises the question of how children can extract the relevant generalizations given syncretism both within and across the inflectional paradigm. I demonstrate how children and adults were at a loss to pluralize nouns that they were unable to assign gender to. In other words, productivity in gender assignment correlates with productivity in plural formation. Since knowledge of gender is contingent on the knowledge of productive nominative singular forms, I propose that gender may be a developmental prerequisite for the acquisition of plural formation in Icelandic due to the statistical primacy of singular forms in the input.

I discuss the theoretical implications of the empirical findings, both for language acquisition and for linguistic theory. I propose that an understanding of children's discovery procedure in acquisition may offer solutions to otherwise intractable problems in linguistic theory. I further propose that learning considerations may shed light on the nature of the variation attested in heritage grammars. In a longitudinal corpus case study, I study how generalizations about gender assignment may undergo change as the result of attrition. I argue that the nature of the changes attested in the corpus as a function of time suggest difficulties with lexical access and retrieval, rather than a systematic re-analysis of the gender system, although the non-target forms are not entirely unconstrained.

Keywords: Gender, inflection, rules, defaults, productivity, defectivity

List of abbreviations

ACC	Accusative
C	Complementizer
DAT	Dative
DEF	Definite
F	Feminine
GEN	Genitive
M	Masculine
N	Neuter
NOM	Nominative
P	Particle
PL	Plural
SG	Singular
Ø	Absence of an overt suffix

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List of papers

Article I: Björnsdóttir, S. M. Productivity and the acquisition of gender. Published in *Journal of Child Language*.

Article II: Björnsdóttir, S. M. Predicting ineffability: Gender and plural formation in Icelandic. Submitted to *Glossa. A Journal of General Linguistics*.

Article III: Björnsdóttir, S. M., M. Westergaard & Terje Lohndal. The effects of attrition on grammatical gender: A view from North American Icelandic. Published in *Heritage Language Journal*.

Part I

1 Introduction

In this dissertation, I study how children discover generalizations about linguistic categories and their inter-relatedness, using grammatical gender and plural formation in Icelandic as a case study. Conversely, I study how these generalizations may undergo change across the lifespan as a result of reduced input and use. Grammatical gender involves the sorting of nouns into two or more classes that is reflected in agreement morphology (Hockett, 1958, p. 231; Corbett, 1991, p. 1). Nouns in Icelandic inflect for gender (masculine, feminine, neuter), case (nominative, accusative, dative, genitive) and number, resulting in nested patterns of inflection[1], traditionally referred to as inflection classes. Inflection classes encompass the set of roots, whose members each share the same set of inflectional realizations (Aronoff, 1994). Therefore, children not only have to learn individual forms and categories in Icelandic; they must also learn how they are related to one another in order to inflect novel nouns. Since young children typically do not get exposed to nouns in fully inflected paradigms, they must somehow construct a system that allows them to generalize beyond experience on the basis of input that is both limited and sparse.

The nature of generalizations in gender assignment and inflectional morphology has been much debated both from a theoretical and an acquisitional perspective: What are the relevant generalizations and how are they discovered in acquisition (see, among many, Boloh & Ibernon, 2010; 2013; Corbett, 1991; Karmiloff-Smith, 1979; Laaha et al., 2006; Rice, 2006; Rodina & Westergaard, 2012; 2015; Spencer, 2002; Steinmetz, 1986; Szagun et al., 2006)? Given the cross-linguistic variation in both gender and inflectional morphology, children must be able to detect a wide variety of patterns from early on. However, the source of their ability to do so and the nature of the resulting generalizations has been contested (e.g. Bybee, 1995; Clahsen, 1999; Marcus et al., 1995; Pinker, 1999; Rumelhart & McClelland, 1986).

Children seem to learn gender at different rates depending on the nature of the target gender system (e.g. Clark, 1985; Karmiloff-Smith, 1979; Levy, 1983; Mills, 1986; Pérez-Pereira, 1991a; Rodina & Westergaard, 2012; 2015; Thomas & Mueller Gathercole, 2007).

[1]The term INFLECTION will be used consistently throughout the dissertation. The same phenomenon may also be referred to as DECLENSION.

Cross-linguistic differences in learning behaviors have been at the forefront of gender acquisition research. Transparency, the strength of a formal cue to gender assignment, has been argued to be predictive of children's behavior in gender acquisition (Slobin, 1977). Children learning a transparent system like Spanish (Pérez-Pereira, 1991) generalize gender assignment patterns from early on, whereas children learning a non-transparent (opaque) system, like Norwegian (Rodina & Westergaard, 2015), follow a protracted development. The question is how children discover whether the target gender system is transparent or not? The source of these cross-linguistic behavioral differences has been unclear, resulting in divergent conclusions and interpretations of the nature of the learning process in gender acquisition. I argue that a theory of grammatical gender acquisition must explain the source of children's ability to generalize – and their failure to do so – in gender assignment.

Noun pluralization in Icelandic cross-cuts both gender and inflection classes, which raises the question of how children can extract the relevant generalizations about plural formation given syncretism both within and across linguistic categories. In order to pluralize novel nouns in Icelandic, children must somehow discover the relation between forms and categories in nominal morphology. The relation between gender and inflection in grammar has been much debated: Is there a causal relation between the two categories, and, if so, what is the direction of causation (Berg, 2019; Corbett, 1999; Doleschal, 2000; Enger, 2004; Spencer, 2002; Wurzel, 1987)? I address this question by studying how generalizations about gender assignment guide children's inferences about plural forms in Icelandic and vice versa.

Grammatical gender and inflectional morphology have been identified as domains of grammar where heritage speakers differ from the baseline (Benmamoun et al., 2013; Lohndal & Westergaard, 2016; Montrul, S. & Perpiñan, 2008; Polinsky, 2008). However, the nature of these differences has been contested. In this dissertation, I also study the effect of attrition on grammatical gender in North American Icelandic. I propose that studying how generalizations are affected by attrition can shed light on the cognitive processes involved when a gender system proceeds from native-like proficiency to non-target proficiency as a result of reduced input and use.

The findings presented in this dissertation are divided into three articles. In the first article: Productivity and the acquisition of gender, I study the acquisition of grammatical gender in Icelandic using corpus-based and experimental methods. I demonstrate how a learning model (Yang, 2005; 2016) can predict both the conditions under which children generalize and their failure to do so in gender assignment, using Icelandic as a case study. Specifically, in a series of corpus studies, I show how productivity and absence thereof can be predicted given an estimate of a child‘s lexical experience in gender acquisition. These predictions were borne out in an elicited production task for children and adults. The findings suggest that grammatical gender can be learned both on a rule-based and on an item-to-item basis.

I argue that children's differing learning trajectories of gender cross-linguistically are a direct reflection of a learning process guided by the search for productivity. Crucially, however, the absence of productivity does not constitute as evidence against rule-based learning. Rather, it is a direct consequence of a learning process guided by a search for productivity that fails to succeed and results in rote memorization. As a point of comparison, the empirical results were evaluated against the predictions of an alternative model of productivity (Baayen, 1989; 1991; 1993). I argue that the empirical results suggest that the division line between productive and unproductive processes in gender assignment is categorical, rather than gradient, in nature.

In the second article: Predicting ineffability: Gender and inflection in Icelandic, I investigate how knowledge of grammatical gender facilitates children's induction of plural forms for novel nouns using the same corpus-based and experimental methods. A learning model (Yang, 2005; 2016) was used on the Tagged Icelandic corpus (Helgadóttir et al., 2012) to predict productivity – and absence thereof – in the correspondences between gender and plural suffixes. These predictions were borne out in an elicited production task on children and adults that elicited both gender agreement and plural marking. The results indicate that productivity in gender assignment correlates with productivity in plural formation. Correspondingly, ineffability in gender assignment correlates with ineffability in plural formation.

A second elicited production task tested whether children and adults could infer the gender and nominative singular forms of novel plural nouns. The predictions of the learning model were borne out for adults, but only partially for children. I propose that the differences in adult and child behavior in the study may be explained in terms of the statistical primacy of singular forms in acquisition. Inflectional forms typically show an uneven frequency distribution as mandated by Zipf's law (Zipf, 1949). As a result, children will likely encounter many more nouns in the singular than the plural. Based on these findings, I argue that the relation between gender and inflection is derivative, arising from the use of productive nominative singular forms. Since such forms comprise the basis for gender acquisition, gender may be a developmental prerequisite for learning plural formation in Icelandic.

The third article: The effects of attrition on grammatical gender: A view from North American Icelandic, consists of a longitudinal corpus case study of how grammatical gender may undergo change as the result of attrition. The corpus (82,000 tokens) comprises the written letters of a speaker of North American Icelandic in Canada who wrote to a relative in Iceland for over 70 years. The data are unique since it is rare to have data from a single speaker in an imbalanced bilingual setting over such an extended period of time. The writer was a second-generation immigrant from Iceland, whose domestic language in early life was Icelandic, but shifted to English later on. There are virtually no non-target forms attested in the first four decades of letter writing. However, in the last three decades of writing, there is an increase in non-target forms. Therefore, these late developments seem to reflect attrition due to reduced input and use of Icelandic. Approximately 1% of all noun tokens in the corpus were affected by non-target gender agreement. Productive and unproductive processes in Icelandic gender assignment were equally affected, suggesting that the gender system did not undergo a systematic re-analysis. In other words, non-target agreement distributed across nouns at random. However, the variation was not unconstrained since the non-target gender agreement was characterized by the over-generalization of neuter as an agreement default. I argue that the variation attested in the last three decades of letter writing reflects a trend towards a systematic reduction of the gender agreement system characterized by the loss of feminine.

The dissertation is in two parts. Part I provides a general introduction to the overarching issues and outstanding questions in prior research on grammatical gender and inflectional morphology and how the present findings speak to them. Part II consists of the three articles. Part I is structured as follows: In section two, I provide a general overview of the central questions in theoretical research on grammatical gender. Prior findings and issues in the acquisition of grammatical gender are summarized in section three. Section four discusses the interaction between gender and inflection and its implication for theory and acquisition. In section five, I give a brief overview of productivity. In addition, I introduce two contrasting models of productivity that were used to generate predictions for learning in the first article of this dissertation. Section six provides a descriptive overview of Icelandic noun inflection. In section seven, I discuss and motivate the main research questions that are addressed in this dissertation. Both the corpus-based and experimental methods are provided in section eight. In section nine, I formulate the predictions for each study. The results are presented in section 10, followed by a general discussion in section 11 and some directions for future research. Section 12 concludes the first part of the dissertation.

2 Grammatical gender

2.1 Gender assignment rules

Gender systems differ cross-linguistically with respect to what kind of information is informative in gender assignment. Gender assignment of a noun may be determined by its meaning, formal properties or both (Comrie, 1999; Corbett, 1991). A typological distinction has been made between strict semantic systems and formal systems (Corbett, 2013).

Gender assignment in semantic systems is determined by semantic patterns including, but not restricted to, natural gender (biological sex) and animacy. An example of such a system is Amharic, a Semitic language spoken in Ethiopia. Amharic has no productive formal correlates of gender, and gender assignment is determined by natural gender (Kramer, 2015, p. 15). Formal systems can make use of morphological or phonological rules or both. While the distinction is not always clear, phonological rules are usually taken to refer to a single form of the noun, whereas morphological rules typically make reference to inflectional paradigms. Formal systems are attested in typologically unrelated languages, such as Russian and Qafar. In spite of cross-linguistic diversity, gender systems have been argued to be rooted in nominal semantics universally, such that there are no purely formal systems of gender assignment (Corbett, 2013). Similarly, Dahl (2000) and Nesset (2006) have argued for the precedence of gender assignment rules based on natural gender.

Gender assignment rules, or correlates, often have exceptions. This fact has standardly been interpreted as the result of rule conflicts, raising questions concerning their resolution. The most widely discussed type of exception is where a semantic rule overrides a formal rule. For instance, the nominative singular suffix *–a* is a productive correlate of feminine in Russian. Nevertheless, *pap-a* ('daddy') is masculine because of the referent's natural gender (henceforth this phenomenon will be referred to as *papa*-type nouns):

(1) Moj-**Ø** pap-**a** prišel-**Ø** (Russian)
my-M.SG daddy-M.SG come-M.PST
'My daddy came.'

So-called hybrid nouns may display variable gender agreement due to the apparent conflict between form and meaning. For instance, *das Mädchen* ('the girl') is a neuter noun in German in spite of its female reference. However, it may be referred to anaphorically by a female personal pronoun (*sie* 'she') which is atypical since German nouns are standardly referred to by anaphors that correspond to their formal gender (Corbett, 1991, p. 228). To account for such patterns Corbett (1991) has argued for a universal hierarchy by which semantic rules outrank formal rules in gender assignment.

Another type of exception is the case where two or more formal gender correlates are in conflict. For example, the suffix *-nis* is attested on both feminine and neuter nouns in German, but not masculine. Steinmetz (1986, p. 200) discusses the gender assignment of *Gefängnis* ('prison-N') and *Gedächtnis* ('memory-N') in light of the of the ambiguity of the suffix with respect to gender assignment. There are three gender assignment rules relevant for these nouns, listed in (2):

(2) a. German nouns ending in *-nis* are feminine (e.g. *die Finsternis* 'darkness').
b. German nouns ending in *-nis* are neuter (e.g. *das Zeugnis* 'testimony').
c. German nouns with the prefix *ge-* are neuter (e.g. *das Geräusch* 'noise').

Steinmetz argues that the gender assignment of *Gefängnis* and *Gedächtnis* can be explained by a principle of Gender Tally. The principle is defined in terms of an instruction: "Count the number of times each gender is assigned and assign the gender with the highest value" (Steinmetz, 1986, p. 193). The principle correctly predicts neuter assignment on the grounds that there are more gender correlates associated with neuter for these nouns than feminine. Thus, (2b-c) point towards neuter, whereas only (2a) points towards feminine.

A challenge for Gender Tally is accounting for cases where there is a "tie" between genders. In such cases, Steinmetz argues for a resolution by a default hierarchy. He proposes that all gendered languages have a gender default (markedness) hierarchy. A default hierarchy comes into play when there are competing rules for the gender assignment of a noun; the gender which outranks its competitors on the hierarchy will win. The hierarchy for German gender assignment, on Steinmetz's analysis, is given in (3) as an example:

(3) Masculine > Feminine > Neuter (German)

The hierarchy in (3) states that masculine is the least marked gender in German, followed by feminine, then neuter. This approach has been formalized in optimality-theoretic terms by Rice (2006), whereby gender assignment conflicts are represented as violable constraints. On Rice's analysis, semantic rules have no privileged status. He argues that examples like (1) are weak arguments for the precedence of semantic rules in gender assignment. Since masculine is standardly assumed to be the default gender in Russian, the pattern in (1) could be the result of an over-application of the default gender. He then proceeds to discuss cases in German where an account assuming semantic precedence would make false predictions. For instance, nouns ending in *–ucht* tend to be feminine, e.g., *die Frucht* ('fruit'). Köpcke (1982) states that superordinate nouns are assigned neuter. But, in spite of being a superordinate noun, *die Frucht* is feminine. Therefore, a semantic generalization does not seem to take precedence in this case. Ultimately, however, Rice's argument against semantic precedence rests on the validity of Köpcke's generalization that superordinate nouns in German are neuter.

Unresolved issues in Steinmetz's analysis include what determines the ranking of individual rules. Nesset (2006) argues that the possibility of rule paradoxes makes rule ordering in grammar unfeasible. Instead, he argues that gender assignment rules are not ordered unless universal principles force them to. One such principle is his Core Semantic Over-ride Principle (p. 1386), which states that rules referring to natural gender take precedence in gender assignment. Apart from this principle, ranking should be determined by type frequency, as mandated by the Elsewhere Condition (Kiparsky, 1972): A gender category with more members receives a higher ranking than a gender with fewer members (p. 1389). Finally, rule conflicts are resolved by Gender Tally.

The above discussion leads to a fundamental question: What is a gender assignment rule? This question has posed significant analytical challenges in research on grammatical gender. Analyses of individual gender systems may differ not only regarding the nature of the gender assignment rules proposed, but also regarding their number. This issue reflects a more general problem: Anything can be stated as a linguistic rule to account for all the idiosyncrasies that typically reside in the lexicon. Several scholars have observed this problem. For instance, in his critique of Köpcke and Zubin's (1984) influential analysis of the German gender system, Comrie (1999, p.461) argues that their analysis includes principles of such complexity "that their validity is questionable". In a similar spirit, Rodina and Westergaard (2015) raise concerns regarding the psychological plausibility of Trosterud's (2001) analysis of the Norwegian gender system, which contains no less than 43 gender assignment rules with numerous exceptions. These issues reflect the need for independently motivated rules of gender assignment.

2.2 Default genders

The notion of a default has been defined in numerous ways in the literature, often in terms of principles such as the Elsewhere Condition (Kiparsky, 1973), Proper Inclusion Precedence (Koutsoudas et al., 1974) and the Panini Principle (Zwicky, 1989). These principles share the idea that a particular case may over-ride a wider generalization (see Bauer, 2001, pp. 60-74 for a discussion). Standard definitions of gender defaults conform to this idea: A default gender is the gender assigned in the absence of any gendered information in a lexical entry (Aronoff, 1994, p. 100; Harris, 1991, p.44). Speakers of gendered languages not only need to internalize gender assignment rules or patterns – they also need to learn what gender to assign in the absence of such a rule.

Gender defaults have been more disputed than other morphological defaults. Greenberg (1966, p. 38) notes that the main challenge in identifying and motivating gender defaults is the problem of "inter-linguistic comparability". In other words, there is no universal default gender. Greenberg (1966, p. 39) states two tendencies about the default behaviors of genders, provided in (4):

(4) a. Where masculine and feminine genders exist with or without further genders, the masculine usually appears to be the unmarked gender.
b. Where a neuter exists alongside of a masculine and feminine, the neuter is the most marked category and can be opposed to the masculine/feminine.

While these tendencies seem to have some descriptive validity, at least for Indo-European languages, they are not absolute. For instance, feminine has been claimed to be the default gender in Zayse and Zargulla, two related Afro-Asiatic dialects (Kramer, 2015, p. 79).

A theory of grammatical gender must be able to predict the conditions for the emergence of a default gender. This involves demarking the boundary between productive and unproductive processes in gender assignment, as a default form is expected when no productive process is attested. Such a demarcation has analytical consequences. For instance, recall Rice's (2006) argument against semantic precedence whereby *papa*-type nouns in Russian reflect the over-application of a masculine default. This argument does not go through if one assumes principles such as the Elsewhere Condition, as the nominative singular suffix –*a* is a productive correlate of feminine and, hence, not a context where one would expect the occurrence of a default form. A default form should not over-ride a more specific, productive generalization.

Default hierarchies rest on the assumption that all gender systems have a default. In fact, Rice (2006, p. 12) claims that no gender system shows a random distribution across genders in the absence of a gender assignment rule. While this has been a standard assumption in research on grammatical gender, defectivity and gaps have been widely acknowledged in morphological theory beyond gender (see, among many, Albright, 2003; Dabrowska, 2001; 2005, Sims, 2006; Steriade, 1997). Therefore, there is no a priori reason to assume that all gender systems will have a default.

Some gender systems show variability in their default behaviors. For instance, masculine is productive in Russian and Dutch; it is extended to novel nouns and over-generalized in acquisition (Rodina & Westergaard, 2012; Unsworth & Hulk, 2008). However, in both languages, neuter occurs in syntactic contexts where agreement is expected to be inert. These include clausal and oblique subjects, as well as weather predicates, cf. (5) for Russian.

(5) Byl-**o** xolodn-**o**. (Russian)
was-N.SG cold-N.SG
'It was cold.'

The question is why morphological productivity is not reflected in the syntax? Traditionally, it has been assumed that syntactic and morphological default genders align in a language (see e.g. Aronoff, 1994). However, Corbett (2000) argues that the two forms operate at different linguistic levels; masculine is the default at the word-level, while neuter is the syntactic default. In a similar spirit, Lohndal & Westergaard (2021) argue for the necessity of separate agreement and assignment defaults in the case of grammatical gender. Default variability has also been argued to reflect differences between linguistic and learner defaults (see Tsimpli & Hulk, 2013 for evidence from Dutch and Greek). On this view, the discrepancy between morphological and syntactic defaults arises because of a learning problem. Children's late mastery of Dutch inhibits the acquisition of the linguistic default; hence they over-generalize masculine as a default determiner form.

2.3 Summary

Any account of learning must state with precision the object of learning. In this section, I have outlined some analytical challenges and differences in theoretical research on grammatical gender that have made this task far from straightforward. The major challenge is the question of what constitutes a valid generalization about gender assignment. Gender systems typically contain both rules and exceptions, but demarcating the two has not been a focal point in prior research. Instead, patterns on par with *papa*-type and hybrid nouns have motivated the postulation of universal principles in gender assignment. In the next section, I review the main findings in gender acquisition cross-linguistically and discuss how the outstanding issues and concerns raised in this section are also important for acquisition.

3 The acquisition of grammatical gender

3.1 Form versus meaning

The nature of generalizations in the acquisition of grammatical gender has been much debated: What generalizations are available in the input and how are they formed? These questions have been motivated by observations that languages tend to have a wide variety of cues with varying reliability for gender (see e.g. Culbertson et al., 2017 for a discussion). Since nouns have both form and meaning, there is a wide range of distributional information in the input. What information the child learner favors over other information has been a driving question in gender acquisition research.

The role of form versus meaning has been of particular interest, given the standard observation that all noun classification systems exploit semantic information to some extent (Corbett, 1991). Two main hypothetical scenarios have been proposed in gender acquisition: Learning driven by the search for semantic patterns as opposed to learning driven by the search for formal patterns. In the first, the acquisition of grammatical gender is characterized by the child's developing distinction of natural, or semantic, gender. This scenario is compatible with a learning process that is guided by a search for correspondences between form and meaning. Only once the child has formed a new conceptual notion, in this case natural gender, will they learn its corresponding form (Slobin, 1977). An alternative view posits that the learning process is guided by a search for formal patterns amongst nouns in the input (Karmiloff-Smith, 1979; Levy, 1983; Maratsos & Chalkley, 1980). On this view, children's language experience, rather than their conceptual development, constrains the hypothesis space in gender acquisition.

A recurring finding in research on gender acquisition is that children generalize the gender of novel nouns on the basis of formal properties, rather than exploiting semantic information. For instance, in her classic study of French, Karmiloff-Smith (1979) found that children up to the age of ten assigned gender on the basis of noun endings, even when the resulting gender conflicted with the natural gender of the referent. Similarly, children have been shown to generalize based on formal, rather than semantic, properties in the gender assignment of *papa*-type nouns in Russian (Rodina & Westergaard, 2012). A parallel preference was attested in a pronoun comprehension task in German, in which children generalized on the basis of formal, rather than semantic, correlates of gender (Böhme & Levelt, 1979).

A prominent study that claims the opposite effect is Mulford's (1985) study of Icelandic. In a pronoun comprehension task, replicating Böhme & Levelt (1979), formal properties of nouns were held constant, whereas the familiarity of particular referents and the amount of information about natural gender varied. The formal properties were encoded as either nominative singular suffix *–i*, which correlates with masculine, and *–a*, which correlates with feminine. Monosyllabic nouns with consonantal endings were predicted to be correlates of neuter. The referent objects belonged to four categories: People, animals, vehicles and imaginary (nonce). This categorization controlled for the availability of natural gender information and object familiarity (real versus nonce).

The purpose of the study was to test the hypothesis that children primarily rely on formal information in gender assignment. Given this hypothesis and the experimental manipulations, Mulford predicted that children would do equally well in identifying the gender of both familiar and unfamiliar nouns, irrespective of natural gender, provided equivalent formal information. In the task, children were asked to choose the appropriate referent of the pronouns used in the instructions by the experimenter. The pronouns occured in all possible case forms in Icelandic (nominative, accusative, dative and genitive).

Mulford argues that her results did not support this prediction: Children's gender assignment seemed conditioned by natural gender and the familiarity of the referent. In fact, it was not until age seven that children's ability to assign the target gender on the basis of formal properties exceeded chance. For younger children (four-to-six-year-olds), natural gender and familiarity seemed to be the conditioning factors. Therefore, Mulford concludes that formal information alone is not very useful in the acquisition of grammatical gender in Icelandic.

These findings conflict with cross-linguistic findings from other Indo-European languages, including the original study by Böhme & Levelt (1979) on German. Mulford speculates that these differences might be rooted in the opacity of the Icelandic gender system; German nouns might have formal properties that are more predictive of gender than Icelandic. Unfortunately, Mulford only provided general results in the different categories of objects and did not specify those obtained for each gender (masculine, feminine and neuter).

Mulford's study and the interpretation of her findings have been subject to criticism. In particular, Pérez-Pereira (1991b) has criticized the experimental design which he claims is not suitable for teasing apart formal and semantic information. For instance, the names for people were also provided with formal information (i.e. *–i* for masculine and *–a* for feminine), such that there is a combined effect of natural and formal gender in this category. Obviously, this was not the case with nouns for animals and vehicles, which were only presented with formal information. However, he argues that Mulford's claim that natural gender and familiarity guide children’s gender assignment in Icelandic is too strong, given that she did not test these variables in isolation.

Mulford’s findings aside, there is robust cross-linguistic evidence that children can learn gender systems that are detached from any semantic motivation. It has even been claimed that children rely disproportionately on formal properties, such as morphology or phonology, when semantic properties are more reliable predictors of class. Gagliardi & Lidz (2014) argue, using evidence from Tsez, that this apparent asymmetry reflects a distinction between the input and the intake, where intake is the information used by learners. On this view, an intake mechanism somehow places a higher value on phonological rather than semantic information. Gagliardi & Lidz speculate that this distinction may either be rooted in the early availability of phonological information or an inherent bias preferring formal over semantic information. In an artifical language learning study, Culbertson et al. (2017) investigated the former possibility by manipulating the salience and availability of both phonological and semantic information. They found that learners prioritized earlier available cues, even when they were less salient than competitor cues. Therefore, they argue that this inherent bias towards formal information may reflect their early availability. However, in a subsequent study Culbertson et al. (2019) found that both early availability and a bias favoring phonological cues contributed to children’s overreliance on phonology in language acquisition.

3.2 Rules and defaults

The role of rule-based versus prototype and similarity-based generalization in language has been much debated (see, among many, Bybee & Moder, 1983; Pinker & Prince, 1988). While there is general consensus that distributional information plays a role in morphological learning, how this information is made use of and the nature of the generalizations that it gives rise to has been a point of contention. Broadly speaking, two main theoretical positions on this matter can be identified: Dual-route and single-route.

On dual-route approaches, the architecture of grammar consists of two components: A rule-based component and a memory-based component (Clahsen, 1999; Marcus et al., 1995; Pinker & Prince, 1988; Pinker & Prince, 1994; Pinker, 1999). On this view, there is a categorical difference between regular and irregular forms in grammar: Regular forms are produced by a symbolic rule, while irregular forms are based on lexical memory. Only irregular forms are affected by frequency, and a default form is applied whenever memorization fails. On the single-route approach, learning proceeds via pattern association in an associative memory network. The learning process is characterized by matching the statistical distribution of lexically similar items (Plunkett & Marchman, 1991; Rumelhart & McClelland, 1986). Therefore, there is no inherent difference between regular and irregular forms in grammar apart from differences in their statistical distribution.

Grammatical gender was first invoked into this debate by Boloh & Ibernon (2010; 2013), who used grammatical gender in French to argue for a dual-route model of language. French has a gender system that distinguishes between two genders, masculine and feminine. Many noun endings in French correlate with gender. For example, nouns that end in *–o* tend to be masculine (e.g. *un vélo* 'bike-M'), while many feminine nouns ending in *–ion* are feminine (e.g. *une institution* 'institution-F'). Such correlations have sometimes been described as 'probabilistic' since they have exceptions (e.g. Karmiloff-Smith, 1979). Masculine gender constitutes around 58% of all nouns, and masculine is standardly assumed to be the default gender in French (Séguin, 1969).

In her influential work, Karmiloff-Smith (1979) argued that French-speaking children learn gender by internalizing a system of morpho-phonological rules. This system is the source of children's ability to assign gender to novel nouns. This view has been challenged by Boloh & Ibernon (2010; 2013), who replicated Karmiloff-Smith's original (1979) study. The participants in their study showed different response patterns for masculine and feminine: Children made consistent suffix-based responses in the case of masculine, but not for feminine. Boloh & Ibernon (2010; 2013) argue that their findings call into question the use of morpho-phonological rules in gender acquisition. Instead, they propose that masculine is computed by default, whereas feminine assignment is learned by rote in an associative memory system.

Boloh & Ibernon's findings suggest that children may or may not generalize on the basis of the formal properties of nouns in French. Cross-linguistically, children's ability to generalize in gender acquisition seems to vary (see, among many, Clark, 1985; Levy, 1983; Mills, 1986). In some languages, like Spanish, children have been shown to generalize based on noun endings from early on (e.g. Hernandez-Pina, 1984; Pérez-Pereira, 1991a). In other languages, like Norwegian, Dutch and Welsh, children have been found to follow a protracted development (Rodina & Westergaard, 2013; 2015; Thomas & Mueller Gathercole, 2007; Unsworth & Hulk, 2010). These cross-linguistic differences in learning behaviors have been argued to reflect the TRANSPARENCY of the target gender system (Slobin, 1977). Transparent gender systems like, for instance, Spanish, have a set of formal patterns or rules that can serve as the basis for children's generalizations in gender acquisition. Conversely, opaque gender systems, like, for instance, Norwegian, have few or none (Busterud et al., 2019; Lohndal & Westergaard, 2021).

The unresolved issue is what makes a gender system either transparent or opaque to children in acquisition.

3.3 Generalizations in reduced input situations

Speakers of heritage languages typically differ from the baseline due to reduced input and use of the minority language (Benmamoun et al., 2013; Montrul, 2008; Polinsky, 2018). However, the nature and source of these differences has been contested: Do they reflect changes in linguistic knowledge or do they reflect the effects of extra-linguistic factors, such as processing (Polinsky, 2011, 2018)? Moreover, since heritage speakers typically constitute a heteregenous groups of speakers, it is possible that they may differ from the baseline in different ways (Montrul, 2008; Polinsky, 2018). Therefore, one major question in research on heritage grammars is whether they are instantiations of divergent attainment or attrition? In other words, do heritage speakers fail to learn certain structures, or do these structures get acquired, but then undergo attrition due to lack of use or transfer from the dominant language?

Earlier research described heritage language acquisition as “incomplete”, in the sense that heritage speakers failed to acquire certain morphosyntactic features due to limited exposure to the minority language (Montrul, 2008; Polinsky, 2006). However, more recent accounts have emphasized that heritage language competence should be viewed and investigated as different, rather than incomplete (Cuza, 2016; Pascual y Cabo & Rothman, 2012). Fernández-Dobao & Herschensohn (2020) have argued that non-target forms in heritage grammars represent errors of over-generalization, using heritage Spanish as a test case: In a written production study, nine-to-ten-year-old children were found to over-generalize regular inflectional morphology in their heritage Spanish. This pattern mirrors findings from first language acquisition that have shown that children over-regularize but almost never irregularize forms in the target language (Xu & Pinker, 1995). These findings may suggest that irregular forms may be more affected than regular forms in divergent attainment.

Attrition may occur when a heritage speaker reaches age-appropriate proficiency in childhood that later undergoes changes due to reduced input and use. As a result, the heritage speaker’s proficiency may no longer match that of the baseline (Montrul, 2008). Seliger (1991) defined attrition as “the temporary or permanent loss of language ability as reflected in a speaker’s performance or in his or her inability to make grammaticality judgments that would be consistent with native speaker monolinguals of the same age and stage of language development” (p. 661). In this context, language attrition refers to non-pathological language loss in the context of bilingualism and language contact situations.

There is evidence for differences between child and adult heritage speakers. For example, Polinsky (2011) found differences in the comprehension of relative clauses in Russian between the two groups. These findings suggest that divergent attainment and attrition may affect heritage grammars in different ways. For instance, one possibility is that divergent attainment may reflect differences that can be attributed to learning, while attrition may reflect difficulties with lexical access or retrieval (see also Montrul, 2008). Since heritage language varieties are typically characterized by a great deal of inter-and intra-speaker variation, it is important to discern the source of the variability attested. Therefore, understanding the difference between non-target forms affected by divergent attainment and attrition, respectively, may bring us closer towards an understanding of the factors that constrain variation in heritage grammars.

3.4 Summary

There is cross-linguistic evidence that children can learn gender systems that are detached from any semantic motivation (Karmiloff-Smith, 1979 and much subsequent work). Children‘s ability to assign gender based on the formal properties of nouns has been taken as evidence for a formal bias in learning (Culbertsson, 2017; 2019; Lidz & Gagliardi, 2014). However, children do not always generalize on the basis of the formal properties of nouns (e.g Boloh & Ibernon, 2010; 2013; Thomas & Mueller Gathercole, 2007). The question is why this formal bias somtimes fails? In order to understand children's behavior in gender acquisition, we need to understand the conditions under which children form generalizations and when they refrain from doing so. Studying this learning process may also shed light on the nature of the variation attested in heritage grammars.

4 Gender and inflectional morphology

4.1 The problem of induction

Inflectional morphology raises a number of basic analytical questions: What are the units of generalization? Are paradigms primitives or epiphenomena in grammar? Do paradigms have bases and, if so, how are they determined? Irrespective of framework, the same inductive problem remains: What generalizations form the basis of speakers' abilities to predict the inflectional patterns of novel words? Ackerman et al. (2009) frame this question as the PARADIGM CELL FILLING PROBLEM: What licenses reliable inferences about the inflected surface forms of a lexical item?

An important empirical observation about inflectional morphology is that languages typically do not exhaust the number of logically possible inflection classes. Rather, only a small subset is employed, often with considerable syncretism between classes (Carstairs, 1983). For instance, Latvian noun inflection distinguishes between two genders and seven cases. For any one morphosyntactic value there may be one to six allomorphs. In a thought experiment, Carstairs (1983, p. 117) demonstrated that these could, in principle, be mixed and matched to yield 230,400 classes (the product of the number of allomorphs for each morphosyntactic value). However, only seven classes are actually attested. This suggests that "not anything goes" in the organization of inflectional paradigms. Otherwise, one would expect inflectional resources to be distributed in a wildly abundant way, a prediction that is not borne out empirically (e.g. Ackerman & Malouf, 2013; Carstairs, 1987).

The question is what constrains the distribution of inflectional forms? Several constraints across different research programs have been proposed to address this question, such as the Paradigm Economy Principle (Carstairs-McCarthy, 1987), later succeeded by the No Blur Principle (Carstairs-McCarthy, 1994), the Inflection Class Economy Theorem (Müller, 2007) and the Interclass Syncretism Constraint (Noyer, 2005). Although these approaches differ along many dimensions, they share the general working assumption in morphology to avoid accidental homophony and maximize generalizations (see e.g. Halle & Marantz, 2008 for a discussion).

In his influential line of work, Carstairs-McCarthy has proposed that the distribution of forms within an inflectional paradigm is constrained by a principle that seeks to prevent paradigm opacity. In its original version, the principle was formulated as the Paradigm Economy Principle (Carstairs, 1983) which states that there should be one morphosyntactic value whose allomorph should be sufficient to predict the behavior of the entire paradigm. The later version, the No Blur Principle (NBP)[2] states that each affix is either unique to a particular inflection class or the general elsewhere default for the morphosyntactic value it realizes (Carstairs-McCarthy, 1994). Thus, the NBP requires every affix that expresses a particular group of morphosyntactic properties to be either a CLASS-IDENTIFIER or a default for that group of properties. A class-identifying affix is limited to a single inflection class and is, therefore, diagnostic of that class. The NBP generates a number of predictions. First, a noun cannot belong to more than one inflection class. Second, "mixed" paradigms — paradigms with no unique inflectional features of their own — are ruled out.

Carstairs-McCarthy (1989; 1994) assumes that the data about the inflections of a language are stored by speakers in the form of paradigms and, hence, in acquiring a language, speakers acquire a set of paradigms. He has proposed that the NBP follows from a fundamental learning bias, the Principle of Contrast (PC) for lexical learning (Clark, 1987, 1990, 1993). The PC is a pragmatic principle which states that "speakers take every difference in form to mark a difference in meaning" (Clark, 1993, p. 64). However, at the outset, given the rampant syncretism attested in richly inflected languages, inflectional morphology seems to either invalidate the PC or suggest that the principle is irrelevant in the acquisition of inflectional morphology.

Carstairs-McCarthy has attempted to reconcile the NBP with the PC by assuming that inflection class membership can form part of the meaning of an affix. For instance, feminine monosyllabic nouns in Icelandic display both trans-and intra-paradigmatic syncretism. Trans-paradigmatic syncretism involves the homonymy of inflection markers across inflection classes, whereas intra-paradigmatic syncretism involves the homonymy of inflection markers within an inflection class (see e.g. Müller, 2004). The only potentially disambiguating forms for feminine monosyllabic nouns in Icelandic are the genitive singular and nominative plural. However, even these forms seem rather freely distributed both within and across paradigms, as shown in Table 1:

[2] In more recent work, Carstairs-McCarthy (2010) refers to the NBP as VOCABULAR CLARITY.

Table 1: The distribution of GEN.SG *and* NOM.PL *forms of feminine monosyllabic nouns in Icelandic*

	Class A	Class B	Class C	Class D
GEN.SG	*–ar*	*–ar*	*–ar*	*–ur*
NOM.PL	*–ir*	*–ar*	*–ur*	*–ur*

Carstairs-McCarthy (1994, p. 740) has argued that the distribution of feminine monosyllabic nouns obeys the NBP since each class has a unique class-identifier. For example, nominative plural *–ir* is uniquely associated with Class A, whereas genitive singular *–ur* is uniquely associated with Class D.

However, Müller (2005) has argued that the NBP misses important generalizations as the "most conspicuous property" of Icelandic noun inflection is the constant re-use of inflection markers (affixes). Therefore, any constraint on the distribution of inflectional forms should seek to maximize syncretism and minimize the set of inflection markers. In an alternative analysis, Müller argues that the plural suffixes *–ar*, *–ir* and *–ur* undergo fission, a process in which a single morpheme corresponds to more than one terminal node prior to lexical insertion (Noyer, 1997). Thus, the plural suffixes *–ar*, *–ir*, *–ur* are not primitives, but consist of two parts; the vowel and /r/. Therefore, on this analysis, /r/ is the default plural form in Icelandic.

Classic Word and Paradigm (WP) models assume that each lexeme is presented by a basic, unmodified LEADING FORM that all other inflectional forms are modifications of. These modifications are organized into EXEMPLARY PARADIGMS that are definitional of inflection classes (Matthews, 1991). As a result, the number of different types of leading forms determines the number of inflection classes (Blevins, 2004; Stump, 2001). From a WP perspective, there is no principled reason why each lexeme must be identified by a single leading form. Rather, paradigmatic transparency may reflect a tendency towards lexical economy in inflectional morphology. As a result, WP approaches only claim that there will be a correlation between the number of leading forms and inflection classes (Blevins, 2004).

The most general insight of the classic WP approach is that one inflection tends to predict another. Therefore, the central premise of WP approaches is to account for interdependencies (Matthews, 1991). The challenge consists of demarking the distinction between predictive and non-predictive inflectional forms (Finkel & Stump, 2007). One proposal (Ackerman et al., 2009) has studied how forms in a paradigm are able to predict one another using entropy, an information-theoretic measure (Shannon, 1948). Entropy provides a measure of the predictability of an inflectional form by measuring the degree of surprise at the occurrence of a form.

It has long been observed that certain forms seem to carry more weight than others within an inflectional paradigm. For instance, Lahiri & Dresher (1983) discuss a number of case studies in which independently motivated sound changes in nominative singular forms resulted in wholesale inflection shifts in Germanic. Moreover, some inflectional forms have been argued to play a privileged role in acquisition (Bybee, 1985). However, both the nature and status of such forms have been contested (Carstairs, 1983; Matthews, 1991). Given the sparsity of the input data, the notion of base forms seems feasible in acquisition. Children learning richly inflected languages are unlikely to encounter many fully inflected nouns (see e.g. Chan, 2008). Still, children's inflectional morphology is typically target-consistent from early on, which suggests that they are able to form productive generalizations on the basis of very modest vocabularies (e.g. Szagun et al., 2006).

In Albright (2002), the notion of a base form has been implemented in a model of paradigm learning in which one leading form is used to derive the remaining forms within an inflectional paradigm. On this approach, the leading form is determined by "informativeness in revealing lexical properties" (Albright, 2002; 2004). However, the question is how the informativeness of an inflectional form is determined? The challenge is to determine the selection criterion for base forms since they cannot necessarily be identified by a priori definitions of morphosyntactic marked-ness. For instance, Albright (2004) discusses paradigm leveling in Latin noun inflection, whereby oblique forms influenced the nominative singular form, even if the latter has traditionally been assumed to be the citation form in Latin noun inflection.

The nature of the relevant generalizations in inflectional morphology may be contested, but there is general agreement that inflectional forms do not distribute at random within inflectional paradigms. Different theoretical assumptions lead to different formulations of the learning problem in acquisition. For instance, on Carstairs-McCarthy's approach, the learning process is characterized by a search for forms that can uniquely identify a noun's inflection class. By contrast, standard WP models assume that the learning process consists of identifying the minimal number of leading forms required to predict all inflectional realizations of a novel noun. Ultimately, the question is how children make use of notions such as leading forms, class-identifiers, defaults or bases. Since children do not get exposed to nouns in fully inflected paradigms in acquisition, they must somehow discover how individual forms are related to one another in order to predict a noun's inflectional behavior.

4.2 Gender and inflection: A case study of induction

Grammatical gender is conventionally not considered as an inflectional category since it does not induce sets of forms from a single lexeme. In other words, nouns do not form "gender pairs" in the same way that they form singular-plural pairs (Spencer, 2002, pp. 279-280). However, there is typically a relationship between gender and inflection in languages that encode both. In fusional noun inflection, like, for example, in Russian, Greek and Latin, gender and inflection interact to form inflection classes. Therefore, knowledge of such systems of nominal inflection entails not only knowledge of the individual categories, but also of their interrelatedness. However, the nature of the relation between gender and inflection has been much debated (Berg, 2019; Corbett, 1991; Enger, 2004; Kürschner, & Nübling, 2011; Spencer; 1999). The main point of contention has been the causal relation between the two: Does gender predict inflection or vice versa?

Inflection, unlike gender, does not participate in agreement relations (Alexiadou, 2004; Hockett, 1958). Thus, nouns of the same gender trigger the same agreement, irrespective of inflection. For example, masculine nouns in Icelandic trigger the same agreement morpheme (*–ur*) even if they belong to different inflection classes, as demonstrated in (6):

(6)	a. Falleg-**ur**	feldu-**r**.	(Icelandic)
	beautiful-M.NOM.SG	fur-M.NOM.SG	
	'Beautiful fur.'		
	b. Falleg-**ur**	jakk-**i**	
	beautiful-M.NOM.SG	jacket-M.NOM.SG	
	'A beautiful jacket.'		
	c. Falleg-**ur**	stóll-**Ø**	
	beautiful-M.NOM.SG	chair-M.NOM.SG	
	'A beautiful chair.'		

This fact has motivated a theory of grammar in which gender and inflection are linked to different modules; syntax and phonology, respectively (Alexiadou & Müller, 2008). In addition, this fact has distributional consequences, since it means that there is not necessarily a one-to-one mapping between gender and inflection classes. Several scholars have used this fact to argue that inflection predicts gender, on the grounds that the former carries more information than the latter in isolation (e.g. Corbett, 1991; Spencer, 2002). In other words, since there are typically more inflection classes than genders, it should be "simpler" to predict gender on the basis of inflection rather than vice versa (Spencer, 2002, pp. 36-37). In a similar spirit, Corbett (1991, p. 49) has argued, on the basis of German and Russian, that gender should be inferred on the basis of inflection class, given that nominative singular forms can correlate with more than one gender. For instance, nouns that end in a soft palatalized consonant in the nominative singular in Russian can be either masculine (e.g. *denj'* 'day') or feminine (e.g. *kost'* 'bone') (for discussion, see e.g. Nesset, 2003). As these nouns belong to different inflection classes, their oblique forms can serve as disambiguating forms.

However, evidence from acquisition and diachrony in some languages suggests that the causal relation is reversed. For example, Mills (1986) found that children's mastery of gender preceded their mastery of plural forms in German. Her findings seem to call into question that children make use of knowledge of inflection classes to learn gender. Diachronically, plural forms in German have undergone change in the direction of predictability according to gender (Wurzel, 1998). Therefore, these findings suggest that gender is a conditioning factor in plural formation in German, rather than vice versa.

The question is why there should be an inherent causal relation between gender and inflection? For instance, Enger (2004) has argued for a compromise view that the causal relation need not be fixed, using evidence from Norwegian. While the inflection of most Norwegian nouns can be predicted based on gender, the reverse holds for some nouns that are more frequent in the plural than the singular. Correspondingly, Doleschal (2000) has pointed out, using evidence from Russian, that the direction of causation may go in either direction between gender and inflection, even if one direction will typically be systematically preferred over the other.

The relation between gender and inflection is subject to cross-linguistic variation (e.g. Kürschner & Nübling, 2011) and may undergo diachronic change (Berg, 2019). For example, Icelandic has retained gender distinctions both in the singular and the plural, while Danish has retained gender distinctions in the singular only (for a standard reference grammar, consult Hansen & Heltoft, 2011). Combined, these observations seem to cast doubt on a universal preference in the interdependence between gender and inflection. However, an explanation is still needed of the nature of the correspondences between categories in languages in which such an interdependence holds and how it may be lost.

4.3 Learning to predict: Fusional noun inflection

Fusional noun inflection has raised important questions about the nature of generalizations in morphology. Due to the typically intricate nature of inflectional paradigms, there is often no statistically dominant form, unlike in English noun inflection, where the default plural form *–s* is conflated with frequency. Thus, English noun inflection is not useful as a test case for the study of the role of frequency versus regularity in the productivity of inflectional morphology. However, fusional noun inflection may consist of several productive patterns and exceptions and, therefore, it lends itself ideally to the study of these factors. Fusional noun inflection has often been evoked to argue against rule-based learning and in favor of probabilistic similarity-based generalizations in language (e.g. Köpcke, 1998; Laaha et al., 2006).

Plural formation in German has been at the center of the debate regarding the role of frequency in the formation of morphological generalizations. Nouns in German inflect for gender, case and number. Pluralizing nouns in German involves a choice between five suffixes: *–Ø, –e, –n, –er* and *–s*. Various lexical, phonological and even semantic properties of nouns have been proposed as conditioning factors in the choice of plural suffix (see, among many, Köpcke, 1988; Wurzel, 1998; Wunderlich, 1999). Table 2 shows the frequency distribution of plural suffixes in German (based on CELEX, from Sonnenstuhl & Huth, 2002, p. 278):

Table 2: The frequency distribution of plural types in German

Plural type	Type	Tokens
–Ø	4320 (17%)	87088 (29%)
–e	6836 (27%)	62239 (21%)
–er	1067 (4%)	10158 (3%)
–n	12365 (48%)	134492 (45%)
–s	1061 (4%)	5468 (2%)

Grammatical gender has standardly been recognized as a conditioning factor in German plural formation (Bittner, 2000; Wunderlich, 1999). In particular, the distinction between feminine and non-feminine nouns is important. There is a strong correlation between feminine and *–(e)n*.

Non-feminine nouns take –*e*, unless more specific phonological patterns apply, such as the ones listed in (7):

(7) a. Nouns ending in a reduced syllable take –Ø.
    b. Nouns ending in schwa take –*n*.
    c. Monosyllabic neuter nouns with a back vowel take –*er*.

The plural suffix –*s* is least restricted in its distribution of all the plural suffixes: It can appear with all three genders, any noun ending (consonant or vowel) and syllable number. The status of –*s* within the system has been vigorously debated. Marcus et al. (1995) identified 21 circumstances where the application of a default form would be expected and showed that –*s* could appear with all of them, in spite of low type as well as token frequency. These included low-frequency words, unusual-sounding words, acronyms and nominalizations. These findings seem to lend support to dual-route approaches to morphological learning, since they suggest that productivity is independent of type frequency, which is unexpected on single-route approaches. However, proponents of single-route approaches have used the restrictive distribution of –*s* and the productivity of other patterns in the system as evidence against its default status. Given that –*s* is not globally productive and occurs in predictable contexts, it has been proposed that –*s* is just one of several similarity-based lexical patterns, or schemas, in the German plural system (Bybee, 1995, p. 441; Köpcke, 1998, 1988; Szagun, 2001; Laaha et al., 2006).

German-speaking children have been found to partition nouns systematically from early on. In an elicited production task, Spreng (2003) found that children's responses patterned with gender and productive noun endings. In the absence of a productive pattern, –*s* was substituted for every plural type (Spreng, 2003, p. 170). Similar findings have been obtained in naturalistic settings (Szagun, 2001), but the interpretation of these findings has been disputed. Proponents of dual-route approaches have proposed that German-speaking children draw a categorical distinction between –*s* and other plural processes (although see, for example, Sonnenstuhl & Huth, 2002, for a weaker version of this view). However, proponents of single-route approaches have argued that children learn all these patterns probabilistically. In any case, it seems clear that –*s* is not the only productive plural suffix in German, since children do not uniformly over-generalize –*s*. Rather, they seem to systematically partition nouns into subclasses on the basis of their formal properties.[3]

4.4 Summary

Inflectional morphology, like grammatical gender, has raised many basic analytical questions ranging from the units of generalizations to the nature of the generalizations themselves. However, regardless of framework, the same inductive problem remains: How do children discover the relation between forms and categories in order to inflect novel nouns? The ability to generalize beyond experience is definitional of the notion of productivity. While native speakers typically have clear intuitions about what patterns are productive in the target language, the nature of the underlying generalizations and how they are formed has been vigorously debated. As we shall see, contrasting theories of productivity have different implications for how linguistic generalizations are construed.

[3] Rodina and Westergaard (2012) report similar findings for gender acquisition in Russian whereby children do not extend a pattern to the whole gender category, but only within a certain class or sub-category. They argue that such a pattern lends support to the Micro-cue Model (Westergaard, 2009a; 2009b; 2014).

5 Productivity

5.1 Overview

Productivity has been a central issue in morphological research (Bauer, 2001; Plag, 1999). Baayen and Lieber (1991, pp. 801–2) have even remarked that “morphological theory should account only for processes of word formation which are productive”. Therefore, determining which processes are productive is crucial in order to understand the underpinnings of morphological systems. Still, it has not been common practice to integrate productivity considerations into linguistic theory. This may be due to the existence of numerous definitions and uses of the term productivity (Rainer, 1987).

There is general agreement that linguistic processes can be productive. Proposed conditioning factors in productivity include frequency, semantic coherence and neologisms (Bauer, 2001, p. 32). The disagreement is centered around which processes are productive. A further disagreement is concerned with the nature of productivity in grammar; in particular whether productivity is categorical or gradient (Bybee & Moder, 1983). Finally, even gradient approaches to productivity may disagree on the degrees of productivity of any given process (see e.g. Bybee, 1995).

Productivity has been recognized to play a role in the acquisition of inflectional morphology. For example, Laaha et al. (2006) make use of Schultink’s (1961) definition of productivity as “language-users’ ability to coin unintentionally and, in principle, uncountable number of morphological forms”, to formulate a productivity scale to predict children’s behavior in the acquisition of German plural formation. However, due to the descriptive nature of the scale, their findings are not generalizable beyond German. Ideally, any account of productivity should be able to state the general conditions for the occurrence of productive processes and when these conditions are not met.

While frequency does not necessarily equate with productivity (e.g. Aronoff, 1976, p. 36), distributional properties have standardly been assumed to be involved in the productivity of linguistic patterns. The objective of quantitative approaches to productivity is to formalize speakers’ intuitions by stating the distributional conditions for the occurrence of productive processes in language. Quantitative approaches may differ vastly in what they measure, resulting in different predictions and implications for the nature of linguistic generalizations. Purely quantitative approaches to productivity have faced criticism for failure to incorporate the structural properties of morphological classes (see e.g. Van Marle, 1992). However, ultimately, linguistic theory should be informed by theories of children's ability to extract generalizations on the basis of the distributional properties of the input data. In the next two sub-sections, I discuss two contrasting quantitative models of productivity; the Tolerance Principle (Yang, 2005; 2016) and Baayen's P and P* metrics (1989; 1991; 1992; 1993), whose predictions will be put to test in the first article of this dissertation.

5.2 The Tolerance Principle

Yang (2005; 2016) has proposed a quantitative measure, the Tolerance Principle, to distinguish between productive and unproductive processes in language. The principle is stated in (8):

(8) **The Tolerance Principle**

If R is a productive rule applicable to N candidates, then the following relation holds between N and *e*, the number of exceptions that could but do not follow R: $e \leq \theta_N$ where $\theta_N = N/\ln N$.

The Tolerance Principle quantifies the precise conditions for productive rule formation. The model hypothesizes that a general rule will be formed when doing so is computationally more efficient than storing lexical items. Computational efficiency is computed by calculating the time complexity required for forming a rule with the time complexity required for accessing individual lexical forms.

Suppose that a rule R may in principle apply to a set of N lexical items with a a subset of e items that are exceptions that do not follow R. Let T(N, e) be the expected time of rule R if R is productive with e exceptions. All items that conform to R will have to wait until all the e exceptions have been evaluated and rejected. By contrast, for an exceptional item, the search time is determined by its rank on the frequency list. The expected time complexity is the weighted average of time units over the probabilities of these two sets of items. It is computationally more efficient to form a productive rule only when the number of exceptions is less than the number of items divided by the natural log of the number of items (for a full mathematical derivation of the principle see Yang, 2016, pp. 62-64). The principle is a threshold function that predicts a categorical division between productive and unproductive processes in language. On this approach, the difference between the two is a direct consequence of children's search for productive patterns in learning.

The Tolerance Principle makes use of the Elsewhere Condition (Kiparsky, 1973) which states that when a more specific form (or rule) is available, it is preferred over a more general one. For example, the irregular past tense form *went* would be preferred over a regular past tense form **goed*. The Elsewhere Condition is implemented by the Tolerance Principle as a serial search procedure which is empirically motivated by research on language processing (see Yang, 2016, pp. 49-60). To illustrate this serial procedure, one can think of past tense acquisition in English. The child is faced with verbs that adhere to the regular pattern, 'add *-ed*' and verbs that do not. The Tolerance Principle assumes that, in order to be maximally efficient in forming the past tense of verbs in English, the child is faced with two options: 1) Store all past tense verb forms individually 2) Form a productive rule. In the first case scenario, every item is stored in a list ranked by frequency. This means that the learner must search the list every time there is an occasion to express the past tense of a verb. In the second case scenario, only the exceptions are stored in a frequency-ranked list. The list of exceptions must be searched first before the productive rule can be applied.

The Tolerance Principle operates on type counts. Therefore, productivity in grammar learning on this approach is connected to the number of types over which linguistic patterns are expressed, rather than the number of tokens. This does not mean that token frequency is entirely irrelevant to the Tolerance Principle; the time complexities from which the Tolerance Principle is derived makes use of the distribution of word frequencies, as mandated by Zipf's law (1949) which states that the frequency of a word is approximately inversely proportional to its rank. Thus, relatively few words are used very frequently, while most words occur infrequently and many occurring only once, even in large samples of texts. However, ultimately, the learner only needs to know the number of types and how many of those are exceptions.

While the Tolerance Principle can predict the precise conditions for productive rule formation, it does not follow that children only learn language in a rule-based manner. Children's lexical conservatism in acquisition has often been used as evidence against rule-based learning (Tomasello, 2003; Dabrowska, 2005). The Tolerance Principle can also predict absence of productivity and, as a result, item-based learning (see Yang, 2016, pp. 152-156 on defective inflection in Russian and Polish). On this approach, the absence of productivity is the direct consequence of a learning process guided by a search for productivity that fails to succeed and results in rote memorization.

Morphological classes have structural properties such as, for example, gender, case and number. These properties produce subclasses of words. On this approach, these subclasses are a consequence of learning. The learner searches for productivity within subclasses if no productive rule initially emerges over a full set of items (e.g. all nouns). Thus, the learner's bias to maximize productivity motivates them to apply the Tolerance Principle recursively over a subset of items. The Tolerance Principle (Yang, 2016) can make use of the relevant gender distinction in German, [±feminine], to search for productive plural patterns within subsets of nouns. It is developmentally plausible that children make use of gender distinctions to pluralize nouns since grammatical gender in German seems to be in place from early on. Children's rate of correct gender marking has been reported to be around 80% before the age of three and at near-ceiling by the age of five (Szagun, 2004, p. 15).

In a sample of the 500 most frequent nouns in a corpus of German child-directed speech (MacWhinney, 2000), 166 are feminine. Of these, 146 take the *–(e)n* suffix and 20 are exceptions to this pattern. The Tolerance Principle predicts this pattern to be productive for feminine nouns, since the number of exceptions does not exceed the calculated exception threshold (166/ln166 = 32). Further productive nested patterns can be detected for the other subset, non-feminine nouns, on the basis of specific phonological patterns. For example, in the same sample corpus, of the 83 non-feminine nouns that end in a reduced syllable in the nominative singular, 77 take the null –Ø suffix and six are exceptions. The Tolerance Principle predicts an exception threshold of 83/ln83 = 18. Therefore, this pattern is predicted to be productive for non-feminine nouns that end in a reduced syllable. The patterns in (7b-c) in the previous section are predicted to be productive on the same method. In the absence of a productive phonological pattern, [-feminine] nouns take *–e*. Finally, if none of the productive rules apply based on either gender or phonology, *–s* is predicted to be productive (consult Yang, 2016, pp. 121-136 for a full quantitative analysis).

On this approach, *–s* is predicted to be the default plural suffix in German. This is because the rules are nested. Nouns that can be described by the more specific rules do not constitute exceptions to *–s*; they only apply to their specific subset. While the other productive suffixes apply to nouns with specific formal properties such as gender, *–s* is not restricted in the same way. Instead, it applies to the most general set of nouns after the more specific productive rules have been traversed.

The Tolerance Principle does not make use of any structural bias or endowment, apart from the concatenative operation Merge (Chomsky, 1999), following Fitch et al. (2005). However, it can be understood as a theory of how children discover the structural features of the target grammar by productive rule formation. Therefore, it is compatible with other approaches that assume that children can discover the structural features of the target grammar on the basis of the input. The productive generalizations that children detect distributionally by the Tolerance Principle can be viewed as informative structural cues that guide language acquisition (Dresher & Kay, 1990; Fodor, 1998, Lightfoot, 1999; Lightfoot, 2020; Westergaard, 2009a; 2009b; 2014).

The Tolerance Principle is one threshold function which invites the question of whether the principle is empirically realistic or psychologically feasible. This issue is a recurring point in critiques on the principle, although it reflects a more general challenge to formal language learning models that is not exclusive to the Tolerance Principle (see e.g. Wittenberg & Jackendoff, 2018). Yang (2016) has recognized that it is not at present clear how the principle is executed as a cognitive mechanism of learning. Therefore, it is still an open question how the threshold function is operationalized in the mind. Nevertheless, the Tolerance Principle is an attempt to generate a precise prediction as to when a child learner has sufficient evidence to make a generalization – and when the child learner does not. Ultimately, it is an empirical question whether speakers form linguistic generalizations in accordance with the Tolerance Principle. So far, the model‘s predictions have been borne out in a diverse set of corpus studies, ranging from the English past tense to dative substitution in Icelandic (consult Yang, 2016 for case studies). However, to date there are few studies that have tested the principle‘s predictions using behavioral methods, apart from Schuler et al.‘s (2016) artificial learning study, in which they were borne out for children. Therefore, further behavioral evidence is needed in order to test the empirical validity of the Tolerance Principle.

5.3 Alternative quantitative models of productivity

Baayen and colleagues (1989; 1991; 1993) have proposed a series of influential metrics to quantify linguists' intuitions about productivity. All of the metrics are centered around hapax legomena, i.e. singleton words that appear precisely once in any given corpus. The general idea is that low token frequency should be a strong indication of productivity, given that lexicalized types generally have a higher token frequency than unlexicalized types. Thus, words belonging to unproductive patterns must, by definition, be lexicalized or memorized, whereas words formed by productive processes do not.

The most studied metric proposed by Baayen and colleagues is P, which measures whether a given process is productive or not (Baayen, 1989; 1992; Baayen & Lieber, 1992). On this approach, singleton words are used to provide a numerical estimate of the probability of new words being formed by any given process. The denominator (N) rests on the assumption that a high average token frequency should correlate with a lesser degree of productivity. P is stated in (9), where n_1 represents the number of singleton words that a process applies to and N is the sum of the token frequencies of these items.

(9) $P = n_1/N$

The primary goal of P is to give a statistical measure of the probability of encountering new types (Baayen, 1993, p. 183). If a particular process is productive, the number of possible types it can give rise to is expected to be large. The larger the number of possible types, the less likely it is that they will all occur in a given corpus or that some of them will occur only once. Thus, P measures the relationship between the chance that a given process is put into action and the frequency with which the words that have already been produced by that process are used.

The measure P ignores the number of potential bases that are already available for a particular process. In other words, P does not take type frequency into account when measuring productivity. This has raised a number of concerns (see e.g. Bauer, 2001, p. 154). In order to address these concerns, Baayen (1993, p. 192) has proposed another measure that takes type frequency into account. A second metric, P*, measures the number of singleton words for any given process in a corpus as a proportion of the total number of singleton words in the corpus. P* is stated in (10), where N_1 represents the total number of all singleton words that a process applies to.

(10) $P^* = n_1/N_1$

The primary goal of P* is to give a numerical estimate of the relative rate at which a category is expanding. In other words, it measures the relative type frequency of a given process compared to all other processes. Thus, P* deals with actual rather than potential types by asking: What proportion of new coinages in a corpus make use of any given process ?

Baayen (1993, p. 194) proposed that P and P* should be viewed as two complementary measures; the primary use of P being to distinguish between productive and unproductive processes as such, while P* ranks processes by degrees of productivity. However, the separation between the two metrics seems to imply that type frequency is something separate from productivity. Yet, intuitively, type-frequency would be thought to influence the probability of encountering new types. Therefore, it remains unclear how a direct relationship between the two metrics should be construed (Bauer, 2001, p. 151).

More generally, the over-reliance of hapax legomena in the formulation of Baayen's metrics has been criticized (see e.g. Van Marle, 1992). In addition, it has been called into question whether the metrics are measuring the right thing. For instance, the reliance of P on token frequency means that different corpus analyses may yield different results depending on the size of the corpus. Another issue concerns P*: Is the relevant question for productivity not asking "what proportion of new coinages use process X?" rather than "what proportion of words using process X are new coinages?" (Bauer, 2001, p. 155). These concerns aside, the numerical predictions of the two metrics have been shown to correlate with behavioral results in adult language processing (Hay & Baayen, 2003; Plag & Baayen, 2009).

5.4 Summary

While there is general consensus that productivity is a feature of human language, there has been disagreement regarding what makes a linguistic process productive in the first place. In this section, I have introduced two contrasting quantitative models of productivity that have attempted to formalize speakers' intuitions about productivity. The Tolerance Principle was explicitly designed to account for learning, whereas Baayen's metrics were not. However, given the central role of productivity in language acquisition, any theory of productivity must be able to generate predictions for learning. In the next section, I describe the structural properties of Icelandic noun inflection, the empirical ground on which the predictions of the two models will be put to the test.

6 Noun inflection in Icelandic

6.1 Grammatical gender in Icelandic

Grammatical gender in Icelandic distinguishes between three genders: Masculine, feminine and neuter. The Icelandic gender system is typologically classified as formal (Corbett, 2013).
The three genders are roughly equally frequent (Helgadóttir et al., 2012). Gender distinctions are attested on the definite article, which is a suffix (11a)[4], adjectives (11b), the verbal past participle (11c) and pronouns (11d):

(11) a. Stóll-**inn**, skál-**in**, borð-**ið**.
Chair-M.DEF, bowl-F.DEF table-N.DEF
'The chair, the bowl, the table.'
b. Flott-**ur** stóll, flott-**Ø** skál, flott-**Ø** borð.
Nice-M chair-M, nice-F bowl-F, nice-N table-N
'A nice chair, a nice bowl, a nice table.'
c. Stóllinn er brot-**inn**, skálin er brot-**in**,
The chair-M is broken-M, the bowl-F is broken-F,
borðið er brot-**ið**.
the table-N is broken-N
'The chair is broken, the bowl is broken, the table is broken.'
d. **Hann** er brotinn, **hún** er brotin, **það** er brotið.
He is broken, she is broken, it is broken.
'He (the chair) is broken, she (the bowl) is broken, it (the table) is broken.'

[4] The status of the definite suffix as an exponent of gender has been disputed in closely related languages. For example, traditional Norwegian grammars (such as Faarlund et al., 1997) have considered the definite suffix to be an exponent of gender. This view has been contested by various scholars who argue that the definite suffix in Norwegian does not fall under the standard definition of genders as "classes of nouns reflected in the behavior of associated words" (Corbett, 1991; Hockett, 1958) since it is attached to the noun itself. Instead, it has been proposed that the definite suffix in Norwegian is an exponent of inflection based on various types of evidence, including acquisition, variation and diachrony (Busterud et al., 2019; Lohndal & Westergaard, 2016; Rodina & Westergaard, 2015; Svenonius, 2017). However, it has also been proposed that whether the definite suffix is an exponent of gender or inflection class may differ between Norwegian dialects depending on the nature of the relation between gender and inflection; i.e. whether gender can predict inflection class or vice versa (for a discussion, see Enger, 2004). I leave open the possibility that gender can be re-analyzed as an exponent of inflection under conditions where formal gender assignment cues are weak or have been lost, as proposed by Svenonius (2017).

Anaphoric pronouns must refer to the formal gender of the referent noun irrespective of animacy or biological sex. However, animate nouns that refer to individuals of either sex may be referred to by either masculine or feminine, but not neuter, anaphoric pronouns.[5] For example, *doctor* in (12a) is formally masculine but can be referred to by a feminine anaphor. if the doctor under discussion is female. Conversely, *hero* in (12b) is formally feminine but can be referred to by a masculine anaphor (examples from Sigurðsson, 2019, p. 738):

(12) a. Læknir-**inn**... Hann/Hún/*Það...
doctor-M.DEF$_i$ he$_i$/she$_i$/it$_i$
'The doctor… He/She/It…'
b. Hetja-**n** Hann/Hún/*Það...
hero-F.DEF$_i$ he$_i$/she$_i$/it$_i$
'The hero… He/She/It…'

Variable agreement conditioned by semantic gender seems confined to anaphoric pronouns. Otherwise, formal gender is deterministic of agreement.

In addition to gender, Icelandic distinguishes between four cases: Nominative, accusative, dative and genitive. Gender and case interact to form inflection classes. Nominative singular is the most frequent inflectional form, constituting approximately 40% of all inflectional forms in Icelandic (Helgadóttir et al., 2012). There are correspondences between gender and nominative singular suffix in Icelandic, as Table 3 demonstrates:

Table 3: Correspondences between gender and nom.sg. suffixes in Icelandic

NOM.SG.	**Masculine**	**Feminine**	**Neuter**
–r	Bátu-r ('a boat')	Brúðu-r ('a bride')	NA
–i	Penn-i ('a pen')	NA	NA
–a	Herr-a ('Sir')	Kann-a ('a mug')	NA
–Ø	Guð-Ø ('God')	Hlíð-Ø ('a hill')	Stríð-Ø ('War')

The absence of an overt nominative singular suffix is indicated by the zero suffix –Ø. The correspondences in Table 3 show that there is not necessarily a one-to-one correspondence

[5]In recent years, the gender-neutral pronoun *hán* has been gaining ground.

between gender and nominative singular suffix. Rather, these correspondences can be described as correlations or tendencies: Nouns that take either suffix *–r*[6] or *–i* tend to be masculine. Nouns that take the suffix *–a* tend to be feminine. However, there are various exceptions to these correlations. For example, several common female names in Icelandic, including *Sigríður*, take the suffix *–r*.

The suffixes on the nouns in Table 3 undergo case alternations in oblique forms. For example, the genitive form of *penn-i* (pen-M.NOM.SG) is *penn-a* (pen-M.GEN.SG). However, some nouns do not take the phonemes in Table 3 by suffixation. For instance, the genitive form of *tæki*-Ø (device-N.NOM.SG) is *tæki*-s (device-N.GEN.SG). Thus, /i/ forms part of the noun stem in the case of *tæki*. Some examples of such nouns are provided in (13). Most of these nouns are neuter, although nouns with stem-final /i/ can be either feminine or neuter (13b).

(13) a. Aug**a**-Ø, eyr**a**-Ø.
Eye-N.NOM.SG, ear-N.NOM.SG
'An eye, an ear.'
b. Tæk**i**-Ø, gleð**i**-Ø.
Device-N.NOM.SG, joy-F.NOM.SG
'A device, joy.'
c. Be**r**-Ø, ke**r**-Ø.
Berry-N.NOM.SG, tub-N.NOM.SG
'A berry, a tub.'

While these nouns have oblique forms different from nouns that take these sounds by suffixation, they could be ambiguous to the child learner in gender acquisition given the statistical dominance of nominative singular forms in Icelandic. Therefore, they are counted as exceptions to the correspondences stated in Table 3 in all quantitative analyses presented in this dissertation.

Gender assignment in Icelandic has received relatively little attention as an independent topic of study. However, Steinmetz (1986) lists the following rules, stated in (14):

[6] Most nouns in this class end in *–ur*. The /u/ is assumed to reflect epenthesis, a purely phonological process, independent of gender assignment, which is triggered automatically under suffixation.

(14) **Morphological rules**

Masculine: Nominative singular suffix *–r* and *–i*

Feminine: Nominative singular suffix *–a*, *–ing*, phonological template *ö(C)C*

Semantic rules

Masculine: Winter-affiliated nouns

Feminine: Semantic diminutives

These rules are subsumed in Trosterud's (2005) analysis of gender assignment in Old Norse, which introdues a total of 16 semantic, 10 morphological, and a set of phonological gender assignment rules. Since grammatical gender in Icelandic has been relatively stable diachronically, many of the rules proposed by Trosterud are, in principle, applicable to modern Icelandic. However, some of the rules involve complex semantic categorization such as "nouns denoting time are masculine" (p. 1446). Children cross-linguistically have been shown to be capable of using productive noun-internal distributional cues in gender acquisition from early on, even in the face of conflicting semantic information (cf. the discussion in section three). Therefore, it seems questionable whether such rules are available in acquisition, especially given that it is at present unclear when such semantic categories emerge in cognitive development.

Icelandic reference grammars (see e.g. Kvaran, 2005) have standardly followed the lead of Old Norse reference grammars (Iversen, 1922; Noreen, 1903) by stating the correspondence between gender and inflection classes without discussing specific gender assignment rules. This view assumes that knowledge of a noun's inflection class membership is a prerequisite for knowledge of a noun's gender. The question is what generalizations these correspondences give rise to. This is especially relevant for nouns that lack an overt suffix in the nominative singular form (–Ø). Nouns of all genders fall into this class. There are no clear phonological regularities within this class. For example, many feminine and neuter nouns rhyme, like *borg*-Ø ('a city-F') and *torg*-Ø ('a square-N'). The gender assignment of such nouns may be disambiguated by oblique forms, although all nouns in Icelandic take the same suffixes in the dative and genitive plural. The inflectional paradigms of these nouns are given in (15):

(15)

	Masculine	Feminine	Neuter
		Singular	
NOM.	stóll-Ø	skál-Ø	torg-Ø
ACC.	stól-Ø	skál-Ø	torg-Ø
DAT.	stól-i	skál-Ø	torg-i
GEN.	stól-s	skál-ar	torg-s
		Plural	
NOM.	stól-ar	skál-ar	torg-Ø
ACC.	stól-a	skál-ar	torg-Ø
DAT.	stól-um	borg-um	torg-um
GEN.	stól-a	borg-a	torg-a
	(‘a chair’)	(‘a bowl’)	(‘a square’)

Given the considerable inter-class syncretism in Icelandic noun inflection, an important question is how children navigate this system. While there may be some disambiguating forms or class-identifiers, such as the genitive singular *-ar* for feminines, it is at present unclear how children make use of such forms in acquisition.

Rögnvaldsson (2012, p. 151) has proposed that the most relevant gender distinction in Icelandic is [±feminine]. One argument for this view involves generic reference. The use of a feminine form like *allar,* as in (16), is felicitous only if it is common ground that all referents are female. By contrast, both masculine and neuter can refer to mixed groups.

(16) **Allir**/**Öll**/**Allar** tapa á verðbólgunni.
Everyone-M./N./F.SG loses on the-inflation
‘Everyone loses because of the inflation.’

The same pattern is attested with conjoined noun phrases, although agreement in such contexts is a complex matter that raises a number of issues that are beyond of the scope of this dissertation.[7]

[7] For a discussion on conjoined noun phrases and variable default behavior in Icelandic, consult Kramer, 2015, pp. 142-146 and Þorvaldsdóttir, 2019.

Neuter has standardly been assumed to be the default assignment gender[8] in Icelandic since it is obligatory in syntactic contexts where agreement is expected to be inert, like, for example, with clausal (17a) and oblique (17b) subjects:

(17) a. Að halda þessu fram er ósiðleg-**t**
C maintain this P is unethical-N.SG
'To maintain this is unethical.'
b. Mér er kal-**t**.
me-DAT.SG is cold-N.SG
'I'm cold.'

Diachronically, the default assignment status of neuter has also been contested. Based on a study of Fritzner's (1973) dictionary of Old Norse, Trosterud (2005) argues that neuter was a WEAK DEFAULT in Old Norse, since borrowed nouns occur with all genders, of which only 25% are neuter. This seems to suggest that the productivity of neuter was protracted, at least at an earlier diachronic stage (see also Bjorvand, 1987, for a discussion on gender shifts from neuter to feminine). To date, there is no systematic study of the gender assignment of borrowed nouns in modern Icelandic. Prima facie, it seems like borrowed nouns can, in principle, be of any gender. Some borrowed nouns in Icelandic display both inter- and intra-speaker variation, for instance, *e-mail,* which can be either masculine or neuter. However, a systematic study is needed in order to discern the exact nature of the variation attested.

6.2 Noun pluralization in Icelandic

Marking plurality in Icelandic involves a morphological selection between five plural allomorphs: *–ar*, *–ir*, *–ur*, *–Ø* and *–u*. Standard descriptions of Icelandic noun inflection state that grammatical gender is encoded both in the singular and the plural (see e.g. Kvaran, 2005). Thus, there are correspondences between gender and the choice of plural suffix. Since there are correlations between nominative singular forms and gender assignment (cf. discussion in section 6.1), there are also correspondences between nominative singular and nominative plural suffixes, although there is considerable syncretism. The correspondences between gender, nominative singular suffix and nominative plural suffix are stated in Table 4:

[8] Prior accounts have confounded gender assignment and gender agreement defaults in their discussion of Icelandic (Steinmetz, 1986; Trosterud, 2005). However, as discussed in section 2.2, there are reasons to believe that there is a need for separate assignment and agreement default genders (Corbett, 2000; Lohndal & Westergaard, 2021).

Table 4: Correspondences between gender, nom.sg. suffix and choice of plural suffix

	Masculine				**Feminine**				**Neuter**			
NOM.SG suffix	*–r*	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*
NOM.PL suffix	*–ar*	*–ar*	*–ar*	*–ar*		NA		*–ar*	NA	NA	NA	
	–ir	*–ir*			*–ir*			*–ir*				
	–Ø							*–Ø*				*–Ø*
		–ur					*–ur*	*–ur*				
												–u

Table 5 shows how plural suffixes are mapped on to real nouns by gender:

Table 5: Gender and plural formation in Icelandic

	Masculine	**Feminine**	**Neuter**
–ar	hest-ar ('horses')	skál-ar ('bowls')	
–ir	dal-ir ('valleys')	borg-ir ('cities')	
–Ø	menn-Ø ('men')	mýs-Ø ('mice')	torg-Ø ('squares')
–ur	bænd-ur ('farmers')	kon-ur ('women')	
–u			aug-u ('eyes')

The morphological selection process is confined to nominative plural forms. Masculine nouns undergo a subtraction process in the accusative plural. For example, nominative plural *hest-ar* ('horses') is *hest-a* in the accusative plural. All nouns take the same suffixes in the dative and genitive plural, irrespective of gender or inflection class. Plural nouns in Icelandic are affected by systematic morphophonological processes, such as [ʏ]-umlaut (e.g. Þráinsson, 2017), that are not specific to plural formation. These processes are triggered automatically under suffixation, independently of plural formation.

Grammatical gender narrows down the range of options with respect to plural formation. For example, neuter nouns do not pluralize productively by suffixation. However, there is considerable overlap in the plural marking of masculine and feminine nouns. Most descriptive accounts state a correspondence between masculine and *–ar*. For example, borrowed masculine nouns typically take that suffix (Rögnvaldsson, 2012, p. 171). Synchronically, there is a tendency for some masculine nouns that take *–ir* to drift over to *–ar*, such as *Japan-ir/Japan-ar* (Japanese-M.PL; 'Japanese'). Furthermore, children have been found to overgeneralize *–ar* when pluralizing masculine nouns. (Gíslason et al., 1986). These facts suggest a productive correlation between masculine and *–ar*, in spite of syncretism with feminine.

Feminine nouns that take the nominative singular suffix *–a* invariantly pluralize with *–ur*. Otherwise, feminine nouns select either *–ar* or *–ir*, but rarely *–ur*. Therefore, *–ur* seems productive only in the context of the feminine nominative singular *–a* suffix. Some feminines show free variation between *–ar* and *–ir*, like *lest* ('train') and *hurð* ('door'), with both inter- and intra-speaker variation. Diachronically, feminines have also shifted between the two plural suffixes. For example, both *þjóð* ('nation') and *vél* ('machine') could take either suffix at an earlier diachronic stage. The former can only take *–ir* in modern Icelandic, while the latter invariantly selects *–ar* (Iversen, 1907, p. 52-53). In spite of free variation, many accounts claim that the default plural suffix for feminine nouns is *–ir* (e.g. Bjorvand, 1972; Wurzel, 1987).

While plural forms are standardly assumed to be derived from singular base forms, there are some nouns that have no possible singular forms. Many pluralia tantum nouns in Icelandic are neuter. A few examples are given in (18):

(18) a. Jól-**in** koma./ *Jól-**ið** kemur.
x-mas-N.PL come-PL /x-mas-N.SG come-SG
'X-mas is coming.'

b. Viðskipt-**in** ganga vel./*Viðskipt-**ið** gengur vel.
business-N.PL go-PL well/ business-N.SG go-SG well
'Business is going well.'

c. Verðlaun-**in** eru vegleg-**Ø**./*Verðlaun-**ið** er vegleg-**t**.
prize-N.PL is-PL grand-N.PL/prize-N.SG is-SG grand-N.SG
'The prize is grand.'

d. Vonbrigð-**in** eru mikil-**Ø**./*Vonbrigð-**ið** er mik-**ið**.

disappointment-N.PL is-PL big-N.PL/ disappointment-N.SG is-SG big-N.SG
'It's a big disappointment.'

There are no semantic reasons for this ineffability; the nouns in (15) can be classified into several semantic categories. Rather, it seems to reflect the absence of a productive singular form.

6.3 Summary

In this section, I have given an overview of grammatical gender and plural formation in Icelandic which form the empirical basis of this dissertation. Grammatical gender in Icelandic is an ideal case study to explore some of the issues raised in previous sections, since it has formal gender assignment correlates, albeit with exceptions. Furthermore, in spite its formal typological classification, gender in Icelandic has been used as evidence that children's initial categorization in gender acquisition is driven by semantic distinctions (Mulford, 1985). Since plural formation in Icelandic cross-cuts both gender and inflection classes, it is an interesting case study of the interconnectedness of these categories in acquisition.

7 Research questions

7.1 Overview

The overarching research questions of this dissertation are the following: What constitutes a generalization about gender and inflection, how are such generalizations formed and how may they undergo change? I address these questions by studying how children make use of the distributional information in the input to construct a system that enables them to generalize beyond experience. Conversely, I study how generalizations about gender assignment are affected by reduced input and use across the lifespan.

A major challenge in theoretical research on grammatical gender cross-linguistically has been to identify and motivate gender assignment rules. A great many rules or patterns have been proposed for gender systems cross-linguistically (e.g. Corbett, 1991). However, there has not been general consensus regarding what generalizations form the basis of speakers' ability to assign gender to novel nouns. The nature of the relevant generalizations underlying the structure of inflectional paradigms has also been a source of much debate.

In parallel, explaining how children discover the relevant generalizations in gender and inflectional morphology on the basis of the input data has been the central objective of research on the acquisition of grammatical gender and inflectional morphology. In this dissertation, I study the conditions under which children form generalizations in gender assignment – and the conditions under which they do not – using Icelandic as a case study. I further investigate the nature of the correspondence between gender and inflection in Icelandic, by studying how knowledge of productive generalizations about gender assignment facilitates the induction of plural forms. Conversely, I study whether knowledge of plural forms facilitates the induction of gender and singular forms.

Gender and inflectional morphology are domains of grammar whereby heritage speakers may differ from the baseline (cf. the discussion in section 3.3). However, the source of these differences has been contested: Do they reflect differences in linguistic knowledge or can they be reduced to other extra-linguistic cognitive factors? Changes in linguistic knowledge may result in systematic re-analysis of patterns or errors of over-generalization, whereas the absence of systematicity may reflect other behavioral factors. But, in order to understand what constitutes as systematic errors in the first place, we need to be able to demark generalizations from idiosyncrasies in the baseline system.

In the remainder of this section, I explicitly state the specific research questions for each article and briefly outline how they were addressed. The next section includes a description of the methodology used to generate and test the predictions for each study. Section nine states the predictions, followed by the results in section ten.

7.2 Article I: To generalize or not to generalize in gender assignment?

The first article, Productivity and the acquisition of gender, is concerned with three main research questions:

- How do children and adults form productive generalizations about gender assignment in Icelandic?
- How do children and adults assign gender in the absence of a productive generalization about gender assignment in Icelandic?
- Are there categorical or gradient differences between productive and unproductive generalizations about gender assignment in Icelandic?

To address these questions, a series of corpus analyses were conducted using two contrasting quantitative models of productivity (Baayen, 1989; 1991; 1993; Yang, 2005; 2016). The corpus analyses served to generate predictions for learning that were put to test in an elicited production task which tested the abilities of children and adults to form generalizations about the gender assignment of novel nouns and their failure to do so.

7.3 Article II: The gender-inflection from a learning perspective

In the second article, Predicting ineffability: Gender and plural formation in Icelandic, the bi-directional relation between gender and inflection in acquisition was under study. Specifically, two main research questions were addressed:

- Given the gender of a novel noun, can children and adults infer its plural form?
- Given a novel plural noun, can children and adults infer its gender and nominative singular form?

The Tolerance Principle was used on the Tagged Icelandic corpus (Helgadóttir et al., 2012) to generate predictions regarding the correspondences between gender and plural forms in Icelandic. These predictions were put to the test in two elicited production studies on children and adults that elicited i) gender agreement and nominative plural forms on the basis of nominative singular forms ii) gender agreement and nominative singular forms on the basis of nominative plural forms.

7.4 Article III: Changes to linguistic generalizations under reduced input

The third article, The effect of attrition on grammatical gender: A view from North American Icelandic, consists of a longitudinal corpus case study of North American Icelandic. The study addresses three main questions:

- How is grammatical gender affected by attrition?
- What is the nature of the non-target gender marking that arises as a function of time with reduced input and use of Icelandic?
- What can the nature of the non-target gender marking reveal about the nature of attrition?

To address these questions, we investigated how productive (regular) and unproductive (irregular) processes were affected by the attrition process.

8 Methodology

8.1 Corpus methods

8.1.1 Use of corpora to generate predictions for learning

Quantitative methods were used to formulate predictions for children's learning trajectories of gender and plural formation in Icelandic. Such methods can generate numerical predictions regarding what linguistic generalizations children can, by hypothesis, form on the basis of lexical experience. There is cross-linguistic evidence that children can internalize productive gender assignment rules by the age of three (e.g. Mills, 1986 for German; Pérez-Pereira, 1991a for Spanish; Rodina & Westergaard, 2012 for Russian). Likewise, children have been found to produce plural marking from early on (see, among many, Levy, 1983; Szagun et al., 2006). However, at the age of three, the average child knows only around 500 words (Hart & Risley, 1995; 2003; Szagun et al., 2006). Therefore, predictions for learning based on corpus measures must take children's vocabulary sizes in acquisition into consideration. In addition, since children's linguistic experience is inevitably diverse, predictions based on quantitative measures should ideally be generalizable across corpora.

In the first article of this dissertation, a series of corpus analyses were conducted on child-directed speech, a child‘s spontaneous speech in response to her caregiver (Sigurjónsdóttir, 2007) and the Icelandic SUBTLEX corpus. The child-directed speech consists of 82 recordings that were made approximately once a month when the child was between the ages of 1;6-4;3 years and has a total of around 500,000 tokens. The child's spontaneous speech consists of roughly 7000 tokens. Analyzing both child and caregiver speech provides a realistic estimation of the child's input in acquisition and their own lexical knowledge.

An additional corpus analysis was conducted on the Icelandic SUBTLEX corpus in order to test whether the same numerical predictions hold when a sample is drawn at random from a larger corpus. The Icelandic SUBTLEX corpus contains 8.6 million tokens and consists of corpora based on Icelandic subtitles. A computer simulation model was instructed to draw 500,000 noun tokens, to match the token size of the Icelandic child-directed speech corpus, at random and proportionally to word frequencies.

The purpose of the analyses was to test for productive correspondences between nominative singular suffixes and gender assignment in Icelandic. Nominative singular noun types were extracted from all corpora and categorized by gender and nominative singular suffix

(*–r, –i, –a, –Ø*). Two contrasting quantitative models of productivity, the Tolerance Principle and Baayen's P and P* metrics, were employed in the analyses to generate predictions for children's learning trajectories.

In the second article, the Tolerance Principle was used to predict productive correspondences between gender and plural suffixes – and absence thereof – in the Tagged Icelandic Corpus (Helgadóttir et al., 2012). The corpus consists of 26 million tokens and contains contemporary Icelandic texts collected from various sources between 2006 and 2010.

The top 1000 most frequent nominative plural noun types were extracted from the corpus and tagged for gender and nominative plural suffix (*–ar, –ir, –ur, –u, –Ø*). They were then subjected to two separate quantitative analyses using the Tolerance Principle to predict the conditions under which knowledge of gender facilitates the induction of plural suffix, or vice versa, and when these conditions are not met.

8.1.2 The effect of attrition on gender: A longitudinal corpus case study

The data consist of a longitudinal corpus of letters (82,000 word tokens), written by a speaker of North American Icelandic in Canada over the span of 72 years (1908-1980). The writer was a second-generation immigrant born to Icelandic parents in Canada. Since the parents emigrated four years prior to the writer's birth, it seems plausible to assume that the parental input was consistent with the homeland baseline variety.

The original letters are stored in the National Archives in Blönduós, Iceland (http://www.skjalhun.is). They were photographed and typed into a text editor. Nouns were extracted from letters written between 1950-1980 and coded for gender, number, case and nominative singular suffix. Since the article was focused on gender, the analysis was confined to singular nouns, the vast majority of noun tokens in the corpus (78%), as noun pluralization in Icelandic conflates gender and inflection. Icelandic has no indefinite article. Therefore, a bare noun in isolation carries no information about what gender a speaker has assigned to it. As a consequence, gender agreement was taken to reflect gender assignment. In cases of non-target gender agreement with a noun, the syntactic context and type of agreement form was coded (e.g. DP-internal adjectival agreement). Standard statistical methods, such as generalized linear models were used to confirm the significance or non-significance of each non-target pattern.

8.2 Experiments

8.2.1 Overview

Three experiments put the numerical predictions generated by the corpus analyses, stated in section nine, to the test. All three experiments had two conditions: Productive and unproductive. The first experiment tested children's and adults' abilities to assign gender to novel nouns on the basis of nominative singular forms. In addition, the experiment tested whether there were categorical or gradient differences between participants' response patterns in the two conditions. The second experiment tested children's abilities to pluralize novel nouns on the basis of the same conditions. In the third experiment, the abilities of children and adults to infer the gender and nominative singular forms of novel nouns with either productive or unproductive plural suffixes were put to the test.

All three experiments were embedded in interactive animated video games that were designed using Animaker, an online animation software. In each experiment, the participant was asked to engage with the game verbally to affect the course of events in the storyline and move on to the next test item. Each game was 13 minutes in duration, which included a training session on three real nouns, one for each gender. Participants were tested individually in a quiet room. Their responses were audio recorded and written down by the experimenter.

8.2.2 Participants

Child participants were recruited from a day care centre and a primary school in Reykjavík, where the studies were conducted. Adult participants were recruited at the University of Iceland, Reykjavík. All participants were native speakers of Icelandic with normal hearing and normal to corrected-to-normal vision. No participant reported to have a history of language delay. The data collection was approved by the Norwegian Centre for Research Data. Legal guardians provided informed consent for child participants. Adult participants provided their own. Information about participants is summarized in table six. The total number of participants included in the data analysis is indicated by N.

Table 6: Information about participants

Experiment	Adults		Children		Children's age range
1	**N**	**Excluded**	**N**	**Excluded**	2;9-6;3 years
	18	0	26 (14 F, 12 M)	4	Mean=4;5 years SD=1.33 years
2	**N**	**Excluded**	**N**	**Excluded**	2;4-5;6 years
	20	0	27 (15 F, 12 M)	5	Mean=4;0 years SD=0.1 years
3	**N**	**Excluded**	**N**	**Excluded**	6;3-8;2 years
	20	0	26 (15 F, 11 M)	2	Mean=7;0 years SD=1.33 years

The age range of child participants in the first two experiments was rather similar. However, the age range in the third experiment was considerably higher. The reason for the higher age range was that an initial pilot study for experiment 3 on 10 children (age range 3;10-5,0 years) revealed that children resorted to zero responses in the task. This response pattern may suggest that children at this age have difficulties retrieving base forms from derived forms.

8.2.3 Experiment 1: Predicting ineffability in gender assignment

28 novel nouns were constructed using the Phonological Corpus Tools software (Hall et al., 2016) and checked against Pind‘s (1991) frequency list of Icelandic to control for minimal pairs and phonological neighborhood density. In the productive condition, the nouns carried either the nominative singular suffix *–r*, *–i* or *–a*. In the unproductive condition, participants were exposed to a novel noun, monosyllabic or disyllabic, that did not bear such a suffix (*–Ø*). The stem-final segment of novel nouns in the unproductive condition could be any consonant apart from /r/. The novel noun was paired with a novel object from the Novel Object and Unusual Name (NOUN) database (Horst & Hout, 2016). The 28 pairings are provided in the Appendix.

Prior to test, the participant was exposed to a novel noun-object pairing with an audio stimulus that presented the name of the novel object twice in syntactic contexts where the nominative singular is obligatory, as demonstrated in (19):

(19) a. Þetta er **lerfur**.
this is lerfur-M.NOM.SG.
'This is a lerfur.'
b. Vá! **Lerfur**!
wow lerfur-M.NOM.SG.
'Wow! A lerfur!'

The objective of the game was to obtain new toys by magic by uttering a magical charm which served as the test sentence. The sentence elicited gender distinctions on the definite suffix and gender agreement on the possessive pronominal, as demonstrated on real nouns in (20):

(20) a. Hvar er hattu-r-**inn** **minn**?
where is hat-M.DEF.SG my-M.SG
'Where is my hat?'
b. Hvar er penn-i-**nn** **minn**?
where is pen-M.DEF.SG my-M.SG
'Where is my pen?'
c. Hvar er kann-a-**n** **mín**?
where is mug-F.DEF.SG my-F.SG
'Where is my mug?'
d. Hvar er egg-**ið** **mitt**?
where is egg-N.DEF.SG my-N
'Where is my egg?'

Once the participant had produced the test sentence, the novel object appeared on the computer screen, as if by magic. Figure 1 demonstrates the magic at work in the test scene:

Figure 1: Magic at work in the test scene

There were 14 test items per condition. The test items were organized into seven trials. In each trial, the participant was presented with four test items, two for each condition, in a randomized order.

8.2.4 Experiment 2: Predicting ineffability in plural formation

Twenty-four novel nouns were constructed in the same way as in experiment 1. The nouns were additionally subjected to an acceptability judgement task on 20 adult native speakers in order to control for lexical similarity to existing singular and plural nouns. The novel nouns were paired with novel objects in the form of flying toasters (Glitch, 2012). The pairings are provided in the Appendix. Participants were exposed the novel noun twice in syntactic contexts where the nominative singular is obligatory, as demonstrated in (20) for experiment 1.

In the game, the participant was asked to help animated story protagonists find flying toasters that had gone missing from their scientific laboratory and were now roaming free around the world. In the test scene, flying toasters, ranging from two to four, were seen as either emerging from the background or trying to hide from view. Figure 2 provides a demonstration of one of the test scenes.

Figure 2: Novel objects attempting to hide from view in the test scene

In addition to locating the flying toasters, the participant had to provide the correct number of flying toasters observed in each test scene and inform the story protagonists. The test sentence elicited both gender and plural marking, as demonstrated in (21):

(21) a. Þarna eru **tveir** **lerfar**.
there are two-M.SG lerfur-M.PL
'Here are two lerfur-PL.'

b. Þarna eru **tvær** **buklur**.
there are two-F.SG bukla-F.PL
'Here are two bukla-PL.'

c. Þarna eru **tvö** **súf**.
there are two-N.SG súf-N.PL
'Here are two súf-PL.'

Once the participant had produced the test sentence, the video proceeded on to the presentation of the next test item. There were 12 test items per condition. The test items were organized into six trials. In each trial, the participant was presented with four test items, two for each condition, in a randomized order.

8.2.5 Experiment 3: Predicting ineffability in gender and singular forms

The 24 novel plural nouns in experiment 3 were based on the same lexical roots that were constructed for experiment 2. In the productive condition, participants were exposed to a novel plural noun with either nominative plural suffix *–ar*, *–ur* or *–Ø*. In the unproductive condition, they were exposed to a novel plural noun with the nominative plural suffix *–ir*.

Prior to the test, flying toasters (Glitch, 2012) were presented in groups of two to four. The flying toasters in each group were all of the same specimen. The participant was exposed to the novel noun-objects pairing with an audio stimulus twice in syntactic contexts where the nominative plural is obligatory, as shown in (22):

(22) a. Þetta eru **lerfar**.
these are lerfur-M.NOM.PL.
'Here are lerfar-PL.'
b. Vá! **Lerfar**!
wow lerfur-M.NOM.PL.
c. 'Wow! Lerfar-PL!'

In the game, the participant was asked to find flying toasters that had gone missing from their group of friends (other flying toasters of the same specimen) while travelling. The participant's task involved locating the flying toasters in the test scene and informing the animated story protagonists. Figure three provides an example test scene:

Figure 3: Missing flying toaster located in the test scene

The context of a single missing flying object facilitated a definite interpretation. Therefore, the participant was expected to identify the missing flying object and produce the singular form with the definite suffix. In addition, the participant was elicited to produce the possessive pronominal during the test, as shown in (24). Combined, the definite suffix and the possessive pronominal induced gender distinctions and agreement. The use of the possessive pronominal was intended to emphasize the participant's commitment to finding the missing flying object. In addition, the participant's response was expected to indicate their choice of nominative singular suffix. Examples of elicited responses are provided in (23):

(23) a. Þarna er lerf-**ur-inn** **minn**.
there is lerfur-M.DEF.SG my-M.SG
'Here is my lerfur.'

b. Þarna er bukl-**a-n** **mín**.
there is bukla-F.DEF.SG my-F.SG
'Here is my bukla.'

c. Þarna er súf-**Ø-ið** **mitt**.
there is súf-N.DEF.SG my-N.SG
'Here is my súf.'

Once the participant had produced the test sentence, the game proceeded to the presentation of the next test item. There were 12 test items per condition, as in the second experiment. The test items were organized into six trials. In each trial, the participant was presented with four test items, two for each condition, in a randomized order.

9 Predictions

9.1 Predictions for children's behavior in gender acquisition

9.1.1 Quantitative analyses using the Tolerance Principle

The child-directed speech (Sigurjónsdóttir, 2007) contained 478 nominative singular noun types which constituted approximately 41% of all noun types that were produced. Their numerical distribution by gender and suffix is provided in Table 7. Token numbers are given in brackets. The predicted exception threshold is represented as θ_N.

Table 7: Numerical distribution of nominative singular noun types in Icelandic child-directed speech (Sigurjónsdóttir, 2007)

NOM.SG	M	F	N	θ_N	Productive?
–r	63 (494)	3 (53)	4 (57)	70/ln70=16	Yes (16>7)
–i	82 (449)	4 (55)	8 (218)	94/ln94=21	Yes (21>12)
–a	0	133 (593)	4 (10)	137/ln137=28	Yes (28>4)
–Ø	29 (144)	35 (507)	134 (721)	198/ln198=37	No (37<64)
Total	174	175	150		

Both nominative singular suffixes *–r* and *–i* were predicted to be productive of masculine by the Tolerance Principle, as the number of non-masculine nouns with these suffixes was below the exception threshold (θ_N). Likewise, *–a* was predicted to be productive of feminine.

In the absence of a nominative singular suffix, however, no gender was predicted to be productive. Thus, in spite of the statistical dominance of neuter within this category, the number of non-neuter nouns exceeded the exception threshold. As a result, Icelandic was predicted to lack a gender assignment default in the absence of a productive nominative singular suffix.

The child produced a total of 345 nominative singular noun types in reponse to their care-giver (Sigurjónsdóttir, 2007) which constituted approximately half of all noun types that were produced. Their numerical distribution by gender and suffix is provided in Table 8. Token numbers are given in brackets.

Table 8: Numerical distribution of nominative singular noun types in child naturalistic production

NOM.SG	M	F	N	θ_N	Productive?
–r	47 (167)	3 (4)	2 (12)	52/ln52=13	Yes (13>5)
–i	41 (143)	2 (11)	4 (33)	47/ln47=12	Yes (12>6)
–a	0	97 (221)	4 (18)	101/ln101=22	Yes (22>4)
–Ø	30 (108)	36 (122)	55 (178)	121/ln121=25	No (55<66)
Total	118	138	65		

Table 9 displays the numerical predictions of the Tolerance Principle based on an analysis of a random sample of 500,000 tokens drawn by a computer simulation model. The corpus contained a total of 563 nominative singular noun types. Token numbers are given in brackets.

Table 9: Distribution of noun types by gender and suffix in the SUBTLEX corpus

NOM.SG	M	F	N	θ_N	Productive?
–r	134 (1483)	4 (66)	5 (25)	143/ln143=29	Yes (29>9)
–i	97 (746)	4 (62)	17 (534)	118/ln118=25	Yes (25>21)
–a	1 (617)	92 (808)	2 (15)	95/ln95=21	Yes (21>3)
–Ø	20 (596)	69 (1392)	125 (1441)	214/ln214=40	No (40<89)
Total	252	169	142		

The Tolerance Principle made the same predictions based on the SUBTLEX corpus as on Icelandic child-directed speech (cf. Table 7) in spite of differences both in terms of lexical items and type counts. The same predictions hold because the proportion of exceptions that go against a linguistic pattern relative to the types that conform to a linguistic pattern yields the same results, regardless of the exact number of types involved in the calculations.

9.1.2 Analyses using P and P*

Table 10 demonstrates the numerical results of the corpus analyses using Baayen's P and P* metrics. The denominator of P was the total number of tokens that take a particular suffix. The denominator of P* was the sum of all singletons attested for each gender.

*Table 10: Quantitative analysis of adult, child and SUBTLEX corpora using P and P**

Corpus	**M**				**F**				**N**			
	–r	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*
Adult												
P	0.14	0.19	0.03	0.15	0.21	0.12	0.11	0.08	0.88	0.08	0.9	0.12
P*	0.38	0.49	0.01	0.13	0.1	0.03	0.53	0.34	0	0.03	0.53	0.34
Child												
P	0.02	0.05	0.9	0.54	0.9	0.89	0.2	0.35	0.78	0.25	0.27	0.35
P*	0.48	0.25	0.03	0.19	0.01	0.13	0.74	0.7	0.09	0.2	0.33	0.58
SUBTLEX												
P	0.04	0.05	0	0.02	0.03	0.1	0.05	0.03	0.28	0.22	0	0.04
P*	0.59	0.37	0	0.11	0.022	0.067	0.48	0.61	0.01	0.16	0	0.013

P yielded radically different values depending on the corpus size due to its reliance on token counts (see Bauer, 2001, p. 153 for similar concerns). P* predicted a difference along a continuum in the productivity of individual suffixes to gender assignment. The suffixes –*r* and –*i* were predicted to be most productive of masculine gender and –*a* was predicted to correlate with high or semi-productivity of feminine gender. Conversely, P* predicted low or semi-productivity between neuter and various suffixes.

However, it was impossible to formulate precise predictions based on the analyses since the ranking of individual suffixes varied between corpora. For example, either –*r* or –*i* were predicted to be most productive of masculine. In parallel, differences in the degrees of productivity of –*a* and –Ø to feminine varied between corpora. This variability is the result of the dependency of P* on type counts which may vary from corpus to corpus. As a consequence, the prediction for gender acquisition is that children should treat these suffixes differently depending on their type counts.

9.2 The acquisition of noun pluralization in Icelandic: Predictions

9.2.1 Gender as a conditioning factor in plural formation

The numerical results of a quantitative analysis of the top 1000 most frequent nominative plural noun types in the Tagged Icelandic Corpus (Helgadóttir et al., 2012) using the Tolerance Principle are provided in Table 11:

Table 11: Quantifying correspondences between gender and plural suffixes in Icelandic

Plural suffix	**M**	**F**		**N**	**Productive?**			
					M	**F**		**N**
		–a	–Ø			*–a*	–Ø	
–ar	352	0	59	0	Yes (67>56)	NA	No (38<141)	NA
–ir	37	0	137	0	No (67<371)	NA	No (38<63)	NA
–ur	11	139	3	0	No (67<381)	Yes (28>0)	No (38<196)	NA
–Ø	8	0	1	246	No (67<400)	NA	No (38<199)	Yes (46>7)
–u	0	0	0	7	NA	NA	NA	No (46<246)
Total	408	139	200	253				
$\boldsymbol{\theta_N}$	67	28	38	46				

The analysis incorporated gender as a conditioning factor by adding all noun types by gender and calculating an exception threshold based on the sum of noun types within each gender. The total number of masculine types in the corpus is 352+37+11+8=408. The number of exceptions that a generalization involving masculine nouns is predicted to tolerate is 408/ln408=67. A productive correspondence between masculine and *–ar* is predicted since the number of masculine noun types that do not select *–ar* (37+11+8=56) is below the exception threshold (67). Feminine nouns were subdivided into two categories: Nouns that take the nominative singular suffix *–a* and those that do not. As discussed in section 6.2, nouns in the former category invariantly select the plural suffix *–ur*, whereas nouns in the latter category show free variation between *–ar* and *–ir*, but rarely *–ur*. Hence, these patterns are analyzed separately. The total number of feminine noun types bearing nominative singular *–a* is 139. This number is used to calculate the predicted exception threshold (139/ln139=28). There are no exceptions to this pattern, hence a productive correlation between nominative singular *–a* and nominative plural *–ur* is trivially confirmed.

The number of feminine noun types that bear no overt suffix (–Ø) is (59+137+3+1)=200. The exception threshold is 200/ln200=38. The number of feminine nouns within this class that select *–ir* is 137. Since the number of nouns in this class that take *–ar* is 59, which exceeds the exception threshold (38), no productive correspondence is predicted between feminine and *–ir*. Likewise, the number of nouns that select *–ir* is too great for a productive correlation between feminine and *–ar* to hold (137>38). As a result, there is no plural default form predicted for feminine nouns in the absence of the nominative singular suffix *–a*.

Finally, a productive correspondence between neuter assignment and the plural suffix –Ø was predicted since the number of neuter nouns that select the suffix *–u* is below the exception threshold (46>7). Recall that the Tolerance Principle predicted there to be no productive pattern for neuter in the singular. As a result, neuter assignment was predicted to be learned by rote. While a speaker may productively associate the plural suffix –Ø with neuter, they would have to have memorized that a singular noun is neuter in order to pluralize it with –Ø. Therefore, in the absence of a productive nominative singular form on a novel noun, speakers are predicted to be at a loss with gender assignment and plural formation in Icelandic. In other words, uncertainty in gender assignment is predicted to coincide with uncertainty in plural formation.

9.2.2 Predicting gender on the basis of plural forms

A second quantitative study on the top 1000 most frequent nominative plural noun types in the Tagged Icelandic corpus was conducted using plural suffixes as conditioning factors.

Table 12: Quantifying correspondences between plural suffixes and gender in Icelandic

<table>
<tr><th rowspan="2">Gender</th><th colspan="2" rowspan="2">–ar</th><th colspan="2" rowspan="2">–ir</th><th colspan="2" rowspan="2">–ur</th><th colspan="2" rowspan="2">–Ø</th><th colspan="5">Productive?</th></tr>
<tr><th>–ar</th><th>–ir</th><th colspan="2">–ur</th><th>–Ø</th></tr>
<tr><td>M</td><td colspan="2">352</td><td colspan="2">37</td><td colspan="2">11</td><td colspan="2">8</td><td>Yes</td><td>No</td><td colspan="2">No</td><td>No</td></tr>
<tr><td rowspan="2">F</td><td>–a</td><td>–Ø</td><td>–a</td><td>–Ø</td><td>–a</td><td>–Ø</td><td>–a</td><td>–Ø</td><td>–Ø</td><td>–Ø</td><td>–a</td><td>–Ø</td><td>–Ø</td></tr>
<tr><td>0</td><td>59</td><td>0</td><td>137</td><td>139</td><td>3</td><td>0</td><td>1</td><td>No</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr>
<tr><td>N</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">246</td><td>NA</td><td>NA</td><td colspan="2">NA</td><td>Yes</td></tr>
<tr><td>Total</td><td colspan="2">411</td><td colspan="2">174</td><td colspan="2">153</td><td colspan="2">255</td><td colspan="5" rowspan="2"></td></tr>
<tr><td>θ_N</td><td colspan="2">68</td><td colspan="2">34</td><td colspan="2">30</td><td colspan="2">46</td></tr>
</table>

The analysis incorporated plural suffix as a conditioning factor by adding all noun types by plural suffix and calculating the exception threshold based on the sum of noun types with each plural suffix.

The plural suffix *–ar* was predicted to be productive of masculine since the number of non-masculine nouns (59) that select this suffix did not exceed the exception threshold (68). By contrast, the plural suffix *–ir* was predicted to have no productive gender correlate: The number of feminine nouns that select *–ir* (137) was too high for a productive correlation with masculine given an exception threshold of 34 nouns. Likewise, the number of masculine nouns (37) exceeded the threshold and, thus, prevents a productive correlation with feminine. The plural suffix *–ur* was predicted to correlate productively with the nominative singular suffix *–a* since the exceptions to this pattern (11+3=14) were below the threshold (30). Finally, –Ø was predicted to correlate productively with neuter (46>9).

9.2.3 Summary

The Tolerance Principle was used to predict productive correspondences between gender and plural suffixes in Icelandic based on their distribution within a corpus. Three productive rules in Icelandic plural formation were identified, stated below in (24):

(24) a. PL → *–ar* / [+masculine]

b. PL → *–ur* / [+nom.sg] [a] __ #

c. PL → –Ø / [+neuter]

The rule in (24a) states that masculine nouns in Icelandic pluralize by selecting the plural suffix –*ar*. In (24b), the rule states that a noun carrying the nominative singular suffix –*a* will pluralize with –*ur*. Finally, the rule in (24c) states that neuter nouns do not select an overt plural suffix (–Ø). Other patterns are predicted to be listed in the lexicon and learned by rote.

The interdependencies between forms in gender and plural formation in Icelandic are visualized as a flow chart in Figure 4:

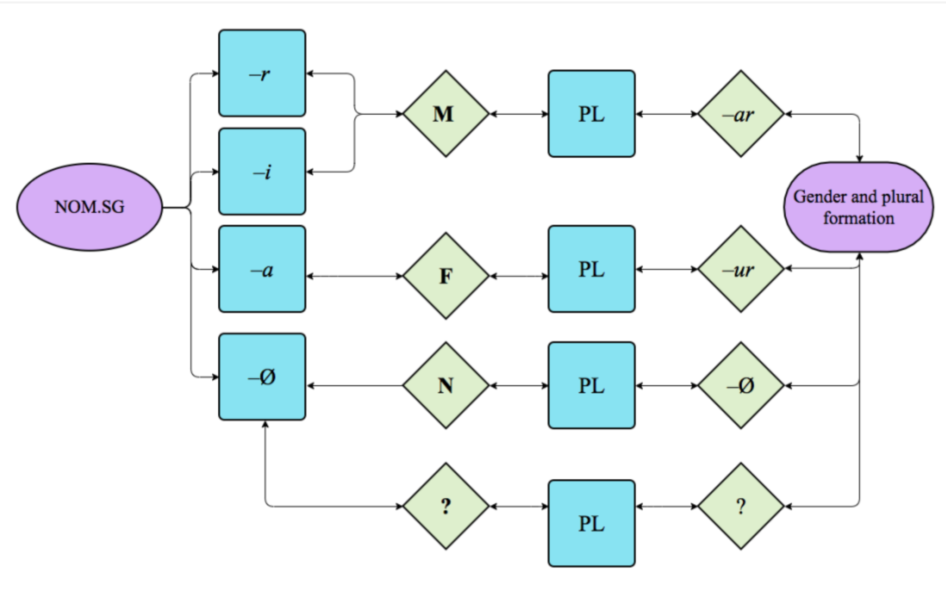

Figure 4: Flow chart of the interdependencies between forms in gender and plural formation in Icelandic

The flow chart illustrates how productive nominative singular forms facilitate the induction of both gender and plural forms in Icelandic. The absence of a productive nominative singular form is predicted to result in ineffability in both gender and plural formation in Icelandic. There is no productive nominative singular form for neuter nouns. However, given knowledge of a noun's neuter assignment, via rote memorization, a speaker is predicted to be able to pluralize neuter nouns productively. Conversely, the plural form –Ø is predicted to facilitate neuter assignment. In other words, the absence of a productive nominative singular form results in a blocking of the flow of information between the processes, resulting in a gap within the system. This gap may account for why numerous neuter nouns in Icelandic have a defective singular paradigm.

9.3 The effect of attrition on grammatical gender

An important finding in research on first language acquisition is that children extend productive, but not unproductive, patterns to novel items, as is evident from the much higher rate of over-regularization errors in comparison to errors of over-irregularization (Xu & Pinker, 1995). For instance, children acquiring English go through a stage in acquisition where they produce forms like **breaked* and **foots*, even if these forms are unattested in the input. Thus, children seem to differentiate between productive and unproductive processes in acquisition. In this dissertation, I study whether the same distinction holds in attrition. I ask what the nature of the non-target forms can reveal how linguistic generalizations may be affected by attrition, using grammatical gender in North American Icelandic as a case study. The Icelandic gender system offers a fruitful ground to delve into this issue since it has both productive and productive processes in gender assignment.

If unproductive forms are more affected than regular ones in attrition, it suggests that productive forms or ‘rules’ are more resilient to language loss than unproductive forms, which presumably must be memorized. The reverse scenario would suggest that attrition could lead to difficulties with maintaining rules or productive patterns. Finally, if productive and unproductive forms are equally affected in attrition, it would suggest that the distinction between the two processes may be irrelevant in attrition.

10 Results

10.1 Experiment 1: Productivity and absence thereof in Icelandic gender assignment

The predictions of the Tolerance Principle for children‘s behavior in gender acquisition in Icelandic are re-capitulated in Table 13 for convenience:

Table 13: Predictions for gender assignment in Icelandic

Nominative singular suffix	Gender
–r, *–i*	Masculine
–a	Feminine
–Ø	?

The Tolerance Principle predicted a categorical division between productive and unproductive suffixes in Icelandic gender assignment, whereas Baayen‘s metrics predicted a difference along a continuum.

Adults’ behavior across the two conditions is summarized in Figure 5. Dots represent individual performance in each condition. Bars are standard error. Productive gender assignment in the productive condition corresponds to mean systematic suffix-based choice of gender: Masculine for nouns with *–r* or *–i*, feminine for nouns with *–a*. Productive gender assignment in the unproductive condition corresponds to mean neuter assignment. While neuter is not predicted to be productive by the Tolerance Principle, this mode of presentation illustrates the difference in response patterns between the productive and unproductive condition.

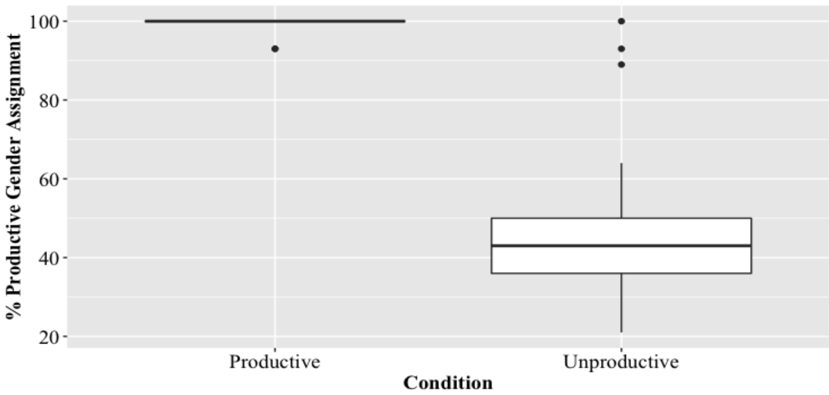

Figure 5: Adults' gender assignment across conditions

Adults made a categorical, suffix-based choice of either masculine or feminine in the Productive condition. They assigned masculine at ceiling (100%) to novel nouns with either suffix *–r* or *–i.* Similarly, they assigned feminine consistently to novel nouns with the suffix *–a* (M = 0.99, SD = .03, SE = .009). Mean neuter assignment in the productive condition was 48% (SD = 0.24, SE = .013). A paired t-test confirmed a significant difference between the two conditions: $t(17) = 9.32$, $p < .001$. There was no significant difference between mean neuter assignment of monosyllabic and disyllabic nouns: $t(17) = -0.24$, $p = 0.81$.

Children's behavior across the two conditions, productive and unproductive, is summarized in Figure 6:

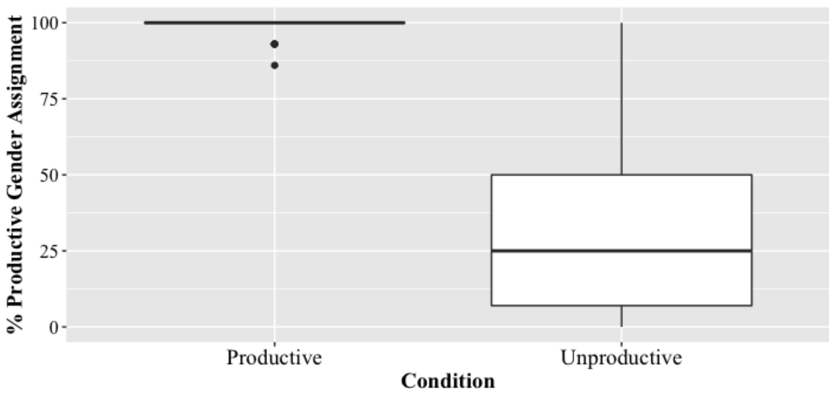

Figure 6: Children's gender assignment across conditions

Children made a categorical, suffix-based choice of either masculine or feminine in the productive condition. They assigned masculine consistently to novel nouns with either suffix *–r* or *–i* (M = 0.99, SD = .037, SE = .007). Likewise, they assigned feminine consistently to novel nouns with the suffix *–a* (M = 0.98, SD = .04, SE = .009). In the unproductive condition, children did not make a systematic choice of neuter (M = 0.29, SD = 0.28, SE = .05). A paired t-test confirmed a significant difference between the means of the two conditions: $t(25) = 11.93$, $p < .001$. There was no significant difference between mean neuter assignment of monosyllabic and disyllabic nouns: $t(24) = -0.52$, $p = 0.61$. The result of a simple regression analysis revealed no correlation between age and mean neuter assignment ($r = .09$).

10.2 Experiments 2 and 3: Gender and plural formation in Icelandic

10.2.1 Elicitation of plural forms based on singular forms

The predictions of the Tolerance Principle for gender and plural formation in Icelandic are recapitulated in Table 14 for convenience:

Table 14: Predicted correspondences between nominative singular forms, gender and plural suffixes in Icelandic

Nominative singular suffix	**Gender**	**Plural suffix**
–r, *–i*	Masculine	*–ar*
–a	Feminine	*–ur*
–Ø	?	?

The predictions stated in Table 14 were borne out for adults in the experiment. Figure 7 visualizes the relationship between choice of plural suffix by nominative singular suffix in adult responses across conditions:

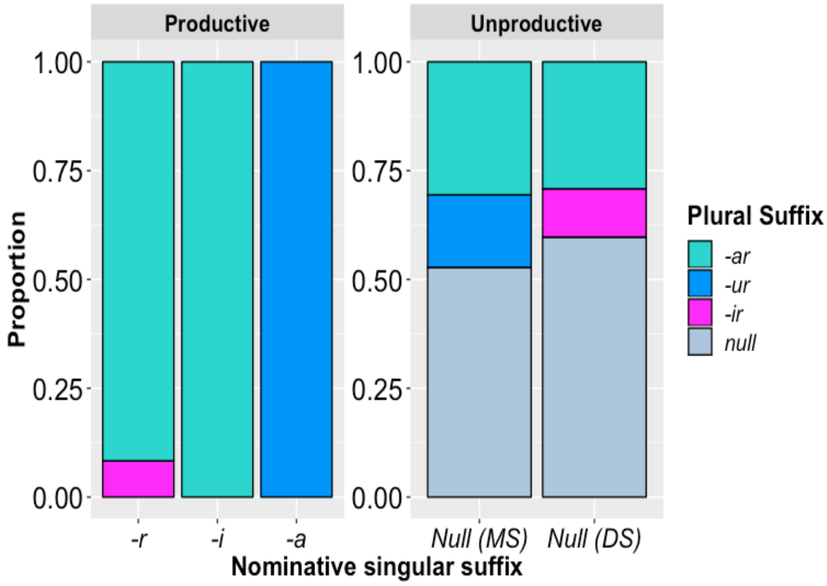

Figure 7: Adults' choice of plural suffix by nominative singular suffix

In the productive condition, adults made a categorical choice of plural suffix: They chose *–ar* consistently as the plural suffix for novel nouns with the nominative singular suffixes *–r* and *–i*, both of which are productive of masculine gender. Likewise, they chose *–ur* (100%) as the plural suffix for novel nouns with the nominative singular suffix *–a*. Response patterns in the unproductive condition were characterized by a great deal of both inter-and intra-speaker variation.

Figure 8 shows the relationship between gender and choice of plural suffix in adult responses:

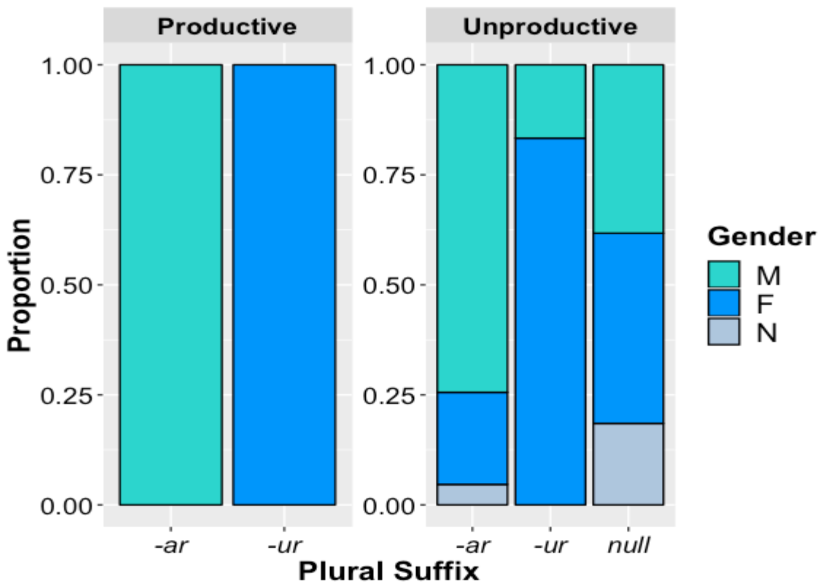

Figure 8: Adults' choice of gender by plural suffix across conditions

The association between gender and choice of plural suffix was significant ($\chi 2(6) = 27.91$, $p < .01$). In the productive condition, masculine invariantly correlated with the choice of *–ar* and feminine with the choice of *–ur*. In the unproductive condition, *–ar* was also categorically associated with masculine and *–ur* with feminine.

The predictions stated in Table 14 were borne out for children in the experiment. Figure 9 visualizes the relationship between choice of plural suffix by nominative singular suffix in child responses across conditions:

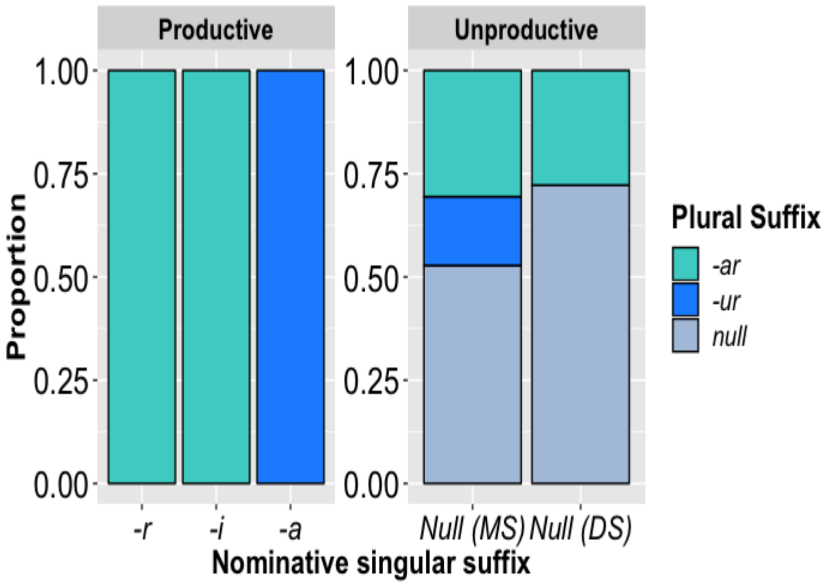

Figure 9: Children's choice of plural suffix by nominative singular suffix across conditions

In the productive condition, children made a categorical choice of a plural suffix: They chose *–ar* (100%) as the plural suffix for novel nouns with the nominative singular suffixes *–r* and *–i*, both of which are productive of masculine. Likewise, they chose *–ur* (100%) as the plural suffix for novel nouns with the nominative singular suffix *–a*. Response patterns in the unproductive condition were characterized by a great deal of both inter-and intra-speaker variation.

Figure 10 visualizes the relationship between gender and choice of plural suffix in children's responses:

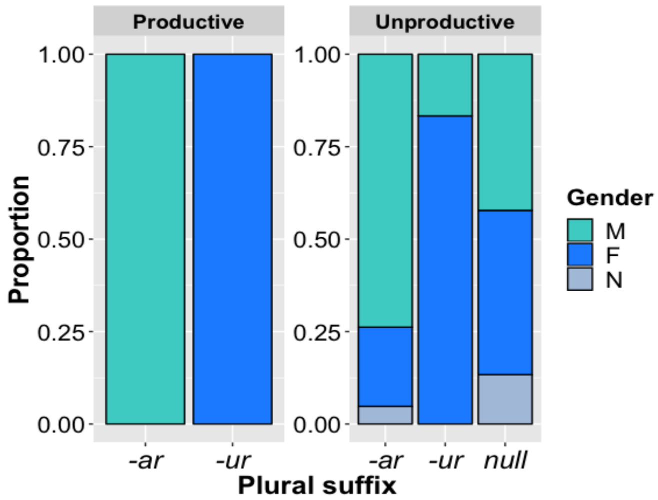

Figure 10: Children's choice of gender by plural suffix across conditions

The association between gender and the choice of a plural suffix was significant ($\chi 2(4) = 182.1$, $p < .01$). In the productive condition, masculine invariantly correlated with the choice of plural suffix *–ar* and feminine with the choice of plural suffix *–ur*. These correlations were also significant in the unproductive condition: *–ar* was categorically associated with masculine and *–ur* with feminine.

10.2.2 Elicitation of singular forms based on plural forms

The predictions generated by the Tolerance Principle based on an analysis of the Tagged Icelandic corpus are recapitulated in Table 15 for convenience:

Table 15: Predicted correspondences between plural suffixes and gender

Nominative plural suffix	Gender	Nominative singular suffix
–ar	Masculine	*–r, –i*
–ur	Feminine	*–a*
–Ø	Neuter	*–Ø*
–ir	?	?

10.2.2.1 Adults

The predictions stated in Table 15 were borne out for adults. Figure 11 demonstrates adults‘ gender assignment by plural suffix:

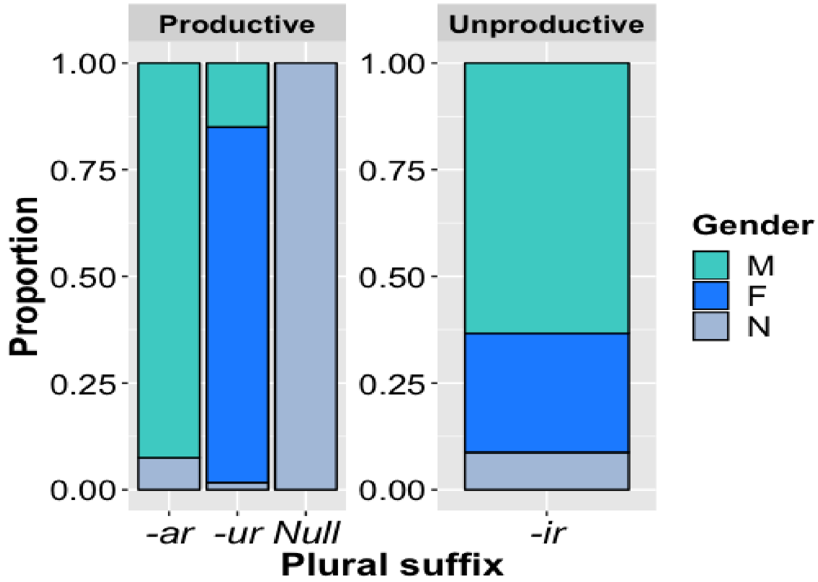

Figure 11: Adults' gender assignment by plural suffix

Adults made categorical choices of gender in the productive condition. They assigned masculine 97.5% (*SD* = .07, *SE* = .02) of the time to novel nouns with *–ar*. By contrast, adults' response patterns was unsystematic in the unproductive condition.

Figure 12 displays adults'choice of nominative singular suffix across conditions:

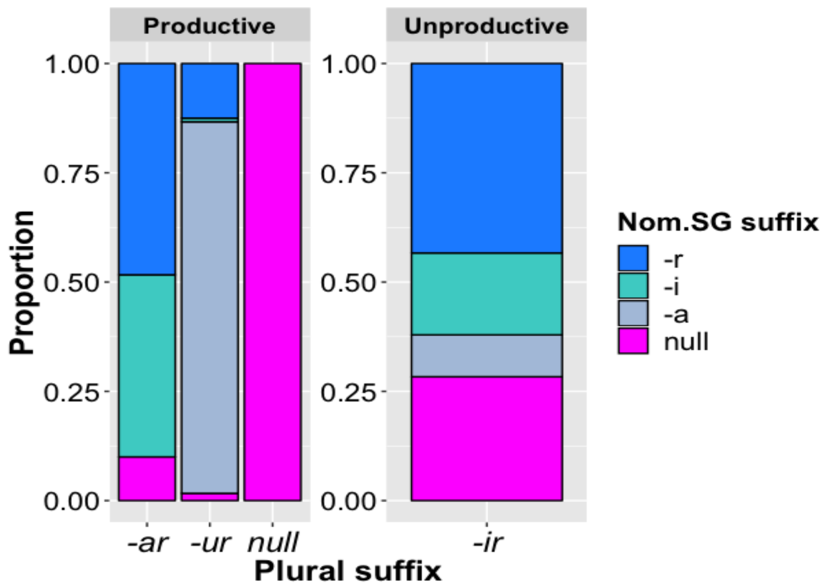

Figure 12: Adults' choice of nominative singular suffix by nominative plural suffix

In the productive condition, adults made categorical choices of a nominative singular suffix. Adults chose either nominative singular suffix *–r* (*M* = 0.55, *SD* = 0.19, *SE* = .04) or *–i* (*M* = 0.44, *SD* = 0.2, *SE* = .04) in the case of a novel noun carrying the plural suffix *–ar*. There was no significant difference between the two means (*t*(20) = -1.34, p = 0.19). There was no systematic correspondence between *–ir* and any nominative singular suffix.

Figure 13 shows children's gender assignment across conditions:

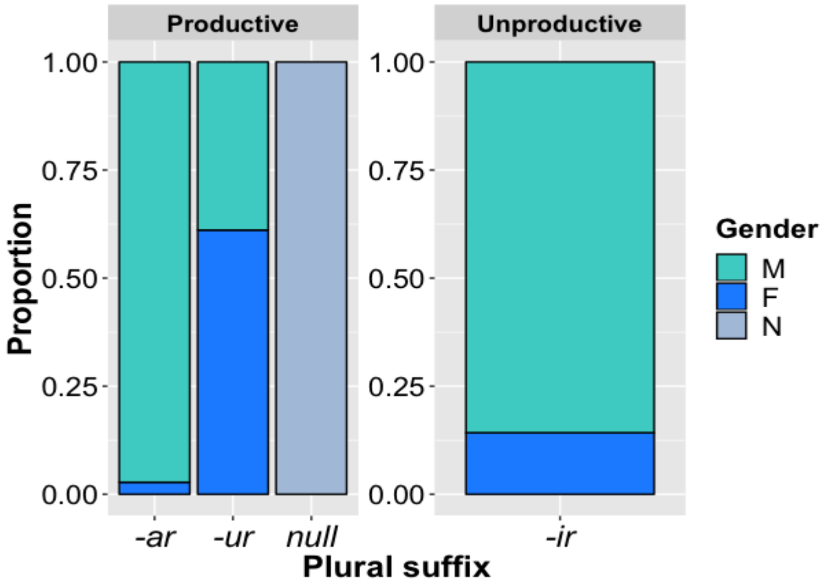

Figure 13: Children's gender assignment by plural suffix

Children made a categorical association with gender in the case of *–ar* and –Ø, in line with the predictions stated in Table 15, but not in the case of *–ur*, in which case they were at chance between a choice of masculine (*M* = 0.42, *SD* = 0.35, *SE* = .07) and feminine (*M* = 0.58, *SD* = 0.37, *SE* = .07). The difference between mean masculine and feminine agreement for this plural suffix was not significant (*t*(24) = 1.16, p = 0.26). Five children used masculine as a default (100%) for this plural suffix and four children used feminine (100%), respectively. There was a significant effect of age on children's percentage feminine responses (*r* = 0.68). In other words, older children were more likely to use feminine agreement with *–ur*. Masculine was the predominant gender in the unproductive condition.

Figure 14 displays children's choice of nominative singular suffix across conditions:

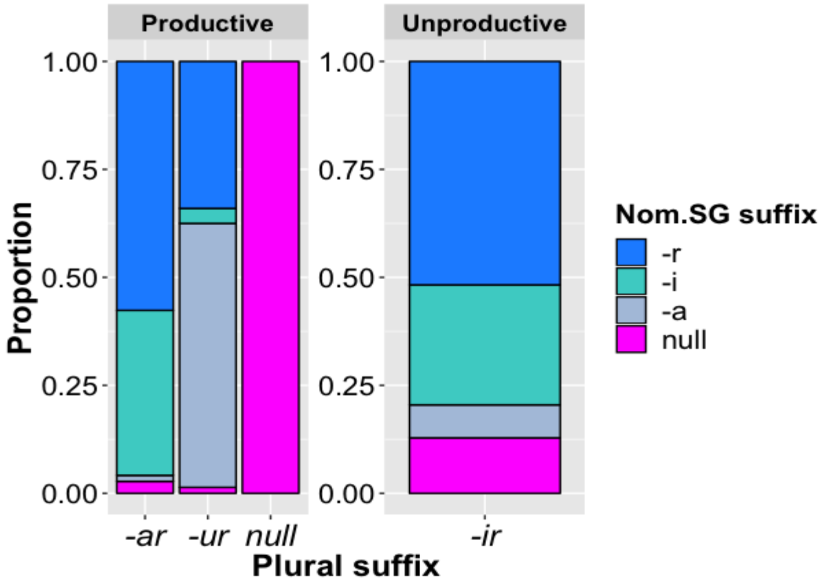

Figure 14: Children's choice of nominative singular suffix by nominative plural suffix

Children were near-categorical in their choice of *–r* as the nominative singular suffix for novel nouns with the plural suffix *–ar* (*M* = 0.71, *SD* = 0.29, *SE* = .06). In the case of a null plural suffix, children always (100%) chose a null nominative singular suffix. Collectively, children were a chance between *–a* (*M* = 0.57, *SD* = 0.35, *SE* = .07) and *–r* (*M* = 0.43, *SD* = 0.35, *SE* = .07) for *–ur*. The choice of *–r* or *–a* was conditioned by gender. The nominative singular suffix *–r* was the most frequent response in the Unproductive condition (*M* = 0.68, *SD* = 0.29, *SE* = .05).

10.3 The effect of attrition on grammatical gender: A longitudinal corpus case study

The distribution of non-target forms by calendar year is shown in Figure 15. The first decades are not included since no such forms were attested in that period. Mean error rate corresponds to mean (%) occurrence of non-target tokens for every 1000 words of text written in a given period of time:

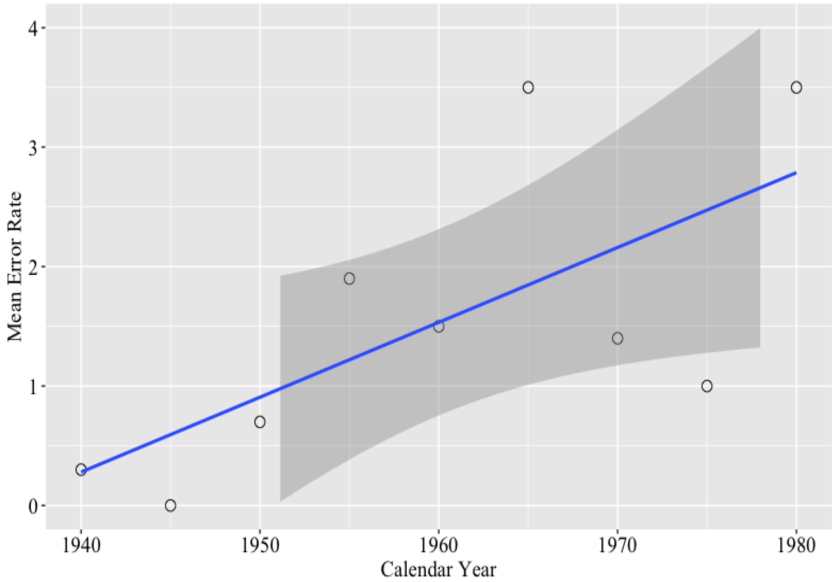

Figure 15: Mean number of non-target tokens by calendar year

The effect of calendar year on mean error rate was significant (r=0.92) as measured by a simple regression model. These findings were taken as representative of attrition, the changes attested to a speaker's competence due to reduced input and use of Icelandic. Overall, non-target gender agreement was attested on 1% noun tokens (a total of 395 occurrences) in the last 30 years of letter writing. The main findings of the corpus study can be summarized as follows:

- Feminine gender was the gender most affected by attrition and the effect was statistically significant (p=0.047), as measured by a generalized linear model, with gender as a fixed effect and lexical identity as a random effect.
- There was no distinction between productive and unproductive processes in the changes attested; both were equally affected (p=0.32), as measured by a generalized linear model with suffix type as a fixed effect and lexical identity.
- Neuter gender was the most frequently over-generalized agreement form.
- The changes attested were argued to reflect a trend towards a systematic reduction of the gender agreement system characterized by the loss of feminine.

11 Discussion

11.1 Overview

As stated in section seven, the overarching research questions of this dissertation are the following: What constitutes a generalization about gender and inflection, how are such generalizations formed and how may they undergo change? I argue that studying the source of children's ability to generalize beyond experience in acquisition may provide insights into how linguistic patterns may be represented in theoretical terms. I further ask how generalizations may undergo change as the result of reduced input and use. I propose that comparing non-target forms attested in first language acquisition to non-target forms attested in attrition may shed light on attrition as a cognitive process.

11.2 Grammatical gender: A theory of transparency

Children's differing learning trajectories cross-linguistically have been at the forefront of gender acquisition research, often with conflicting results and conclusions. As a result, the source of children's different learning behaviors in gender acquisition has been unclear. Children's reliance on formal information in gender acquisition has attracted much attention and has been interpreted to be the result of an early formal bias in acquisition (e.g. Gagliardi & Lidz, 2014; Culbertson et al., 2019). However, children do not always generalize on the basis of formal information in gender acquisition (e.g. Boloh & Ibernon, 2010; 2013; Thomas & Mueller Gathercole, 2007). Therefore, positing an early formal bias does not solve the learning problem. Rather, we need to understand the conditions under which children generalize – and the conditions under which they refrain from doing so – in gender acquisition. In short, we need a theory of the intake.

A multitude of patterns have been proposed in research on grammatical gender cross-linguistically; the question is which of them form part of the system that enables speakers to assign gender to novel nouns? Prior approaches have addressed this issue by establishing criteria based on notions such as RELIABILITY (Plaster et al., 2013) or type predictivity (Boloh & Ibernon, 2010; 2013). Crucially, definitions of such notions is a matter of analysis. For instance, the decision trees used by Gagliardi & Lidz (2014) in their study of gender in Tsez were based on Plaster et al.'s analysis that made use of reliability as a criterion. On this approach, the reliability of a gender assignment rule depends on whether it has exceptions or not. For instance, in Spanish, the suffix *–a* is a correlate of feminine assignment. However, not all feminine nouns have this suffix (e.g. *actriz* 'actress') and some masculine nouns do (e.g. *pijama* 'pajamas'). By contrast, nouns denoting females are invariantly feminine, irrespective of suffix (i.e. *chica* 'girl', *actriz* 'actress'). Based on these facts, Plaster et al. (2013, p. 7) argue that natural gender is a more reliable rule of feminine assignment than the suffix *–a*. However, Spanish-speaking children seem to disagree with this notion of reliability, as they have been found to overgeneralize feminine to nouns with *–a*, even when the referent is male (Pérez-Pereira, 1991a). A theory of gender acquisition must explain what information is reliable from the child's – not the linguist's – perspective. Therefore, analytical tools, such as decision trees, should reflect the outcome of a well-motivated learning process, not stipulated rules from linguistic descriptions.

I have demonstrated how the conditions under which children generalize gender assignment in Icelandic – and their failure to do so – can be predicted by a learning model, the Tolerance Principle (Yang, 2005; 2016), in a series of corpus studies that provide an estimate of the child's lexical experience in gender acquisition. Given the cross-linguistic diversity of gender systems, an account of gender acquisition must be able to explain how children can detect a wide range of patterns on the basis of the input. On the present approach, any generalization about gender assignment can be subjected to the kind of quantitative analysis proposed here to make testable predictions.

I hypothesized that Icelandic-speaking children form generalizations about gender assignment on the basis of a search for productive nominative singular forms, the statistically dominant inflectional form in Icelandic (Helgadóttir et al., 2012). An elicited production task tested the abilities of children and adults to assign gender on the basis of either productive or unproductive nominative singular forms. In the productive condition, both children and adults were categorical in their gender assignment of novel nouns with the nominative singular suffixes *–r*, *–i*, which were assigned masculine, and *–a*, which was assigned feminine. In the unproductive condition, both children and adults assigned gender at random. The behavioral pattern in the productive condition was characterized by categorical, uniform responses, whereas it was characterized by a great deal of both inter-and intra-speaker variation in the unproductive condition. There was no effect of age on children's use of neuter in the unproductive condition. I argue that these findings suggest that gender assignment in Icelandic is both learned on a rule-based and on an item-to-item basis. In other words, I have demonstrated how one and the same gender system can be both transparent and opaque.

The present findings converge with earlier findings indicating that children can learn gender systems that are detached from any semantic motivation (Karmiloff-Smith, 1979 and much subsequent work). However, they conflict with Mulford's (1985) findings, who argues that noun suffixes are not useful in the acquisition of Icelandic gender due to the system's opacity. By contrast, I have argued that gender assignment in Icelandic is transparent and opaque in predictable ways. I would like to suggest that these discrepancies reflect methodological confounds in Mulford's study. First, the suffixes chosen in Mulford's study were *–i*, *–a* and –Ø. The first was predicted to correlate with masculine, the second with feminine and the third with neuter. It is unclear why Mulford did not include *–r* in her study and also why she assumed that –Ø correlated with neuter. The present findings show that there is no productive pattern in the singular for neuter assignment. Therefore, it would be unsurprising if children did not consistently assign neuter in the case of –Ø.

Demarking productive processes from unproductive ones is crucial in order to predict the occurence of default forms in a gender system. The present findings suggest that Icelandic does not have a default assignment gender: In the absence of a productive gender assignment rule, speakers of Icelandic must memorize a noun's gender. These findings conflict with the standard theoretical assumption that neuter is the default assignment gender in Icelandic (e.g. Steinmetz, 1986). Prior studies on gender acquisition have not paid much attention to the acquisition of defaults. Rather, default genders stated in linguistic descriptions have been taken for granted. However, standard syntactic diagnostics may or may not align with assignment defaults, as has been observed for other languages (Corbett, 2000; Lohndal & Westergaard, 2021; Tsimpli & Hulk, 2013). Therefore, a complete theory of gender acquisition must state the conditions under which the child learner can infer a default form – and when those conditions are not met.

While defectivity has been widely acknowledged and investigated in morphology cross-linguistically, it has been largely absent in research on grammatical gender. In fact, hierarchy-based analyses of gender systems rest on the assumption that every gender system will have a default. For instance, Rice (2006, p. 12) has explicitly claimed that no gender system shows a random distribution across genders in the absence of a gender assignment rule. However, the present findings refute this claim. Moreover, they suggest that defaults are not a prerequisite of productivity (contra Clahsen, 1999; Pinker, 1999) as there may be productive patterns in the absence of a default. Importantly, the absence of productivity does not constitute evidence against rule-based learning. Rather, it is the direct consequence of a learning process guided by a search for productivity that fails to succeed and results in rote-memorization.

11.3 Gender and plural formation

The relation between gender and inflection has been a source of much debate (Berg, 2019; Corbett, 1991; Doleschal, 2000; Enger, 2004; Spencer, 2002). The question is under what conditions generalizations about gender may facilitate the induction of other inflectional forms or vice versa. In this dissertation, I addressed this question by studying how children's knowledge of gender may or may not facilitate their inferences about plural forms in Icelandic. Conversely, I studied how plural forms may or may not facilitate their inferences of gender and nominative singular forms.

The Tolerance Principle was used on the Tagged Icelandic corpus to predict productivity and absence thereof in the correspondences between gender and plural forms. The predictions were borne out in an elicited production task with the same conditions as in the gender assignment study, productive and unproductive. Given productive nominative singular forms (*–r*, *–i*, *–a*), children and adults made systematic choices of both gender and plural suffix in the productive condition. In the absence of such forms (–Ø), children and adults made unsystematic choices of both gender and plural formation. Zero responses (stimulus repetition) were only attested in the unproductive condition. Children and adults rarely or never pluralized a neuter noun with an overt suffix. However, zero responses were attested with all genders, notably masculine and feminine. Therefore, it seems plausible that zero responses reflected uncertainty in both gender and plural formation.

In a second corpus analysis, the reverse causal relation between gender and plural forms was under study. The Tolerance Principle predicted productive correspondences between gender and plural formation to be bi-directional. The predictions were put to test in an elicited production task with two conditions: Productive and unproductive. In the productive condition, participants were exposed to a novel noun with a plural suffix with a productive correspondence with gender (*–ar*, *–ur*, –Ø). In the unproductive condition, they were exposed to a novel noun with a plural suffix with no productive correspondence with gender or nominative singular form (*–ir*).

The predictions were borne out for adults in the experiment; they were categorical in their choice of gender and nominative singular suffix in the productive condition. Conversely, adults made unsystematic choices of both gender and nominative singular suffix in the unproductive condition. The predictions were partially borne out for children. Children made consistent and systematic choices of gender and nominative singular suffix in the productive condition in the case of the plural suffixes *–ar* and –Ø, but not in the case of *–ur*. Since *–ur* is homophonous with the nominative singular suffix –(*u*)*r*, which correlates productively with masculine assignment, this response pattern may reflect interference from a more frequent singular form. In the unproductive condition, children had a significant preference for masculine and masculine-productive nominative singular forms. I propose that the differences in adult and child behavior in the study may be explained in terms of the statistical primacy of singular forms in acquisition.

The present findings suggest that children‘s ability to assign gender to and pluralize novel nouns crucially depends on their knowledge of productive nominative singular forms. Conversely, absence of productivity in nominative singular forms correlated with ineffability in gender and plural formation in Icelandic. I argue that the defective singular paradigm of many neuter nouns in Icelandic is a direct consequence of the absence of a productive singular pattern. In parallel, I argue that the free variation between *–ir* and *–ar* in the pluralization of feminine monosyllabic nouns in Icelandic reflects the absence of a default feminine plural form.

Cross-linguistic studies have shown that the frequencies of inflectional categories are quite uneven, following Zipf’s (1949) law. As a result, children will likely encounter most nouns in the nominative singular in the acquisition of Icelandic. Thus, the apparent privileged status of the nominative singular in Icelandic is a reflection of its statistical dominance. I argue that the relation between gender and inflection in Icelandic is derivative, arising from the use of productive nominative singular forms. This interconnectedness is clearly reflected in the empirical results: Productivity in gender assignment correlated with productivity in plural formation. Conversely, ineffability in gender assignment correlated with ineffability in plural formation. Therefore, on this analysis, Icelandic neither has a default gender nor a default plural suffix.

Generally speaking, the singular is used far more frequently than the plural. For example, in one million words of text in English from the manually annotated Brown corpus, singular nouns outnumber plural nouns by a ratio of 2.75:1. Therefore, children‘s input is likely to include many more singular than plural nouns. As a result, grammatical gender may be a developmental prerequisite for learning plural formation in Icelandic. Furthermore, these statistical tendendencies may explain why there is no language attested which encodes gender in the plural, but not in the singular, as stated by Greenberg‘s (1966) universals 37 and 45. The statistical primacy of singular forms means that the loss of a productive generalization in the singular entails the loss of a productive generalization in the plural.

The above facts suggest that the child’s hypothesis space is constrained by the data sparsity of the input. As a result, extrinsic constraints on the number of possible inflectional patterns in language can be dispensed with. This also has important implications for syncretism. Traditionally, morphological theories have assumed that the learner seeks to minimize homonymy (see Halle & Marantz, 2008). But if we assume that learner's task is not to fill in cells in a paradigm, there is no more need for constraints on syncretism (e.g. Noyer, 2005).

Carstairs-McCarthy (1994) has claimed that monosyllabic feminine nouns in Icelandic obey the NBP: The plural suffixes *–ir* and *–ar* signal distinct inflection classes and, as a result, they can serve as class-identifiers for these nouns. On the contrary, I argue that they refute the NBP. The NBP predicts that a noun may only belong to one inflection class. However, the free variation between *–ir* and *–ar* disproves this prediction. Instead, I argue that the arbitrary inflection shifts reflect the absence of a productive plural form for monosyllabic feminine nouns.

The sparsity of the input data casts doubt on the notion of class-identifiers, forms that disambiguate a noun's inflection class membership. Prior learning accounts have called into question that children have enough data to form generalizations based on inflection classes (e.g. Chan, 2008). The present findings seem to lend support to the view that inflection classes are epiphenomena rather than primitives in grammar: While Icelandic plural formation cross-cuts both gender and inflection classes, children and adults were able to make a categorical choice of both gender and plural suffix on the basis of exposure to a single productive nominative singular form.

11.4 Productivity, frequency and rules

I argue that the acquisition of grammatical gender and inflectional morphology is driven by a search for productivity. However, productivity has been a theoretically contested notion (Bauer, 2001). Many contrasting theoretical approaches have recognized the role of type frequency in productivity (Aronoff, 1976; Baayen, 1993; Bybee, 1985; Plunkett & Marchman, 1991). The main point of contention has been the division between productive and unproductive processes. For comparison, the predictions of an alternative quantitative model of productivity were evaluated against the results of the elicited production study. Baayen's P and P* metrics measure productivity at a scalar level and, as a result, predicted differences in terms of degrees amongst the suffixes in the productive condition. However, these predictions were not borne out: There were no differences in the degrees of productivity of the three suffixes in the productive condition. In addition, there were no individual differences in children's mastery of the productive patterns.

Several accounts have contested the claim that there is a categorical division between productive and unproductive processes in language. For instance, Bybee's (1985) Network model states that the degrees of productivity of both productive and unproductive processes are determined by their token frequencies. However, the model makes inaccurate predictions regarding gender assignment in Icelandic: In spite of the statistical dominance of neuter, both in terms of type and token frequency, within the -Ø-class of nouns, it was not consistently chosen in the unproductive condition in the elicited production study.

Likewise, the free variation of monosyllabic feminine nouns (–Ø) between plural suffixes *–ir* and *–ar* follows from the absence of a productive nominative singular form. In spite of the statistical dominance of *–ir,* the number of feminine nouns within this class that select *–ar* is too great for *–ir* be productive. Therefore, feminine nouns were argued to have no default plural form. These findings refute prior claims in the literature (e.g. Bjorvand, 1972) regarding the default status of *–ir* for feminine nouns.

These findings confirm that statistical dominance is not a prerequisite for productivity (e.g. Aronoff, 1976). The present findings thus challenge approaches that conflate frequency with productivity or regularity in learning (e.g. Hudson Kam & Newport, 2005; 2009; Newport, 2019; Rumelhart & McClelland, 1986). A learning account must explain why the child learner fails to generalize highly frequent patterns. On the present approach, the relationship between productivity and frequency is indirect. For the purposes of the Tolerance Principle, what matters for learning is the ratio between the number of types that conform to a linguistic pattern relative to the number of types that do not.

Fusional noun inflection has been evoked to argue against rule-based learning and in favor of probabilistic, gradient patterns in acquisition (e.g. Bybee, 1995; Köcpke, 1998; Laaha et al., 2006). However, I argue that the findings presented in this dissertation demonstrate how children may learn the patterns instantiated by the inflectional features of the target grammar by productive rule formation.

11.5 Productive and unproductive processes in attrition

The effects of attrition were studied in a longitudinal corpus case study of North American Icelandic. The study showed that grammatical gender underwent changes over time in the corpus. Approximately 1% of all noun tokens had non-target gender agreement. Admittedly, the analysis is based on written output, which means that the speaker may have had more time to plan their language than in real-time spoken production. In the absence of studies that compare written and spoken production data, it is impossible to exclude the possibility that the writer's gender system was more attrited than her written output suggests.

In the first article of this dissertation, I showed how children and adults made a categorical distinction between productive and unproductive patterns in Icelandic gender assignment. In the third article, I asked whether the same distinction was maintained in attrition and what the attested differences might tell us about the nature of attrition. The results of the corpus analysis indicate that productive and unproductive patterns were equally affected by attrition. Therefore, the data suggest that gender assignment rules did not undergo a systematic re-analysis whereby irregular patterns regularize. The probabilistic erroneous pattern in non-target gender agreement may suggest difficulties with lexical access or retrieval. However, the variation attested was not entirely unconstrained: Overall, there seemed to be a trend towards a systematic reduction of the gender agreement system characterized by the loss of feminine gender.

The writer consistently over-generalized neuter as default agreement on pronouns, adjectival and verbal predicates. In the case of DP-internal agreement, both masculine and neuter were over-generalized, although neuter was used twice as often as masculine. Therefore, the non-target gender agreement mainly involved the over-generalization of neuter as an agreement default. Feminine agreement was virtually never over-generalized to either masculine or neuter agreement, which indicates that feminine agreement was more affected by attrition than masculine. Hence, the non-target gender agreement suggests the over-generalization of an agreement default.

It is, of course, impossible to determine with certainty which cognitive factors are responsible for the changes attested in the study. However, a study that compared older native Icelandic-speakers with heritage speakers suggested that the latter group had significantly more difficulties making use of morphosyntactic cues in sentence comprehension (Magnúsdóttir et al., 2018). Therefore, difficulties in the maintenance of morphological patterns in the minority language seem to result from imbalanced bilingualism rather than cognitive aging per se.

The nature of the variation attested in heritage grammars has been debated with divergent findings and conclusions. Prior studies have reported different populations within heritage speaker communities. This suggests that heritage grammars may be affected differently depending on which cognitive processes are involved. Our results suggest that attrition may result in probabilistic erroneous production in the case of morphosyntax. The nature of the non-target forms, however, is not unconstrained, but rather characterized by a preference for default agreement forms.

11.6 Directions for future research

I propose that further research on the acquisition of grammatical gender may shed an interesting light on the relation between syntax and morphology in grammar. For instance, many gender systems display default variability. In this dissertation, I have proposed an account which can predict the conditions under which children can generalize an assignment default – and the conditions under which they can not. However, additional research is needed on how children form generalizations about agreement defaults.

For a comprehensive account of Icelandic noun inflection, the present findings must be supplemented with studies of the acquisition of case. I propose that case can be studied based on the same logic as gender and plural formation: By formulating predictions on the basis of the input data and studying the inter-connectedness of inflectional forms. Structural versus morphological case assignment has been much debated (see e.g. Legate, 2008). The acquisition of case assignment may inform theories of case by revealing the source of children's generalizations when learning case distinctions.

Since diachronic changes have been argued to be rooted in learning (Lightfoot, 1979; 1991; 2020; Roberts, 2007), the predictions of any learning account should be testable against diachronic data. The relation between gender and inflection may undergo change diachronically, as evident by the different developments in Insular versus Mainland Scandinavian (e.g. Berg, 2019; Enger, 2004). I propose that studying the nature of these different developments may provide an interesting case study in how inter-connected linguistic patterns may undergo re-structuring or change over time as a result of learning.

12 Conclusion

The great many patterns proposed in research on grammatical gender and inflectional morphology have raised a number of analytical issues. However, once generalizations can be teased apart from exceptions, we can define what is linguistically explainable and what is not. Therefore, productivity considerations may eliminate intractable problems from the burden of linguistic explanation.

I argue that an understanding of how the child learner forms generalizations in acquisition may shed light on the nature of linguistic structures. Ultimately, findings from language acquisition and learning may explain facts about the distribution of forms across the paradigms generated by the inflectional features of a language. In this dissertation, I have used gender and plural formation in Icelandic to illustrate such a learning-based approach to linguistic structure. I have proposed an account, whereby the child learner discovers linguistic categories, such as gender and number, and their interrelatedness, by searching for productive patterns in the input data. I have also demonstrated the relevance of this approach beyond first language acquisition, by highlighting the importance of understanding how generalizations are formed in order to understand how they may change.

I propose that the child's discovery procedure in acquisition can account for distributional facts in language. For example, the defective singular paradigm of neuter nouns and the arbitrary inflection shifts among feminine nouns in Icelandic follow naturally from a learning account where a search for productivity fails and results in ineffability. On such an account, extrinsic constraints or stipulations may be dispensed with. Therefore, I argue that insights from acquisition and learning may offer solutions to otherwise intractable problems in linguistic theory.

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Appendix

Experiment 1: Novel objects and their corresponding nouns


Lerfur


Krandi


Bukla


Rúf


Kútes


Sappur


Lerri


Rala

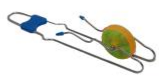

Kurk


Ratef


Mækur


Tukki


Húla


Mirg


Farem


Tirgur


Dubbi


Darga


Súf


Múkaf

Múka Glæf Silám

Fóma Lirg Rútis

Experiments 2 and 3: Novel objects and their corresponding nouns

(The same novel objects were used in both plural studies)


Lerfur


Ruli


Bukla


Súf


Kútes

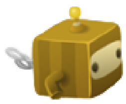

Tirgur

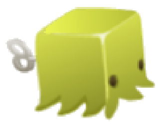

Krandi


Derga

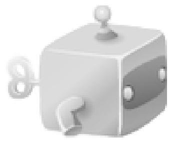

Turk


Ratef


Mekur


Lurpi


Mæka


Mæf


Farem


Rulur

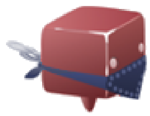

Tauli


Fóma


Lirg


Múkaf

Kurk



Sakem

Part II: The articles

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Productivity and the acquisition of gender

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Abstract

Children's differing learning trajectories cross-linguistically have been at the forefront of gender acquisition research, often with conflicting results and conclusions. As a result, the source of children's different learning behaviors in gender acquisition has been unclear. I argue that children's gender acquisition is driven by the search for productive patterns. First, I provide corpus studies where the predictions of a learning model (Yang, 2016) are formulated. Second, I report the results of an elicited production task on Icelandic-speaking children (N = 26, ages 2;6-6;3 years) and adults (N = 18) that puts these predictions to test. The results suggest that Icelandic-speaking children and adults draw a categorical distinction between productive and unproductive suffixes in Icelandic gender assignment. I discuss the implications of these findings for morphological learning beyond gender acquisition.

Keywords: gender; morphology; rules; defaults; productivity

Introduction

Grammatical gender has conventionally been defined as the sorting of nouns into classes as reflected in agreement morphology (Corbett, 1991; Hockett, 1958). Gender systems differ cross-linguistically with respect to what kind of information is predictive of gender assignment. A distinction has been made between STRICT SEMANTIC SYSTEMS, as exemplified by the gender systems of the Dravidian languages, and FORMAL SYSTEMS, as exemplified by typologically diverse languages, such as Qafar and Russian (Corbett, 2013). Given the typological diversity of gender systems, children must be able to detect a wide range of formal and semantic regularities on the basis of language-specific data.

In her seminal study, Karmiloff-Smith (1979) showed that French children were able to assign gender on the basis of noun endings. Moreover, the children seemed to rely on noun endings even if the resulting gender were at odds with the biological sex of the referent. Similar results have been obtained many times cross-linguistically (Clark, 1985; Hernández-Pina, 1984; Levy, 1983; Mills, 1986; Rodina & Westergaard, 2012; 2013; 2015). Collectively, the results of this body of research suggest that children can learn gender systems that are detached from any semantic motivation. However, research on more typologically diverse gender systems is needed in order to determine whether this early formal bias is an artifact of the language sample or a finding about early grammatical representation.

Children's learning trajectories of grammatical gender vary cross-linguistically (Mills, 1986). Gender systems have been divided into two groups from an acquisitional perspective: Transparent and opaque (Slobin, 1977). Transparent gender systems have a set of productive patterns for gender assignment, whereas opaque gender systems have few or none. Productive rules in transparent systems, such as Spanish and Russian, are typically in place by the age of three (Lew-Williams & Fernald, 2007; Rodina & Westergaard, 2012), whereas the paucity of such rules in opaque systems, like Norwegian and Dutch, results in late mastery (Rodina & Westergaard, 2013; Unsworth & Hulk, 2010). Transparent or opaque, gender acquisition involves detecting language-specific patterns and evaluating whether they are useful for learning or not. In other words, the child learner must somehow outweigh the evidence for and against a pattern in order to determine whether or not it can be used to form a generalization about gender assignment.

Even within a transparent gender system, gender assignment rules[1] may be learned at different rates. Mills (1986) proposed, using evidence from German, that gender assignment rules were acquired in order of CLARITY. By her definition, clarity is determined by the scope of the rule and the number of exceptions; the greater the scope of the rule and the fewer exceptions, the earlier the rule is acquired. For example, she argued that the rule with the greatest scope in German is "nouns that end in –e are feminine" because of the high frequency of the pattern and the low number of exceptions (p. 85). However, even the role of frequency has been debated. For instance, Henzl (1975) argued, using evidence from Czech, that children first formulated gender assignment rules on the basis of noun endings which are "least ambiguous", irrespective of frequency.

Hitherto it has been unclear what makes a gender system either transparent or opaque to the child learner. In parallel, it has been unclear how the child learner can determine the scope of a gender assignment pattern. Therefore, a theory of gender acquisition is needed that can both identify the conditions under which a gender assignment pattern is useful to the learner – and when these conditions are not met.

In this paper, I propose an approach whereby gender acquisition is characterized by a search for productive gender assignment rules guided by a learning model (Yang, 2005; 2016). First, I discuss prior research on productivity in first language acquisition. Second, I introduce the Tolerance Principle, a quantitative model of productivity (Yang, 2005; 2016). I discuss the relevance of quantitative methods for research on gender acquisition and demonstrate how the approach works using grammatical gender in Spanish as a test case. Next, I show how predictions for Icelandic gender acquisition can be made on the basis of child-directed speech and child naturalistic data. Moreover, I show how these predictions robustly hold when samples are created from other corpora to approximate children's vocabulary size during the stages of gender acquisition. Subsequently, I present the results of an elicited production task on Icelandic children and adults. Finally, I discuss an alternative view of productivity (Baayen, 1989; 1992; 1993) and evaluate its predictions against the empirical results. The paper concludes with a discussion of the implications of these findings for morphological learning beyond gender acquisition.

Productivity and absence thereof in language acquisition

Language acquisition involves learning words and how to inflect them. The source of children's ability to learn inflectional patterns has been a point of contention for theories of morphological learning. In her famous Wug experiments, Berko (1958) showed convincingly that English-speaking children extend productive inflectional patterns like, for example, the plural suffix –s, when inflecting novel words. Children have also been found to over-generalize productive patterns in naturalistic settings even though this may result in forms that are not attested in the input, such as *foots and *breaked (Pinker & Prince, 1994). Children's ability to extend productive patterns in both experimental and naturalistic settings has been taken as evidence for rule-based learning in acquisition.

However, sometimes productivity fails. Gaps within an inflectional paradigm are the result of having no acceptable morphological option or default (Baronian & Kulinich, 2012; Halle, 1973; Fanselow & Féry, 2002; Orgun & Sprouse, 1999; Pertsova, 2005). Morphological gaps are common cross-linguistically. For instance, many English speakers find the past participles of certain irregular verbs, like stride, problematic (Pinker, 1999). Similarly, there are no acceptable 1SG forms for a handful of verbs in Spanish (Albright, 2003). There are no semantic reasons for this ineffability. Rather, it seems to reflect speakers' failure to generate a systematic pattern or a rule. Morphological gaps have posed a challenge to rule-based accounts, as the unavailability of a rule or a default form is unexpected.

The learning trajectory of Polish noun inflection suggests that children do not need to resort to defaults in order to learn inflectional morphology (Dabrowska, 2001; 2005). Polish nouns are inflected for gender, case and number. The most important factor in determining the choice of inflectional ending is gender (Dabrowska, 2001, p. 558). The most interesting case is the choice of ending for masculine genitive singular nouns: masculine singular nouns in Polish can take either –a or –u as a genitive ending in a seemingly unpredictable fashion. While –a is the most frequent masculine genitive singular ending, it does not seem to have the status of a default, since loanwords and low frequency masculine singulars can take either ending.

In a series of longitudinal corpus case studies, Dabrowska (2001) showed that Polish noun inflection was largely in place by the age of 2;0. Furthermore, Polish-speaking children made few errors with masculine genitive singular nouns in spite of the arbitrary distribution of the two endings. In case of errors, children made unsystematic choices of either ending.

These findings have been taken as evidence against rule-based learning (Clahsen, 1999; Pinker, 1999). Instead, Dabrowska (2001, 2005) argued that they lent support to USAGE-BASED approaches to language acquisition (Tomasello, 1992; 2003). Hence, the absence of productivity has raised key questions about the nature of the mechanism underlying linguistic creativity.

Predicting productivity and absence thereof

The Tolerance Principle

There is general agreement that language has both productive and unproductive patterns. However, the division line between the two has been a point of contention. Yang (2005; 2016) has proposed a model of linguistic productivity, the Tolerance

Principle, to account for how children distinguish between productive and unproductive patterns on the basis of positive evidence in the input. The Tolerance Principle quantifies the precise conditions for productive rule formation. The model hypothesizes that a general rule will be formed when doing so is computationally more efficient than storing lexical forms. The principle is stated in (1).

(1) The Tolerance Principle

If R is a productive rule applicable to N candidates, then the following relation holds between N and e, the number of exceptions that could but do not follow R:

$$e \leq \theta N \text{ where } \theta N = N/\ln N$$

The Tolerance Principle states that it is computationally more efficient to form a productive rule only when the number of exceptions is less than the number of items divided by the natural log of the number of items. Computational efficiency is computed by calculating the time complexity required for forming a rule with the time complexity required for accessing individual lexical forms. Crucially, the division between productive and unproductive processes is a categorical one on this approach.

The Tolerance Principle makes use of the Elsewhere Condition (Kiparsky, 1973), which states that when a more specific form (or rule) is available, it is preferred over a more general one. For example, went is the past tense form for the verb go, so it overrides the regular but ungrammatical *goed. The Elsewhere Condition is implemented by the Tolerance Principle as a serial search procedure, which is empirically motivated by research on language processing (see Yang, 2016, pp. 49–60).

To illustrate this serial procedure, one can think of past tense acquisition in English. The child is faced with verbs that adhere to the regular pattern, "add -d", and verbs that do not. The Tolerance Principle assumes that, in order to be maximally efficient in forming the past tense of verbs in English, the child is faced with two options: 1) Store all past tense verb forms individually 2) Form a productive rule. In the first case scenario, every item is stored in a list ranked by frequency. This means that the learner must search the list every time there is an occasion to express the past tense of a verb. In the second case scenario, only the exceptions are stored in a frequency-ranked list. The list of exceptions must be searched first before the productive rule can be applied.

The Tolerance Principle operates on type counts. Therefore, productivity in grammar learning on this approach is connected to the number of types over which linguistic patterns are expressed, rather than the number of tokens. The same view has been adopted by a wide variety of research programs (Aronoff, 1976; Baayen, 1993; Bybee, 1985; Plunkett & Marchman, 1991).

Given a well-defined hypothesis space, the Tolerance Principle can be used as a quantitative measure to predict whether any given linguistic pattern can be perceived by the child learner as productive or not. The Tolerance Principle is just one thresholding function and has a wide range of empirical support (consult Yang, 2016 for case studies). In addition, the predictions of the Tolerance Principle have been borne out for children in experimental settings (Schuler et al., 2016).

Language acquisition involves not only detecting productive patterns, but also unproductive patterns. The Tolerance Principle not only models the conditions for productive rule formation; it can also identify conditions under which no productive rule is available (Gorman & Yang, 2018). For example, the Tolerance Principle can predict the absence of a default genitive ending for Polish masculine singulars on a numerical basis. Table 1 shows the numerical distribution of Polish masculine genitive singular nouns by ending (adapted from Yang, 2016, based on CHILDES).

Table 1. Numerical Distribution of Genitive Endings for Masculine Singular Nouns in Polish

	Suffix	Types	Productive?
GEN.SG	*–a*	837 (62%)	No (516>188)
	–u	516 (38%)	No (837>188)
Total		1353	
θ_N		1353/ln1353=188	

An analysis using the Tolerance Principle revealed that in spite of the statistical majority of –a as the genitive ending of masculine singulars, the number of nouns that take the alternative ending is too great for –a to be productive. On this approach, therefore, absence of productivity does not constitute as evidence against rule-based learning. Rather, it is the direct consequence of a learning process guided by a search for productivity that fails to succeed and results in rote memorization.

Relevance to gender acquisition

Approaches using quantificational methods have the advantage of being able to make clear, testable predictions on the basis of input data. In this section, I will briefly showcase how the present approach works using the Spanish gender system as an example.

The Spanish gender system distinguishes between masculine and feminine nouns. There are correlations between nominal morphology and gender assignment: Nouns that take the suffix –o tend to be masculine, whereas nouns that take the suffix –a tend to be feminine. In an eye-tracking study, Lew-Williams and Fernald (2007) showed that Spanish-learning children, aged 2;10–3;6 years, were able to use gender-marked articles to establish reference of such nouns. Thus, young Spanish-learning children had internalized productive gender assignment rules in spite of an estimated vocabulary of only 500 words.

The distribution of noun types across gender and suffix in a longitudinal corpus of Spanish child-directed speech (Linaza et al., 1981) is provided below in Table 2. The corpus reflects the interaction between a caregiver and their child between the ages of two and four. Therefore, it should give a reasonable estimate of a child's vocabulary size in Spanish gender acquisition.

An analysis using the Tolerance Principle confirmed the productivity of –o to masculine and –a to feminine. In the absence of a suffix, the Tolerance Principle predicted masculine to be the default gender in Spanish.

These predictions are consistent with studies on Spanish gender acquisition in both naturalistic and experimental settings: Children generalize masculine to nouns with the suffix –o and feminine to nouns with the suffix –a. In the absence of a productive suffix,

Table 2. Numerical Distribution of Noun Types by Gender and Suffix in Spanish Child-Directed Speech

Suffix	M	F	θ_N	Productive?
–*o*	113	2	115/ln115=24	Yes (24>2)
–*a*	8	116	124/ln124=26	Yes (26>8)
–*ø*	102	16	118/ln118=25	Yes (25>16)
Total	223	134		

they resort to the default gender: namely, masculine (see, among many, Clark, 1985; Hernández-Pina, 1984; Mariscal, 2008; Pérez-Pereira, 1991).

The Icelandic gender system

Icelandic has a gender system that distinguishes between masculine, feminine and neuter. Typologically, the Icelandic gender system has been classified as formal (Corbett, 2013). Icelandic has rich agreement morphology that manifests itself on the definite article, which is a suffix (2a), adjectives (2b), the past participle (2c) and pronouns (2d). Anaphoric pronouns must refer to the formal gender of the referent noun irrespective of animacy or biological sex.

(2) a. Stóll-**inn**, skál-**in**, borð-**ið**.
Chair-M.DEF, bowl-F.DEF table-N.DEF
'The chair, the bowl, the table.'

b. Flott-**ur** stóll, flott-**ø** skál, flott-**ø** borð.
Nice-M chair-M, Nice-F bowl-F, nice-N table-N
'A nice chair, a nice bowl, a nice table.'

c. Stóllinn er brot-**inn**, skálin er brot-**in**,
The chair-M is broken-M, the bowl-F is broken-F,
borðið er brot-**ið**.
the table-N is broken-N
'The chair is broken, the bowl is broken, the table is broken.'

d. **Hann** er brotinn, **hún** er brotin, **það** er brotið.
He is broken, she is broken, it is broken.
'He (the chair) is broken, she (the bowl) is broken, it (the table) is broken.'

The three genders are roughly equally frequent: 32% are masculine, 38% feminine and 30% are neuter (Helgadóttir et al., 2010). These numbers are consistent with the input corpora that will be examined later in the paper.

In addition to gender, Icelandic distinguishes between four cases: Nominative, accusative, dative and genitive. Gender and inflection in Icelandic interact to form INFLECTION CLASSES, which are standardly defined as a set of roots that each share the same set of inflectional realizations (Aronoff, 1994).

Icelandic reference grammars (see e.g., Kvaran, 2005) have standardly followed the lead of Old Norse reference grammars (Iversen, 1922; Noreen, 1903) by stating the correspondence between gender and inflection without discussing specific gender assignment rules. The idea is that the gender of a noun can be determined by its inflection class membership to some extent.

Nominative singular is the most frequent inflectional form in Icelandic, constituting 40% of all nominal forms (Helgadóttir et al., 2010). Furthermore, due to syncretism in the nominal paradigm, many forms are identical to the nominative singular in oblique cases. There are strong correlations between nominative singular morphology and gender assignment in Icelandic as in other fusional languages like, for example, German and Russian (Corbett, 1991). In particular, three nominative singular suffixes are predictive of either masculine or feminine, respectively.[2]

(3) a. Nouns that take the nominative singular suffix –r are typically masculine.[3]
b. Nouns that take the nominative singular suffix –i are typically masculine.
c. Nouns that take the nominative singular suffix –a are typically feminine.

Table 3 demonstrates how these suffixes map on to real nouns in Icelandic.

While these patterns are robust in Icelandic, they do have exceptions. For instance, some feminine nouns take the nominative singular suffix –r. Diachronically, most of these nouns have shifted to masculine (Iversen, 1922; Noreen, 1903).

Table 3. Mappings between Gender and Nominative Singular Suffixes in Icelandic

	–r	*–i*	*–a*
Masculine	sokku-r ('a sock')	burst-i ('a brush')	NA
Feminine	brúðu-r ('a bride')	NA	fat-a ('a bucket')
Neuter	NA	NA	NA

The absence of an overt nominative singular suffix is indicated by -ø. Some nouns do not take the phonemes in Table 3 by suffixation. Instead, they form part of the noun's stem, as shown in (4). These nouns tend to have low type but high token frequency. Most of these nouns are neuter, although nouns with stem-final /i/ can be either feminine or neuter (4b).

(4) a. Aug**a**-ø, eyr**a**-ø.
Eye-N.NOM.SG, ear-N.NOM.SG
'An eye, an ear.'

b. Tæk**i**-ø, gleð**i**-ø.
Device-N.NOM.SG, joy-F.NOM.SG
'A device, joy.'

c. Be**r**-ø, ke**r**-ø.
Berry-N.NOM.SG, tub-N.NOM.SG
'A berry, a tub.'

While these nouns have oblique forms different from nouns that take these sounds by suffixation, they could be ambiguous to the child learner in gender acquisition given the statistical dominance of nominative singular forms in the input. Therefore, these nouns are counted as exceptions to the general patterns stated in (3) in subsequent quantitative analyses.

The choice of nominative singular suffix is a result of morphological, rather than phonological selection. The same root may select for more than one suffix to yield a minimal pair as in (5a). Some borrowed nouns show variation in the choice of suffix, which in turn affects gender assignment (cf. 5b-c).

(5) a. Sæt-**i**, sæt-**a**.
Cutie-M, cutie-F
'Male cutie, female cutie.'

b. Djóku-**r**, Djók-**ø**.
Joke-M, joke-N
'A joke.'

c. lúpp-**a**, lúpp-**ø**.
loop-F, loop-N
'A loop.'

There is no productive nominative singular suffix for neuter nouns. The stem-final segment of neuter nouns can consist of any phonotactically legal consonant or a vowel (see above). There are no clear phonological patterns specific to neuter. For instance, many neuter monosyllabic nouns rhyme with feminine monosyllabic nouns.

(6) a. Borg-ø, torg-ø.
city-F, square-N
'A city, a square.'

b. Ull-ø, gull-ø,
wool-F, gold-N
'Wool, gold.'

Neuter has standardly been assumed to be the default gender in Icelandic (Steinmetz, 1985). This assumption will be challenged later in this paper.[4]

Most nouns in Icelandic are assigned only one gender. In case of variation in gender assignment, however, nouns that lack an overt nominative singular suffix are the primary targets. These nouns have also undergone gender shifts diachronically (Noreen, 1903; Iversen, 1922). The attested variation seems arbitrary. Similarly, there is both inter-speaker and intra-speaker variation in the gender assignment of some borrowed nouns in Icelandic. Thus, while the choice of nominative singular suffix clearly determines the gender of both jeppi and paranója, the absence of such a suffix seems to correlate with variation in gender assignment, as shown in Table 4.

Table 4. Gender Assignment of Borrowed Nouns in Icelandic

Noun	Gender	Meaning
Jepp-i	M	'A jeep'
Paranój-a	F	'Paranoia'
Jógúrt-ø	M, F, N	'Yoghurt'
E-mail-ø	M, N	'E-mail'

To conclude this section; given the statistical dominance of nominative singular morphology, it seems plausible to assume that Icelandic children learn these inflectional patterns early and use them as base forms in gender acquisition.

Gender acquisition in icelandic: a longitudinal corpus case study

Data

The data consist of longitudinal recordings of a caregiver's speech to an Icelandic-speaking child and the child's spontaneous speech in response (Sigurjónsdóttir, 2007). A total of 82 recordings were made approximately once a month when the child was between the ages of 1;6–4;3 years. The child-directed speech contained around half a million tokens; whereas the child's spontaneous speech contained around 7000 tokens.

Procedure

Nominative singular noun types were extracted from the corpus and tagged for gender and suffix. Child and adult data were analyzed separately. The purpose of the child analysis was to test whether the same predictions could be made on the basis of the child's vocabulary. Both child and adult data were subjected to a quantitative analysis using the Tolerance Principle. In addition, the child naturalistic data was subjected to an error analysis.

Analysis of child-directed speech

The caregiver's speech contained 478 nominative singular noun types, which constituted approximately 41% of all noun types that were produced. Their numerical distribution by gender and suffix is provided in Table 5. Token numbers are given in brackets.

Table 5. Numerical Distribution of Nominative Singular Noun Types in Icelandic Child- Directed Speech

NOM.SG	M	F	N	θ_N	Productive?
–R	63 (494)	3 (53)	4 (57)	70/ln70=16	Yes (16>7)
–i	82 (449)	4 (55)	8 (218)	94/ln94=21	Yes (21>12)
–a	0	133 (593)	4 (10)	137/ln137=28	Yes (28>4)
–ø	29 (144)	35 (507)	134 (721)	198/ln198=37	No (37<64)
Total	174	175	150		

Both nominative singular suffixes –r and –i were predicted to be productive of masculine by the Tolerance Principle, as the number of non-masculine nouns with these suffixes was below the exception threshold (θN). Likewise, –a was predicted to be productive of feminine.

In the absence of a nominative singular suffix, however, no gender was predicted to be productive. Thus, in spite of the statistical dominance of neuter within this category, the number of non-neuter nouns exceeded the exception threshold. As a result, Icelandic was predicted to lack a default gender in the absence of a productive nominative singular suffix.

Analysis of child naturalistic production

The child produced a total of 345 nominative singular noun types, which constituted approximately half of all noun types that were produced. Their numerical distribution by gender and suffix is provided in Table 6. Token numbers are given in brackets.

Table 6. Numerical Distribution of Nominative Singular Noun Types in Child Naturalistic Production

NOM.SG	M	F	N	θ_N	Productive?
–*R*	47 (167)	3 (4)	2 (12)	52/ln52=13	Yes (13>5)
–*i*	41 (143)	2 (11)	4 (33)	47/ln47=12	Yes (12>6)
–*a*	0	97 (221)	4 (18)	101/ln101=22	Yes (22>4)
–*ø*	30 (108)	36 (122)	55 (178)	121/ln121=25	No (55<66)
Total	118	138	65		

The same predictions were made on the basis of the child‘s spontaneous speech as on the child-directed speech, even if the child‘s production contained fewer noun types. The child was predicted to have internalized three productive rules of gender assignment in the absence of a default gender.

Error analysis of child naturalistic speech

The child was 100% target-consistent with nouns that take suffixes –r, –i and –a in the corpus. This means that the child had internalized the gender of these nouns before their second birthday. The child‘s non-target-consistent gender agreement exclusively targeted nouns that had no overt nominative singular suffix (–ø), with an error rate of 4.6%. The nouns affected alternated between all three genders. Examples of this are provided below in Table 7.

Table 7 Non-Target-Consistent Gender Agreement in Icelandic Child Naturalistic Production Child Production

Child Production	Target-Consistent Use	Meaning
*Krús-ið mitt mug-N.DEF my-N	Krús-in mín mug-F.DEF my-F	‘My mug’
*Falleg-ø kjóll beautiful-F dress-F	Falleg-ur kjóll beautiful-M dress-M	‘A beautiful dress’
*Úr-inn minn watch-M.DEF my-M	Úr-ið mitt watch-N.DEF my-N	‘My watch’

The child's non-target consistent gender agreement did not suggest the application of a default gender. Rather, the pattern attested appeared unsystematic.

Corpora as an estimate of linguistic experience

Corpus data is a sample of linguistic experience. Any two sets of corpora are unlikely to contain the exact same linguistic items. This is analogous to child language acquisition; children's linguistic experience is inevitably variable.

So far, the corpus analyses in this paper have been based on small corpora. However, a small vocabulary is developmentally appropriate in the study of gender acquisition. Gender, in languages with productive gender assignment rules, is largely in place by the age of three when children typically know only a few hundred words (Hart & Risley, 1995; 2003; Szagun et al., 2006). The question is how children can converge on the target gender system on the basis of a vocabulary that is both small and variable from child to child.

One way to address this question is to study differences between corpora of different sizes and genres. Kodner (2019) studied the differences between corpora derived from adult literary genres and child-directed speech in a series of case studies. He found that once adult literary corpora had been trimmed by frequency, they had statistically similar type counts to child-directed speech corpora in spite of lexical differences. In other words, the main difference between adult literary corpora and child-directed speech involved low frequency lexical items. One implication of these findings is that children's grammar learning may be based on high frequency lexical items, rather than adult-size lexicons.

In this section, predictions will be made using the Tolerance Principle on the basis of an adult online corpus. The objective is to establish whether the same predictions can be made when lexical items are drawn at random using a computer simulation model from a much larger language sample.

Furthermore, predictions will be formulated on the basis of the top few hundred most frequent noun types.

Data

The data consist of a corpus of 8.6 million tokens (https://github.com/hermitdave/FrequencyWords/blob/master/content/2018/is/is_full.txt) that were extracted from the SUBTLEX corpus (http://www.opensubtitles.org/). Corpora based on subtitles have been shown to be a good approximation of spoken languages (https://www.ugent.be/pp/experimentele-psychologie/en/research/documents/subtlexus).

Procedure

A computer simulation model was run on the corpus. The model was instructed to draw 500,000 noun tokens, to match the token size of the Icelandic child-directed speech corpus, at random and proportionally to word frequencies. Noun types that occurred less frequently than once per million words were excluded from the analysis. Nominative singular noun types were extracted from the sample and categorized by gender and suffix. They were then subjected to a quantitative analysis using the Tolerance Principle.

Results

563 nominative singular noun types were attested in a random sample of 500,000 words in the SUBTLEX corpus. Their numerical distribution by gender and suffix is provided in Table 8. Token numbers are given in brackets.

The Tolerance Principle made the same predictions based on the SUBTLEX corpus as on Icelandic child-directed speech (cf. Table 5) in spite of differences both in terms of lexical items and type counts.

Table 8. Distribution of Noun Types by Gender and Suffix in the SUBTLEX Corpus

NOM.SG	M	F	N	θ_N	Productive?
–r	134 (1483)	4 (66)	5 (25)	143/ln143=29	Yes (29>9)
–i	97 (746)	4 (62)	17 (534)	118/ln118=25	Yes (25>17)
–a	1 (617)	92 (808)	2 (15)	95/ln95=21	Yes (21>3)
–ø	20 (596)	69 (1392)	125 (1441)	214/ln214=40	No (40<89)
Total	252	169	142		

Formulating predictions for small vocabularies

Table 9 shows the predictions of the Tolerance Principle on the basis of the top 100 and top 300 most frequent nominative singular noun types in the SUBTLEX corpus.

Table 9. Distribution of the most Frequent Noun Types in the SUBTLEX Corpus by Gender and Suffix

	M		F		N		θ_N		Productive?	
NOM.SG	Top 100	Top 300	Top 100	Top 300	Top 100	Top 300	Top 100	Top 300	Top 100	Top 300
–r	20	68	2	5	0	3	7	17	Yes	Yes
–i	24	47	1	7	2	9	8	14	Yes	Yes
–a	0	1	22	74	1	5	7	18	Yes	Yes
–ø	10	15	9	27	14	28	9	16	No	No

The Tolerance Principle made the same predictions as before, irrespective whether the analysis was based on the top 100 or top 300 most frequent noun types.

Discussion

Children‘s linguistic experience is inevitably variable: Children are unlikely to know the exact same words and their vocabulary sizes differ, even for children at the exact same age. In spite of lexical differences, however, children acquiring the same language are able to discover what the target grammar is.

The Tolerance Principle operates on types. As a consequence, what matters for learning is the number of lexical items that exhibit a specific property, rather than which exact lexical items those are. In this section, I have shown that, while the type counts of grammatical properties may differ from corpus to corpus, the predictions are the same. This is because the proportion of exceptions that go against a linguistic pattern relative to the types that conform to a linguistic pattern yields the same results, regardless of the exact number of types involved in the calculations.

Child-directed speech and adult corpora have been shown to converge on high frequency lexical items (Kodner, 2019). Therefore, it is plausible that children base their grammar learning mainly on high frequency lexical items. An analysis of the most frequent noun types in the SUBTLEX corpus using the Tolerance Principle predicted an early division between productive and unproductive suffixes in Icelandic gender assignment.

Experimental study

Participants

26 children (M = 4;5 years, SD = 1.33 years, age range = 2;9–6;3 years; 14 females, 12 males) and eighteen adult controls participated in this study. An additional four children participated, but were excluded from analysis due to failure to understand the task or unwillingness to engage with the game. Children were recruited from a day-care centre in suburban Reykjavík, where the study was conducted. Adult participants were recruited at the University of Iceland, Reykjavík. All participants were native speakers of Icelandic with normal hearing and normal to corrected-to-normal vision. No participant identified as bilingual/multilingual or reported to have a history of language delay.

Design

An elicited production task was designed with two conditions: Productive and Unproductive. In the Productive condition, participants were exposed to a novel noun with either suffix –r, –i or –a. In the Unproductive condition, participants were exposed to a novel noun, monosyllabic or disyllabic, that did not bear such a suffix.

Predictions

The Tolerance principle predicted that participants would make categorical suffix-based choice in gender assignment in the Productive condition, but arbitrary gender choices in the Unproductive condition.

Materials

28 nonce nouns were designed. The novel nouns all conformed to phonetic and phonological restrictions in Icelandic. To control for phonological neighbourhood density, the Phonological Corpus Tools software (Hall et al., 2016) was used to check for minimal pairs with nouns included in Pind's (1991) frequency list of Icelandic. The stem-final segment of novel nouns in the Unproductive condition could be any consonant except /r/. The novel nouns are given in Table 10.

Table 10. Test Items by Nominative Singular Suffix

–r	*–i*	*–a*	*–ø* MS	*–ø* DS
Lerfur	Krandi	Bukla	Rúf	Kútes
Sappur	Lerri	Rala	Kurk	Ratef
Mækur	Tukki	Húla	Mirg	Farem
Tirgur	Dubbi	Darga	Súf	Múkaf
		Múka	Glæf	Silám
		Fóma	Lirg	Rútis
			Turk	Tækill

The novel nouns were paired with inanimate novel objects from the Novel Object and Unusual Name (NOUN) database (Horst & Hout, 2016). Figure 1 shows an example of a novel object used in the study:

Figure 1. A Novel Object at Exposure to Test

There were fourteen test items per condition. The test items were organized into seven trials. In each trial, the participant was presented with four test items, two for each condition, in a randomized order.

The test sentence served the purpose of a magical charm to be uttered by the participant in lieu of more traditional charms like 'hocus pocus'. The construction induced gender agreement on the definite suffix and possessive pronominal, as shown for real nouns in (7):

(7) a. Hvar er hattu-r-**inn minn**?
where is hat-M.DEF.SG my-M
'Where is my hat?'

b. Hvar er penn-i-**nn minn**?
where is pen-M.DEF.SG my-M
'Where is my pen?'

c. Hvar er kann-a-**n mín**?
where is mug-F.DEF.SG my-F
'Where is my mug?'

d. Hvar er egg-**ið mitt**?
where is egg-N.DEF.SG my-N
'Where is my egg?'

The construction was chosen in light of the fact that children acquiring Icelandic have been shown to comprehend and produce main clause *wh*-questions early. Moreover, *wh*-questions with *where* are among the earliest interrogative questions attested in Icelandic child language, with no reported erroneous use (Sigurjónsdóttir, 1991).

Procedure

The task was embedded in an animated interactive movie that was played off a computer screen. The movie was designed using Animaker, an online animation video maker and was thirteen minutes long. Children and adults were tested individually in a quiet location at a day care center and at the University of Iceland.

The objective of the task was to help the movie's story protagonist obtain novel toys by magic. However, in order for the novel toys to come to be obtained, the participant had to be able to use the name of the novel toy in a sentence at test. The participant was shown a picture of the novel object and heard its name twice in syntactic contexts where the nominative singular is obligatory, as (8) demonstrates.

(8) a. Þetta er **lerfur**.
this is lerfur-M.NOM.SG.
'This is a lerfur.'

b. Vá! **Lerfur**!
wow lerfur-M.NOM.SG.
'Wow! A lerfur!'

After the participant had produced the test sentence, the novel object appeared by magic as shown in Figure 2.

Figure 2. Magic at work in the Test Scene

Prior to test, there was a training session in which the participant observed the story protagonist either succeed or fail with the magic. The purpose of these scenes was to provide the participant with both positive and negative reinforcement. Subsequently, the participant was trained on three real nouns of each gender.

Results

Children

Children's behavior across the two conditions is summarized in Figure 3. Dots represent individual performance in each condition. Bars are standard error. Productive gender assignment in the Productive condition corresponds to mean systematic suffix-based choice of gender: Masculine for nouns with *–r* or *–i*, feminine for nouns with *–a*. In order to confirm the unproductivity of neuter in Icelandic, productive gender assignment in the Unproductive condition corresponds to mean neuter assignment.

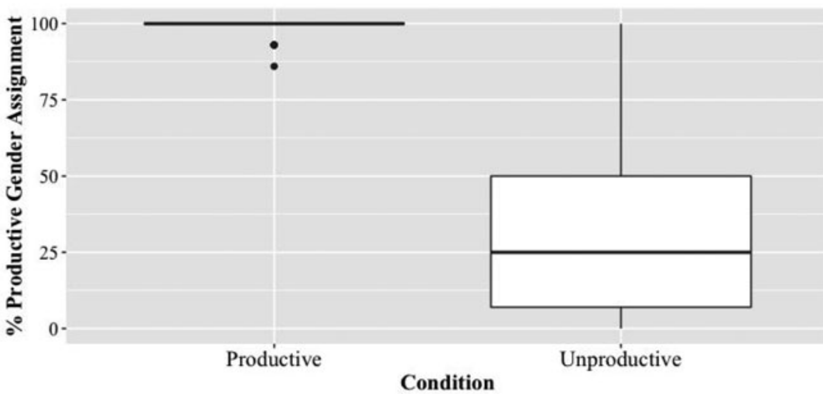

Figure 3. Children: Gender Assignment across Conditions

Children made a categorical, suffix-based choice of either masculine or feminine in the Productive condition. They assigned masculine consistently to novel nouns with either suffix *–r* or *–i* ($M = 0.99$, $SD = .037$, $SE = .007$). Likewise, they assigned feminine consistently to novel nouns with the suffix *–a* ($M = 0.98$, $SD = .04$, $SE = .009$). The percentage of neuter assignment in the Productive condition was 2.35%, which is not statistically significant from zero. In the Unproductive condition, children did not make a systematic choice of neuter ($M = 0.29$, $SD = 0.28$, $SE = .05$). A paired t-test confirmed a significant difference between the means of the two conditions: $t(25)$ =11.93, $p < .001$.

Figure 4 shows the distribution of children's responses in the Unproductive condition. Omission was defined as silence at test. Variable assignment was defined as the repetition of a test item twice, or more often, with variable gender agreement.

Gender assignment in the Unproductive condition was characterized by a great deal of inter-and intra-speaker variation. Collectively, the children did not behave categorically in this condition, although six children did make categorical choices of gender. Nevertheless, these children were categorical in different ways: Three assigned feminine categorically or near-categorically, two assigned masculine categorically and one assigned neuter categorically.

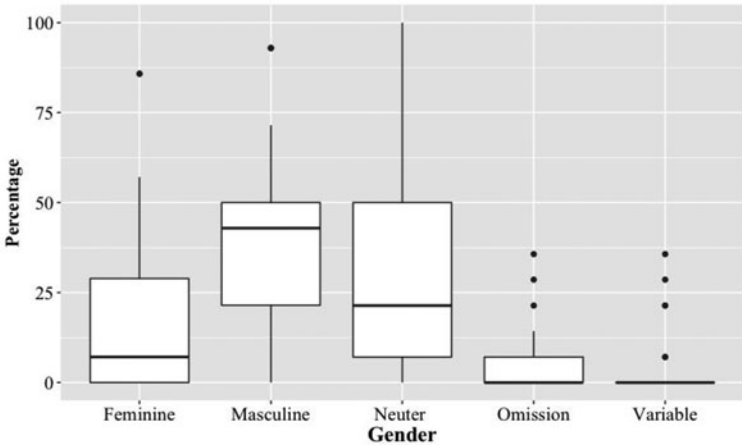

Figure 4. Children: Gender Assignment in the Unproductive Condition

A paired t-test revealed no significant difference between mean neuter assignment of monosyllabic and disyllabic nouns: $t(24) = -0.52$, $p = 0.61$. Figure 5 shows gender assignment of monosyllabic and disyllabic nouns in the Unproductive condition.

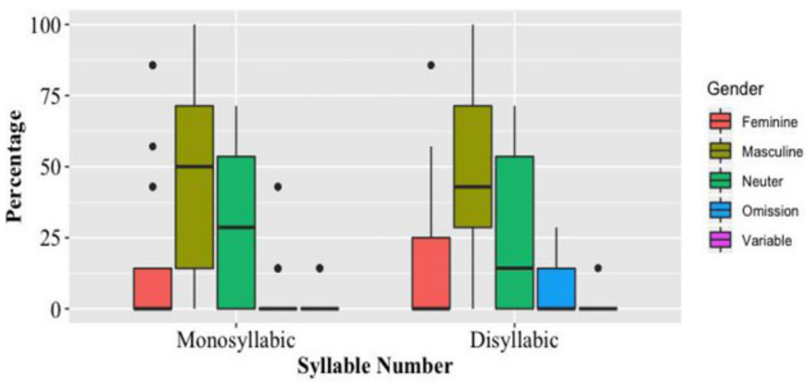

Figure 5. Children: Gender Assignment and Syllable Number in the Unproductive condition

In order to assess the relationship between age and neuter assignment, a simple regression analysis was conducted. The relationship is visualized in Figure 6. The result of the analysis showed no correlation between age and mean neuter assignment ($r = .09$).

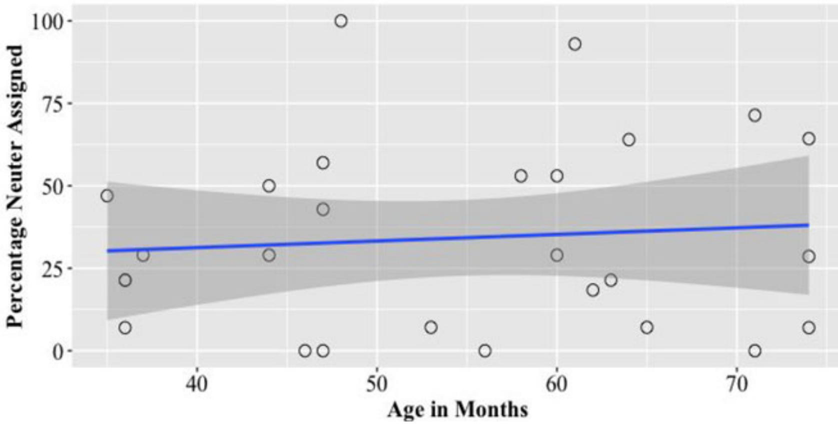

Figure 6. Effect of Age on Neuter Assignment

Adults

Adults' behavior across the two conditions is summarized in Figure 7. Dots represent individual performance in each condition. Bars are standard error. As before, productive gender assignment in the Productive condition corresponds to mean systematic suffix-based choice of gender: Masculine for nouns with –*r* or –*i*, feminine for nouns with –*a*. In order to confirm the unproductivity of neuter in Icelandic, productive gender assignment in the Unproductive condition corresponds to mean neuter assignment.

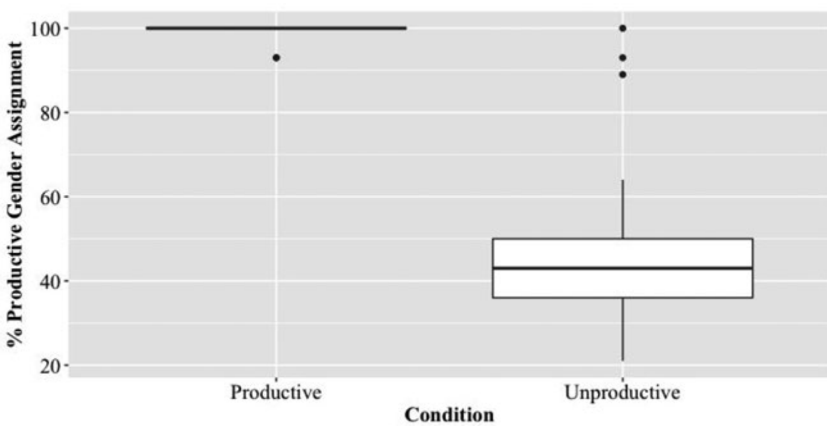

Figure 7. Adults: Gender Assignment across Conditions

Adults made a categorical, suffix-based choice of either masculine or feminine in the Productive condition. They assigned masculine at ceiling (100%) to novel nouns with either suffix –*r* or –*i*. Similarly, they assigned feminine consistently to novel nouns with the suffix *–a* ($M = 0.99$, $SD = .03$, $SE = .009$). Mean neuter assignment in the Unproductive condition was 48% ($SD = 0.24$, $SE = .013$). A paired t-test confirmed a significant difference between the two conditions: $t(17) = 9.32$, $p < .001$.

Figure 8 displays the distribution of adults' responses in the Unproductive condition. Gender assignment in the Unproductive condition was characterized by inter-and intra-speaker variation. Collectively, adults did not behave categorically in this condition, although three chose consistently neuter.

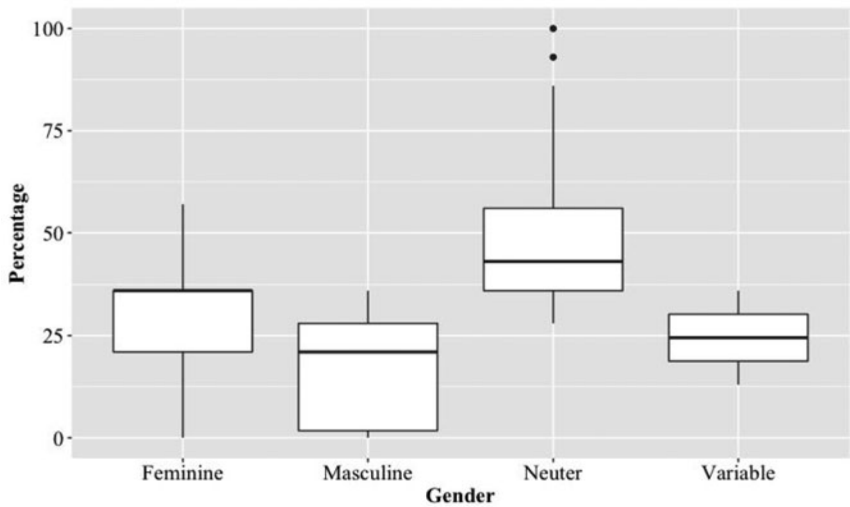

Figure 8. Adults: Gender Assignment in the Unproductive Condition

A paired t-test showed no significant difference between mean neuter assignment of monosyllabic and disyllabic nouns: $t(17) = -0.24$, $p = 0.81$. Figure 9 shows the distribution of gender assignment by syllable number.

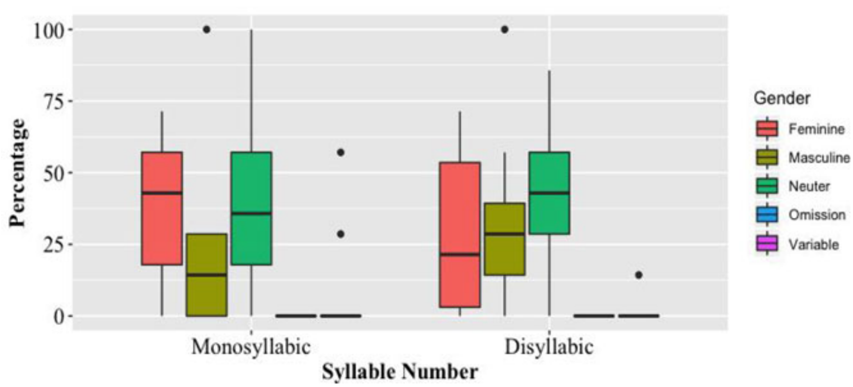

Figure 9. Adults: Gender Assignment and Syllable Number in the Unproductive Condition

Discussion

Overall, there were minimal differences between children's and adults' behavior in the task. However, adults assigned neuter significantly more frequently than children, as measured by a Welch's t-test: $t(31.54) = 2.39$, $p = .023$. There was no effect of age on children's performance. This suggests that a categorical distinction between productive and unproductive suffixes in Icelandic gender assignment can be made before the age of three on the basis of lexical experience, as predicted by the Tolerance Principle.

An alternative view of productivity

Productivity: categorical or gradient?

The Tolerance Principle predicted a categorical division between productive and unproductive processes in Icelandic gender assignment. However, a body of research has argued for an alternative view of productivity. On this view, productivity should be viewed and measured as a gradient phenomenon (Hay & Baayen, 2005; McClelland & Bybee, 2007). As a consequence, the difference between productive and unproductive patterns is not a categorical one and a pattern may be semi-productive.

A series of metrics to quantify morphological productivity at a scalar level have been proposed by Baayen and colleagues (Baayen, 1989; 1992; 1993). All of the metrics are centered around hapax legomena: namely, singleton words that appear precisely once in any given corpus. The general idea is that low token frequency should be a strong indication of productivity, given that lexicalized types in general have a higher token frequency than unlexicalized types.

The most studied metric proposed by Baayen and colleagues is P, which measures whether a given process is productive or not on the basis of token frequency. P is stated in (9), where n_1 represents the number of singleton words that a process applies to and N is the sum of the token frequencies of these items.

(9) $N = n_1/N$

The primary goal of P is to give a statistical measure of the probability of encountering new types (Baayen, 1993, p. 183). The larger the number of possible types, the more likely it is that they will not all occur in a given corpus or that some of them will occur only once.

A second metric, P*, compares one process against all other processes (Baayen, 1993). P* is stated in (10), where N_1 represents the total number of all singleton words that a process applies to.

(10) $P^* = n_1/N_1$

The primary goal of P* is to give a numerical estimate of the relative rate at which a category is expanding.

Baayen (1993, p. 194) proposed that P and P* should be viewed as two complementary measures; the primary use of P being to distinguish between productive and unproductive processes as such, while P* ranks proceses by degrees of productivity.[5]

 https://doi.org/10.1017/S0305000920000732

Baayen‘s P and P* metrics were not explicitly designed to account for learning. Nevertheless, they have clear implications for learning. A comparison of the predictions of the Tolerance Principle and Baayen‘s metrics contributes to the dispute whether morphological learning involves detecting categorical or gradient patterns. Therefore, the three data sets presented in this paper were subjected to quantitative analyses using Baayen‘s P and P* metrics and their predictions evaluated against the empirical results.

Analysis using Baayen‘s P and P* metrics

Both P and P* are gradient measures of productivity, whereas the results of the elicited production task suggest that both children and adults make a categorical distinction between productive and unproductive suffixes in Icelandic gender assignment. This does not necessarily invalidate P and P* as quantitative measures. For instance, it is conceivable that there exists some quantitative threshold value that can be used to define productivity or absence thereof. How to construct such a threshold is beyond the scope of this paper. However, in the analysis below, I demonstrate important inconsistencies of the two metrics and discuss what gives rise to them.

Table 11 provides the results of a quantitative analysis using Baayen’s P and P* metrics on Icelandic child-directed speech (adult), child naturalistic speech (child) and the SUBTLEX corpus. The denominator of P was the total number of tokens that take a particular suffix. The denominator of P* was the sum of all singletons attested for each gender.

There were two major types of inconsistencies in the values of the measures. First, P yielded radically different values depending on the corpus size due to its reliance on token counts (see Bauer, 2001, p. 153 for similar concerns). As a result, productive suffixes could be assessed as less productive than unproductive suffixes. Bold font in Table 11 indicates values that predict the productivity of unproductive patterns.

P* ranked suffixes more accurately; i.e. *–r* and *–i* were predicted to be most productive of masculine and *–a* was predicted to correlate with high or semi-productivity of feminine. Still, the ranking of the productive suffixes was variable between the two corpora (e.g., the productivity of *–r* and *–i* to masculine). This is because the value of P* is dependent on type counts which may vary between suffixes from corpus to corpus. As a result, the prediction for gender acquisition is that children should treat these suffixes differently depending on their type counts. However, neither children nor adults made such a distinction between the three productive suffixes in the elicited production task. Instead, they made a categorical distinction between productive and unproductive suffixes which is unaccounted for on a gradient approach to productivity.

General discussion and conclusion

In this paper, I have presented an approach whereby gender acquisition is driven by a search for productive patterns. Prior accounts have proposed that transparency is predictive of children’s behavior in gender acquisition. I argue that transparency is a direct reflection of productivity. As a consequence, I propose that the term transparency be replaced with productivity.

Typological research on gender systems has revealed a wide range of possible gender assignment patterns (Corbett, 1991; 2013). Therefore, a theory of gender acquisition is

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Table 11. Quantitative Analysis of Adult, Child and SUBTLEX Corpora

	M				F				N			
Corpus	*–r*	*–i*	*–a*	*–ø*	*–r*	*–i*	*–a*	*–ø*	*–r*	*–i*	*–a*	*–ø*
Adult												
P	0.14	0.19	0.03	0.15	**0.21**	0.12	0.11	0.08	**0.88**	0.08	**0.9**	0.12
P*	0.38	0.49	0.01	0.13	0.1	0.03	0.53	0.34	0	0.03	0.53	0.34
Child												
P	0.02	0.05	**0.9**	0.54	**0.9**	**0.89**	0.2	0.35	**0.78**	0.25	0.27	0.35
P*	0.48	0.25	0.03	0.19	0.01	0.13	0.74	0.7	0.09	0.2	0.33	0.58
SUBTLEX												
P	0.04	0.05	0	0.02	0.03	**0.1**	0.05	0.03	0.28	0.22	0	0.04
P*	0.59	0.37	0	0.11	0.022	0.067	0.48	0.61	0.01	0.16	0	0.013

needed that can account for how children can detect any kind of gender assignment pattern; be it semantic, morphological or phonological.

The present theory offers a general approach to how children detect gender assignment patterns. I have shown how predictions can be made using corpora as an estimate of the child's lexical experience in gender acquisition. As a result, any generalization about gender assignment can be subjected to the kind of quantitative analysis, proposed here, to make testable predictions.

Prior accounts of learning have argued that children categorically follow patterns that are frequent in the input in either experimental or naturalistic settings (Hudson Kam & Newport, 2005; 2009; Newport, 2019). However, a learning account must also be able to explain why children fail to generalize categorically on the basis of high frequency forms. Roughly a third of all noun tokens in Icelandic are neuter. Neuter nouns are also statistically dominant in the class of nouns that lack an overt nominative singular suffix. Still, neuter was not consistently chosen in the Unproductive condition. The unproductivity of neuter was predicted by the Tolerance Principle due to the number of masculine and feminine nouns of the same pattern.

Results from artificial language learning studies have shown that children tend to regularize linguistic patterns in the input data, even when these patterns show variability or inconsistencies (Hudson Kam & Newport, 2005; 2009). Thus, children do not merely reproduce the input statistics. However, the same studies found a different behavioral pattern for adults. Unlike children, adults matched the token frequencies of linguistic patterns instead of producing them in a categorical fashion.

Children and adults‘s response patterns in the present study were strikingly similar. The main difference involved the choice of neuter in the Unproductive condition, where adults used neuter significantly more often than children. This may suggest that some adult participants were trying to match the input statistics. Prior studies have shown that adults use irregular forms more often than children in experimental settings (see e.g., Berko, 1958). The source of child and adult differences in experimental settings remains unclear. In the present study, however, differences were only apparent in the Unproductive condition.

The results of the present study suggest that learning involves forming type-driven generalizations. Many contrasting theoretical approaches have recognized the role of type frequency in productivity. However, the main point of contention has been the division line between productive and unproductive processes. For instance, Bybee's (1985) Network model argues against a categorical division between productive and unproductive processes. Instead, the degrees of productivity of both productive and unproductive processes are determined by their token frequencies. As we have seen, such an approach makes inaccurate predictions with respect to Icelandic gender assignment. Baayen's approach is in the same gradient spirit and both types and tokens are made use of in his productivity calculations.

The empirical results presented in this paper do not support a gradient view of productivity: There were no differences in the degrees of productivity of the three suffixes in the Productive condition. In spite of statistical dominance, neuter was not consistently chosen in the Unproductive condition. Rather, the absence of a default gender manifested itself in inter-and intra-speaker variation. Hence, productivity resulted in categorical, uniform responses, whereas absence thereof resulted in inconsistency and differences in response patterns.

Notes

[1] The term RULE is used in an atheoretical way in this paper and is compatible with other related terms such as PATTERN, REGULARITY or SCHEMA. On the present approach, rule formation is a consequence of a search for productive patterns in language acquisition. The author makes no commitment as to how rules discussed in this paper should be formulated or represented in theoretical terms.

[2] There exist two other correlations between nominative singular forms and gender assignment in Icelandic. Namely, nouns that end in either *–ing* or *–un* are invariantly feminine. However, only five noun types with *–ing* and two with *–un* were encountered in a corpus of child-directed speech (Sigurjónsdóttir, 2007). It is, therefore, a possibility that these patterns are not frequent enough to be detected by young children in gender acquisition.

[3] The majority of nouns in this class have an /u/ inserted between the suffix *–r* and *–i*. This is standardly assumed to be the result of an epenthesis rule (Thráinsson, 2017). In other words, the epenthesis is a purely phonological process, independent of gender assignment: that is, triggered automatically under suffixation.

[4] In linguistic research, default forms are expected when agreement is inert like, for instance, in the case of clausal subjects. However, it is at present unclear what role such forms play in the acquisition of gender assignment rules. For instance, Tsimpli and Hulk (2013) pointed out that children acquiring Dutch and Russian, over-generalize masculine despite that theoretically neuter has been claimed to be the default in both languages.

[5] Baayen has proposed additional metrics to address some concerns raised by his critics, but discussing them specifically is beyond the scope of this paper. The later metrics introduced by Baayen all rest on the same theoretical assumptions.

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Predicting ineffability: Gender and inflection in Icelandic
(Manuscript)

Predicting ineffability: Gender and inflection in Icelandic

Abstract

The structure of inflectional paradigms is characterized by interdependencies between forms and categories. The question is what the nature of these interdependencies are and how they are discovered in acquisition. In this article, I approach these issues from a learning perspective using gender and plural formation in Icelandic as a case study. Specifically, I investigate how knowledge of grammatical gender facilitates the induction of other plural forms or vice versa. Noun pluralization in Icelandic cross-cuts both gender and inflection classes, raising the question of how children can extract the relevant generalizations given syncretism both within and across inflectional paradigms. In a corpus study, I show how predictions regarding the productivity of correspondences between gender and plural forms in Icelandic can be formulated by a learning model (Yang, 2005; 2016). These predictions were put to the test in two elicited production studies on both children and adults. I demonstrate how both children and adults were at a loss to pluralize nouns that they were unable to assign gender to. Thus, productivity in gender assignment correlates with productivity in plural formation. Since knowledge of gender is contingent on the knowledge of productive nominative singular forms, I propose that gender may be a developmental prerequisite for the acquisition of plural formation in Icelandic due to the statistical primacy of singular forms in the input. I argue that gaps within the inflectional paradigm of Icelandic nouns follow naturally from a learning process guided by productivity that fails and results in rote memorization.

Keywords: Gender, inflection, defaults, defectivity, acquisition

1. Introduction

Inflection classes, standardly defined as the set of roots whose members each share the same set of realizations (Aronoff, 1994), raise a number of important analytical questions: What are the units of generalization? Are inflection classes primitives or epiphenomena in grammar? However, the central issue is understanding the source of speakers' ability to generalize beyond experience in inflectional morphology: How can speakers predict the inflectional realizations of novel nouns?

Nouns in Icelandic inflect for gender, case and number, resulting in nested patterns of inflection, traditionally referred to as inflection classes. Speakers of Icelandic not only need to know the individual forms and categories – they must also know how they interact with one another in order to be able to inflect novel nouns. These facts raise important questions regarding the nature of the interdependencies between linguistic categories in inflectional morphology. For instance, the relation between gender and inflection has been debated: Is there a causal relation between the two categories? If so, what is the direction of causation?

These questions are related to the question of which forms facilitate the induction of others within an inflectional paradigm. It has long been observed that some inflectional categories or forms seem to carry more weight than others, as evidenced by analogy and acquisition (Albright, 2003; Bybee, 1985; Lahiri & Dresher, 1983). For example, the role of gender in the acquisition of fusional noun inflection has been debated (see e.g. Mills, 1986 and Spreng, 2003 for German). In parallel, the role of gender versus inflection as catalysts for diachronic change in nominal morphology has been widely discussed (e.g. Berg, 2019; Enger, 2004; Wurzel, 1987).

The relation between gender and inflection may differ cross-linguistically and under-go diachronic change (Kürschner, & Nübling, 2011). For example, some languages, like Icelandic, have retained gender distinctions both in the singular and in the plural, while Danish has retained gender distinctions in the singular only (Hansen & Heltoft, 2011). However, there is no language attested which encodes gender in the plural, but not in the singular, as stated by Greenberg's (1966) universals 37 and 45. Given the language-specific nature of the interdependencies between linguistic categories, children in acquisition must somehow discover whether the relation between forms or categories facilitates the induction of new forms in the target language or not. The question is how these correspondences are discovered, given that there is not always a one-to-one correspondence between morphosyntactic value and phonetic form. In other words, how can children extract the relevant generalizations in light of syncretism both within and across linguistic categories in nominal morphology?

In this article, I investigate the relation between gender and inflection from a learning perspective, using Icelandic as a case study. Specifically, I study how knowledge of gender facilitates the induction of plural forms in Icelandic and vice versa. Since plural formation in Icelandic cross-cuts both genders and inflection classes, it provides an ideal case study for investigating how the child learner may discover productive correspondences between linguistic forms and categories.

I argue that children's acquisition of inflectional paradigms is driven by a search for productive correspondences between inflectional forms, guided by a learning model (Yang, 2005; 2016). First, I formulate predictions for productivity and absence thereof in the correspondences between gender and plural suffixes in Icelandic (Helgadóttir et al., 2012). Second, I put these predictions to the test in two elicited production studies that investigate the bidirectional relation between gender and inflection in Icelandic. I demonstrate how children's knowledge of gender in Icelandic facilitates their inferences about plural forms. Conversely, I show how children's ineffability in gender correlates with ineffability in plural marking. I argue that the relation between gender and inflection is derivative, arising from productive nominative singular forms. I further propose that findings from language acquisition and learning may shed light on the distribution of forms across the paradigms generated by the inflectional features of a language.

The article is organized as follows: In section two, I discuss prior approaches to paradigmatic relations and review contrastive arguments regarding the nature of the gender-inflection relation in grammar. Section three provides a description of gender and plural formation in Icelandic, followed by corpus analyses to generate predictions for learning in section four. The method underlying the elicited production tasks is described in section five, followed by the results in section six. In section seven, I provide a general discussion of the findings and their theoretical implications. Section eight concludes this article.

2. Background

2.1 Constraining the distribution of inflectional forms

A number of proposals have been put forth claiming that paradigms have internal structure instead of being mere random assemblages of allomorphs or other forms (see, among many, Baerman, 2014; Blevin, 2004). These proposals are motivated by the observation that the number of attested inflection classes is much lower than are logically possible. For instance, Latvian noun inflection distinguishes between two genders and seven cases. For any one morphosyntactic value there may be one to six allomorphs. In a thought experiment, Carstairs-McCarthy (1983, p. 117) showed that these could, in principle, be mixed and matched to yield 230,400 classes (the product of the number of allomorphs for each morphosyntactic value). However, only seven classes are actually attested. This suggests that "not anything goes" in the organization of inflectional paradigms. Otherwise, one would expect inflectional resources to be distributed in a wildly abundant way, a prediction that is not borne out empirically (cf. e.g. Ackerman & Malouf, 2013; Carstairs, 1987).

In an influential line of work, Carstairs-McCarthy has proposed that the distribution of forms within an inflectional paradigm is constrained by a principle that seeks to prevent paradigm opacity (Carstairs, 1983; Carstairs-McCarthy, 1987; 1994). The principle predicts that a word can only belong to a single inflection class and rules out paradigms with no unique inflectional features of their own. In its original version, the principle was stated as the Paradigm Economy Principle (Carstairs, 1983). The principles states that there should be only one morphosyntactic value whose allomorph should be sufficient to predict the behavior of the entire paradigm. The later version, the No Blur Principle (NBP) states that each affix is either unique to a particular inflection class or the elsewhere default for the morphosyntactic value it realizes (Carstairs-McCarthy, 1994)[1].

Carstairs-McCarthy argues that the principle follows from a fundamental learning bias, the Principle of Contrast (PC) for lexical learning (Clark, 1987, 1990, 1993). The PC is a pragmatic principle which states that "speakers take every difference in form to mark a difference in meaning" (Clark, 1993, p. 64). However, at the outset, given the rampant syncretism attested in richly inflected languages, inflectional morphology seems to either invalidate the PC or suggest that the principle is irrelevant in the acquisition of inflectional morphology.

Carstairs-McCarthy has attempted to reconcile the NBP with the PC by assuming that inflection class membership can form part of the meaning of an affix. For instance, there is both trans-and intra-paradigmatic syncretism in the distribution of genitive singular and nominative plural forms of monosyllabic feminine nouns in Icelandic, as demonstrated in Table 1 (from Carstairs-McCarthy, 1994, p 740):

	Class A	Class B	Class C	Class D
GEN.SG	*–ar*	*–ar*	*–ar*	*–ur*
NOM.PL	*–ir*	*–ar*	*–ur*	*–ur*

Table 1: *The distribution of* GEN.SG *and* NOM.PL *forms of monosyllabic feminine nouns in Icelandic*

The affixes in Table 1 are "competitors" in the sense that they realize exactly the same morphosyntactic properties and are indistinguishable either phonologically or semantically.

[1]In recent work, Carstairs-McCarthy refers to the NPB as *vocabular clarity* to account for inflectional morphology in multilingual situations (Carstairs-McCarthy, 2010). In this paper, I will consistently use the term NBP.

Carstairs-McCarthy argues that the competing affixes obey the PC on the assumption that inflection class membership forms part of the meaning of an affix. On this approach, the suffix *–ir* would not only have the meaning “nominative plural” but “nominative plural, class A”.

However, Müller (2005) has argued that the NBP misses important generalizations as the “most conspicuous property” of Icelandic noun inflection is the constant re-use of inflection markers (affixes). Therefore, any constraint on the distribution of inflectional forms should seek to maximize syncretism and minimize the set of inflection markers. In an alternative analysis, Müller argues that the plural suffixes *–ar, –ir* and *–ur* undergo fission, a process in which a single morpheme corresponds to more than one terminal node prior to lexical insertion (Noyer, 1997). Thus, the plural suffixes *–ar, –ir, –ur* are not primitives, but consist of two parts; the vowel and /r/. Therefore, on this analysis, /r/ is the default plural form in Icelandic.

Classic Word and Paradigm (WP) models assume that each lexeme is presented by a basic, unmodified or leading form, that all other inflectional forms are modifications of. These modifications are organized in exemplary paradigms that are definitional of inflection classes (Matthews, 1991). As a result, the number of different types of leading forms or principal parts determines the number of inflection classes (Blevins, 2004; Stump & Finkel, 2009). From a WP perspective, there is no principled reason why each lexeme must be identified by a single leading form. Rather, paradigmatic transparency may reflect a tendency towards lexical economy in inflectional morphology. As a result, WP approaches only claim that there will be a correlation between the number of leading forms and inflection classes (Blevins, 2004).

The most general insight of the classic WP approach is that one inflection tends to predict another. Therefore, the central premise of WP approaches may be characterized as accounting for interdependencies (Matthews, 1991; 1997). The challenge consists of demarking the distinction between predictive and non-predictive principal parts (Stump & Finkel, 2009). One proposal (Ackerman et al., 2009) has studied how forms in a paradigm are able to predict one another using entropy, an information-theoretic measure (Shannon, 1948). Entropy provides a measure of the predictability of an inflectional form by measuring the degree of surprise at the occurrence of a form.

These two contrastive approaches seem to converge on the assumption that certain forms carry more weight than others within an inflectional paradigm, although they differ with respect to the nature of such forms. It has long been observed that certain forms within a paradigm can influence the direction of analogical change. For instance, Lahiri & Dresher (1983) discuss a number of case studies in which independently motivated sound changes in nominative singular forms resulted in wholesale inflection shifts. Some inflectional forms also seem to play a privileged role in acquisition (Bybee, 1985).

These empirical observations have motivated the notion of bases in inflectional morphology (Albright, 2002). However, the problem resides in the selection criterion for bases since they cannot necessarily be identified by a priori definitions of morphosyntactic markedness. For instance, Albright (2004) discusses paradigm leveling in Latin noun inflection, whereby oblique forms influenced the nominative singular form, even if the latter has traditionally been assumed to be the citation form in Latin noun inflection.

Given the cross-linguistic diversity in inflectional morphology, the question is how children can construct hypotheses about inflectional patterns on the basis of the input. Cross-linguistic studies on vocabulary development have shown that productive inflectional morphology is largely in place around the age of three, when children know, on average, only around 500 words (Hart & Risley, 1995; 2003; Szagun et al., 2006). Furthermore, the frequencies of inflectional forms cross-linguistically have been shown to be quite uneven, following Zipf's (1949) law which states that the frequency of a form is approximately inversely proportional to its rank. Given the number of possible inflectional forms in fusional noun inflection, the number of fully inflected nouns is expected to be low in child-directed input. As a result, it is unlikely that children have encountered all possible inflectional forms in acquisition. Thus, children are not presented with nouns in fully inflected paradigms in acquisition. Rather, they must somehow discover how individual forms are related to one another in order to predict a noun's inflectional behavior.

2.2. Gender and inflection

The relation between gender and inflection has been widely discussed (Berg, 2019; Corbett, 1991; Kürschner, & Nübling, 2011; Spencer; 2002). In spite of their interaction, gender has conventionally not been regarded as an inflectional category. For instance, gender does not induce sets of forms from a single lexeme. In other words, nouns do not form "gender pairs" in the same way that nouns form singular-plural pairs (Spencer, 2002, pp. 279-280). Moreover, unlike gender, inflection does not participate in agreement relations (Alexiadou, 2004; Hockett, 1958). Thus, nouns of the same gender trigger the same agreement, irrespective of inflection. For example, masculine nouns in Icelandic trigger the same agreement morpheme (*–ur*) even if they belong to different inflection classes, as shown in (1):

(1) a. Falleg-**ur** feldu-**r**.
Beautiful.M.NOM.SG fur.M.NOM.SG
'Beautiful fur.'
b. Falleg-**ur** jakk-**i**
beautiful.M.NOM.SG jacket.M.NOM.SG
'A beautiful jacket.'
c. Falleg-**ur** stóll-**ø**
beautiful.M.NOM.SG chair.M.NOM.SG
'A beautiful chair.'

This fact has motivated a theory of grammar in which gender and inflection are linked to different modules; syntax and phonology, respectively (Alexiadou & Müller, 2008). In addition, this fact has distributional consequences, since it means that there is not necessarily a one-to-one mapping between gender and inflection classes. The main point of contention has been the causal relation between the two categories: Does gender predict inflection or vice versa?

There is evidence from acquisition and diachrony that gender predicts inflection: Mills (1986) found that grammatical gender was largely in place in German by the age of three, whereas plural formation was in place much later. Plural forms in German have also undergone change diachronically in the direction of predictability according to gender, suggesting that the latter is the conditioning factor (Wurzel, 1998).

Proponents of the opposite view have argued that inflection carries more information than gender alone. Since there are typically more inflection classes than genders, it should be "simpler" to predict gender on the basis of inflection rather than vice versa (Spencer, 2002, pp. 36-37). In a similar spirit, Corbett (1991, p. 49) has argued, on the basis of German and Russian, that gender should be inferred on the basis of inflection class, given that nominative singular forms can correlate with more than one gender. For instance, nouns that end in a soft palatalized consonant in the nominative singular in Russian can be either masculine (e.g. *denj'* 'day') or feminine (e.g. *kost'* 'bone') (see Nesset, 2003 for a discussion). However, these nouns belong to different inflection classes which means that their oblique forms can serve as disambiguating forms.

A compromise view has been proposed by Enger (2004), based on evidence from Norwegian, that inflection may predict gender for some nouns that are more frequent in the plural than in the singular. Similarly, Doleschal (2000, p. 125) has argued against a universal preference in the interdependence between gender and inflection class. She argues, based on evidence from Russian, that even in one and the same language, mappings may occur in both directions, although typically one direction will be systematically preferred over the other.

The relation between gender and inflection may differ cross-linguistically (see Kürschner, & Nübling, 2011 for the relation between gender and inflection in Germanic). The relation between gender and inflection may also undergo diachronic change (Berg, 2019). For instance, some languages, like Icelandic, have retained gender distinctions both in the singular and the plural, while Danish has retained gender distinctions in the singular only (Hansen & Heltoft, 2011). Therefore, children must somehow discover whether the relation between forms or categories facilitates the induction of new forms or not in the target language or not.

3. Gender and plural formation in Icelandic

3.1 Gender in Icelandic: Patterns and their acquisition

Grammatical gender in Icelandic distinguishes between three genders: Masculine, feminine and neuter. The Icelandic gender system is typologically classified as formal (Corbett, 2013). The three genders are roughly equally frequent (Helgadóttir et al., 2012). Gender distinctions are attested on the definite article, which is a suffix, adjectives, the verbal past participle and pronouns.

There are correspondences between gender and nominative singular suffixes in Icelandic, as Table 2 demonstrates:

NOM.SG.	**Masculine**	**Feminine**	**Neuter**
–r	Bátu-r (‘a boat’)	Brúðu-r (‘a bride’)	NA
–i	Penn-i (‘a pen’)	NA	NA
–a	Herr-a (‘Sir’)	Kann-a (‘a mug’)	NA
–ø	Guð-ø (‘God’)	Hlíð-ø (‘a hill’)	Stríð-ø (‘War’)

Table 2: *Correspondences between gender and NOM.SG. suffixes in Icelandic*

The absence of an overt nominative singular suffix is indicated by *–ø*. The correspondences in Table 2 show that there is not necessarily a one-to-one mapping between gender and nominative singular suffix. However, there are correlations: Nouns that take either suffix *–r*[2] or *–i* tend to be masculine. Nouns that take the suffix *–a* tend to be feminine. There are various exceptions to these correlations. For instance, several common female names in Icelandic, including *Sigríður*, take the suffix *–r*. Neuter has standardly been assumed to be the default gender in Icelandic (e.g. Steinmetz, 1985) since it is attested in contexts where agreement is assumed to be inert, such as on clausal and oblique subjects.

In a series of corpus analyses, predictions regarding the productivity of nominative singular suffixes to gender assignment were formulated using a learning model (Yang, 2005; 2016). The suffixes *–r* and *–i* were predicted to be productive of masculine. The suffix *–a* was predicted to be productive of feminine. In the absence of these suffixes (*–ø*), no gender was predicted to be productive. In other words, in the absence of a productive suffix, speakers of Icelandic were predicted to rote-memorize gender assignment. These predictions were put to the test on both adults (*N* = 18) and children (*N* = 26, ages 2;6-6;3 years) in an elicited production task with two conditions: Productive and unproductive (Björnsdóttir, 2021). In the productive condition, participants were exposed to a novel noun with a productive nominative singular suffix (*–r*, *–i*, *–a*). In the unproductive condition, they were exposed to a novel noun (monosyllabic or disyllabic) that did not bear such a suffix (*–ø*).

The results suggest that both children and adults draw a categorical distinction between productive and unproductive suffixes in Icelandic. In the productive condition, they made categorical suffix-based choices of gender (masculine for *–r* and *–i*, feminine for *–a*). By contrast, they made unsystematic choices of gender in the unproductive condition, with neuter constituting less than half of both adult and child responses. There was no effect of age on children's neuter assignment in the unproductive condition (r=.09). Therefore, neither adults nor children resorted to neuter as a default in the absence of a productive nominative singular suffix.

3.2 Noun pluralization in Icelandic

Marking plurality in Icelandic involves a morphological selection between five plural allomorphs: *–ar, –ir, –ur, –Ø* and *–u*. Standard descriptions of Icelandic noun inflection state

[2] Most nouns in this class end in *–ur*. The /u/ is assumed to reflect epenthesis, a purely phonological process, independent of gender assignment, which is triggered automatically under suffixation.

that grammatical gender is encoded both in the singular and the plural (see e.g. Kvaran, 2005). Thus, there are correspondences between gender and the choice of plural suffix. Since there are correlations between nominative singular forms and gender assignment there are also correspondences between nominative singular and nominative plural suffixes, although there is considerable syncretism. The correspondences between gender, nominative singular suffixes and nominative plural suffixes are stated in Table 3.

	Masculine				**Feminine**				**Neuter**			
NOM.SG suffix	*–r*	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*	*–r*	*–i*	*–a*	*–Ø*
NOM.PL suffix	*–ar*	*–ar*	*–ar*	*–ar*		NA		*–ar*	NA	NA	NA	
	–ir	*–ir*			*–ir*			*–ir*				
	–Ø							*–Ø*				*–Ø*
		–ur					*–ur*	*–ur*				
												–u

Table 3: Correspondences between gender, NOM.SG. suffix and choice of plural suffix

Table 4 shows how plural suffixes are mapped on to real nouns by gender:

NOM.PL	Masculine	Feminine	Neuter
–ar	hest-ar (‘horses’)	skál-ar (‘bowls’)	NA
–ir	dal-ir (‘valleys’)	borg-ir (‘cities’)	NA
–ur	bænd-ur (‘farmers’)	kon-ur (‘women’)	NA
–Ø	menn-Ø (‘men’)	mýs-Ø (‘mice’)	torg-Ø (‘squares’)
–u	NA	NA	aug-u (‘eyes’)

Table 4: Gender and plural formation in Icelandic

The morphological selection process is confined to nominative plural forms. Masculine nouns undergo a subtraction process in the accusative plural. For example, nominative plural *hest-ar* (‘horses’) is *hest-a* in the accusative plural. All nouns take the same suffixes in the dative and genitive plural, irrespective of gender or inflection class. Plural nouns in Icelandic are affected by systematic morphophonological processes, such as [Y]-umlaut (e.g. Þráinsson, 2017), that are not specific to plural formation. These processes are triggered automatically under suffixation, independently of plural formation.

Grammatical gender narrows down the range of options with respect to plural formation. For example, neuter nouns do not pluralize productively by suffixation. Still, there is considerable overlap in the plural marking of masculine and feminine nouns. Most descriptive accounts state a correspondence between masculine and *–ar*. For example, borrowed masculine nouns typically select *–ar* (Rögnvaldsson, 2012, p. 171). Synchronically, there is a tendency for some masculine nouns that select *–ir* to drift over to *–ar*, such as *Japan-ir/Japan-ar* (Japanese.M.PL; ‘Japanese’). Furthermore, children have been found to overgeneralize *–ar* when pluralizing masculine nouns (Gíslason et al., 1986). These facts seem to suggest a productive correspondence between masculine and *–ar*, in spite of syncretism with feminine.

Feminine nouns that take the nominative singular suffix *–a* invariantly pluralize with *–ur*. Otherwise, they take either *–ar* or *–ir*, but rarely *–ur*. Therefore, *–ur* seems productive only in the context of the feminine nominative singular *–a* suffix. Many monosyllabic feminine nouns show free variation between *–ar* and *–ir,* like *lest* ('train') and *hurð* ('door'), with both inter-and intra-speaker variation. Diachronically, feminines have also shifted between the two plural suffixes. For example, both *þjóð* ('nation') and *vél* ('machine') could take either suffix at an earlier diachronic stage. The former can only take *–ir* in modern Icelandic, while the latter invariantly selects *–ar* (Iversen, 1907, p. 52-53). In spite of free variation, many accounts claim that the default plural suffix for feminine nouns is *–ir* (e.g. Bjorvand, 1972; Wurzel, 1987).

While plural forms are standardly assumed to be derived from singular base forms, there are some nouns that have no possible singular forms. Many pluralia tantum nouns in Icelandic are neuter. A few examples are given in (2):

(2) a. Jól-**in** koma./ *Jól-**ið** kemur.
x-mas.N.PL come.PL /x-mas.N.SG come.SG
'X-mas is coming.'

b. Viðskipt-**in** ganga vel./*Viðskipt-**ið** gengur vel.
business.N.PL go.PL well/ business.N.SG go.SG well
'Business is going well.'

c. Verðlaun-**in** eru vegleg-**ø**./*Verðlaun-**ið** er vegleg-**t**.
prize.N.PL is.PL grand.N.PL/prize.N.SG is.SG grand.N.SG
'The prize is grand.'

d. Vonbrigð-**in** eru mikil-**ø**./*Vonbrigð-**ið** er mik-**ið**.
disappointment.N.PL is.PL big.N.PL/ disappointment.N.SG is.SG big.N.SG
'It's a big disappointment.'

There are no semantic reasons for this ineffability; the nouns in (2) can be classified into several semantic categories. Rather, it seems to reflect the absence of a productive singular form.

4. The relation between gender and inflection: Predictions for learning

4.1 The Tolerance Principle

Yang (2005; 2016) has proposed a quantitative measure, the Tolerance Principle, to distinguish between productive and unproductive processes in language. The principle is stated in (3):

(3) **The Tolerance Principle**

If R is a productive rule applicable to N candidates, then the following relation holds between N and *e*, the number of exceptions that could but do not follow R: $e \leq \theta_N$ where $\theta_N = N/\ln N$.

The model hypothesizes that a general rule will be formed when doing so is computationally more efficient than storing lexical forms. Computational efficiency is computed by calculating the time complexity required for forming a rule with the time complexity required for accessing individual lexical forms. The Tolerance Principle quantifies the precise conditions for productive rule formation. It is computationally more efficient to form a productive rule only when the number of exceptions is less than the number of items divided by the natural log of the number of items. The principle is a threshold function that predicts a categorical division between productive and unproductive processes in language. On this approach, the difference between the two is a direct consequence of children's search for productive patterns in learning.

The Tolerance Principle makes use of the Elsewhere Condition (Kiparsky, 1973) which states that when a more specific form (or rule) is available, it is preferred over a more general one. For example, the irregular past tense form *went* would be preferred over a regular past tense form **goed*. The Elsewhere Condition is implemented by the Tolerance Principle as a serial search procedure which is empirically motivated by research on language processing (see Yang, 2016, pp. 49-60). To illustrate this serial procedure, one can think of past tense acquisition in English. The child is faced with verbs that adhere to the regular pattern, 'add *-ed*' and verbs that do not. The Tolerance Principle assumes that, in order to be maximally efficient in forming the past tense of verbs in English, the child is faced with two options: 1) Store all past tense verb forms individually 2) Form a productive rule. In the first case scenario, every item is stored in a list ranked by frequency. This means that the learner must search the list every time there is an occasion to express the past tense of a verb. In the second case scenario, only the exceptions are stored in a frequency-ranked list. The list of exceptions must be searched first before the productive rule can be applied.

The Tolerance Principle operates on type counts. Therefore, productivity in grammar learning on this approach is connected to the number of types over which linguistic patterns are expressed, rather than the number of tokens. This does not mean that token frequency is entirely irrelevant to the Tolerance Principle; the time complexities from which the Tolerance Principle is derived makes use of the distribution of word frequencies, as mandated by Zipf's (1949) law which states that the frequency of a word is approximately inversely proportional to its rank. As a result, relatively few words are used very frequently, while most words occur infrequently and many occur only once, even in large samples of texts. However, ultimately, the learner only needs to know the number of types and how many of those are exceptions.

While the Tolerance Principle can predict the precise conditions for productive rule formation, it does not follow that children only learn language in a rule-based manner. Children's lexical conservatism in acquisition has often been used as evidence against rule-based learning (Tomasello, 2003; Dabrowska, 2005). The Tolerance Principle can also predict the absence of productivity and, as a result, item-based learning (see Yang, 2016, pp. 152-156 on defective inflection in Russian and Polish). Crucially, however, absence of productivity does not constitute evidence against rule-based learning. Rather, it is the direct consequence of a learning process guided by a search for productivity that fails to succeed and results in route memorization.

Morphological classes have structural properties such as gender and case. These properties produce subclasses of words. On this approach, these subclasses are a consequence of learning. The learner searches for productivity within subclasses if no productive rule initially emerges over a full set of items (e.g. all nouns). Thus, the learner's bias to maximize productivity motivates them to apply the Tolerance Principle recursively over a subset of items. In other words, the absence of a global default in an inflectional system probes the learner to search for sub-regularities.

4.2 Corpus analyses

The top 1000 most frequent nominative plural noun types in the Tagged Icelandic Corpus (Helgadóttir et al., 2012) were subjected to an analysis using the Tolerance Principle, with gender as a conditioning factor, as shown in Table 5:

Plural suffix	M	F		N	Productive?			
					M	F		N
		–a	*–Ø*			*–a*	*–ø*	
–ar	352	0	59	0	Yes (67>56)	NA	No (38<141)	NA
–ir	37	0	137	0	No (67<371)	NA	No (38<63)	NA
–ur	11	139	3	0	No (67<381)	Yes (28>0)	No (38<196)	NA
–ø	8	0	1	246	No (67<400)	NA	No (38<199)	Yes (46>7)
–u	0	0	0	7	NA	NA	NA	No (46<246)
Total	408	139	200	253				
θ_N	67	28	38	46				

Table 5: *Quantifying correspondences between gender and plural suffixes in Icelandic*

The analysis incorporated gender as a conditioning factor by adding all noun types by gender and calculating an exception threshold based on the sum of noun types within each gender. The total number of masculine types in the corpus is 352+37+11+8=408. The number of exceptions that a generalization involving masculine nouns is predicted to tolerate is 408/ln408=67. On this analysis, there is a productive correlation between masculine and *–ar* since the number of masculine nouns that do not select *–ar* (37+11+8=56) is below the exception threshold (67).

Feminine nouns were subdivided into two categories: Nouns that take the nominative singular suffix *–a* and those that do not. As discussed in section 3, nouns in the former category invariantly select the plural suffix *–ur*, whereas nouns in the latter category show free variation between *–ar* and *–ir*, but rarely *–ur*. Hence, these patterns are analyzed separately. The total number of feminine noun types bearing the nominative singular suffix *–a* is 139. This number is used to calculate the predicted exception threshold (139/ln139=28). There are no exceptions to this pattern, hence a productive correlation between nominative singular *–a* and nominative plural *–ur* is trivially confirmed.

The number of feminine noun types that bear no overt suffix (–ø) is (59+137+3+1=200). This number yields an exception threshold of 200/ln200=38. The number of feminine nouns within this class that select *–ir* is 137. Since the number of nouns within this class that take *–ar* is 59, which exceeds the exception threshold (38), no productive correlation is predicted between feminine and *–ir*. Likewise, the number of nouns that select *–ir* is to great for a productive correlation between feminine and *–ar* to hold (137>38). As a result, there is no plural default form predicted for feminine nouns in the absence of the nominative singular suffix *–a*. Finally, a productive correspondence between neuter assignment and –ø was predicted since the number of neuter nouns that select the suffix *–u* is below the exception threshold (46>7).

Based on this analysis, three productive rules of plural formation in Icelandic can be identified and stated in (4):

(4) a. PL → –ar / [+masculine]

b. PL → –ur / [nom.sg] [a] __ #

c. PL → –ø / [+neuter]

Other patterns are listed in the lexicon and learned by rote. Recall that the Tolerance Principle predicted there to be no productive pattern for neuter in the singular. As a result, neuter assignment was predicted to rote-memorized. While a speaker may productively associate the plural suffix –Ø with neuter, they would have to have memorized that a singular noun is neuter in order to pluralize it with –Ø. Therefore, in the absence of a productive nominative singular form on a novel noun, speakers are predicted to be at a loss with both gender assignment and plural formation in Icelandic. In other words, uncertainty in gender assignment is predicted to coincide with uncertainty in plural formation.

A second study tested the productivity of the same mappings, except with the causal relation reversed. Plural suffixes were used as conditioning factors in a corpus analysis using the Tolerance Principle on the top 1000 most frequent noun types in the Tagged Icelandic Corpus. The suffix *–u* was excluded from this study due to its low frequency. The purpose of the study was to generate predictions for children's learning: Given knowledge of a plural form, can children infer the noun's gender? The analysis is provided in Table 6:

Gender	*–ar*		*–ir*		*–ur*		*–Ø*		**Productive?**				
									–ar	*–ir*	*–ur*		*–Ø*
M	352		37		11		8		**Yes**	No	No		No
F	*–a*	*–Ø*	*–a*	*–Ø*	*–a*	*–Ø*	*–a*	*–Ø*	*–Ø*	*–Ø*	*–a*	*–Ø*	*–Ø*
	0	59	0	137	139	3	0	1	No	No	**Yes**	No	No
N	0		0		0		246		NA	NA	NA		**Yes**
Total	411		174		153		255						
$\boldsymbol{\theta_N}$	68		34		30		46						

Table 6: *Quantifying correspondences between plural suffixes and gender in Icelandic*

The plural suffix *–ar* was predicted to be productive of masculine since the number of non-masculine nouns (59) that select this suffix did not exceed the exception threshold (68). By contrast, the plural suffix *–ir* was predicted to have no productive gender correlate: The number of feminine nouns that select *–ir* (137) was too high for a productive correlation with masculine given an exception threshold of 34 nouns. Likewise, the number of masculine nouns (37) exceeded the threshold and, thus, prevents a productive correlation with feminine. The plural suffix *–ur* was predicted to correlate productively with the nominative singular suffix *–a* since the exceptions to this pattern (11+3=14) was below the threshold (30). Finally, *–ø* was predicted to correlate productively with neuter (46>9).

The predicted interdependencies between forms in gender and plural formation in Icelandic is visualized as a flow chart in Figure 1:

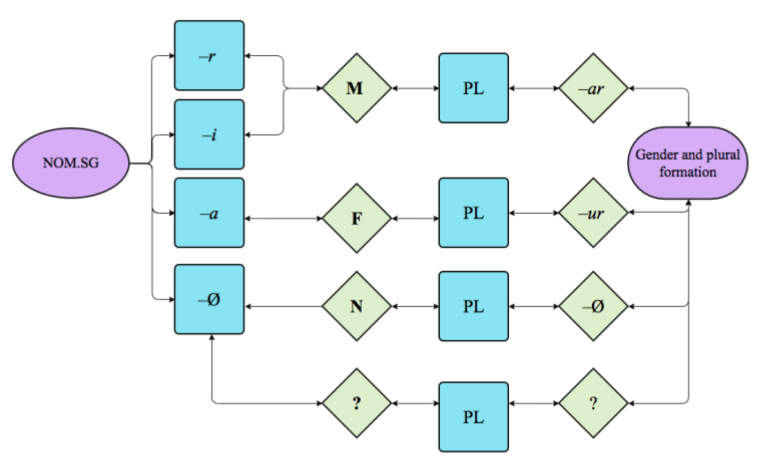

Figure 1: Flow chart of the interdependencies between forms in gender and plural formation in Icelandic

The flow chart illustrates how productive nominative singular forms facilitate the induction of both gender and plural forms in Icelandic. The absence of a productive nominative singular form is predicted to result in ineffability in both gender and plural formation in Icelandic. There is no productive nominative singular form for neuter nouns. However, given knowledge of a noun's neuter assignment, via rote memorization, a speaker is predicted to be able to pluralize neuter nouns productively. Conversely, the plural form –Ø is predicted to facilitate neuter assignment. In other words, the absence of a productive nominative singular form results in a blocking of the flow of information between the processes, resulting in a gap within the system. This gap may account for why numerous neuter nouns in Icelandic have a defective singular paradigm.

5. Experiments

5.1 Overview

Two experiments tested the prediction that productivity in gender assignment correlates with productivity in plural formation in Icelandic. Both experiments had two conditions: Productive and unproductive. The first experiment tested the abilities of children and adults to infer the gender and plural forms of novel nouns in the nominative singular. Conversely, the second experiment tested the abilities of children and adults to infer the gender and nominative singular forms of novel plural nouns.

Both experiments were embedded in interactive animated video games that were designed using Animaker, an online animation software. In each experiment, the participant was asked to engage with the game verbally to affect the course of events in the storyline and move on to the next test item. Each game was 13 minutes in duration, which included a training session on three real nouns, one for each gender. Participants were tested individually in a quiet room. Their responses were audio recorded and written down by the experimenter

5.2 Experiment 1: Elicitation based on single forms

5.2.1 Materials

The test items consisted of 24 novel nouns, 12 for each condition. In the productive condition, the novel noun had a productive nominative singular suffix (*–r* or *–i* for masculine, *–a* for feminine). In the unproductive condition, the novel noun did not bear such a suffix. Table 7 shows the test items sorted by condition:

Productive			**Unproductive**	
–r	*–i*	*–a*	–ø Monosyllabic	–ø Disyllabic
Lerfur	Ruli	Bukla	Súf	Kútes
Tirgur	Krandi	Darga	Turk	Ratef
Mekur	Lurpi	Mæka	Mæf	Farem
Rullur	Tauli	Fóma	Lirg	Múkaf
			Kurk	Sakem
			Glæf	Lútis

Table 7: *Test items per condition*

The novel nouns were paired with novel objects in the form of flying toasters (Glitch, 2012). Prior to test, the participant was introduced to the novel object with a picture, as Figure 2 demonstrates:

Figure 2: A novel object prior to test

Simultaneously, the participant was exposed to an audio stimulus which repeated the novel noun twice in syntactic contexts where the nominative singular is obligatory, as shown in (5):

(5) a. Þetta er **lerfur**.
this is lerfur.M.NOM.SG.
'This is a lerfur.'
b. Vá! **Lerfur**!
wow lerfur.M.NOM.SG.
'Wow! A lerfur!'

The test items were organized into six trials, each consisting of two test items from each condition, presented in a randomized order.

5.2.3 Procedure

Children and adults were tested individually in a quiet location at a day care center or at the University of Iceland. The objective of the task was to locate flying toasters that had gone missing from a scientific laboratory. In the test scene, two-to-four flying toasters either emerged from the background or attempted to hide from view. In addition to locating the novel objects, the participant was asked to provide the correct number of flying toasters observed in each test scene. Figure 3 shows an example of a test scene after the novel objects had come to view.

Figure 3: Example test scene

After having located and identified the number of flying objects, the participant was asked to communicate their knowledge to the story protagonist. The test sentence elicited gender agreement on the numeral in addition to plural marking, as exemplified by (6).

(6) a. Þarna eru **tveir** **lerfar**.
there are two.M.SG lerfur.M.PL
'There are two lerfurs.'

b. Þarna eru **tvær** **buklur**.
there are two.F.SG bukla.F.PL
'There are two buklas.'

c. Þarna eru **tvö súf**.
there are two.N.SG bukla.N.PL
'There are two súfs.'

Once the participant had produced the test sentence, the video proceeded on to the presentation of the next test item. Prior to test, the participant received training with real nouns of each gender.

5.2.2 Participants

27 children (*M* = 4;0 years, *SD* = 10 months, age range = 2;4-5;6 years; 15 females, 12 males) and 20 adult controls participated in this study. An additional five children participated, but were excluded from analysis due to failure to understand the task or unwillingness to engage with the game. Children were recruited from a day-care center in suburban Reykjavík, where the study was conducted. Adult participants were recruited at the University of Iceland, Reykjavík. All participants were native speakers of Icelandic with

normal hearing and normal to corrected-to-normal vision. No participant reported to have a history of language delay. Participants provided informed consent.

5.3 Experiment 2: Elicitation based on plural forms

5.3.2 Materials

The test items consisted of 24 novel nouns, 12 for each condition. In the productive condition, the novel noun had a nominative plural suffix with a productive gender correlate (–*ar* for masculine, –*ur* for feminine and –ø for neuter). In the unproductive condition, the novel noun had a nominative plural suffix with no such productive gender correlate (–*ir*). Table 8 shows the test items sorted by condition:

Productive			**Unproductive**	
–ar	*–ur*	*–ø*	*–ir*	
Lerfar	Kurkur	Súf	Lurgir	Fólir
Lurpar	Buklur	Turk	Ralir	Lerpir
Krandar	Rulur	Glæf	Flúsir	Mæfir
Mekar	Taulur	Lirg	Sergir	Turgir
Dergar	Saulur	Mirg	Mukkir	Túsir
			Tefir	Kúfir
			Fekir	Belir
			Múlir	Rúfir

Table 8: *Test items per condition*

The novel nouns were paired with novel objects in the form of flying toasters (Glitch, 2012), just like in Experiment 1. However, this time the novel objects were presented in groups of two to four. Each group contained novel objects of the same specimen. Prior to test, the participant was introduced to the novel objects with a picture, as Figure 4 demonstrates.

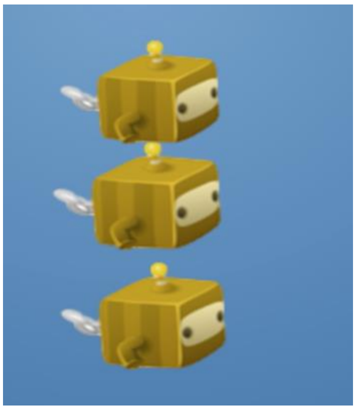

Figure 4: Novel objects prior to test

Simultaneously, the participant was exposed to an audio stimulus which repeated the novel noun twice in syntactic contexts where the nominative plural is obligatory, as shown in (7):

(7) a. Þarna eru **lerfar**.
these are lerfur.M.NOM.PL.
'Here are lerfs.'
b. Vá! **Lerfar**!
wow lerfur.M.NOM.PL.
'Wow! Lerfs!'

The test items were organized into six trials, each consisting of two test items from each condition, presented in a randomized order.

5.3.3 Procedure

Children and adults were tested individually in a quiet location at a primary school in Reykjavík or at the University of Iceland. In the video, one of the novel objects went missing from the group. The task consisted of locating the missing novel object in the test scene. Figure 5 provides an example of a test scene once the missing object had been identified.

Figure 5: Example test scene

The participant was asked to identify the missing flying object and produce the singular form of the novel noun. Since the context of the single missing object facilitated a definite interpretation, the participant was expected to produce the singular form with the definite suffix, as shown in (8). The definite suffix induced gender distinctions. In addition, the participant was asked to produce the possessive pronominal, which elicited gender agreement. The participant's response indicated their choice of nominative singular suffix.

(8) a. Þarna er lerfu-**r**-**inn** **minn**.
there is lerfur.M.DEF.SG my-M.SG
'Here is my lerfur.'

b. Þarna er bukl-**a**-**n** **mín**.
there is bukla.F.DEF.SG my-F.SG
'Here is my bukla.'

c. Þarna er súf-**ø**-**ið** **mitt**.
there is súf.N.DEF.SG my.N.SG
'Here is my súf.'

Once the participant had produced the test sentence, the video proceeded on to the presentation of the next test item. Prior to test, the participant received training with real nouns with each of the four plural suffixes (*–ar*, *–ur*, *–*Ø, *–ir*).

5.3.3 Participants

26 children (*M* = 7;0 years, *SD* = 1.33 years, age range = 6;3-8;2 years; 15 females, 11 males) and 20 adult controls participated in this study. An additional two children participated, but were excluded from analysis due to failure to understand the task or unwillingness to engage with the game. The children were recruited from a primary school in Reykjavík, where the

study was conducted. The age range was higher in this study since an initial pilot study on 10 children (age range 3;10-5,0 years) revealed that children resorted to zero responses in the task. This response pattern may suggest that children at this age have difficulties retrieving singular forms on the basis of plural forms. Adult participants were recruited at the University of Iceland, Reykjavík. All participants were native speakers of Icelandic with normal hearing and normal to corrected-to-normal vision. No participant reported to have a history of language delay. Participants provided informed consent.

6. Results

6.1 Experiment 1

The predictions for experiment 1 are recapitulated in Table 9, for convenience:

Nominative singular suffix	Gender	Plural suffix
–r, –i	Masculine	*–ar*
–a	Feminine	*–ur*
–Ø	?	?

Table 9: *Predictions for experiment 1*

6.1.1 Adults

The predictions stated in Table 7 were borne out for adults. Figure 6 visualizes the relationship between nominative singular suffix and choice of plural suffix in adult responses:

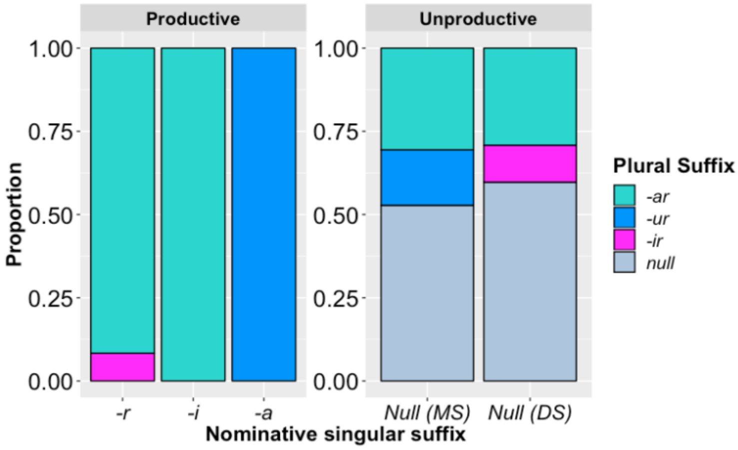

Figure 6: Adults‘ choice of plural suffix by nominative singular suffix across conditions

In the productive condition, adults made a categorical choice of plural suffix: They chose *–ar* consistently as the plural suffix for novel nouns with the nominative singular suffixes *–r* and *–i*, both of which are productive of masculine. Likewise, they chose *–ur* (100%) as the plural suffix for novel nouns with the nominative singular suffix *–a*. Response patterns in the unproductive condition were characterized by a great deal of both inter-and intra-speaker variation. A null suffix (zero response or stimulus repetition) constituted around one half of all responses (*M* = 0.48, *SD* = 0.31, *SE* = .07). The second most frequent plural suffix was *–ar* (*M* = 0.33, *SD* = 0.27, *SE* = .06), followed by *–ir* (*M* = .08, *SD* = 0.11, *SE* = .06) and *–ur* (*M* = .08, *SD* = 0.1, *SE* = .02). Over half (12) of participants never used *–ir*. Adults were equally likely to choose a null suffix for novel monosyllabic and disyllabic nouns: $t(22) = 22$, $p < 0.55$.

Figure 7 visualizes the relationship between gender assignment and plural suffix in adult responses:

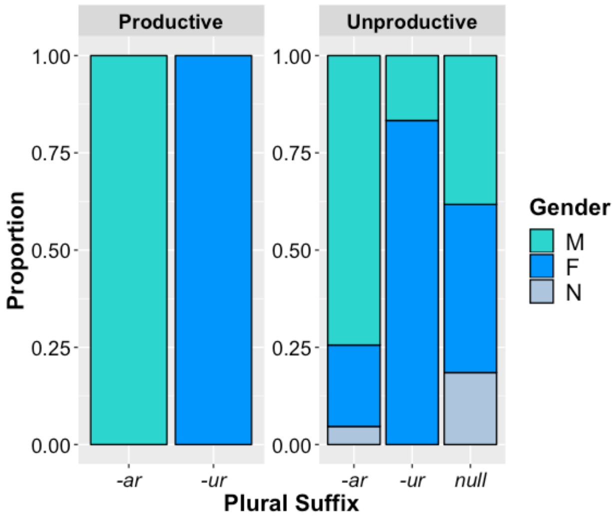

Figure 7: Adults‘ gender assignment by plural suffix accross conditions

The association between gender and choice of plural suffix was significant ($\chi 2(6) = 27.91$, p < .01). In the productive condition, masculine invariantly correlated with the choice of *–ar* and feminine with the choice of *–ur*. In the unproductive condition, *–ar* was also categorically associated with masculine and *–ur* with feminine. Collectively, adults did not assign gender systematically in the cases they chose a null plural suffix. However, three adults always used masculine agreement conjointly with a null plural suffix and one adult used feminine categorically. Overall, masculine was the most frequently used gender in such cases (*M* = 0.53, *SD* = 0.27, *SE* = .06), followed by feminine (*M* = 0.27, *SD* = 0.2, *SE* = .01) and neuter (*M* = 0.2, *SD* = 0.18, *SE* = .009). Almost one half of adults (eight) never used neuter in the task.

6.1.2 Children

The predictions stated in Table 7 were also borne out for children. Figure 8 visualizes the relationship between nominative singular suffix and choice of plural suffix in child responses:

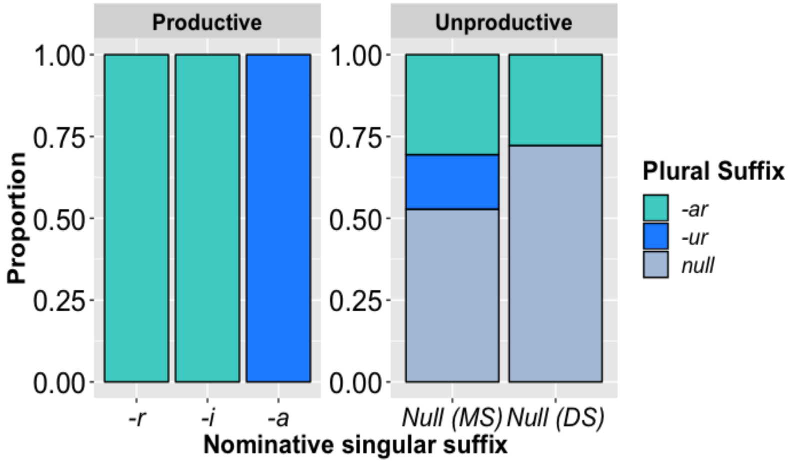

Figure 8: Children's choice of plural suffix by nominative singular suffix across conditions

In the productive condition, children made a categorical choice of a plural suffix: They chose –*ar* (100%) as the plural suffix for novel nouns with the nominative singular suffixes –*r* and –*i*, both of which are productive of masculine. Likewise, they chose –*ur* (100%) as the plural suffix for novel nouns with the nominative singular suffix –*a*. Response patterns in the unproductive condition were characterized by a great deal of both inter-and intra-speaker variation. Overall, children selected a null suffix (zero response or stimulus repetition) 52.3% of the time (*SD* = 0.35, *SE* = .069). One child made a categorical choice of a null suffix. On average, children chose –*ar* 33% of the time (*SD* = 0.29, *SE* = .001). Three children were near-categorical in their choice of –*ar*. No child chose –*ur* consistently (*M* = .087, *SD* = 0.12, *SE* = .023). Children never chose –*ir*. A null suffix was consistently selected for disyllabic nouns (*M* = 0.98, *SD* = 0.22, *SE* = .04). Responses distributed at chance between null and other suffixes in the case of monosyllabic nouns (*M* = 0.51, *SD* = 0.22, *SE* = .01).

Figure 9 visualizes the relationship between gender assignment and plural suffix in child responses:

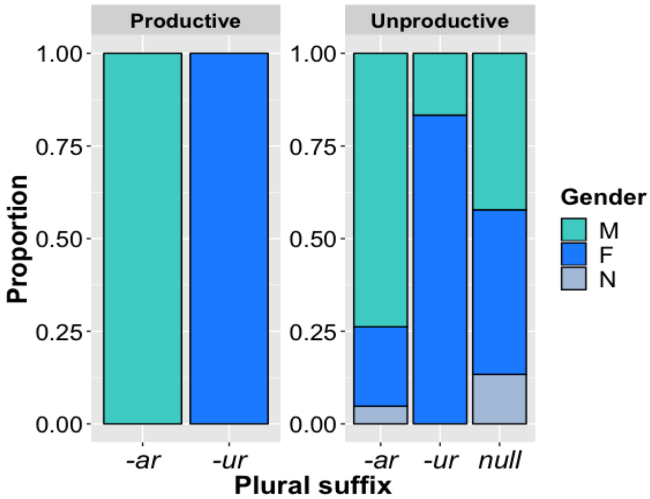

Figure 9: Children's gender assignment by plural suffix across conditions

The association between gender and the choice of a plural suffix was significant ($\chi 2(4)$ = 182.1, p < .01). In the productive condition, masculine invariantly correlated with the choice of plural suffix *–ar* and feminine with the choice of plural suffix *–ur*. These correlations were also significant in the unproductive condition: *–ar* was categorically associated with masculine and *–ur* with feminine. Masculine was most frequently chosen with a null suffix (*M* = 0.6, *SD* = 0.29, *SE* = .06), followed by feminine (*M* = 0.32, *SD* = 0.25, *SE* = .05). Neuter was chosen, on average, 8% with a null suffix (*SD* = 0.13, *SE* = .025).

6.2 Experiment 2

The predictions for experiment 2 are recapitulated in Table 10, for convenience:

Nominative plural suffix	**Gender**	**Nominative singular suffix**
–ar	Masculine	*–r, –i*
–ur	Feminine	*–a*
–ø	Neuter	*–Ø*
–ir	?	?

Table 10: *Predictions for experiment 2*

6.2.1 Adults

Figure 10 visualizes the relationship between nominative singular suffix and choice of plural suffix in adult responses:

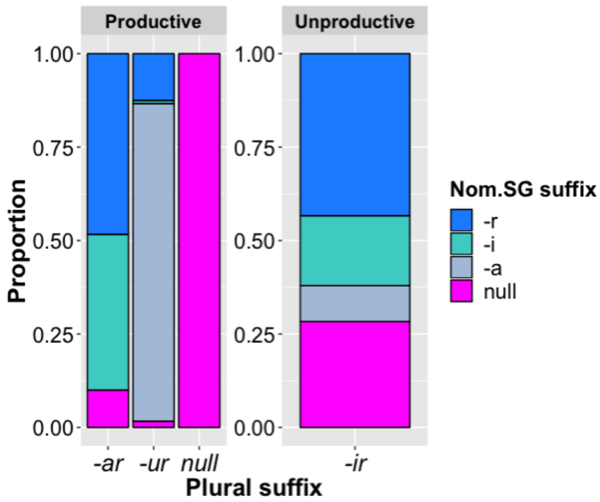

Figure 10: Adults' choice of nominative singular suffix by nominative plural suffix

Adults made a categorical association between productive nominative plural suffixes and corresponding productive nominative singular suffixes. In the productive condition, adults made categorical choices of a nominative singular suffix. Adults chose either nominative singular suffix *–r* (*M* = 0.55, *SD* = 0.19, *SE* = .04) or *–i* (*M* = 0.44, *SD* = 0.2, *SE* = .04) in the case of a novel noun carrying the plural suffix *–ar*. There was no significant difference between the two means (*t*(20) = -1.34, p = 0.19). Most adults made a categorical choice of *–a* (*M* = 0.85, *SD* = 0.15, *SE* = .03) for novel nouns with *–ur*. In the case of a null plural suffix, adults always (100%) chose a null nominative singular suffix.

There was no systematic correspondence between *–ir* and any nominative singular suffix. All possible forms were attested with both inter-and intra-speaker variation: *–r* (*M* = 0.42, *SD* = 0.17, *SE* = .03), *–ø* (*M* = 0.35, *SD* = 0.25, *SE* = .06), *–i* (*M* = 0.13, *SD* = .05, *SE* = .01) and *–a* (*M* = 0.1, *SD* = 0.14, *SE* = .03).

Figure 11 visualizes the relationship between gender assignment and plural suffix in adult responses:

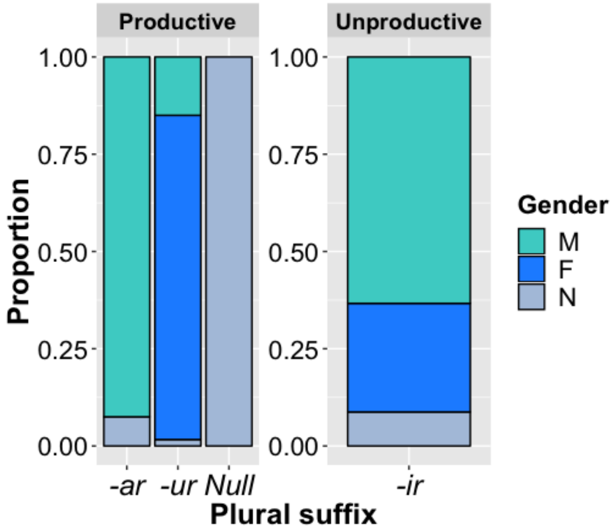

Figure 11: Adults' gender assignment by plural suffix

Adults made categorical choices of gender in the productive condition. They assigned masculine 97.5% (*SD* = .07, *SE* = .02) of the time to novel nouns with *–ar*. Neuter was used for this plural suffix, on average, 2.5% of the time (*SD* = .08, *SE* = .01), which is not statistically different from zero. Adults chose feminine categorically for *–ur* (*M* = 0.87, *SD* = 0.15, *SE* = .03). Other responses for this suffix consisted of masculine (*M* = 0.1, *SD* = 0.16, *SE* = .04) and neuter (*M* = .02, *SD* = .06, *SE* = .0003). Neuter was always (100%) chosen for novel plural nouns with a null suffix.

6.2.2 Children

Figure 12 visualizes the relationship between nominative singular suffix and choice of plural suffix in child responses:

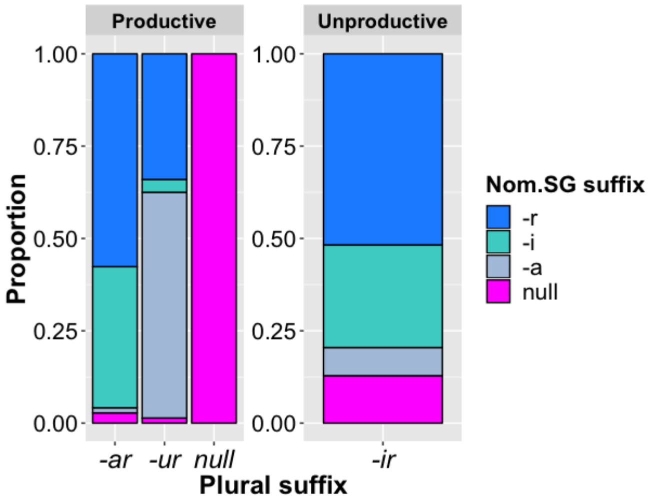

Figure 12: Children’s choice of nominative singular suffix by nominative plural suffix

Children were near-categorical in their choice of *–r* as the nominative singular suffix for novel nouns with the plural suffix *–ar* (*M* = 0.71, *SD* = 0.29, *SE* = .06). In the case of a null plural suffix, children always (100%) chose a null nominative singular suffix. Collectively, children were a chance between *–a* (*M* = 0.57, *SD* = 0.35, *SE* = .07) and *–r* (*M* = 0.43, *SD* = 0.35, *SE* = .07) for *–ur*. Five children consistently used *–r* (100%) and four used *–a* (100%). The choice of nominative singular suffix was conditioned by gender. The nominative singular suffix *–r* was the most frequent response in the Unproductive condition (*M* = 0.68, *SD* = 0.29, *SE* = .05).

Figure 13 visualizes the relationship between gender assignment and plural suffix in child responses:

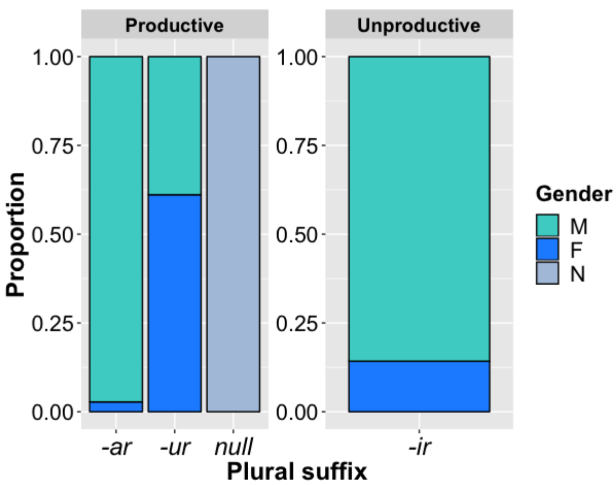

Figure 13: Children‘s gender assignment by plural suffix

Children made a categorical choice of masculine (100%) for novel plural nouns with *–ar*. Likewise, they chose neuter consistently (100%) for novel nouns without an overt plural suffix (null). However, in the case of *–ur*, they were at chance between a choice of masculine (M = 0.42, SD = 0.35, SE = .07) and feminine (M = 0.58, SD = 0.37, SE = .07). The difference between mean masculine and feminine agreement for this plural suffix was not significant ($t(24) = 1.16$, $p = 0.26$). The high standard deviation for *–ur* suggests differences in children's individual response patterns. Five children used masculine as a default (100%) for this plural suffix and four children used feminine (100%), respectively. There was a significant effect of age on children's percentage feminine responses (r = 0.68). In other words, older children were more likely to use feminine agreement with *–ur*. In the Unproductive condition, children made a categorical choice of masculine (M = 0.9, SD = 0.1, SE = .02).

6.3 Discussion

6.3.1 Experiment 1

Given novel nouns with productive nominative singular suffixes, children and adults made categorical choices in both gender assignment and plural marking. In the absence of a productive nominative singular suffix, they assigned gender to and pluralized nouns at random. Hence, productivity in gender assignment correlated with productivity in plural formation. There were no age effects in the task; the distinction between productive and unproductive processes in both gender and plural marking in Icelandic seems to be in place by the age of three. Therefore, young children seem able to use productive nominative singular forms to guide their inferences about gender and inflection of novel nouns.

There were minimal differences between children and adults in the task. Collectively, both adult and children responses were distributed between null and other forms in plural marking in the unproductive condition. Children never used the plural suffix *–ir* and adults rarely did so either. Neuter constituted less than 10% of children's responses and around a fifth of adults' responses in the unproductive condition.

The interpretation of zero responses in experimental settings has been debated (Berko, 1958; Köpcke, 1998). In the case of Icelandic, a zero response is ambiguous between the choice of a null suffix and stimulus repetition. In the former scenario, the choice may reflect the application of a productive rule, whereas in the latter, it may reflect uncertainty. Zero responses were only attested in the unproductive condition. Children and adults rarely or never pluralized a neuter noun with an overt suffix. However, zero responses were attested with all genders, notably masculine and feminine. Therefore, zero responses seem to reflect uncertainty in both gender and plural formation.

6.3.1 Experiment 2

The results indicate that adults can infer the gender and nominative singular form of novel nouns with a productive nominative plural suffix. In the productive condition, adults made categorical choices of gender and nominative singular suffixes: Masculine was consistently assigned and either masculine-productive nominative singular suffix *–r* or *–i* were selected in the case of the plural suffix *–ar*. In parallel, feminine and *–a* were chosen in the case of *–ur*. Finally, neuter and nominative singular –ø were invariantly chosen in the case of –ø. By contrast, adults' gender assignment and choices of nominative singular forms distributed at random in the unproductive condition. In other words, the plural suffix *–ir* did not guide adults' inferences about the gender or inflection of novel nouns. Thus, adult responses in experiment 2 conformed with the predictions of the Tolerance Principle.

Children made a categorical association between *–ar* and masculine and –ø and neuter, respectively. However, children's responses were bimodally distributed with respect to the plural suffix *–ur*; some children categorically assigned masculine and selected a masculine-productive nominative singular suffix, while others categorically assigned feminine and selected nominative singular *–a*. The ability to associate nominative plural *–ur* with feminine increased significantly with age. Most masculine nouns that select the nominative singular suffix *–r* get /u/ as the result of an epenthesis process that operates independently of plural formation. Therefore, the masculine nominative singular suffix *–(u)r* may be homophonous with the feminine plural *–ur*. As a result, the association between *–ur* and masculine in younger children may reflect an interference from the homophonous nominative singular suffix *–(u)r*.

In the unproductive condition, children had a clear preference for masculine and masculine-productive nominative singular suffixes, even if *–ir* is more frequent on feminine than masculine nouns. Thus, children's response patterns in the unproductive condition differed from that of adults. While the source of this response pattern is at present unclear, children clearly did not treat *–ir* as a default plural suffix for feminine nouns.

7. General discussion

There is general agreement across frameworks that inflectional paradigms contain both generalizations and idiosyncratic patterns. However, demarking the distinction between the two has been a challenge, especially in light of syncretism both within and across inflectional paradigms (see, among many, Anderson, 1992; Blevins, 2004; Carstairs, 1983; 1989; 1994; Halle & Marantz, 2008; Finkel & Stump, 2004; 2009; Noyer, 2005; Stump, 2001).

Syncretism raises the question of why a single affix or form can belong to more than one inflection class. In an influential line of work, Carstairs-McCarthy (1989; 1994; 2010) has argued that the acquisition of inflectional morphology is guided by the search for class-identifiers, inflectional forms that can uniquely disambiguate a noun's inflection class. Thus, children search for correspondences between morphosyntactic value and phonetic form as mandated by the Principle of Contrast (Clark, 1985), which states that children look out for single mappings between function and form. On this view, children seek to avoid syncretism between inflection classes. Carstairs-McCarthy's (1994) No Blur Principle, a constraint on paradigmatic opacity, is motivated by this hypothetical learning process.

Feminine monosyllabic nouns in Icelandic have been argued to comply with the NBP (Carstairs-McCarthy, 1994). However, I argue that they, in fact, violate the NBP. Many monosyllabic feminine nouns in Icelandic show free variation between the plural suffixes *–ir* and *–ar* both synchronically and diachronically. These suffixes cannot serve as class-identifiers, as they distribute at random. As a result, feminine monosyllabic nouns in Icelandic have no unique inflection class, contra the predictions of the NBP. On the present approach, ineffability in plural formation is a natural consequence of a learning process guided by the search for productivity that fails and results in rote-memorization. In parallel, I argue that the multitude of neuter pluralia tantum nouns in Icelandic is a direct reflection of the absence of a productive nominative singular form.

A recurring question in research on inflectional morphology is the question of which forms facilitate the induction of other forms within an inflectional paradigm. Leading forms, principal parts and class identifiers have been postulated to account for how speakers can infer the inflectional realizations of novel nouns. The existence of such forms has also been argued to constrain the distribution of inflectional forms in language, as there can only be as many inflectional paradigms as there are leading forms, principal parts or class identifiers. However, the nature of such forms has hitherto been unclear. How are such forms discovered in acquisition in light of data sparsity in the input and cross-linguistic diversity?

The present findings show that productive nominative singular forms facilitate the induction of gender and plural formation in Icelandic, whereas unproductive nominative singular forms do not. Due to the Zipf-like distribution of inflectional morphology, children will likely encounter most nouns in the nominative singular in acquisition in Icelandic.

Therefore, children‘s hypothesis space in acquisition may be constrained by the sparsity of the input data. As a consequence, there may be no need for extrinsic constraints on the distribution of inflectional forms since the child learner does not have the resources to consider all logically possible inflectional patterns in the first place. Instead, they must learn how to generalize beyond experience on the basis of individual inflectional forms.

The role of nominative singular forms as catalysts in gender and inflection shifts in Germanic has been observed (e.g. Lahiri & Dresher, 1983). Diachronically, whole-sale inflection shifts may also be the result of the uneven frequency distribution of inflectional forms. Speakers‘ inferences about inflectional morphology may, of necessity, be based on the most frequent inflectional forms. However, this fact does not preclude other inflectional forms from being productive. For example, while the nominative singular is standardly assumed to be the citation form in Latin noun inflection, there are cases whereby such forms seem to have been influenced by oblique forms, rather than vice versa (Albright, 2004). Similarly, the empirical results from Icelandic revealed a productive pattern in the nominative plural, in spite of the absence of a productive nominative singular form. Therefore, the status of the nominative singular as a base form in Germanic noun inflection is likely derivative.

The causal relation between gender and inflection has been much debated (Corbett, 1991; Doleschal, 2000; Enger, 2004; Spencer, 2002). I argue that the relation between gender and inflection is derivative, arising from the use of shared nominative singular forms, which form the basis of children‘s inference due to their statistical dominance. As a a result, there is no inherent causal relationship between the two categories. However, there seems to be a systematic preference in the direction of causation between the two categories in many languages. For example, gender seems to have influenced the direction of analogical change in German (Wurzel, 1987). Furthemore, gender has been argued to be in place prior to plural formation in German (Mills, 1986). Another indication of a causal relation between the two categories comes from typology: Greenberg‘s (1966) universals 37 and 45 state that a language only has gender distinctions in the plural if it has gender distinctions in the singular. In other words, all gender systems encode gender in the singular, but only some in the plural.

I propose that the apparent causal relation between gender and inflection is a reflection of the uneven frequency distributions of inflectional forms. Generally speaking, singular forms are used far more frequently than plural forms. For about four million words of child-directed English in the CHILDES database (MacWhinney, 2000), processed by a modern part of speech tagger, the ratio between the average singular noun frequency and the average plural frequency is 1.89:1. An even more striking asymmetry (2.75:1) is attested in a sample of one million words in the manually annotated Brown corpus. Therefore, the asymmetry between the use of singular and plural forms seems to reflect a robust fact about language usage.

While the results of experiment 1 demonstrate that children can infer both gender and plural formation on the basis of productive nominative singular forms in Icelandic, the child's lexical experience will likely be skewed in favor of singular forms. Since productive singular forms comprise the basis of grammatical gender acquisition, gender may be a developmental prerequisite for learning plural formation. Furthermore, the statistical dominance of singular forms means that the loss of a productive generalization in the singular entails the loss of a productive generalization in the plural. Therefore, I propose that typological patterns may be explained in terms of the statistical tendencies in language and how they are learned in acquisition.

8. Conclusion

I have demonstrated how children and adults can infer both gender and plural forms of novel nouns in Icelandic on the basis of productive nominative singular forms, as predicted by a learning model (Yang, 2005; 2016). By contrast, the absence of a productive nominative singular form resulted in ineffability in both gender and plural marking. I argue that the relation between gender and inflection is derivative, arising from the use of statistically dominant base forms. The interconnectedness between the two categories is clearly reflected in the present findings: Productivity in gender assignment correlated with productivity in plural formation. Conversely, absence of productivity in gender assignment correlated with absence thereof in plural formation. As a a result, there is no inherent causal relationship between the two categories. However, since gender acquisition involves detecting productive singular forms, gender may be a developmental prerequisite for learning plural forms, given the uneven frequency distributions of singular and plural forms. I argue that the present findings illustrate how statistical tendencies in language and learning may shed light on the organizational principles of inflectional paradigms.

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