Communicating Causality

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1 Project Overview

Knowledge of causal processes is vital for all aspects of our lives, from mundane consumer choices to high-impact socio-political decision making. Much of our causal knowledge is acquired not from individual experience, but from cultural transmission via language. While theorists have amassed a large body of philosophical and psychological understanding about causation, surprisingly little research has been devoted to a theoretical understanding of the processes that underlie communication of causal information and the role of the linguistic signal in this transmission.

The main objective of this project is to apply methods and tools from experimental pragmatics to shed light on a wide range of puzzles about causal language and cognition. We introduce a new pragmatic framework, the "CommuniCause" approach, which makes new and empirically testable predictions and offers a unified explanation for a number of disparate phenomena, both old and new. CommuniCause brings together two important strands of research that have been isolated until now, in a way that will benefit both communities. It draws on established philosophical theorizing and recent computational models of individual causal cognition, but is distinguished by its focus on linguistic factors: the speaker's choice among the variety of linguistic expressions available, and the impact that this choice has on a recipient's pragmatic interpretation. CommuniCause promises advances to linguistic pragmatics as well, by confronting theories and models with a range of intricate puzzles that have not previously been treated from a linguistic perspective.

The project explores the extent to which this pragmatic approach can explain key features of causal inference. One is the problem of causal selection, how we identify one event as the cause of another. When two cars collide, why do we think that the driver that ran the red light was "the cause" of the accident, rather than the safe but unlucky driver? Another puzzle involves the interpretation of correlational evidence: Why do people interpret "Aspartame is linked to cancer" as implying that aspartame consumption causes cancer, and not the other way around? The CommuniCause perspective suggests treating these puzzles as traces of pragmatic reasoning: in interpreting what others have said, we can use what we know about how speakers make choices to infer what they are probably trying to convey.

In a number of experiments, we will explore the detailed predictions of the framework for how speakers make complex choices among various ways of expressing themselves, how causal

and non-causal language is interpreted in context, and how linguistic framing influences causal reasoning processes. If these results validate our approach, we can conclude that language matters in causal thought and talk to a much greater extent than previously realized.

A particularly interesting contribution of this project with important practical implications is the juxtaposition of causal and non-causal language. We investigate the conditions under which speakers choose non-causal expressions (e.g., "If A, then B" or "A is associated with B") to convey causal meaning, and the circumstances under which listeners infer causal information from expressions that are merely correlational. Contrary to widespread conception, we do not consider causal inference from non-causal language a fault or an irrationality. Rather, the CommuniCause approach is able to shed light on the efficiency and systematicity of this phenomenon, thereby providing a better grip on avoiding miscommunication between domain experts and lay audiences in important areas like health communication.

2 Vision

Understanding the causal structure of the world is an issue of fundamental importance in human life. Our ability to infer such relationships is vital in making intelligent decisions on practical everyday issues: for instance, whether I should feed my children vegetables or sweets depends on what I take to be the likely causal effects of these choices. Acquiring causal information is also a basic goal of many academic pursuits, and is critical for global policy making, among other domains. Accordingly, there is a vast academic literature on causation, with many of the key questions and initial answers coming from philosophy (Mill, 1856; Hart and Honoré, 1959; Lewis, 1973; Hitchcock, 2020).

The study of causation has also flourished in recent cognitive science (Gopnik et al., 2004; Griffiths and Tenenbaum, 2009). However, this literature focuses primarily on individual cognition and learning from direct experience, with relatively little attention to the social transmission of causal information. This is a major lacuna: the ability to disseminate complex causal knowledge beyond the scope of individual experience is a unique human skill, vital to the accumulation of cultural knowledge across generations (Henrich, 2016). Natural language is a crucial tool that is specialized for this task. Connecting the study of causal cognition with natural language pragmatics thus promises to shed important light on both fields.

Human languages have sophisticated repertoires for talking about causes and effects, allowing us to convey causal relationships to individuals who have not directly witnessed the evidence for them. There has been considerable work in linguistics on structural aspects of causal language—their syntax and semantics—but no precise, comprehensive framework has been offered for understanding how both causal and non-causal language can be used to transmit causal knowledge. While important first steps have been taken in this direction (Hilton, 1990; Beller and Gerstenberg, 2023), we currently lack a fully specified theory that integrates our understanding of causal language and causal cognition with the rich existing body of research on natural language pragmatics and language understanding. By bringing these areas together in a collaborative interdisciplinary project, we seek to contribute a formally and empirically supported explanation of why speakers convey causal information with specific linguistic expressions, and of why listeners draw particular causal

inferences from both causal and non-causal language.

We therefore introduce the CommuniCause framework as a source of ideas and testable hypotheses about the way that linguistic, cognitive, and social/communicative factors interact in the communication of causal information. The framework is rooted in linguistic theory and experimental pragmatics, but draws on insights on causation and causal meaning from philosophy, psychology, computer science, and beyond. CommuniCause treats communication as an approximately optimal solution to the problem of efficiently communicating relevant causal knowledge between two or more minds within the limits imposed by natural language. Causal communication is therefore a compression problem, balancing the need to convey practically important information against the limitations of time and energy imposed by the linguistic channel (Kemp, Xu, et al., 2018; Zaslavsky et al., 2018). Equally, it is a matter of strategic choice, with speakers and listeners reasoning about each others' choices and strategies in order to pack as much useful information as possible into the linguistic signal (Frank and Goodman, 2012; Franke, 2017).

CommuniCause generates predictions, some of them novel, about how speakers choose linguistic forms to convey causal information and how listeners interpret them. At the most basic level, we predict that causal talk is influenced by shared knowledge of interlocutors, the practical relevance of information, and recoverability of causal meaning and other important contextual information from a limited linguistic signal. More specifically, the view of linguistic communication as compression also emphasizes a crucial role of linguistic form, leading to predictions about causal framing, namely how and why small changes in formulation can lead to different mental models of the causal facts. In short: we submit that in understanding causation, **language matters** to a much greater extent than has been appreciated to date.

Another important prediction is that non-causal language will frequently have causal implications, a phenomenon that is widely observed but often misdiagnosed as a cognitive error. This project will explore how and why people draw causal inferences from non-causal language and the contextual and linguistic factors that influence this process. At the same time, it will allow us to draw out practical steps for improving public-facing communication about causation, correlation and risk. The final phase of the project focuses on conveying the project's findings to a non-specialist audience and flesh out its usefulness for this specific application. We will explore ways to help doctors and other experts engaged in risk communication to avoid miscommunications by better understanding how causal and statistical language is understood in ordinary use.

Our hope is that research in experimental and computational pragmatics will benefit from insights generated by engagement with a new research area that is more complex than most previous areas of focus, and by exploring several under-utilized experimental techniques that we explore. Conversely, research on causation can benefit from a raft of novel hypotheses generated by the linguistic orientation of CommuniCause, and from the use of linguistically-aware experimental methods drawn from experimental pragmatics.

CommuniCause is motivated by the idea that many aspects of how humans think and reason about causality are influenced by language, because this is the primary method we have available for the social transmission of causal information. Theories of causal talk and thought that draw carefully on what we know about pragmatic communication, backed up by experimental methods drawn from the rich body of research in experimental pragmatics, promise to shed new light on the

nature of causal cognition and communication.

3 Approach

The CommuniCause project starts from a core claim of linguistic pragmatics (Grice, 1975; Sperber and Wilson, 1995): language production is shaped by a balance between informativity and efficiency. That is, speakers strive to convey enough relevant information for practical purposes, leaving out what is already known, practically irrelevant, or contextually recoverable. Listeners, in turn, enrich interpretation using contextual information and knowledge of how speakers choose utterances.

The importance of conversational pragmatics for core phenomena in the study of causation has been noted in a small but important body of work (van Fraassen, 1980; Lewis, 1986; Hilton, 1990; Driver, 2007; Swanson, 2010). This project builds on recent developments in experimental and computational pragmatics, using extensive experimental methods and probabilistic modeling to shed new light on old puzzles about causation, and to explore interesting new predictions and phenomena.

3.1 The CommuniCause framework

For transparency and conceptual precision, the CommuniCause approach draws on formal, computationally implemented probabilistic models, as in the Rational Speech Act (RSA) framework (Frank and Goodman, 2012). In prior work, we explored an RSA model in which agents communicate causal information with conditionals (Grusdt, Lassiter, and Franke, 2022). This project expands the empirical focus to a wide range of causal and non-causal language, considering effects of context and psycholinguistic factors on causal communication.

CommuniCause uses Structural Causal Models (SCMs, Pearl 2009) to model information flow. SCMs consist of a graph showing causal relationships among variables, together with specifications of how values of variables are determined (Fig. 1). This framework has been extremely productive in linguistics, philosophy, psychology and elsewhere (e.g., Danks, 2014; Lassiter, 2017). CommuniCause assumes that utterances are chosen to convey relevant aspects of a speaker's beliefs about the causal structure of the world. To model these beliefs, we follow a successful line of research in which causal judgments and predictions are obtained by mentally simulating (sampling) possible world states in a mentally represented SCM (Icard et al., 2017; Gerstenberg, 2022; Quillien and Lucas, 2023).

These insights from probabilistic pragmatics and causal cognition lead to the (simplified) picture of causal communication in Fig. 1. A speaker selects an expression based on (i) their beliefs about the causal facts, (ii) a simulated model of a literal listener, who-based on their (world and contextual) knowledge—stochastically associates each expression with compatible SCMs, and (iii) a utility function that determines how successful each expression is. A pragmatic listener reasons about the speaker's encoding strategy to infer: (i) the speaker's causal beliefs, and (ii) other parameters, e.g., what the speaker considers relevant.

Key predictions of CommuniCause are that expression choice and interpretation depend on the knowledge states of interlocutors, practical relevance of information, and the recoverability of

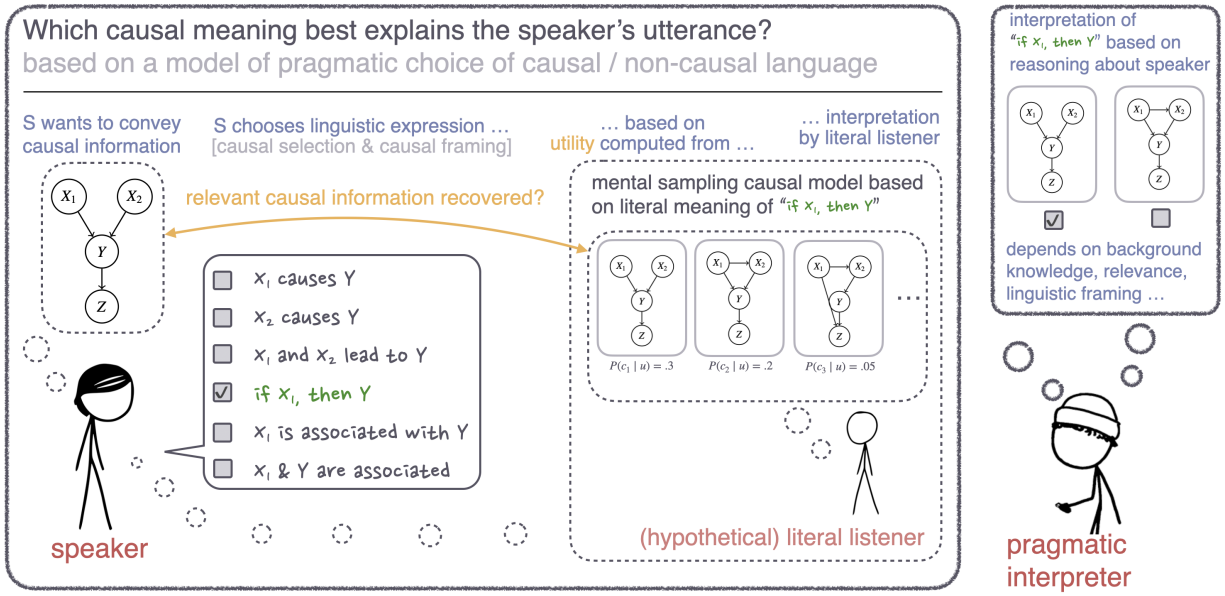

Figure 1 Schematic overview of pragmatic communication of causal information in the CommuniCause approach.

adequate causal models from the given expressions. While previous work has shown that some of these factors matter (van Fraassen, 1980; Hilton, 1990; Slugoski et al., 1993), CommuniCause offers a unified explanatory framework and makes more extensive and precise predictions once modeling assumptions are fleshed out in detail (WP5). For example, to model relevance, we adopt Question-under-Discussion (QUD) theory from linguistic pragmatics (Beaver et al., 2017), but also consider related gradient measures (van Rooij, 2001).

The explanatory power of CommuniCause will be tested on well-studied puzzles and under-explored phenomena. A long-standing issue is the problem of causal selection (Mill, 1856; Hart and Honoré, 1959; Quillien and Lucas, 2023). While an enormous number of factors contribute causally to any particular event Y, very few are intuitively acceptable in the frame "___ caused Y." CommuniCause envisages a unified explanatory account of causal selection (WP1, WP3) that also carries over to the neglected issue of vertical causal selection (WP1). It predicts that non-causal language can carry causal information (WP2), a topic that has not received systematic attention. While previous experimental work has almost exclusively investigated meta-level intuitions about adequacy of descriptions in particular situations, CommuniCause explicitly addresses interpretation and also explores the speaker's production perspective (WP4).

A further prediction of CommuniCause is that causal framing can have far-reaching consequences. The linguistic form of sentences makes a crucial contribution to the causal information they convey by constraining QUDs, determining alternatives, conditioning awareness of possibilities,

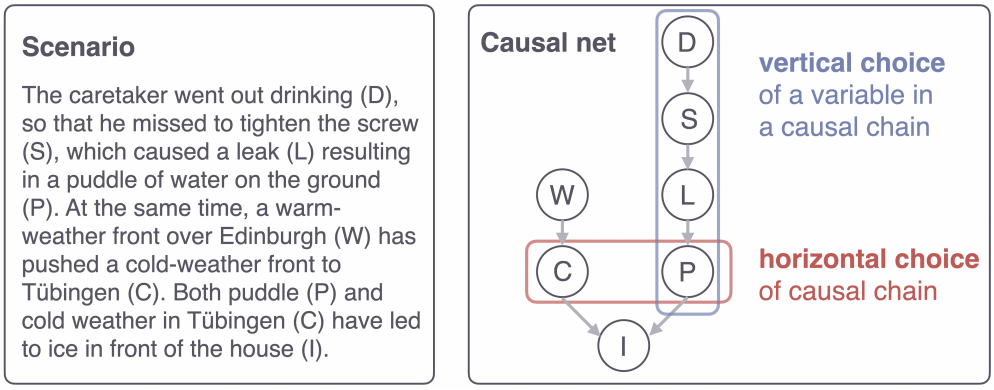

Figure 2 Example illustrating different dimensions of causal selection. While all variables are causally relevant to ice (I), a single variable is typically cited when others are recoverable or irrelevant.

and influencing sampling-based inference. The role of linguistic form in causal communication underscores our claim that language matters in the study of causation to a much greater extent than previously appreciated.

3.2 CommuniCause sub-projects

WP1: Pragmatics of causal language. WP1 focuses on the pragmatics of causal language, in particular the problem of causal selection (see above):

RQ WP1: Can CommuniCause explain key patterns of causal selection?

Horizontal causal selection involves the choice among a set of causal chains which jointly influence an event. In Figure 2, this corresponds to the choice to report on the chain ending with C, the chain ending with P, or both. Horizontal selection tends to favor less predictable influences: for example, in wintertime we are inclined to identify the unexpected puddle as the cause of the ice rather than the expected cold weather.

Simulation-based models of causal strength (Icard et al., 2017; Quillien and Lucas, 2023) account for the effects of expectations, but do not explain other pragmatic influences on causal selection. For instance, Slugoski et al. (1993) show experimentally that when X and Y jointly cause Z, and the listener knows about X only, speakers preferentially cite Y as the cause of Z. Speakers do not simply select the "stronger" cause in a fixed psychological sense, but prefer causes that are informative to their listeners, as a pragmatic theory would predict. Other results point in the same direction: e.g., causal selection is sensitive to the question that has been asked (Hilton, 1990). WP1 will integrate formal models of causal strength into the comprehensive CommuniCause model.

Vertical causal selection, involving the choice among events in a chain, has received much less attention (Swanson, 2010). In Figure 2, several events from the chain ending with P could be selected, depending on context. If an accident occurred and a policeman asks why there was ice, it

would be uncooperative to report on the puddle rather than the caretaker's carelessness. However, current models of causal selection predict that the last element in a nondeterministic causal chain always has greatest causal strength. A major deliverable of WP1 is to develop a solution to this problem, showing that the much-discussed problem of causal selection cannot be resolved without careful attention to pragmatic factors:

Prediction WP1.1 (mutual knowledge): Mutual knowledge of interlocutors influences the informativity of causal statements, and therefore their probability of being selected.

Prediction WP1.2 (relevance): Relevance plays a decisive role in causal selection. If every causal claim is an answer to an implicit question (Hart and Honoré, 1959; van Fraassen, 1980), different questions, triggered by different practical interests, make different causal explanations appropriate.

Prediction WP1.3 (recoverability): Efficient communication omits recoverable material. In horizontal selection, predictable events tend to be omitted. In vertical selection, events are selected that allow listeners to recover decision-relevant aspects of the full causal model.

Prediction WP1.4 (linguistic form): Choice of expression subtly influences the representation of the causal process. E.g., finely specified event descriptions ("Ball A's speed caused B to go through the gate") trigger different alternatives and mental simulations than granular descriptions ("A caused B to go through the gate").

In close collaboration with WP4-5, WP1 will systematically test qualitative predictions in a series of experiments of increasing complexity (Fig. 2). We start with simple experiments in which participants select a description of a scene from a curated list. The scene will be presented verbally, pictorially, or as a video (see WP4). The situations described will systematically manipulate contextual recoverability and relevance, in close collaboration with the modeling project WP5. Effects of linguistic form will be tested by drawing on related investigations in WP2-3 and production results from WP4.

WP2: Pragmatics of non-causal language. People readily infer causal relationships from non-causal language, including statements of correlation, in apparent violation of the mantra "Correlation does not imply causation" (Gershman and Ullman, 2023). One prominent interpretation of this tendency points to systematic errors in human judgment (Tversky and Kahneman, 1982; Ariely, 2008). In contrast, our previous work showed that causal inferences can arise rationally from non-causal language (Grusdt, Lassiter, and Franke, 2022; Lassiter and Franke, 2024). WP2 will therefore ask:

RQ WP2: How and why do non-causal expressions convey causal information?

Concrete predictions to be tested include:

Prediction WP2.1 (world knowledge): World knowledge conditions causal inferences from non-causal language by influencing plausibility and informativity as well as QUD choice.

Prediction WP2.2 (relevance): If a listener needs causal information to make a decision, it would be uncooperative to provide merely correlational information unless it can inform causal inferences. Therefore, we expect practical relevance of information to have an impact on causal inferences from non-causal language.

Prediction WP2.3 (recoverability): Speakers preferentially use correlational language to convey causal knowledge when the listener is able to construct a bridging inference (Clark, 1977) to recover the intended causal claim from context.

Prediction WP2.4 (linguistic form): Since linguistic form can signal aspects of relevance (such as the QUD, and alternative expressions), we predict effects on causal inferences from non-causal language as well.

Preliminary results provide preliminary support for these predictions (Lassiter & Franke, 2024). Replicating a result of Gershman and Ullman (2023), we found that participants interpreting "A is associated with B" mostly (68%) selected B as the cause. When we looked at "A and B are associated", there was a stark difference: only 30% chose B in this case. We hypothesize that this pattern can be understood in terms of the effect of subjecthood on topicality (Reinhart, 1981), which in turn constrains the QUD (Beaver et al., 2017). If so, effects of form are interpretable only within a linguistic theory of information structure. Indeed, a second pilot found a large effect of a different information-structural manipulation ("as for" contrastive topic). In a third experiment, when participants where informed that A or B was a drug or that A or B was a disease, their choices were very strongly influenced, dominating the previously observed position effects. In a further set of experiments, we have found that participants are sensitive to the background purpose of communications in deciding whether to interpret correlational information as implying causal directionality. This world-knowledge effect is readily understood within CommuniCause: the category of the objects influences whether questions about causes vs. effects are more informative.

WP2 will expand on these initial experiments to probe syntactic and information-structural effects with grammatically diverse expressions (e.g., "linked to/are linked", "related to/are related", "goes together with"). In lockstep with WP1 and WP4, we will perform contextual manipulations of world knowledge, relevance, and recoverability in suitable experimental paradigms (see WP4) with careful controls. In collaboration with WP4, we will adapt psycholinguistic methods to investigate predictions around recoverability, which we hypothesize to explain why speakers frequently cite correlations when causal inferences are intended.

WP3: Explaining the relevance of prescriptive norms. While WP1 explores effects of statistical expectations on causal selection, recent work has shown that moral/prescriptive norms have similar effects (Hitchcock and Knobe, 2009). Mental-simulation accounts of causal strength can make room for this result by assuming that norm-conforming situations are oversampled, but this does not explain why prescriptive norms have this puzzling effect. Alternatively, pragmatic accounts have been suggested (Driver, 2007) but not worked out in convincing detail. Empirical evidence is mixed. Hitchcock and Knobe (2009) find an effect of prescriptive norms even when they are claimed not to be contextually relevant, but Samland and Waldmann (2016) show that the prescriptive effects can

be eliminated by a manipulation of QUD-based relevance. WP3 will use CommuniCause to resolve this controversy:

RQ WP3: Can effects of prescriptive norms, and their putative contextual variability, be explained by conversational pragmatics?

CommuniCause does not issue a "yes" or "no" answer to this question, but provides a new conceptual framework and novel empirical avenues for resolving it. Concretely, WP3 explores:

Prediction WP3.1 (Mutual Knowledge): Causal selection is sensitive to the listener's information (Slugoski et al., 1993). We will test a novel prediction: if all causal facts are known, causal statements predominantly convey prescriptive norms.

Prediction WP3.2 (Relevance): Experimental manipulations targeting our QUD inference component should affect the importance of prescriptive norms. For instance, modifying the practical decision context may render a QUD about responsibility more or less relevant than one about mechanisms.

Prediction WP3.3 (Linguistic form): We expect effects of linguistic forms which variably signal information structure and QUD-compatibility (Samland and Waldmann, 2016). We will explore a variety of further manipulations, including topicality manipulations and linguistic framing of equivalent event descriptions (Kahneman and Miller, 1986).

Prediction WP3.4 (Beyond "cause"): The literature on prescriptive norms in causal selection has focused entirely on the item "cause". A pragmatic theory makes an underexplored prediction: we should find related effects with a wide variety of causal language—"make", "enable", "affect", "break", "shatter", among others—and also in causal inference from non-causal language (WP2).

Methodologically, WP3 is tightly integrated in the workflow of the other experimental WPs (Fig. 2). We expect it to generate one journal paper each year, distributed across the relevant disciplines.

WP4: Experimental designs and expression choice . WP4 has two roles: to complement previous WPs with a focus on expression choice, and to support them with experimental materials. As for speaker production, WP4 asks:

RQ WP4: Which contextual factors govern the choice between causal and non-causal language, type vs. token causation, and the choice between ways of identifying events (e.g., the choice between "the ball caused" and "the speed/trajectory of the ball caused")?

To address these issues WP4 will collect data from speaker expression choice experiments. To allow for relatively flexible, but still controllable choice spaces, we adapt the refrigerator magnet task from our prior work on conditionals (Grusdt and Franke, 2021) to the domain of causal language. This task offers participants a set of words or constructions which they can use to build sentences. The advantage of this approach is that it strikes a good balance between free text generation and control on what descriptions are useful for the experimental purpose. WP4 will run pilot studies to gauge which set of expressions is most conducive. Results from WP4 will tie in directly with

the more interpetation-based perspective of other WPs. For example, if WP4 finds that speakers tend to choose non-causal language even when communicating causal information is important, this supports the hypotheses of WP2 that inferring causal information from non-causal language can be rational.

Moreover, WP4 contributes to all previous WPs by developing, testing and implementing material for different kinds of experimental stimuli and designs that adequately manipulate important contextual factors, such as knowledge, relevance and recoverability. In keeping with the previous literature, we will use text-based vignettes (Samland and Waldmann, 2016; Icard et al., 2017), and image-based stimuli (Quillien and Lucas, 2023). We also use stimuli that rely on intuitive physics, showing animations of moving objects, possibly stopping the animations at strategic moments to trigger uncertainty about the future (Gerstenberg, 2022).

By supporting the workflow of all other experimental WPs, WP4 adds coherence to the project, but also ensures that the PhD student shepherding WP4 contributes to the other experimental projects as a co-author. On top of that, WP4 will also generate at least two journal publications on its own. Finally, the results from the production studies will be released as an openly available corpus of pragmatic language production, and all experimental methods will be openly released as reusable components of the magpie framework for browser-based experiments (Franke, Ji, et al., 2021).

WP5: Probabilistic modeling . Complementing the empirical and conceptual work in other WPs, WP5 will flesh out the assumptions of CommuniCause in computational probabilistic models, drawing out precise qualitative predictions of the approach. WP5 will draw out the contribution of CommuniCause to formal pragmatics most clearly: modeling the communication of causal information raises fundamental questions for linguistic theory—for instance, regarding the linguistic (Katzir, 2007) and conceptual alternatives (Buccola et al., 2021) activated during causal communication.

WP5 is structured to consecutively cover increasingly complex cases.

Extending a base model from prior work (Grusdt, Lassiter, and Franke, 2022), we cover larger causal models and a wider range of linguistic expressions. We then incorporate divergences between interlocutors' knowledge (Goodman and Stuhlmüller, 2013), as well as QUD-based relevance (Kao et al., 2014) and numerical measures of relevance (van Rooij, 2001; Franke, de Jager, et al., 2012). The notion of recoverability—while intuitively accessible and readily manipulated in experiments—is challenging to flesh out precisely in computational terms. Our approach combines insights from work on unawareness in game theory and formal epistemology (Heifetz et al., 2006; Franke, 2014) with the notion of "model expansion" from cognitive science (Rutar et al., 2022). The idea is to define the "recoverability probability" of coming to mentally represent a particular causal model C (Kemp, Goodman, et al., 2010). In language understanding, we hypothesize that this probability will depend on (i) how different C is from the set of causal nets the listener already represents, and (ii) the prior probability of C. The latter incorporates both prior world knowledge and a preference for simpler models (Gopnik et al., 2004).

Public engagement . Because causal knowledge is vital to effective decision-making, an understanding of causal communication is necessary for effective public messaging around healthcare, disaster management, and other risky decision contexts (Naik et al., 2012; Jones, 2013)). CommuniCause offers new insights into the complex strategies that ordinary language users adopt in causal communication. Causal communication will be most effective when experts understand these strategies and employ them effectively, rather than relying on technical concepts of statistics and specialized jargon. The results of CommuniCause can therefore offer practical lessons to improve communication between scientists, policy-makers and the public.

In the final stages of the project, the whole team will therefore write a non-technical position paper aimed at Communication Research or a similar high-impact journal in applied communications. Focusing on conveying causal information in healthcare contexts, but drawing out broader lessons, this paper will summarize the approach and empirical findings of CommuniCause, and will formulate actionable advice for how to communicate causal information clearly and effectively drawn from the results of the work packages described above.

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