# Personae under uncertainty: The case of topoi

**Bill Noble** and **Ellen Breitholtz** and **Robin Cooper**
Univerisity of Gothenburg
bill.noble@gu.se
ellen.breitholtz@ling.gu.se
robin.cooper@ling.gu.se

**Abstract**

In this paper, we propose a probabilistic model of social signalling which adopts a persona-based account of social meaning. We use this model to develop a socio-semantic theory of conventionalised reasoning patterns, known as *topoi*. On this account the social meaning of a topos, as conveyed in a argument, is based on the set of ideologically-related topoi it indicates in context. We draw a connection between the role of personae in social meaning and the *category adjustment effect*, a well-known psychological phenomenon in which the representation of a stimulus is biased in the direction of the category in which it falls. Finally, we situate the interpretation of social signals as an update to the information state of an agent in a formal TTR model of dialogue.

## 1 Introduction

Consider the (somewhat dramatic) Example 1, from Lavelle et al. (2012), a corpus of dialogues where participants are instructed to resolve a moral dilemma. The subjects are asked to decide, based on limited information, who out of four passengers in a hot air balloon to sacrifice in order to save the other three.

Example 1

39 C: Well I'm not throwing a kid out [I just couldn't cope with it].

42 A: And the other thing is I mean what what what she achieves er in her life if she becomes as famous as famous as Mozart erm will go on er [forever]=

45 A: So I mean the person it seems like the person with least value is the .

48 B: [she's] pregnant.

51 B: [So you're] killing two people instead of one.

52 C: Yhh and another thing is would he be able to pilot the balloon if his wife is overboard?

Apart from communicating semantic content, arguments often implicitly evoke a *topos*, a pattern of reasoning the speaker draws on to warrant their argument. For example, the argument against sacrificing the pregnant woman (1-51) relies on a topos such as *if you have to choose between killing $n$ and $m$ people and $m < n$ then choose $m$.*

Upon recognizing the evoked topos, an interlocutor may draw certain conclusions about the speaker, namely that they are the *kind of person* who reasons in this way. Given that information, the interlocutor may, in turn, choose to frame their arguments in a way that appeals to the kind of person they infer the speaker to be.

Such topoi can be seen as signals conveying *social meaning* by association with *personae* or stereotypical categories of people (Eckert, 2012). The use of personae as a *semantic medium* in a theory of social meaning is analogous to how possible worlds (Lewis, 1970), infons, or situation types (Barwise and Perry, 1983) are used in truth-theoretic accounts of propositional meaning. Just as declarative sentences restrict the set of possible worlds or situation types, the social meaning of a social signal restricts the personae attributed to the speaker. Recent work by Burnett (2017), for example, uses game theoretic modelling to formalise social meaning in terms of personae. In contrast to Burnett (2017), who considers dialectical variables orthogonal to semantic content, we consider the social meaning of topoi in argumentation, following Breitholtz (2014). We develop a probabilistic model that formalises the relationship between topoi and personae through Bayesian inference and integrate this account into a formal TTR model of dialogue by defining an update to the information state of an agent.

## 2 Personae, topoi, and social meaning

In this section, we give background on the rhetorical and sociolinguistic phenomena we seek to model.

### 2.1 Personae

The variationist branch of sociolinguistics is interested in the construction of linguistic style through the use of *linguistic variables* (Hudson, 1996). A variable is any axis along which an individual's language may differ from someone else in the same community. Linguistic variables can be found at all levels of linguistic analysis, including phonetics (e.g., accent), prosody, lexical choice, morphology, and syntax.

Some of the earliest work in variationist sociolinguistics, for example, studies phonetic variations different groups of speakers on the island of Martha's Vineyard (Labov, 1963). This *first wave* of variationist sociolinguistics (Eckert, 2012), is principally concerned with variation across macrosociological categories such as race, class and gender .

The second wave of variationist study was interested in more fine-grained social categories, sometimes referred to as *personae* (Eckert, 2012). A persona is a widely recognised social category which is available as a reference point for the expression of social identity in a given community. For example, Eckert (1989, 2008) identifies the personae of "jock" and "burnout" as central to the social semiotic system of an early-2000s Detroit-area high school. Through their dress, behaviour, and linguistic style, students signal identification with or distance from the established personae.

Third-wave sociolinguistics considers the role of variation in the expression of social meaning, rather than merely reflective of social categories (Eckert, 2012). Personae are the semantic common ground that makes communicating social meaning possible. In a given speech community, a linguistic *variant* (the expression of a linguistic variable) constitutes a *social signal* in virtue of its association with one or more personae. Speakers identify themselves as ideologically aligned with a given persona by adopting variants associated with it. This is referred to as *projecting* a persona. Speakers typically do not identify uniquely with one persona, however. Each individual constructs a unique style, mixing and matching variants associated with different personae in a process Eckert (2000) refers to as *bricolage*.

While previous work assumed that linguistic variables were orthogonal to propositional meaning, third-wave sociolinguistics acknowledges that that separation is not always possible. Eckert (2008) writes that her view of linguistic style "precludes the separation of form from content, for the social is eminently about the content of people's lives". In the following section we present *topoi*, a pragmatic phenomenon that play a role in semantic content, but that we argue can also be viewed as a constituent of linguistic style.

### 2.2 Topoi

Argumentation and reasoning in dialogue is predominantly *enthymematic*, that is, it partly relies on what is "in the mind" ($\dot{\epsilon}\nu\theta\acute{\upsilon}\mu\eta\mu\alpha$) of the listener (Breitholtz, 2014). Aristotle referred to the principles of reasoning which enthymematic arguments are based on as the *topoi* of the arguments. For Aristotle, a topos was a "place" or "field", where a public speaker or a participant in a dialectic debate could find ideas on which to build his argument.

In the 20th century the idea of topos has been taken up in linguistics by Ducrot (1980) and Anscombre et al. (1995) who suggest that every link between a statement and another statement, or between a statement and (for example) an exhortation in discourse is a topos and that topoi are thus essential to any theory of semantics beyond the sentence, as well as important for contextual interpretation of lexical meaning. One of the leading ideas in Ducrot's take on topoi, is that topoi are not part of factual knowledge about the world, but part of "ideology", that is the agent's conception of acceptable ways to make inferences. This does not mean that topoi are unrelated to facts—for example, a topos of gravity is not likely to be unrelated to the way gravity works. However, it is clear that a large number of topoi are related to ethical considerations such as what is good or beneficial, and these cases are clearly ideological in the sense that they are relative to context.

For example, Ducrot discusses different ways of arguing about giving tips. One individual might encourage another to give a tip to a porter who "carried the bags all the way here", while someone else might advise against it, for the reason that the porter is already paid to carry bags, and why should you pay someone for something they are already paid to do? This is an example of how different topoi may apply in one situation, and lead to inconsistent results or conclusions. Which topoi we appear to draw on while making an argument in a given situation thus gives our interlocutors information of an ideological nature. This is true both in situations where we reason from a context (a set of premises present in a context) to a conclusion, and when we have a particular conclusion in mind that we argue for. In the first case, applying different topoi might lead to different conclusions, but in both cases the implicit ideological information conveyed might differ depending on the topos used.

We argue that topoi, in virtue of their ideological association, constitute social signals that contribute to the persona projected by a dialogue participant, much like use of particular linguistic variants. Topoi are an attractive subject of study as social signals since, unlike social variables like physical appearance or pronunciation, they may be extracted from written text or transcribed dialogues.

## 3 Two probabilistic models of social meaning

In this section, we develop a simple probabilistic model that associates topoi with personae. In particular, we model how the use of a topos by one agent results in an update to another agent's model of their persona. Since we restrict our attention to a single utterance, we refer to the listener, whose internal state is updated, as *Self* and the speaker, who evoked the topos, as *Other*.

We present two versions of the model. In the *first-order model*, Self models Other as a simple categorical probability distribution over personae. In the *second-order model*, Self represents Other as a Dirichlet distribution over *possible* categorical distributions over personae.

In both cases, the event being modelled is the same: Other ($O$) invokes a topos ($\tau$) in a dialogue with Self ($S$). Then, Self's updates their model of Other as a result of that social signal.

Unlike the social signaling game from Burnett (2017)'s, which is based on rational speech acts (Frank and Goodman, 2012), we do not assume any level of social recursion in the speaker; that is, the speaker does not consult a model of the listener's model of themself when producing an utterance.

We assume that each agent has access to a set of personae, $\Pi = \{\pi_1, ..., \pi_K\}$, and topoi, $\Psi = \{\tau_1, ..., \tau_N\}$. A probability distribution $\varphi_\pi$ is assigned to each persona $\pi$ such that:

$$\varphi_\pi(\tau) = P_S(\tau \mid \pi). \tag{1}$$

The probability given by $\varphi_\pi(\tau)$ is the likelihood that someone projecting $\pi$ will evoke $\tau$. This distribution models the idealogical association between topoi and personae—it is what gives the topoi their social meaning. For now, we assume that $\Pi$, $\Psi$ and $\varphi$ are shared community resources.

We begin with the first-order model as a demonstration of the setting and, after discussing its weaknesses, move on to the second-order model.

### 3.1 First-order model

In the first-order model, Self models Other as categorical probability distribution over personae. Let $\theta_{S,O}$ be $S$'s model of $O$; that is, the probability, according to $S$, that $O$ will project the persona $\pi$:

$$\theta_{S,O}(\pi) = P_S(\pi \mid O) \tag{2}$$

When $O$ evokes $\tau$, $S$ updates their prior model of $O$ accordingly. Intuitively, $S$ learns that $O$ is more likely to project personae that are likely to evoke $\tau$:

$$\Delta_1(\theta_{S,O}, \varphi, \tau) = \lambda\pi . \frac{\varphi_\pi(\tau) \cdot \theta_{S,O}(\pi)}{\sum_{\pi'} \varphi_{\pi'}(\tau) \cdot \theta_{S,O}(\pi')} \tag{3}$$

In Bayesian terms, the update function gives the posterior distribution of $\theta_{S,O}$, given $\tau$:

$$\begin{aligned}\frac{\varphi_\pi(\tau) \cdot \theta_{S,O}(\pi)}{\sum_{\pi'} \varphi_{\pi'}(\tau) \cdot \theta_{S,O}(\pi')} =& \frac{P(\tau \mid \pi) \cdot P_S(\pi \mid O)}{P_S(\tau)} \\ =& P_S(\pi \mid \tau, O)\end{aligned}$$

To make the situation more concrete, consider again utterance 51 from Example 1. Among the topoi elicited by this utterance is the assumption that, given the choice, it's always better to kill fewer people. Let's call this utterance $\tau_3$ and let $\Delta_1(\theta_{S,O}, \varphi, \tau_3) = \hat{\theta}_{S,O}$.

We may imagine any number of personae associated with $\tau_3$, but most relevant are those personae based on different kinds of moral reasoning. In this case, $S$ believes that the *humanist* and *cold rationalist* personae give some prior probability to the evoked topos (see figure 1). Self updates their model of Other in proportion to the product of the likelihood of the topos given the persona, and the persona's prior probability for Other.

In this first-order model, $\theta_{S,O}$ has two possible interpretations:

1. It represents Self's uncertainty about which persona Other projects (but Self assumes that Other uniquely projects one persona).

2. It represents Self's belief about Other's persona tendencies—i.e., their *bricolage* (but no uncertainty is modelled).

Both of these interpretations have drawbacks. The (false) assumption that each person projects a unique persona results in inconsistency when an agent observes an interlocutor evoke both $\tau_1$ and $\tau_2$ that don't appear in any of the same personae. However, if $\theta_{S,O}$ instead represents Self's take on Other's bricolage of personae, the lack of uncertainty leaves the Bayesian belief revision given by Equation 3 unfounded. To simultaneously account for bricolage and uncertainty, we must add a second layer of analysis to the agent model.

### 3.2 Second-order model

In the second-order model, we assume that Self attributes some particular distribution over personae to Other, but that their representation captures uncertainty about exactly what distribution it is. Thus, instead of a prior over personae, $S$'s model of $O$ is a prior over distributions over personae. For this, we use a Dirichlet distribution parametrized by $K$-dimensional positive real-valued $\boldsymbol{\alpha}_{S,O}$.

The Dirichlet distribution is a probability density function defined as follows:

$$f(\theta; \boldsymbol{\alpha}_{S,O}) = \frac{1}{B(\boldsymbol{\alpha}_{S,O})} \prod_{i=1}^{K} \theta(\pi_i)^{\alpha_{S,O,i}}$$

where the domain, $\theta$, is defined on the $K$-simplex—the space of all possible categorical probability distributions in $\mathbb{R}^K$. Unlike the parameter for a categorical distribution, there is no requirement that $\boldsymbol{\alpha}_{S,O}$ sum to 1. In general, higher overall values for $\boldsymbol{\alpha}_{S,O,i}$ tend to produce flatter distributions, whereas lower values favour sparser ones. For this reason, the Dirichlet parameter is sometimes referred to as a *concentration parameter*.

A higher relative value for a given $\alpha_{S,O,i}$ means the Dirichlet is biased in favour of $\theta$'s that assign a high probability to $\pi_i$. In fact, by integrating over $\theta$, we arrive again at the marginal probability that $S$ assigns a given persona for $O$:

$$\begin{aligned}P_S(\pi_i \mid O) &= \int \mathcal{D}(\theta; \boldsymbol{\alpha}_{S,O}) \theta(\pi_i) d\theta \\ &= \frac{\alpha_{S,O}, i}{\sum \boldsymbol{\alpha}_{S,O}}\end{aligned} \tag{4}$$

As before, Self updates their model of Other based on the topos they evoked. This time, Self interprets $\tau$ by way of a particular persona—the persona *projected* by the social signal. We define the persona projected by $\tau$ (according to $S$) as the as the most likely persona, given the topos and Self's model of Other. This is given by Bayes rule and Equa-

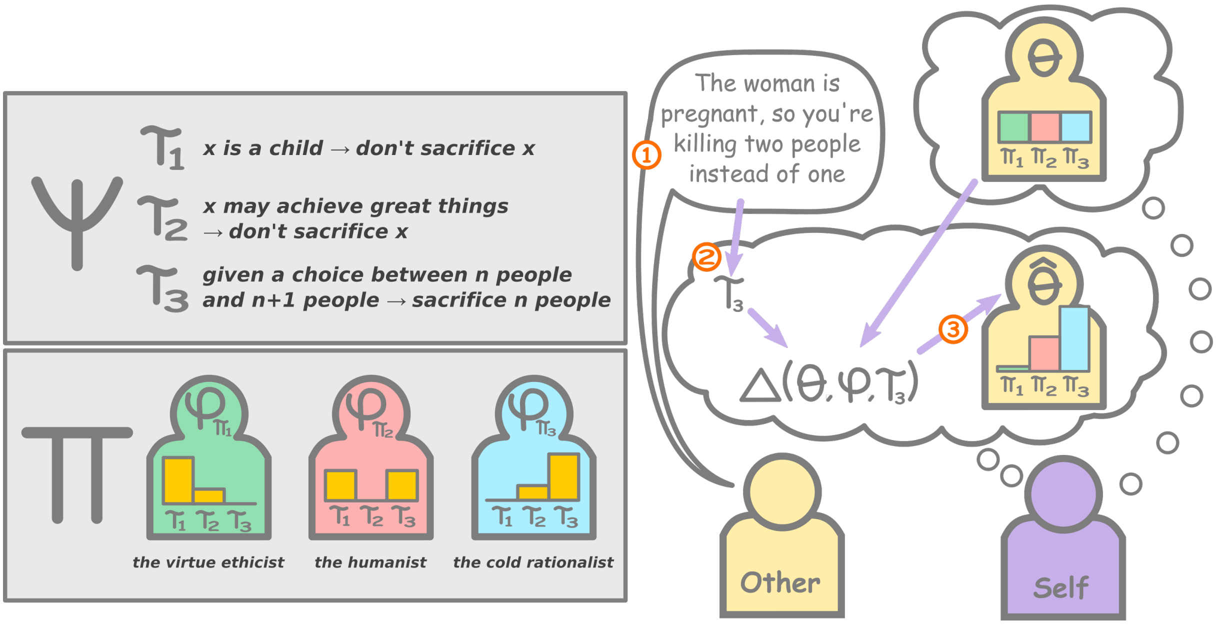


Figure 1: Using the shared topoi, personae, and topos distribution for personae (left), Self updates their representation of Other (right) as follows: (1) Other utters 1-51. (2) Self interprets 1-51 as evoking $\tau_3$. (3) Other applies the update function from Equation 3, incorporating their prior model of Other, the topos distributions for personae, and the evoked topos.

tion 4:

$$
\begin{aligned}
\mathrm{Proj}(\alpha_{S,O}, \varphi, \tau) &= \underset{i \leq K}{\operatorname{argmax}}\, P(\pi_i \mid \tau) \\
&= \underset{i \leq K}{\operatorname{argmax}}\, P(\tau \mid \pi_i) \cdot P_S(\pi_i \mid O) \\
&= \underset{i \leq K}{\operatorname{argmax}}\, \varphi_{\pi_i}(\tau) \cdot \frac{\alpha_{S,O,i}}{\sum \boldsymbol{\alpha}_{S,O}}
\end{aligned} \tag{5}
$$

Now let $\mathrm{Proj}_S(\alpha_{S,O}, \varphi, \tau) = \hat{\pi}$. The projected persona is used to update $S$'s model of $O$ as follows:

$$
\Delta_2(\alpha_{S,O,i}, \hat{\pi}) = \begin{cases} \alpha_{S,O,i} + 1 & \text{for } \pi_i = \hat{\pi} \\ \alpha_{S,O,i} & \text{otherwise} \end{cases} \tag{6}
$$

Note that the updated model $O$ is equal to the Bayesian posterior distribution, given that $\hat{\pi}$ was observed. This is a result of the conjugacy of the Dirichlet distribution over the categorical. For proof, let $\Delta_2(\boldsymbol{\alpha}_{S,O}, \tau) = \hat{\boldsymbol{\alpha}}_{S,O}$ in the following:

$$
\begin{aligned}
D(\theta, \hat{\boldsymbol{\alpha}}_{S,O}) &= \int \prod_{i=1}^{K} \theta(\pi_i)^{\hat{\alpha}_{S,O,i}} d\theta \\
&= \int \theta(\hat{\pi}) \prod_{i=1}^{K} \theta(\pi_i)^{\alpha_{S,O,i}} d\theta \\
&= P(\hat{\pi} \mid \theta) \cdot P(\theta \mid \boldsymbol{\alpha}_{S,O}) \\
&= P(\theta \mid \hat{\pi}, \boldsymbol{\alpha}_{S,O})
\end{aligned}
$$

This conjugacy result means that updating the persona model is very simple—we simply add 1 to $\boldsymbol{\alpha}_{S,O}$ in the position corresponding to the projected persona (as in Equation 6).

In $\Delta_1$, Self updates their model of Other considering all of the personae that Other *might have* been projecting by evoking $\tau$—propagating uncertainty about the projected persona to the update function. In $\Delta_2$, Self assumes that Other is using projecting the maximum likelihood (given $\tau$) persona, $\hat{\pi}$, and updates the posterior accordingly. It would be interesting to compare $\Delta_2$ to a second-order model that is uncertain about the projected persona. Unfortunately, the Dirichlet distribution is not conjugate over the likelihood, $P(\tau \mid \theta)$, meaning that the traditional Bayesian posterior, $P(\theta \mid \tau, \boldsymbol{\alpha}_{S,O})$, is not itself Dirichlet, but rather a mixture of Dirichlet distributions.

Nevertheless, the second-order model performs better than the first-order model in preliminary signaling games simulations. After ten exchanges, a second-order listener's model of the speaker is closer to the speaker's actual persona distribution than that of a first-order listener. Furthermore, as discussed in the following section, similar probabilistic models of the *category adjustment effect* make a

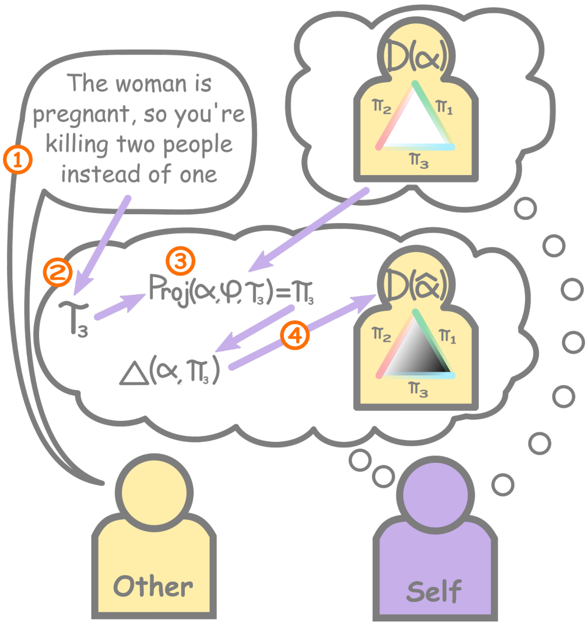


Figure 2: Using the same $\Psi$, $\Pi$, and $\varphi_\pi$'s as Figure 1, Self updates their second-order representation of Other as follows: (1) Other utters 1-51. (2) Self interprets 1-51 as evoking $\tau_3$. (3) Self interprets $\tau_3$ as projecting $\pi_3$, according to Equation 5. (4) Self updates their prior according to Equation 6.

similar assumption.

## 4 The category adjustment effect

The category adjustment effect is a phenomenon in which the perception of a stimulus is biased in the direction of the centre of the category in which it falls. Category effects are, for example, an explanation for why phonetic differences are easier to detect when they cross phoneme boundaries (Liberman et al., 1967; Feldman et al., 2009).

The category adjustment model (Huttenlocher et al., 2000), describes the category adjustment effect in explicitly Bayesian terms, with the category acting as a prior distribution over stimuli. Cibelli et al. (2016), use this model to test a version of the Sapir-Whorf hypothesis. In a series of experiments they show that the semantics of colour terms have an effect on colour perception. For example, when asked to recall the colour of a displayed colour swatch, speakers were biased towards the mean of the colour category in which the swatch fell.

Eckert (2008) defines the meaning of a linguistic variable, its *indexical field*, as the "constellation of ideologically related meanings" that arises in virtue of the variable's relationship with one or more personae. Viewed through the lens of category adjustment, the social interpretation of a linguistic variable is mediated by the social categories (personae) associated with it. In our model, idealogical relatedness is represented by the conditional distribution of topoi given a persona ($\varphi$ from §3). This distribution corresponds to the prior from the category adjustment model. This framework suggests two empirical questions for future work.

The first question concerns the propagation of uncertainty about the projected persona. Is it the case that, as in the original category adjustment model, the interpretation of a social signal is mediated by a *single nearest category* (the projected persona from §3.2), or does it take into account all of the personae that the speaker *might be* projecting (as in §3.1)?

Second, is there a category adjustment effect on the listener's judgment of *which* topos is being evoked? Since we are focused on updates to the listener's model of the speaker's persona, we don't model uncertainty about the evoked topos, but a given argument may have multiple possible warrants. It seems reasonable to assume that the listener would take their persona model of the speaker and associations between personae and topoi into account when judging which topos was evoked.

## 5 Information state update

In order to use the above technique to account for social meaning dynamics in interaction, we integrate our model with an information state update account of dialogue, an approach successfully used to model various dialogue phenomena (Larsson and Traum, 2000; Ginzburg, 2012). We see this as pointing to a general method for incorporating previous work on social meaning, for example, Burnett (2017), into an account of incremental updates of social meaning in a idealogical context. This continues the work of Breitholtz and Cooper (2019).

To represent the evolving information states of agents involved in interaction, we use dialogue gameboards (Lewis, 1979; Ginzburg, 1994; Larsson, 2002; Ginzburg, 2012). In order to account for coordination phenomena in dialogue, such as misunderstandings and clarifications, it is important that the information state of the participants are modelled as separate gameboards, representing each agent's view of the conversational game currently being played. The gameboards are split into two fields, one for information that the speaker takes to be private, one field for information that he or she takes to be shared in the dialogue. On our account dialogue participants are represented twice on the DGB. In Figure 3 we see that the shared information about the participants is just referential. The information about perceived personae of the dialogue participants can be found in the private-field of the DGB, where the labels 'other' and 'self' are associated with the corresponding individuals in the shared field. The superscripted up arrow indicates that the path points to an object three levels up in the record type.

As an interaction progresses the DGBs of the participants evolve in accordance with update rules. In Figure 4 we represent the update rule 'f$_{\text{UpdatePersonae}}$' which is a function which takes an information state and an utterance event and returns a type for the updated information state. This function is used in the action rule 'UpdatePersonae' given in Figure 5. This action rule has three conditions. The first one requires that the agent's, $S$, current information state, $s_{i,S}$, is judged by $S$ to be of some type, $T$. The second condition requires that $T$ is a subtype of the type required for $r$ in 'f$_{\text{UpdatePersonae}}$'. The third condition requires that the current utterance, $u^*$, is of the type required for $u$ in 'f$_{\text{UpdatePersonae}}$'. If these conditions are fulfilled $S$ is licensed or "afforded" (indicated by the wavy line) to make a judgement about $S$'s updated information state, $s_{i+1,S}$, namely that it of the type which $S$ judged the current information state to be of asymmetrically merged, indicated by $\boxed{\dot{\wedge}}$ with the result of applying the update function to the current information state and the current utterance. The operation of asymmetric merge on record types in TTR corresponds to priority unification in feature based systems. It will preserve all the information in both types except that if the two types have different information on a given path then the information from the second type will be in the result but not that from the first type. (See Cooper and Ginzburg, 2015 and Cooper, in prep for more details.)

These definitions rely on two types which depend on the set of topoi, $\Psi$, which are currently under consideration. The first type is *Persona*$(\Psi)$. A witness for this type is a distribution over $\Psi$. (In a more complete treatment this would just be one of a number of components that make up a persona.) That is,

> $f$ : *Persona*$(\Psi)$ iff $f$ is a function with domain $\Psi$ and range in $[0, 1]$ such that $\sum_{t \in \Psi} f(t) = 1$

The second type we use is *PersConcFunc*$(\Psi)$, the type of Persona Concentration Functions for $\Psi$. This is defined as

$$(\mathit{Persona}(\Psi) \rightarrow \mathit{Real}_{(0,\infty+)})$$

That is, *PersConcFunc*$(\Psi)$ is the type of functions from distributions over $\Psi$ to positive real numbers greater than 0.

## 6 Conclusion

In this paper we present a probabilistic model that accounts for the social meaning of topoi. We suggest that, as in the case of colour perception, the interpretation of social signals is subject to a category adjustment effect induced by social categories, or personae. Finally, we incorporate this model into an integrated account of linguistic interaction. We do this by defining a TTR update rule which is referenced in an action rule showing how speakers change their model of their interlocutor based on social signalling.

We see three major avenues for future work stemming from the basic model presented here. First, systems of social meaning are not monolithic or static—we should account for variation and change in the available personae, topoi, and the associations between the two. Second, this model could be used in a game-theoretic analysis of argumentation. Based on the persona that a speaker projects, which topoi should an interlocutor use to warrant their arguments? Finally, as discussed in §4, how does the listener's model of the speaker persona affect which topos they interpret as warranting the speaker's argument?

$$\left[\begin{array}{ll}
\text{private:} & \left[\begin{array}{ll}
\text{topoi:set}(\textit{Topos}) & \\
\text{participants:} & \left[\begin{array}{ll}
\text{other:} & \left[\begin{array}{l}
\text{x=}\Uparrow^{3}\text{shared.participants.O:}\textit{Ind} \\
\text{pcf:}\textit{PersConcFun}(\Uparrow^{2}\text{topoi})
\end{array}\right] \\
\text{self:} & \left[\begin{array}{l}
\text{x=}\Uparrow^{3}\text{shared.participants.S:}\textit{Ind} \\
\text{pcf:}\textit{PersConcFun}(\Uparrow^{2}\text{topoi})
\end{array}\right]
\end{array}\right]
\end{array}\right] \\
\text{shared:} & \left[\begin{array}{ll}
\text{topoi:} & \left[\begin{array}{ll}
\text{prev:}\textit{RecType} & \\
\text{curr:} & \left[\begin{array}{l}
\text{topos:}\textit{Topos} \\
\text{speaker:}\textit{Ind}
\end{array}\right]
\end{array}\right] \\
\text{participants:} & \left[\begin{array}{l}
\text{O:}\textit{Ind} \\
\text{S:}\textit{Ind}
\end{array}\right]
\end{array}\right]
\end{array}\right]$$

Figure 3: Representation of participants on the DGB

$$\lambda r{:}\left[\begin{array}{ll}
\text{private:} & \left[\begin{array}{ll}
\text{topoi:}\mathrm{set}(\textit{Topos}) & \\
\text{participants:} & \left[\begin{array}{ll}
\text{other:} & \left[\begin{array}{l}
\text{x:}\textit{Ind} \\
\text{pcf:}\textit{PersConcFunc}(\Uparrow^{2}\text{topoi})
\end{array}\right]
\end{array}\right]
\end{array}\right]
\end{array}\right] .$$

$$\lambda u{:}\left[\begin{array}{ll}
\text{s-event:} & \left[\begin{array}{l}
\text{sp=}r\text{.private.other.x:}\textit{Ind} \\
\text{topos:}\textit{Topos} \\
\text{proj-pers=proj(topos, s-event.sp):}\textit{Topos}
\end{array}\right]
\end{array}\right] .$$

$$\left[\begin{array}{ll}
\text{private:} & \left[\begin{array}{ll}
\text{topoi=}r\text{.private.topoi:}\mathrm{set}(\textit{Topos}) & \\
\text{participants:} & \left[\text{other:}\left[\text{pcf=}\Delta_{2}(r\text{.private.participants.other.pcf, }u\text{.proj-pers):}\textit{PersConcFunc}(\Uparrow^{2}\text{topoi})\right]\right]
\end{array}\right]
\end{array}\right]$$

Figure 4: $\mathrm{f}_{\textsc{UpdatePersonae}}$

$$\begin{array}{c}
s_{i,S} :_S T \\[1em]
T \sqsubseteq \left[\begin{array}{ll}
\text{private:} & \left[\begin{array}{ll}
\text{topoi:}\mathrm{set}(\textit{Topos}) & \\
\text{participants:} & \left[\begin{array}{ll}
\text{other:} & \left[\begin{array}{l}
\text{x:}\textit{Ind} \\
\text{pcf:}\textit{PersConcFunc}(\Uparrow^{2}\text{topoi})
\end{array}\right]
\end{array}\right]
\end{array}\right]
\end{array}\right] \\[1em]
u^{*} :_S \left[\begin{array}{ll}
\text{s-event:} & \left[\begin{array}{l}
\text{sp=}s_{i,S}\text{.private.other.x:}\textit{Ind} \\
\text{topos:}\textit{Topos} \\
\text{proj-pers=proj(topos, s-event.sp):}\textit{Topos}
\end{array}\right]
\end{array}\right] \\
\hline
s_{i+1,S} :_S T \boxed{\underset{\cdot}{\wedge}} \mathrm{f}_{\textsc{UpdatePersonae}}(s_{i,S})(u^{*})
\end{array}$$

Figure 5: UpdatePersonae: Updating personae on the DGB according to the second-order model

## References


Jean-Claude Anscombre et al. 1995. Théorie des topoï. *Hermès*, 15:185–198.

Jon Barwise and John Perry. 1983. *Situations and Attitudes*. MIT Press.

Ellen Breitholtz. 2014. Reasoning with topoi - towards a rhetorical approach to non-monotonicity. In *Proceedings of the 50:th anniversery convention of the AISB*, pages 190–198. AISB.

Ellen Breitholtz and Robin Cooper. 2019. Integrating personae in a TTR account of interaction. Presented at Integrating Approaches to Social Meaning.

Heather Burnett. 2017. Signalling games, sociolinguistic variation and the construction of style. *Linguistics and Philosophy*, pages 1–32.

Emily Cibelli, Yang Xu, Joseph L. Austerweil, Thomas L. Griffiths, and Terry Regier. 2016. The Sapir-Whorf Hypothesis and Probabilistic Inference: Evidence from the Domain of Color. *PLOS ONE*, 11(7):e0158725.

Robin Cooper. in prep. From perception to communication: An analysis of meaning and action using a theory of types with records (TTR). Draft of book chapters available from `https://sites.google.com/site/typetheorywithrecords/drafts`.

Robin Cooper and Jonathan Ginzburg. 2015. Type theory with records for natural language semantics. In Shalom Lappin and Chris Fox, editors, *The Handbook of Contemporary Semantic Theory*, second edition, pages 375–407. Wiley-Blackwell.

Oswald Ducrot. 1980. *Les Échelles Argumentatives*. Les Éditions de Minuit.

Penelope Eckert. 1989. *Jocks and burnouts: Social categories and identity in the high school*. Teachers college press.

Penelope Eckert. 2000. *Linguistic Variation as Social Practice: The Linguistic Construction of Identity in Belten High*. Number 27 in Language in Society. Blackwell Publishers, Malden, Mass.

Penelope Eckert. 2008. Variation and the indexical field. *Journal of Sociolinguistics*, 12(4):453–476.

Penelope Eckert. 2012. Three waves of variation study: The emergence of meaning in the study of variation. *Annual Review of Anthropology*, 41:87–100.

Naomi H. Feldman, Thomas L. Griffiths, and James L. Morgan. 2009. The influence of categories on perception: Explaining the perceptual magnet effect as optimal statistical inference. *Psychological Review*, 116(4):752–782.

Michael C. Frank and Noah D. Goodman. 2012. Predicting pragmatic reasoning in language games. *Science*, 336(6084):998.

Jonathan Ginzburg. 1994. An update semantics for dialogue. In *Proceedings of the Tilburg International Workshop on Computational Semantics*, Tilburg, The Netherlands.

Jonathan Ginzburg. 2012. *The Interactive Stance: Meaning for Conversation*. Oxford University Press.

Richard A Hudson. 1996. *Sociolinguistics*. Cambridge university press.

J. Huttenlocher, L. V. Hedges, and J. L. Vevea. 2000. Why do categories affect stimulus judgment? *Journal of Experimental Psychology. General*, 129(2):220–241.

William Labov. 1963. The Social Motivation of a Sound Change. *WORD*, 19(3):273–309.

Staffan Larsson. 2002. *Issue-Based Dialogue Management*. PhD Thesis, University of Gothenburg, Gothenburg, Sweden.

Staffan Larsson and David Traum. 2000. Information state and dialogue management in trindi dialogue move engine tool kit. *Natural Language Engineering*, 6:323–240.

Mary Lavelle, Patrick GT Healey, and Rosemarie McCabe. 2012. Is nonverbal communication disrupted in interactions involving patients with schizophrenia? *Schizophrenia bulletin*, 39(5):1150–1158.

David Lewis. 1970. General Semantics. *Synthese*, 22(1/2):18–67.

David Lewis. 1979. Scorekeeping in a Language Game. In Rainer Bäuerle, Urs Egli, and Arnim von Stechow, editors, *Semantics from Different Points of View*, Springer Series in Language and Communication, pages 172–187. Springer, Berlin, Heidelberg.

A. M. Liberman, F. S. Cooper, D. P. Shankweiler, and M. Studdert-Kennedy. 1967. Perception of the speech code. *Psychological Review*, 74(6):431–461.