

A Conceptual Spaces Model of Socially Motivated Language Change

Heather Burnett and Olivier Bonami

Laboratoire de Linguistique Formelle

Université Paris Diderot & CNRS

Abstract

This paper outlines a formal model of socially motivated language change which unites insights from identity-oriented theories of language change with formal theories of language use and understanding. We use (Gärdenfors, 2000)'s *Conceptual Spaces* framework to formalize socially motivated ideological change and use signaling games with an *iterated best response* solution concept (Franke, 2009; Frank and Goodman, 2012) to formalize the link between ideology, linguistic meaning and language use. We then show how this new framework can be used to shed light on the mechanisms underlying socially-motivated change in French grammatical gender.

1 Introduction

Since the mid 1990s, the development of mathematical and computational models of language variation and change, such as (Clark and Roberts, 1993; Niyogi and Berwick, 1997; Yang, 2000; Yang, 2002; Kauhanen and Walkden, 2018) among others, has yielded enormous advances in our understanding of the cognitive processes that underly these phenomena. However, although it has been observed since at least (Labov, 1963) that many (if not most) linguistic changes are socially conditioned, formal models have been almost exclusively focused on the grammatical and/or psychological aspects of change, neglecting its social aspects. On the other hand, many non-mathematically oriented approaches in sociolinguistics and linguistic anthropology (see (Bucholtz and Hall, 2005; Bucholtz and

Hall, 2008) for an overview) have stressed the role that social meaning, ideologies and identity construction play in language use, and they have developed articulated theories of how meaning and ideological structure mediate the relation between social change and language change. The goal of this paper is to outline a model which brings together insights from identity-oriented theories of language change and unites them with formal theories of language use and understanding. More specifically, we use (Gärdenfors, 2000; Gärdenfors, 2014)'s *Conceptual Spaces* framework to formalize speaker/listener ideological change and use epistemic game theory, particularly signaling games with an *iterated best response* solution concept, such as the *Rational Speech Act* model (RSA) (Franke, 2009; Frank and Goodman, 2012; Burnett, 2017) to formalize the link between ideology, linguistic meaning and language use. We then show how this new framework can be used to shed light on the mechanisms underlying socially-motivated change in French grammatical gender.

2 Variation and change in French g-gender

French is a g(rammatical) gender language, which means that its grammar sorts all nouns into two classes, masculine and feminine, that determine patterns of agreement in sentences (Hockett, 1958; Corbett, 1991). Although with inanimate nouns, there is no relation between noun meaning and g-gender, there is a non-arbitrary relation between social and grammatical gender with most human nouns. This paper focuses on change in the use of nouns denoting social functions. When referring to a woman,

either the feminine or the masculine can be used with these nouns; whereas, only the masculine can be used to refer to a man (1)-(2).

- (1) a. **Le** président ‘*the (fe)male president*’
 b. **La** présidente ‘*the female president*’
 (2) a. **Le** ministre ‘*the (fe)male minister*’
 b. **La** ministre ‘*the female minister*’

(Burnett and Bonami, 2018) present a study of variation and change in g-gender of terms of address for women (*Madame le/la N*¹) in the transcripts of the debates of the *Assemblée Nationale* (French House of Representatives) from 1983-2005. This corpus features a high degree of intra-speaker variation in g-gender, an example of which is shown in (3) for *Madame le/la ministre* ‘Madam Minister’.

- (3) a. **M. Jean-Marc Ayrault.** Madame **le** ministre de l’environnement, plus de 6 000 personnes ont défilé, samedi dernier, dans les rues de Nantes... (29/01/1997)
 b. **M. Jean-Marc Ayrault.** Monsieur le président, madame **la** ministre, mes chers collègues,... (19/12/1997)

The use of grammatical gender in expressions referring to women has been the subject of enormous amounts of prescription and language planning, see (Houdebine, 1998; Burr, 2003; Viennot, 2014) among others, and these actions can be naturally divided into two main waves of activism at the end of the 20th century. The first wave centered around on March 11th 1986, when the Socialist Prime Minister Laurent Fabius legislated the use feminine grammatical gender (eg. *la ministre, la présidente*) in the *Assemblée Nationale* and in official documents. Figure 1 shows the proportion of the use of feminine vs masculine grammatical gender in female terms of address (*Madame le/la N*) in the *Assemblée Nationale* from 1983 to 2005. This figure shows that use of the feminine form is extremely limited throughout the 1980s, and that Fabius’ language policy in 1986 had little to no effect on the speech of the politicians.

However, twelve years later, on March 6th 1998,

¹The authors focused on terms of address because the title (*Madame*) allowed for the automatic identification of female referents from the transcripts.

the Socialist Prime Minister Lionel Jospin issued a statement (a *circulaire*) acknowledging that Fabius’ policy was never obeyed/enforced and recalling to the government that they are supposed to be using feminine g-gender. Figure 1 shows that the second wave of activism has very different results, with use of the feminine form rising dramatically in 1997-98, around the time of Jospin’s statement.

(Burnett and Bonami, 2018) argue that the striking contrast between the mid 1980s and the mid 1990s, and the reason Jospin’s reiteration of Fabius’ language policy was successful when the original policy failed, was due to a change in the **social context** in which the policies were enacted. Whereas, in the 1980s, social and political attention to issues of gender equality was limited, the mid-1990s saw an explosion of public reflection on the properties of female politicians and the place of women in government within the context of the *parité* political movement (Gaspard et al., 1992), which aimed to ensure equal representation of men and women across electoral lists.

(Burnett and Bonami, 2018) show that the spread of the use of feminine g-gender mirrors the spread of the support for *parité*, with left wing politicians, who supported *parité* early, using significantly more feminine (61% F 1356/2133) than right wing politicians (28% F 793/2023), who only supported the movement after mid 1998 (Bereni, 2007). Furthermore, right wing politicians who actively support *parité*, such as Roselyne Bachelot (81% F 105/129), behave like left wing politicians. Following (Ramsay, 2003; Achin et al., 2007; Julliard, 2012; Montini, 2017) among others, (Burnett and Bonami, 2018) argue that the *parité* movement was accompanied by enormous discussion in news and literary media, and many of the discourses emerging from these discussions constructed female politicians as having stereotypically feminine properties, such as being *sensitive, pragmatic* and *honest*. Thus, the authors propose that the *parité* movement and the public discussion surrounding it served to introduce new social types (or **personae**) for female politicians into the ideologies of French speakers in the late 1990s. (Burnett and Bonami, 2018) show that politicians in their corpus, such as Bachelot and Ségolène Royal, who personally construct a new feminine persona, use significantly more feminine than their female

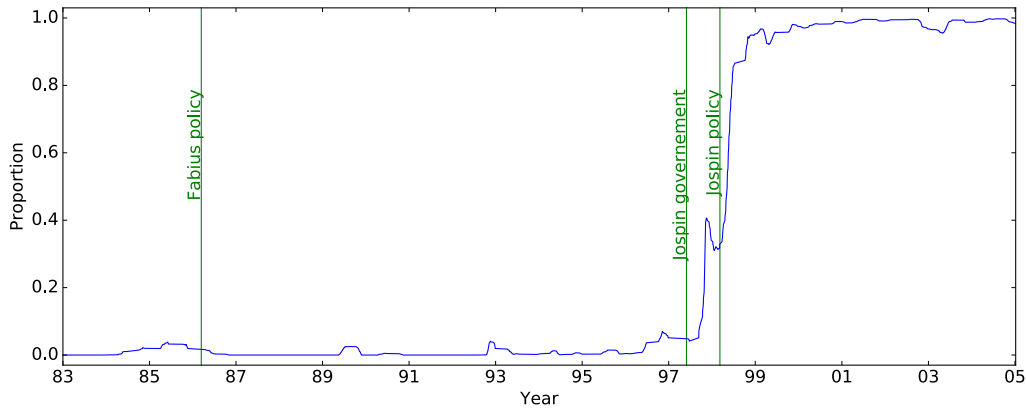


Figure 1: Prop. of Madame la N vs Madame le N (1983-2005).

party colleagues who have a more masculine gender construction, such as Michèle Alliot-Marie and Martine Aubry. Furthermore, women constructing a feminine persona, such as Royal, are referred to significantly more often in the feminine than women constructing less a feminine persona, like Aubry.

Social meaning of French g-gender

To account for these patterns, following (McConnell-Ginet, 2013), (Burnett and Bonami, 2018) propose that French feminine g-gender marking has **social meaning**; in particular, the authors propose that feminine g-gender marking (F) is associated with, or *indexes* (Ochs, 1992), sets of properties called their *indexical fields* (Eckert, 2008), notated [F], which contain properties stereotypically associated with women at the time, such as those referenced in the discourses on female politicians mentioned above (4-a). Correspondingly, masculine g-gender marking indexes properties stereotypically associated with men at the time (4-b).

- (4) a. [F] = {sensitive, pragmatic, non-dominant, honest... }
 b. [M] = {tough, abstract, dominant, dishonest... }

Since the new feminine personae have stereotypically feminine properties, speakers are predicted to use the feminine when attempting to construct such a persona and/or when describing someone who instantiates one. Conversely, they are predicted to use the masculine when constructing a more stereo-

typically masculine persona or when referring to women with a more stereotypically masculine gender presentation. In the 1980s, all personae for female politicians had masculine properties; therefore, the masculine form dominated. As speaker ideologies change to incorporate the new feminine personae in the mid 1990s and speakers started viewing themselves and others in these terms, and the feminine became more useful and eventually replaced the masculine in the Assemblée Nationale with the help of Jospin’s *circulaire*.

(Burnett and Bonami, 2018) provide an intuitive explanation of the change and why Jospin’s reiteration of Fabius’ policy was successful; however, they do not make completely explicit how the development of the new personae translates into the change from masculine g-gender to feminine g-gender, and why Fabius’ and Jospin’s language policies had different statuses. Therefore, in the rest of this paper, we flesh out the relation between ideological change, language change and language policy in terms of the *Conceptual Spaces* and signaling games.

3 Ideological change in Conceptual Spaces

To formalize ideological change, we will make use of formal tools from the *Conceptual Spaces* framework for lexical semantics (Gärdenfors, 2000; Gärdenfors, 2014). In this approach speaker and listener conceptual and ideological structures are represented as a tuple $\langle D, \text{sim}, \text{PERS} \rangle$, where $\langle D, \text{sim} \rangle$ is an $|D|$ -dimensional vector space with a relation *sim* measuring distance between points, and *PERS* is a distinguished set of points. Socially meaningful

expressions are interpreted into these vector spaces whose dimensions are found in their indexical fields. In synchronic research, the dimensions and personae in the spaces can be constructed based on experimental data, as in (Douven, 2016), and the indexical fields associated with sociolinguistic variants can likewise be determined by experimentation (see, for instance, (Campbell-Kibler, 2007; Levon, 2014; Podesva et al., 2015)). The study that we are modeling in this paper is a historical one, and it’s possible that g-gender’s indexical fields have changed in the past twenty years. Therefore, we will use simulations to illustrate how our formal model works.

In the analysis of the social meaning of French g-gender, we will take the dimensions from public discourses about French politicians in the 1990s described in (Burnett and Bonami, 2018), shown in (5). This being said, for ease of visualisation, we will limit our illustration to a three dimensional space consisting of *Institutional dominance*, *Abstraction* and *Toughness*.

(5) **4 dimensions of ideological space**

- a. Institutional dominance
(dominant ↔ non-dominant)
- b. Abstraction (abstract ↔ pragmatic)
- c. Toughness (tough ↔ sensitive)
- d. Honesty (dishonest ↔ honest)

We propose that personae are represented as distinguished points within this space (i.e. PERS) according to their properties,² and changes in speakers and listeners’ ideological structure will be modeled as changes in how personae are distributed across the ideological space. For example, suppose we consider most politicians’ ideological structures in 1986, i.e. when Fabius formulated the first language policy. (Burnett and Bonami, 2018) argue that there was a very tight correlation in the minds of politicians between institutional dominance, abstraction and toughness at this time, and we can represent this as a correlation between values on the different dimensions. Of course we do not know exactly how many personae a speaker represents and how exactly they are arranged in the ideological space, so as a demonstration of how the framework works, we generated 20 points in the conceptual space such that

²Our personae play the role of Gärdenfors’ *prototypes*.

10 occupy the higher two thirds of the space on the dominance, abstraction, and toughness scales, while 10 occupy the lower two thirds of the space, using the *rand* function in Octave (Eaton et al., 2015). Thus, we propose that most politicians in the AN have an ideological structure similar to that found in Figure 2 in 1986.

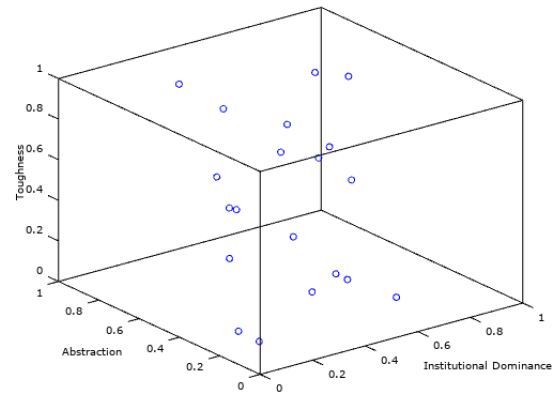


Figure 2: Ideological structure in the late 1980s (PERS₈₆)

Observe that there are some significant empty spaces in the cube shown in Figure 2. Most importantly, no personae are highly dominant, very pragmatic and also very sensitive in this model.

Both the truth conditional and social meanings of linguistic expressions pick out regions of the ideological space, and speakers use their language to communicate information about the location of the individual that they are talking about. By analogy with Gärdenfors’s work on prototypes in lexical semantics, we assume that the arrangement of personae in the space imposes constraints on which regions noun phrases like *le ministre* and *la ministre* can identify. Given an n-dimensional conceptual space and a distinguished set of points, there is a natural way of partitioning this space into discrete regions: **voronoi polygons**. The voronoi polygon associated with a persona p_i , $v(p_i)$, is the set of points that lie closer to p_i than to any other persona in the domain (6-a). The **Voronoi tessellation** generated by a set of personae PERS, $V(\text{PERS})$, is the collection of voronoi polygons associated with every persona in PERS (6-b).

- (6) Let $p_i \in \text{PERS}$ be a persona.
 - a. $v(p_i) := \{x | \forall j (\text{sim}(x, p_i) \leq \text{sim}(x, p_j))\}$

$$b. V(\text{PERS}) := \{v(p_i) | p_i \in \text{PERS}\}$$

Thus, the voronoi tessellation of the personae in the 1986 model are shown (in two dimensions for readability) in Figures 3 and 4.³

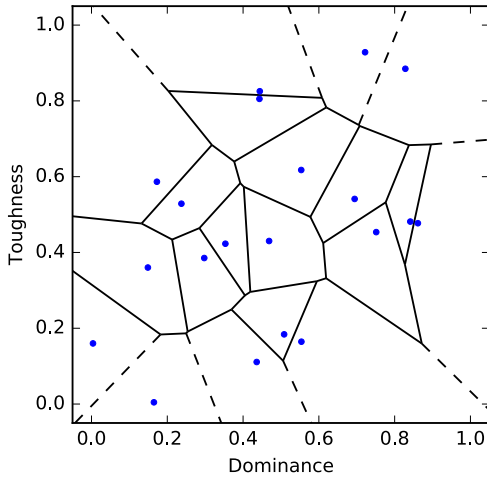


Figure 3: 1986 ideological space: Dominance vs Toughness

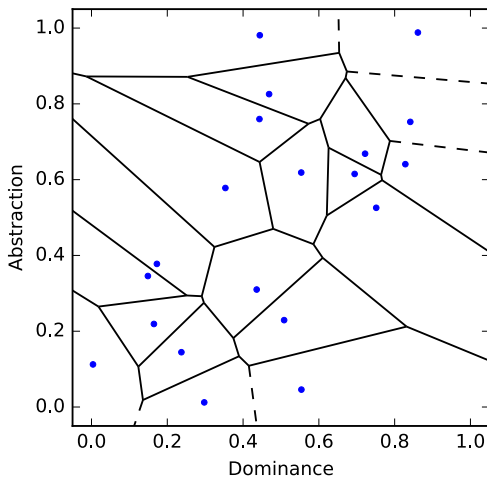


Figure 4: 1986 ideological space: Dominance vs Abstraction

Crucially, in this model, individuals that are both highly institutionally dominant and very sensitive fall within the ideological region of a less dominant persona (Figure 3). Likewise, highly dominant and very pragmatic individuals are obligatorily grouped

³All the tessellations in this paper were calculated using Octave.

into the region defined by the less dominant persona (Figure 4).

Function nouns and indexical fields

The nouns that alternate in the Assemblée Nationale corpus all refer to very powerful government positions (*ministre, garde des sceaux, président(e)* etc.). Therefore, it seems reasonable to assume that, in virtue of occupying one of these positions, individuals in the denotation of a word like *ministre* (written \llbracket ministre \rrbracket) acquire a high level of institutional dominance. For convenience, we will assume that the level of institutional dominance of ministers is greater than or equal to 0.7, as shown in (7). This is materialized by the red line in Figures 5 and 6: all ministers are by virtue of their function to the right of that line.

- (7) \llbracket ministre \rrbracket is a subset of the set of individuals that lie in the voronoi polygons associated with personae whose institutional dominance exceeds 0.7.

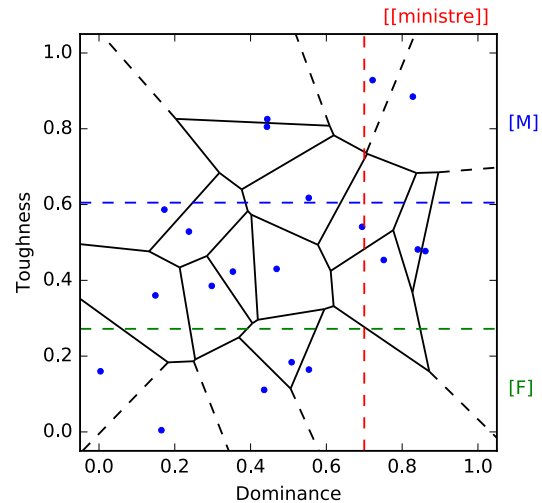


Figure 5: Dominance vs. toughness in 1986: No minister is sensitive enough to be within the feminine indexical field

We propose that grammatical gender marking (M/F) also picks out regions: the space associated with all the personae that have a high level of **at least one** of the properties in the indexical field (Burnett, 2017). So the social meaning of masculine g-gender is the concave region within the cube containing all the personae that are above the third quartile on

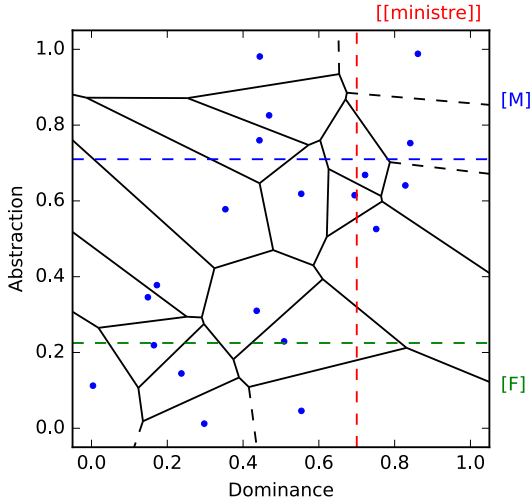


Figure 6: Dominance vs. abstraction in 1986: No minister is pragmatic enough to be within the feminine indexical field

the institutional dominance, abstraction or toughness scales. In the two-dimensional projections of Figures 5 and 6, this is materialized by the horizontal blue lines: all and only individuals above those lines are in the masculine indexical field. In 1986, it happens that there is a strong correlation between the three dimensions. As a result, 1986 personae compatible with masculine cluster in the upper right corners of the two squares in Figures 5 and 6.

Following the analysis in (4), the social meaning of feminine g-gender corresponds to the concave region associated with all the personae that are lower than the first quartile on the dimensions in the indexical field. In the two-dimensional projections of Figures 5 and 6, this is materialized by the horizontal green lines: all and only individuals below those lines are in the feminine indexical field. Again, in 1986, having a low value in one dimension predicts having a low value in other dimensions, so that personae compatible with the feminine cluster in the lower left corners of the two squares in Figures 5 and 6.

The ideological structure in 1986 is such that the space picked out by the indexical field of the feminine is disjoint from $[[ministre]]$: in both Figure 5 and Figure 6, the rectangle to the right of the red line and below the blue line is empty. So, in this model, the expression *la ministre* does not pick out a populated chunk of ideological space; this makes reference to

a woman minister in the feminine very unlikely.

In contrast, in 1998, speakers' ideological structures are very different: the lower righthand corner of the ideological space contains personae who are both sensitive and pragmatic, but also highly dominant. These are the *feminine political personae* described above, who are instantiated by individuals like Bachelot and Royal. A model of such an ideological space is shown in Figure 7: although the relationship between other dimensions has not changed (i.e. there is still a correlation between abstraction and toughness), there has been a weakening of the relationship between institutional dominance and the other dimensions.

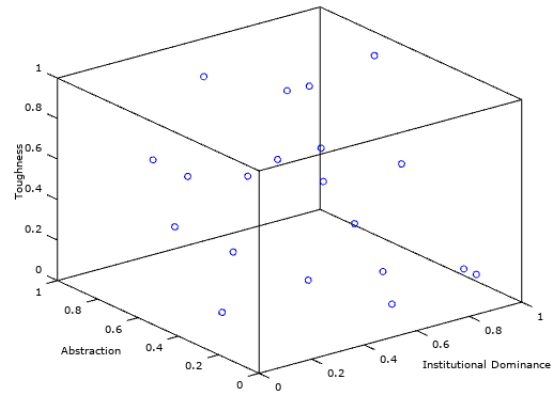


Figure 7: Ideological structure in the late 1990s (PERS₉₈)

Keeping the same definitions as in the 1986 model, we see that these new personae change the denotation of *ministre* and the indexical fields of M and F. Firstly, $[[ministre]]$ now has more polygons of personae in its denotation. This is materialized in the two-dimensional projections in Figures 8 and 9 by having more points to the right of the red line.

Secondly, some of these ministers stand within the indexical field of the feminine, because they are very sensitive or pragmatic (Figure 8). Thus, we observe the following facts comparing the models:

- (8) a. $[[ministre]]_{86} \cap [F]_{86} = \emptyset$.
- b. $[[ministre]]_{98} \cap [F]_{98} \neq \emptyset$.

We propose that this difference is what explains that use of the feminine to refer to a female minister was just unavailable in 1986 but was possible in 1998.

Also noticeable is the fact that the relevant ministers, by virtue of being dominant, also stand within

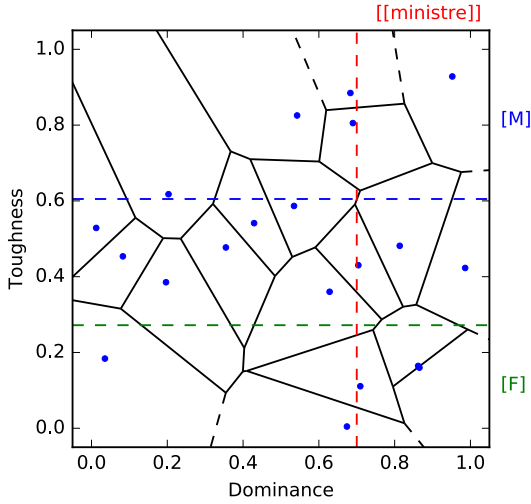


Figure 8: Dominance vs. toughness in 1998: Some ministers are sensitive enough to be within the feminine indexical field

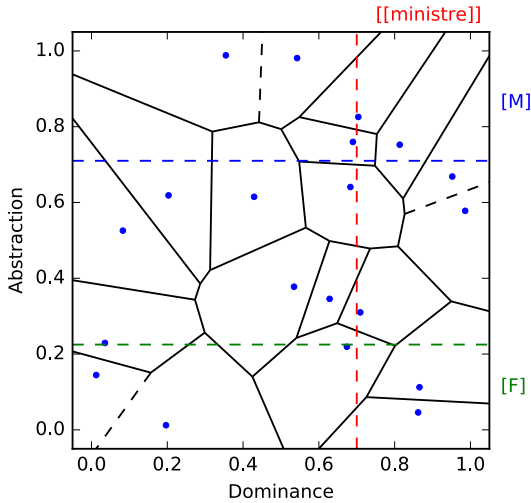


Figure 9: Dominance vs. abstraction in 1998: Some ministers are pragmatic enough to be within the feminine indexical field

the masculine indexical field (the third quartile of dominance, not materialized in the Figures, is at 0.76, just to the to the right of the red line).

$$(9) \quad \llbracket \text{ministre} \rrbracket_{98} \cap [F]_{98} \cap [M]_{98} \neq \emptyset.$$

This explains why there can be variation in 1998: both the use of the feminine and the use of the masculine to refer to a female minister convey a relevant social message.

4 Linking ideology and language use

When it comes to capturing the relationship between conceptual spaces and communication, the majority of the work has focused on how multi-dimensional spaces with prototypes constrain meanings in the context of **signaling games** (Jäger, 2007; Jäger and Van Rooij, 2007; Warglien and Gärdenfors, 2013; Gärdenfors, 2014). In this paper, we will also use signaling game architecture combined with an iterated best response solution concept of the kind used by (Franke, 2009; Frank and Goodman, 2012; Burnett, 2017) and many others. The basic structure of the game is as follows: the speaker (S) knows the location of a (female) minister in ideological space and wishes to communicate that location to the listener. In order to do this, they choose how they gender mark *ministre* using the determiner *le* or *la*. The listener (L) hears *le/la ministre* and updates their beliefs with respect to the location of the referent in their conceptual space. More formally, we represent each time period as a game as follows:

(10) Model for 1986

$$G_{86} = \langle S, L, \langle D, \text{sim}, \text{PERS}_{86} \rangle, M, [\cdot], C, P \rangle:$$

- a. S, L are the players.
- b. $\langle D, \text{sim}, \text{PERS}_{86} \rangle$ is the ideological space in Figure 2.
- c. $M = \{le, la\}$ is a set of messages.
- d. $[\cdot]$ is an indexation relation mapping each message to its indexical field.
$$\begin{aligned} [le] &= [M]_{86} \\ [la] &= [F]_{86} \end{aligned}$$
- e. C is a **cost function** assigning a natural number to each message.
- f. P_{86} is a probability distribution over $\{v(p) : p \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}\}$, encoding L's **prior beliefs** concerning in which voronoi polygon the referent is located.

(11) Model for 1998

$$G_{98} = \langle S, L, \langle D, \text{sim}, \text{PERS}_{98} \rangle, M, [\cdot], C, P \rangle:$$

- a. S, L are the players.
- b. $\langle D, \text{sim}, \text{PERS}_{98} \rangle$ is the ideological space in Figure 7.
- c. $M = \{le, la\}$ is a set of messages.
- d. $[\cdot]$ is an indexation relation mapping each message to its indexical field.
$$[le] = [M]_{98}$$

$$[la] = [F]_{98}$$

- e. C is a cost function assigning a natural number to each message.
- f. P_{98} is a probability distribution over $\{v(p) : p \in \text{PERS}_{98} \cap \llbracket \text{ministre} \rrbracket_{98}\}$.

For convenience, we assume that both P_{86} and P_{98} are uniform distributions over $\{v(p) : p \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}\}$ and $\{v(p) : p \in \text{PERS}_{98} \cap \llbracket \text{ministre} \rrbracket_{98}\}$,⁴ as shown in Tables 1 and 2.

Dominance	Abstraction	Toughness	P
0.83	0.64	0.88	0.2
0.75	0.53	0.45	0.2
0.84	0.75	0.48	0.2
0.72	0.67	0.93	0.2
0.86	0.99	0.48	0.2

Table 1: L 's prior belief distribution over voronoi polygons associated with personas in the 1986 model

Dominance	Abstraction	Toughness	P
0.70	0.83	0.43	0.143
0.81	0.75	0.48	0.143
0.95	0.67	0.93	0.143
0.71	0.31	0.11	0.143
0.99	0.58	0.42	0.143
0.87	0.11	0.16	0.143
0.86	0.05	0.16	0.143

Table 2: L 's prior belief distribution over voronoi polygons associated with personas in the 1998 model

Following (Frank and Goodman, 2012), we assume that S and L 's actions are calculated based on a number of steps. When L hears a message, the first thing they do is condition their prior beliefs on the meaning of the message, as shown in (12) (for the 1986 model).

$$(12) \quad P_{86}(v(p)|m) = \frac{P_{86}(v(p) \cap [m])}{P_{86}([m])}$$

As shown in Table 3, since there are no ministers who are located within the indexical field of la , $P_{86}(v(p)|la) = 0$, for all $p \in \llbracket \text{ministre} \rrbracket_{86}$. However, since there are two personae in $[F]$ in $\llbracket \text{ministre} \rrbracket_{98}$, P_{86} conditioned under la for these two personae is 0.5.

⁴This assumption does not affect our formal results.

Dominance	Abstraction	Toughness	le	la
0.83	0.64	0.88	0.2	0
0.75	0.53	0.45	0.2	0
0.84	0.75	0.48	0.2	0
0.72	0.67	0.93	0.2	0
0.86	0.99	0.48	0.2	0

Table 3: L 's belief distribution over polygons conditioned on the indexical field associated with a message, in the 1986 model

Dominance	Abstraction	Toughness	le	la
0.70	0.83	0.43	0.143	0
0.81	0.75	0.48	0.143	0
0.95	0.67	0.93	0.143	0
0.71	0.31	0.11	0.143	0
0.99	0.58	0.42	0.143	0
0.67	0.11	0.16	0.143	0.5
0.86	0.05	0.16	0.143	0.5

Table 4: L 's belief distribution over polygons conditioned on the indexical field associated with a message, in the 1998 model

Again following (Frank and Goodman, 2012), we assume that speaker utility is calculated based on message **informativity**, which is calculated based on the *negative surprisal* (positive natural log probability (Shannon, 1948)) of the prior conditioned on the the message, minus whatever costs are assigned to m by C , as shown in (13) (for the 1986 model).

$$(13) \quad U_S(v(p), m) = \log(P_{98}(v(p)|m)) - C(m)$$

We will use the cost functions to model the effects of the language policies.⁵ Both in 1986 and 1998, we have two situations: **before** the policy, where there no message costs: $C(le) = C(la) = 0$, and **after** the policy, where there is a cost for using the masculine: $C(la) = 0, C(le) \neq 0$.

To account for variability in action selection, we assume that the speaker chooses a message based on the *soft-max choice rule* (Luce, 1959; Sutton and Barto, 1998) (14), where λ is a parameter governing how (non)deterministic the choice is.

$$(14) \quad S(m|v(p)) \propto \exp(\lambda * U_S(v(p), m))$$

⁵This seems reasonable, given that disobeying the policy has monetary costs. For example, in 2014, Julien Aubert (UMP) was required to pay 1378 euros for saying *Madame le président*.

Results

Our model makes predictions concerning the probability that the speaker will use *le* or *la* to describe some female minister. Firstly, as shown in Theorem 1, in the 1986 model, where there are no costs put on the messages (i.e. before Fabius’ policy), we predict that speakers categorically use the masculine in the 1986 model. This is due to the fact in (8-a): the regions picked out by the feminine’s indexical field are disjoint from where the ministers lie.

Theorem 1 Before Fabius’ policy (1986). *Let $C(le) = C(la) = 0$. For all (non- ∞) values for λ , all $v(p) \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}$, $S(la|v(p)) = 0$ and $S(le|v(p)) = 1$.⁶*

Furthermore, we show that, with the 1986 ideological structure, adding costs to the masculine does not predict an increase in use of the feminine, as shown in Theorem 2. This is because the calculation of speaker utility (13) in the RSA model prioritizes informativity over message costs.

Theorem 2 After Fabius’ policy (1986). *Let $C(la) = 0$. For all values $n \in \mathbb{N}$ such that $C(le) = n$, and for all (non- ∞) values for λ , all $v(p) \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}$, $S(la|v(p)) = 0$ and $S(le|v(p)) = 1$.⁷*

On the other hand, in both models for 1998, the feminine is predicted to be used, particularly to communicate that the referent lies close to the new feminine personae. For example, if we set $\lambda = 2$, for illustration, we see that use of *la* to communicate the polygons in the bottom right corner of the ideological space is predicted to be 0.925 in 1998, as shown in Table 5.

Dominance	Abstraction	Toughness	<i>le</i>	<i>la</i>
0.87	0.11	0.16	0.075	0.925
0.86	0.05	0.16	0.075	0.925

Table 5: Probability of *S* choosing a message conditioned on the polygon in which *S* locates the referent, before policy

⁶PROOF. Suppose $\lambda = n \neq \infty$ and let $p \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}$. By Table 3, $P_{86}(v(p)|la) = 0$, so by (13), $U_S(v(p), la) = -\infty$. Therefore, by (14), $S(la|v(p)) = 0$ and $S(le|v(p)) = 1$. ■

⁷PROOF. Let $C(le) = n$, $\lambda = m$ and $p \in \text{PERS}_{86} \cap \llbracket \text{ministre} \rrbracket_{86}$. Since $P_{86}(v(p)|la) = 0$ (see proof of Theorem 1), $U_S(v(p), la) = -\infty + 1 = -\infty$. So, by (14), $S(la|v(p)) = 0$ and $S(le|v(p)) = 1$. ■

Likewise, if we add a cost to using the masculine (say $C(le) = 1$), the probability of using *la* increases to 0.971, as shown in Table 6.

Dominance	Abstraction	Toughness	<i>le</i>	<i>la</i>
0.87	0.11	0.16	0.029	0.971
0.86	0.05	0.16	0.029	0.971

Table 6: Probability of *S* choosing a message conditioned on the polygon in which *S* locates the referent, after policy

Thus, the model correctly predicts 1) increase of the feminine from 1986 to 1998, and 2) effectiveness of language policy in 1998 but not in 1986.

5 Conclusion

We presented a formal model of socially driven linguistic change that is centered around the relationship between ideological structure and linguistic meaning. In our approach, which follows (Foucault, 1976; Butler, 1993; Butler, 1997; Livia and Hall, 1997) among others, social changes and discourse about them construct and change speaker/listener ideologies. These ideologies then constrain what meanings can be assigned to linguistic expressions in the way proposed by (Gärdenfors, 2000; Gärdenfors, 2014). Expressions’ meanings then determine how they can be used in communication, as in the *Rational Speech Act* model.

We used our model to explicitly characterize both the ideological change in late 1990s and the consequences that this change had on the use of *le ministre* vs *la ministre*. We therefore conclude that frameworks such as *Conceptual Spaces* and the *RSA* are promising for capturing the link between ideologies and linguistic production, and that tools from formal semantics and pragmatics have a role to play in the study of sociolinguistic phenomena.

Acknowledgments

We thank Paul Égré, Gerhard Jäger, Denis Paperno, three anonymous reviewers, and audiences at ENS Paris, ZAS Berlin, Stanford University and the Ohio State University for helpful comments. This work was supported by a grant overseen by the French National Research Agency (ANR) as part of the “Investissements d’Avenir” program (reference: ANR-10-LABX-0083).

References

- Catherine Achin, Lucie Bargel, Delphine Dulong, Eric Fassin, Christine Guillonnet, Stéphanie Guyon, Clémence Labrouche, Stéphane Latté, Pierre Leroux, Sandrine Lévêque, Frdrique Matonti, Marion Paoletti, Christiane Restier-Melleray, Philippe Teillet, and Aurilia Troupel. 2007. *Sexes, genre et politique*. Economica, Paris.
- Laure Bereni. 2007. *De la cause à la loi. Les mobilisations pour la parité politique en France (1992-2000)*. Ph.D. thesis, Université Panthéon-Sorbonne-Paris I.
- Mary Bucholtz and Kira Hall. 2005. Identity and interaction: A sociocultural linguistic approach. *Discourse studies*, 7(4-5):585–614.
- Mary Bucholtz and Kira Hall. 2008. All of the above: New coalitions in sociocultural linguistics. *Journal of Sociolinguistics*, 12(4):401–431.
- Heather Burnett and Olivier Bonami. 2018. Linguistic prescription, ideological structure and the actuation of linguistic changes: Grammatical gender in French parliamentary debates. in *revision for Language in Society*.
- Heather Burnett. 2017. Sociolinguistic interaction and identity construction: The view from game-theoretic pragmatics. *Journal of Sociolinguistics*, 21(2):238–271.
- Elisabeth Burr. 2003. Gender and language politics in France. *Gender across languages*, 3:119–139.
- Judith Butler. 1993. *Bodies that matter: On the discursive limits of sex*. Taylor & Francis.
- Judith Butler. 1997. *Excitable speech: A politics of the performative*. Psychology Press.
- Kathryn Campbell-Kibler. 2007. Accent,(ing), and the social logic of listener perceptions. *American speech*, 82(1):32–64.
- Robin Clark and Ian Roberts. 1993. A computational model of language learnability and language change. *Linguistic Inquiry*, 24(2):299–345.
- Corbett. 1991. *Gender (Cambridge textbooks in linguistics)*. Cambridge University Press.
- Igor Douven. 2016. Vagueness, graded membership, and conceptual spaces. *Cognition*, 151:80–95.
- John W. Eaton, David Bateman, Sören Hauberg, and Rik Wehbring. 2015. *GNU Octave version 4.0.0 manual: a high-level interactive language for numerical computations*.
- Penelope Eckert. 2008. Variation and the indexical field. *Journal of sociolinguistics*, 12(4):453–476.
- Michel Foucault. 1976. *Histoire de la sexualité (Tome 1)-La volonté de savoir*. Editions Gallimard.
- Michael C Frank and Noah D Goodman. 2012. Predicting pragmatic reasoning in language games. *Science*, 336(6084):998–998.
- Michael Franke. 2009. *Signal to act: Game theory in pragmatics*. Ph.D. thesis, Institute for Logic, Language and Computation, Amsterdam.
- Peter Gärdenfors. 2000. *Conceptual spaces: The geometry of thought*. MIT press.
- Peter Gärdenfors. 2014. *The geometry of meaning: Semantics based on conceptual spaces*. MIT Press.
- Françoise Gaspard, Claude Servan-Schreiber, and Anne Le Gall. 1992. *Au pouvoir citoyennes!: Liberté, égalité, parité*. Seuil.
- Charles F. Hockett. 1958. *A course in modern linguistics*. New York: Macmillan.
- Anne-Marie Houdebine. 1998. La féminisation des noms de métiers. *Paris: Harmattan*.
- Gerhard Jäger and Robert Van Rooij. 2007. Language structure: psychological and social constraints. *Synthese*, 159(1):99–130.
- Gerhard Jäger. 2007. The evolution of convex categories. *Linguistics and Philosophy*, 30(5):551–564.
- Virginie Julliard. 2012. *De la presse à Internet: la parité en questions*. Hermès science publications.
- Henri Kauhanen and George Walkden. 2018. Deriving the constant rate effect. *Natural Language & Linguistic Theory*, 36(2):483–521.
- William Labov. 1963. The social motivation of a sound change. *Word*, 19(3):273–309.
- Erez Levon. 2014. Categories, stereotypes, and the linguistic perception of sexuality. *Language in Society*, 43(05):539–566.
- Anna Livia and Kira Hall. 1997. It’s a girl!: Bringing performativity back to linguistics. *Queerly phrased: Language, gender, and sexuality*, pages 3–18.
- R Duncan Luce. 1959. On the possible psychophysical laws. *Psychological review*, 66(2):81.
- Sally McConnell-Ginet. 2013. Gender and its relation to sex: the myth of “natural” gender. *The Expression of Gender*, pages 3–38.
- Frédérique Montini. 2017. *Le genre présidentiel*. Editions la découverte.
- Partha Niyogi and Robert C Berwick. 1997. A dynamical systems model for language change. *Complex Systems*, 11(3):161–204.
- Elinor Ochs. 1992. Indexing gender. *Rethinking context: Language as an interactive phenomenon*, 11:335.
- Robert J Podesva, Jermy Reynolds, Patrick Callier, and Jessica Baptiste. 2015. Constraints on the social meaning of released /t/: A production and perception study of us politicians. *Language Variation and Change*, 27(01):59–87.
- Raylene L Ramsay. 2003. *French women in politics: writing power, paternal legitimization, and maternal legacies*. Berghahn Books.

- Claude Shannon. 1948. A mathematical theory of communication. *Bell System Technical Journal*, 27:379–423.
- Richard S Sutton and Andrew G Barto. 1998. *Reinforcement learning: An introduction*. MIT press.
- Éliane Viennot. 2014. Non, le masculin ne l'emporte pas sur le féminin. *Petite histoire des résistances de la langue française*.
- Massimo Warglien and Peter Gärdenfors. 2013. Semantics, conceptual spaces, and the meeting of minds. *Synthese*, pages 1–29.
- Charles D Yang. 2000. Internal and external forces in language change. *Language variation and change*, 12(3):231–250.
- Charles D Yang. 2002. *Knowledge and learning in natural language*. Oxford University Press.