Reasoning in multiparty dialogue involving patients with schizophrenia

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1 Introduction

Interacting with others frequently involves making common-sense inferences linking context, background knowledge and beliefs to utterances in the dialogue. As language users we are generally good at this kind of dialogical reasoning, and might not even be aware we are involved in it while we engage in conversation. However, sometimes it is not obvious how a particular contribution should be interpreted in terms of the underpinning assumptions warranting an inference. In dialogue involving participants who demonstrate atypical linguistic behaviour, such as patients with schizophrenia, the effects may be even more marked.

In this paper we will discuss some theoretical tools for modelling reasoning in dialogue that also allow for incoherence and misunderstanding between dialogue participants. We suggest using an information state update approach where dialogue game boards cast in TTR (a type theory with records, see section 2.3) are used to model the individual takes of the dialogue for each dialogue participant throughout a reasoning sequence. Our approach focuses on *topoi* – underpinning warrants – that are evoked by *enthymematic* arguments in the dialogue, and suggests that participants drawing on different topoi may interpret the same argument in different ways.

As part of the Dialogical Reasoning in Patients with Schizophrenia (DRiPS) project (Breitholtz et al., 2015), we aim to apply these techniques to a population in which both communication and reasoning are generally known to be impaired – namely patients with schizophrenia (see section 2.2). In addition we want to explore the possibility that patient speech may differ from non-patient speech in subtle but measurable ways that do not necessarily lead to overt disruptions or lack of cohesion.

1.1 Outline

The outline of the chapter is as follows:

First, we give an overview of work on reasoning in dialogue, interaction involving patients with schizophrenia, and gameboard semantics. We will then analyse some relevant sequences of a corpus of interactions involving patients with schizophrenia, which provide examples of two different argumentation strategies. We analyse the selected sequences focusing on reasoning, but also how reasoning in the material interacts with other dialogue phenomena such as turn taking, grounding and feedback. We describe some aspects of the reasoning in our excerpt using a game board semantics cast in TTR. Finally we draw some conclusions about how a model including enthymemes and topoi can be used to describe and predict some features of dialogues which may lead to different interpretations.

2 Background

2.1 Reasoning in dialogue

In addition to the traditional inter- and intrasentential structures normally assumed in linguistic theory such as questions, dialogue requires us to deal with phenomena such as clarifications, repair, overlap and split utterances. These can all be linked to reasoning in dialogue (Jackson and Jacobs, 1980; Breitholtz and Cooper, 2011; Breitholtz, 2014; Breitholtz and Howes, 2015). Reasoning in dialogue is *enthymematic*, that is, the arguments presented lack some premises which would be required in a fully logical chain of reasoning. Instead, enthymematic arguments (*enthymemes*) rely on notions or warrants in the minds of the listeners. These are often referred to as *topoi* (Aristotle, ca. 340 B.C.E./2007; Ducrot, 1988; Anscombre, 1995). When we interact we expect certain topoi to be common ground, or – especially if they are not controversial or odd – to be accommodated (adopted by dialogue participants) during the course of the interaction. If conversational participants access different topoi to serve as underpinnings for a particular argument, this may lead to misunderstandings and other disruptions in the dialogue. Though complex, the rhetorical competence needed to use and interpret enthymemes exists in most adult language users, and the ability to reason about interlocutors' intentions and the rhetorical resources they have access to is an important component of theory of mind.

2.2 Social interaction and reasoning in schizophrenia

Schizophrenia is a severe psychiatric disorder that affects millions of people worldwide. Difficulty interacting with others is one of the most debilitating features of the disorder. Patients are known to have difficulty with language (Covington et al., 2005; Stephane et al., 2014) and reasoning (Hooker et al., 2000; Zajenkowski et al., 2011; Contreras et al., 2016; McLean et al., 2017). These social deficits present prior to the onset of defining symptoms of schizophrenia, such as hallucinations or delusional beliefs and impair patients' ability to gain and maintain employment (Marwaha and Johnson, 2004) or to develop relationships and build supportive social networks (Norman et al., 2005). However, the reasons for patients' social deficits are poorly understood and treatment options remain limited (Horan and Green, 2017).

A wealth of evidence suggests that patients have difficulty perceiving and interpreting social cues from the world around them including interpreting others' emotions and inferring others' thoughts, also known as theory of mind (Green et al., 2015;

Brüne, 2005; Penn et al., 2008). Reasoning deficits have also been identified in this patient group, particularly biases of jumping to conclusions and evidence integration (McLean et al., 2017). Moreover, it has been hypothesised that reasoning impairments may underpin patients' social deficits (Corcoran and Frith, 2005).

However, these findings are derived from the results of off-line pen and paper tasks, completed in isolation. They differ substantially from actual social interaction with others and it is unclear if patients' performance on such tasks reflects their social deficit as it presents during their social encounters with others. Indeed, recent evidence suggests that patients' performance on such reasoning tasks reflects the cognitive demands of the task rather than patients' reasoning ability (Klein and Pinkham, 2018).

The few studies that have investigated patients' social interactions directly, with a control condition, reveal that patients display atypical patterns of participation (Lavelle et al., 2014) and gesture use (Lavelle et al., 2013), which predict patients' poorer social success (Lavelle et al., 2015).

Furthermore, the presence of a patient with schizophrenia in an interaction influences the nonverbal behavior of their interacting partners, both in clinical contexts (Lavelle et al., 2015) and during first meetings with unfamiliar strangers, despite the diagnosis of the patient being undisclosed to their interacting partners (Lavelle et al., 2013, 2014). Preliminary studies indicate that this is also true in dialogue for disfluencies (Howes et al., 2017), reasoning (Breitholtz et al., 2015), and the relationship between self-repair and gesture (Howes et al., 2016).

Interestingly, despite these measurable differences in the behaviour of patients and their partners, this is not at a conscious level. Dialogue participants are not aware that they are conversing with a patient, or that they are altering their behaviour due to subtle differences in how the interaction unfolds. This also means that from the researcher's perspective, obvious differences between patients and controls should not be expected from gross observation of the dialogues – but may be uncovered by appropriately fine-grained methods of analysis.

Given this converging evidence for deficits in patients' reasoning in dialogue, we present a methodology for formally investigating how such reasoning operates in general with the aim of applying it to patient interactions. We hypothesise that patients are less successful in communicating which topoi they are drawing on when introducing arguments, and may use more unusual topoi. That is, the interactions are 'coherent', provided that a suitable topos is supplied and successfully identified by their interlocutors.

2.3 Using Gameboard semantics to analyse reasoning in dialogue

In this paper we build on accounts given in previous work (Breitholtz et al., 2015; Breitholtz and Howes, 2015), by modelling how dialogue participants present, identify and refute enthymematic arguments in terms of the respective information states of the participants at each point in the dialogue. Following Ginzburg (2012), we employ a gameboard semantics cast in TTR, a type theory with records (Cooper, 2005, 2012). This model provides a notion of information state update, called KoS by Ginzburg (2012), and discussed in relation to dialogue systems in Traum and Larsson (2003). Information state models show how coordination of the dialogue gameboard (DGB) progresses with successive utterances. The DGB provides a structured characterisation of the information available to dialogue participants and divides it into public or *shared* (what is taken to be in common ground) and *private*, offering a principled way in which asymmetries in common ground can be represented. This is crucial for accounting for situations where utterances have been interpreted differently by different conversational participants, as well as how misunderstandings caused by such divergence may be repaired (Breitholtz et al., 2017).

In TTR we model the dialogue gameboard representing the information state of a conversational participant as a *record type* which is incrementally updated during the course of the dialogue. Like other rich type theories, TTR has the advantage of being able to handle utterances as well as utterance types, which is essential for analysing meta-communicative aspects of interaction. For an in-depth introduction to records and record types including formal definitions, see Cooper (2005, 2012); Cooper and Ginzburg (2015). Gameboard style dialogue semantics cast in TTR can be found for example in Ginzburg (2012); Cooper and Ginzburg (2015); Breitholtz (2014), Cooper (in prep).

3 Material

3.1 Participants

The examples discussed here are taken from a corpus consisting of triadic conversations of approximately five minutes. There are 20 interactions involving one patient and two healthy controls who were unaware of the patient's diagnosis, and 20 control interactions, each involving three healthy participants (Lavelle et al., 2013). Twenty patients with a diagnosis of schizophrenia (6 male, 14 female) and one hundred non-psychiatric healthy participants – forty in the patient condition (21 male, 19 female) and sixty in the control condition (34 male, 26 female). Participants within each triad were unfamiliar to each other. Patients' symptoms were assessed using the Positive And Negative Symptom Scale for Schizophrenia (PANSS; Kay et al., 1987). This provides an index of symptom severity across patients' three main symptom clusters: (1) positive symptoms, which are the additional features that occur with the disorder such as hallucinations or delusional beliefs, (2) negative symptoms, which represent a reduction in usual function such as social withdrawal, diminished affect, apathy and anhedonia and (3) general symptoms, which represent general cognitive functioning such as attention, and anxiety. As shown in Table 1, patients displayed relatively low PANSS scores both for positive ($M = 15.8$; $s.d. = 6.76$), and negative ($M = 9.95$; $s.d. = 3.36$) symptoms. Thus, the patients in this study were not experiencing severe symptoms.

	Min	Max	M	SD
Years diagnosed	2	46	15.00	10.26
PANSS positive	7	37	15.80	6.76
PANSS negative	7	19	9.95	3.36
PANSS general	16	59	28.41	10.42

Table 1: Patient symptoms severity measured using the positive and negative syndrome scale

3.2 Task

The subjects were asked to discuss and make a decision regarding a moral dilemma called the balloon task. The task requires interlocutors to reach agreement on which of four passengers should be thrown out of a hot air balloon that will otherwise crash, killing all the passengers, if one is not sacrificed. The choice is between Dr Robert Lewis – a cancer research scientist, who believes he is on the brink of discovering a cure for cancer; William Harris – the balloon pilot who is the only passenger with any experience of flying the balloon; Susanne Harris – William's wife, a primary school teacher who is 7 months pregnant with their second child; Heather Sloan – a nine-year old musical child prodigy who is considered by many to be a "twenty-first century Mozart". This task is known to elicit dialogues containing extended reasoning sequences.

3.3 Topoi in the balloon task

We assume that in every speech situation there is a set of topoi which are salient or readily available to the participants of the speech event. Some of these are what Aristotle refers to as "common topoi", that is, topoi which can be drawn on in any situation. In addition to these there are topoi which are particular to the genre, or type of situation, such as "if someone is of value they should be saved" "if someone is of more value than someone else the person with the most value should be saved". Topoi like these are rules of thumb that would be generally acceptable to most people, but they would only be evoked in contexts where they are relevant, such as when discussing the balloon task.

Another type of topos which is specific to a particular situation type are topoi pertaining to a particular *social activity* (Allwood, 2000; Linell, 2009), such as court room interactions or other professional and institutionalised activities. Other topoi are interpersonally salient, that is, participants in an interaction know that they are accepted by the other participants. In a context where participants know each other well, such as a discussion in a family or between friends, we can expect a comparatively high number of such topoi.

Participants in our experiment however, do not have any previous knowledge of each other, so the only topoi that can be expected by participants to be known by other participants are common topoi and those pertaining to the situation and the nature of the task. However, the participants are provided with a description of the balloon passengers and a scenario where the facts have been chosen to make all passengers seem worthy of saving by tapping into topoi most people would consider valid. The fact that all of the passengers, by most standards, are worthy of saving, provokes discussion among the participants. In the data there are few arguments that explicitly challenge the validity of the topoi evoked by the information given in the description of the task. An example of this kind of argument from our corpus is shown in 1, below:[1] "I think they should dash the child ... who listens to classical music?".

[1] Overlapping utterances are shown aligned and marked by square brackets.

(1) 54 A: I think they should dash the child.
55 B: ⟨ laughter/⟩ [⟨ laughter/⟩]
56 A: [It's just a child]
57 B: The prodigy, no[oo]
58 A: [who listens] to classical music? (GP10)

4 Reasoning with topoi

In this section we will first make some general points regarding enthymematic reasoning in the balloon task and then take a look at some examples of dialogue sequences from our corpus where coherence to a significant degree depends on the enthymemes conveyed and the underlying topoi.

The point of the task is to create a moral dilemma that requires the participants to discuss and reason about who should be thrown out of the balloon to save the others. The information provided to the participants taps into topoi that are generally considered morally valid. Much of the argumentation concerns how well the situation actually fits these topoi. For example, the participants know that the child is a prodigy who is expected to do great things in music. Most participants agree that the quality of doing great things in music is worth being saved for. However, they might question the validity of an argument like "the child must be saved – she will do great things in music" by questioning whether she actually will do great things just because she is *expected* to do great things. The enthymeme in (2) where c is used to represent the child prodigy in the balloon task scenario, $\varepsilon_{\text{make\_music}}$ is evoking a topos like that in (3) where x is a variable over individuals, $\tau_{\text{make\_music}}$ of which the enthymeme is an instantiation. Here we are using informal notation to represent the enthymemes and topoi rather than indicating the type theoretic objects which we use to model enthymemes and topoi in TTR. The wavy line indicates that they correspond to soft (defeasible) inference rules.

(2)
$$\varepsilon_{\text{make\_music}} = \frac{\text{make\_great\_music}(c)}{\text{should\_be\_saved}(c)}$$

(3)
$$\tau_{\text{make\_music}} = \frac{\text{make\_great\_music}(x)}{\text{should\_be\_saved}(x)}$$

However, if the situation did not warrant the use of (2), then (3) could not easily be used to support an argument for saving the prodigy. So it could be argued that we don't know for sure that the child prodigy will make great music, which makes the consequent less compelling. In enthymematic reasoning context plays an important role and we see that much of the reasoning in our corpus aims at establishing, at least among themselves, more facts about the context than is given in the description of the task. One such example is the short exchange in (4):

(4) 49 A: I wanna wanna know what she plays but
[you know what I mean]
50 B: [apparently she's] the next Mozart
51 A: the next Mozart so piano (GP13)

(4) conveys the enthymeme *she is the next Mozart* therefore *she plays the piano*, $\varepsilon_{\text{mozart\_piano}}$ (5). For this enthymeme to be valid, we must assume a commonly accepted principle of inference – a topos – that makes this true. In this case such a topos would be something like "If someone is a Mozart, they play the piano", $\tau_{\text{mozart\_piano}}$ (6).

(5) $$\varepsilon_{\text{mozart\_piano}} = \frac{\text{is\_a\_Mozart}(c)}{\text{plays\_the\_piano}(c)}$$

(6) $$\tau_{\text{mozart\_piano}} = \frac{\text{is\_a\_Mozart}(x)}{\text{plays\_the\_piano}(x)}$$

This exchange is interesting in that the answer given by B to the question introduced by A in line 47 does not provide any information not already known to all participants of the conversation. Adhering to the Gricean maxim of quality (Grice, 1975), she doesn't give any more information than she has evidence for, believing that this piece of information could be a good enough clue to lead A to an answer. This sequence confirms that topoi play an important role in reasoning, suggesting that different ideas between dialogue participants about which topoi are salient in a particular dialogue could have a serious impact on discourse coherence, particularly in argumentative dialogues.

We will now move on to a longer sequence where we will consider two phenomena which could both lead to mismatches with regard to the dialogue participants' respective take on the shared state of the dialogue – the ranking of topoi and incremental reasoning by participants in the dialogue. The sequence in (7)[2] occurs early on in one of the patient dialogues. A and C are healthy controls and B is a patient.

[2]Double square brackets indicate 3-way overlap.

(7) 19 A: The guy who is gonna cure cancer isn't everyone almost gonna cure cancer [let's be honest].

20 B: [Yeah].

21 A: There's always another doctor out there who is I'm I'm almost curing cancer but he hasn't really.

22 B: And is he is he is he gonna be kind of erm generous about it or is he gonna sell

23 B: the the

24 C: Sell [sell]=

25 B: [cure].

26 C: =the drug to make lots [of money].

27 B: [Yeah] exactly it's

28 C: But but yeah those things apart I I I still think he's probably the most important person in in the balloon as he has the power the power to save lives all round the world from then on.

29 B: Or the power to make money.

30 B: on [[<unclear/>]]

31 A: [[So are we we having]]

32 C: [[<unclear/>]]

33 C: I don't care about that actually [the fact]=

34 B: [Yeah]

35 C: =that the fact that he is going to cure cancer is is the most important. (GP12)

Speaker A initiates a sequence about the doctor by introducing an argument which is elaborated in A's second utterance. By asking a question, B then introduces another argument relating to the doctor. This argument is co-constructed with speaker C, who nevertheless rejects it in his two last utterances. In our analysis of the excerpt above we focus mainly on two things – A's argument in 19 which is elaborated in line 21, possibly indicating that A does not consider it specific enough – and the exchange between B and C in lines 22–35. A's utterance in 19 seems to be an argument against the doctor believing he is on the brink of discovering a cure for cancer as a reason for saving him. However, there are at least two ways in which this enthymeme could make sense. One interpretation is that A argues that since there are so many doctors who are on the brink of discovering a cure for cancer, losing one of them is not a huge problem. Consequently the fact that the doctor might be on the brink of discovering a cure is not a good reason for saving him. The second interpretation is that there are many doctors who *believe* they are on the brink of discovering a cure – but they never actually are. This means that the doctor's claim should not be taken seriously. Both of these interpretations, and possibly others, are available after A's utterance of 19. However, after the utterance in 21 one of these interpretations is no longer on the table. We argue that the elimination of one of the possible interpretations is an example of incremental reasoning where increasingly specified versions of an enthymeme are conveyed to maximise the chance of the listener interpreting the enthymeme based on the intended topos.

4.1 Incremental reasoning

The balloon task is set up to provoke discussion, and the information provided about each passenger is meant to tap into widely accepted ideas regarding what is valuable. For example, the prospect that the doctor will cure cancer, seems to make him valuable in the eyes of most dialogue participants in our data – usually based on the notion that if someone does something that benefits humanity in general, or at least a large number of people, that is a good reason for saving that person. We refer to this as $\tau_{\text{do\_good}}$. In lines 19–21 of (7) dialogue participant A does not actually question $\tau_{\text{do\_good}}$, but he still argues against the idea that the doctor's possibly curing cancer is a reason for saving him.

The enthymeme introduced in utterance 19, $\varepsilon_{\text{cure\_everyone}}$, leaves the topos open for interpretation, as there are at least two salient topoi that could underpin the argument. One of these is that if "everyone" does something, then it is not necessary to save one person who does this, since there will always be someone else who can do it. We see a topos like this in (9).

(8)
$$\varepsilon_{\text{cure\_everyone}} = \frac{\forall x \text{ cure\_cancer}(x)}{\neg \text{ should\_be\_saved}(d)}$$

(9)
$$\tau_{\text{one\_of\_many}} = \frac{\forall x P(x) \qquad P(y)}{\neg \text{ should\_be\_saved}(y)}$$

Another possible topos is one saying roughly that if everyone says they are doing x but don't actually do x, and one individual says he is doing x, then he should not (in our dilemma) be saved since he is not to be trusted. We see such a topos in (10).

(10)
$$\tau_{\text{not\_to\_be\_trusted}} = \frac{\forall x(\text{say}(x, P(x)) \rightarrow \neg P(x)) \qquad \text{say}(y, P(y))}{\neg \text{ should\_be\_saved}(y)}$$

A's second utterance in line 21 conveys the enthymeme in (11) which is a specification of $\varepsilon_{\text{cure\_everyone}}$, and thus blocks the interpretation that evokes $\tau_{\text{one\_of\_many}}$.

(11)
$$\varepsilon_{\text{not\_to\_be\_trusted}} = \frac{\forall x(\text{say}(x, P(x)) \rightarrow \neg P(x)) \qquad \text{say}(d, P(d))}{\neg \text{ should\_be\_saved}(d)}$$

In this dialogue there is no evidence as to which topos is evoked on B's dialogue gameboard by the first utterance (u_1). In (12) we see a representation of a scenario where B first accommodates the topos $\tau_{\text{one\_of\_many}}$, and then, when this topos is blocked by u_2, updates it to $\tau_{\text{not\_to\_be\_trusted}}$.

(12)

u_1: **A**/The guy who is gonna cure cancer isn't everyone almost gonna cure cancer [let's be honest].

A	**B**
$\varepsilon_{\text{cure\_everyone}}$	$\varepsilon_{\text{cure\_everyone}}$
$\tau_{\text{not\_to\_be\_trusted}}$	$\tau_{\text{one\_of\_many}}$

u_2: **A**/There's always another doctor out there who is I'm almost curing cancer but he hasn't really.

$\varepsilon_{\text{not\_to\_be\_trusted}}$	$\varepsilon_{\text{not\_to\_be\_trusted}}$
$\varepsilon_{\text{cure\_everyone}}$	$\varepsilon_{\text{cure\_everyone}}$
$\tau_{\text{not\_to\_be\_trusted}}$	$\tau_{\text{not\_to\_be\_trusted}}$

We have now sketched an account of how potential mismatches in the topoi evoked in a dialogue in relation to a particular enthymeme can lead to dialogue participants incrementally specifying the enthymeme under discussion to limit the set of topoi which could be drawn on to underpin the enthymeme, in order to prevent misunderstanding. In a conversation where there is indication that the overlap between the sets of topoi available to participants is smaller than usual, which has been suggested to be the case in conversations between patients and non-patients (Breitholtz et al., 2015), interlocutors may be more inclined to use such strategies. However, the account given is somewhat simplified with regard to the actual enthymemes used. In fact, the argument in (11) is not an argument against saving the doctor, but rather an argument against the enthymeme in (8). Handling meta-argumentation requires an analysis where enthymemes and topoi are treated as semantic objects. We will develop such analysis in Section 5.

4.2 Ranking of topoi

The second segment we will consider is the one in lines 22–35. This exchange is interesting in two ways. Firstly, the argument presented by interlocutor B is unusual in balloon task dialogues (Breitholtz and Howes, 2015). This is interesting since the balloon task, possibly due to its restricted domain, tends to generate a relatively limited set of argument types. Breitholtz and Howes (2015) report that for a balloon task corpus (Concannon et al., 2015) with nearly 500 arguments, 21 different argument types made up 97% of the arguments used, with only 6 argument types occurring fewer than five times. The oddity of the argument is confirmed by the fact that it is explicitly rejected by C. Rejection is generally considered a dispreferred response (Schegloff, 2007; Levinson, 1983), thus an interlocutor openly rejecting an argument indicates that he strongly disagrees with it (Concannon et al., 2016). Second, we can note that speaker C correctly interprets what B is saying, which involves inference based on a topos close to the one intended by B to underpin his argument. Despite this C clearly does not agree that this topos is relevant in this context. Thus, dialogue participants seem to agree on which topoi are evoked, and also agree that they are valid, but there seems to be a mismatch regarding how the participants rank the topoi in their respective preference hierarchies. We will now look at this sequence in terms of rhetorical structure and consider the enthymemes introduced and the topoi evoked in the dialogue.

Starting in line 22 in (7), B argues that the doctor might sell the cancer drug to make money rather than giving it up for free. Thus, goes B's argument, the doctor's reasons for inventing the cure may not be honourable, which would make him less of a good person and thus less deserving of being saved. B's utterances in line 22 – 25 introduces the enthymeme in (13), let's call it $\varepsilon_{\text{sell\_cure}}$ where we use d to represent the doctor in the scenario.

(13)
$$\varepsilon_{\text{sell\_cure}} = \frac{\text{sell\_cure}(d)}{\neg\ \text{should\_be\_saved}(d)}$$

(13) is an instantiation of the topos (14).

(14)
$$\tau_{\text{sell\_cure}} = \frac{\text{sell\_cure}(x)}{\neg\ \text{should\_be\_saved}(x)}$$

We could see this topos as being derived from the topoi in (15).

(15) a. $\tau_{\text{sell\_make\_money}} = \frac{\text{sell\_cure}(x)}{\text{make\_money\_on\_people\_in\_need}(x)}$

b. $\tau_{\text{make\_money}} = \frac{\text{make\_money\_on\_people\_in\_need}(x)}{\neg\ \text{should\_be\_saved}(x)}$

In utterance 28 C protests against B's argument, conveying an enthymeme like (16), $\varepsilon_{\text{save}}$, which evokes a topos like (18b), $\tau_{\text{doing\_good}}$.

(16)
$$\varepsilon_{\text{save}} = \frac{\text{save\_people}(d)}{\text{should\_be\_saved}(d)}$$

$\varepsilon_{\text{save}}$ in (16) is an instantiation of the topos in (17).

(17)
$$\tau_{\text{save}} = \frac{\text{save\_people}(x)}{\text{should\_be\_saved}(x)}$$

which could be derived from the two topoi in (18).

(18) a. $\tau_{\text{save\_people}} = \frac{\text{save\_people}(x)}{\text{doing\_good\_for\_humanity}(x)}$

b. $\tau_{\text{doing\_good}} = \frac{\text{doing\_good\_for\_humanity}(x)}{\text{should\_be\_saved}(x)}$

B persists, again drawing on $\tau_{\text{make\_money}}$. Her utterance in line 29 conveys an enthymeme like that in (19), $\varepsilon_{\text{power\_make\_money}}$.

$$(19) \quad \varepsilon_{\text{power\_make\_money}} = \frac{\text{got\_power\_to\_make\_money}(d)}{\neg\ \text{should\_be\_saved}(d)}$$

In this case there is no communication problem – dialogue participant C seems to interpret B's contributions in the intended way. However, although C might recognise the topos $\tau_{\text{sell\_cure}}$, he does not assign as much weight to it as to $\tau_{\text{doing\_good}}$.

In terms of information state updates, we assume that B and C have access to the same topoi at the outset of this sequence – ones evoked by the background information. However, we only add topoi to the shared information states as they are evoked by speech events. In lines 22–26 B questions the doctor's motives for finding a cure, conveying the enthymeme $\varepsilon_{\text{sell\_cure}}$, evoking a topos like $\tau_{\text{make\_money}}$. These are at the top of their respective stacks at the beginning of line 28 where C makes clear that he does not agree that $\tau_{\text{make\_money}}$ is more important than $\tau_{\text{doing\_good}}$. In line 29 B evokes $\tau_{\text{make\_money}}$ yet again. C explicitly says that he does not rank $\tau_{\text{make\_money}}$ as highly as $\tau_{\text{do\_good}}$, further emphasising his standpoint. This kind of update, which has been accounted for in previous literature (Breitholtz et al., 2017), does not capture the development of the preferences of the dialogue participants. In addition to the stacks keeping track of the temporal ordering of enthymemes and topoi, we may want to add a component of the DGB that accounts for the preference hierarchy of topoi evoked in the dialogue. This component would be an ordered list rather than a stack, and possibly also be related to particular issues or questions under discussion in the discourse.

5 Towards a TTR analysis

As we noted in (4.1), the informal sketch of an analysis we gave in the previous section is not the only way that the argument in line 19 of example (7) could be interpreted. Consider again the argument concerning the doctor that "everyone [is] almost gonna cure cancer". We interpreted this as contributing to an argument that the doctor should not be saved. However, possibly a more likely interpretation is that the dialogue participant is not arguing that the doctor should not be saved but rather arguing against the argument that the doctor should be saved because he thinks he is about to cure cancer. That is, what is being presented is a meta-argument about arguments rather than a direct argument to the conclusion about whether the doctor should be saved. In our informal notation from the previous section it might look as follows: suppose that we have the topos in (20).

$$(20) \quad \tau_{\text{cure}} = \frac{\text{cure\_cancer}(x)}{\text{should\_be\_saved}(x)}$$

Then the enthymeme $\varepsilon_{\text{cure\_everyone}}$ given in (8) introduced by "everyone [is] almost gonna cure cancer" could be understood as warranted by a chain of inferences including (21).

(21) $$\frac{\forall x\ \mathrm{cure\_cancer}(x)}{\neg\ \mathrm{applicable}(\tau_{\mathrm{cure}})}$$

This means that we need to think of enthymemes and topoi as objects in our semantic universe rather than rules of inference which are external to the semantic universe. The obvious choice of object for representing them is some kind of function and this is indeed what is used to model them in a TTR type-theoretic universe.

A central dictum of type theoretic approaches to semantics is that of "propositions as types" (see, for example, Ranta, 1994, for a linguistic discussion of this notion which comes originally from intuitionistic logic). A type used as a proposition is "true" just in case there is something of the type. Following Ranta's idea that declarative sentences in natural language correspond to types of events (or situations) this will mean that we can model inference rules as functions from one type to another (again the idea that inference rules can be construed as functions is something originally associated with intuitionistic approaches to logic). Suppose that we want to model a standard non-defeasible inference rule from A to B. The corresponding function would be of the type $(A \rightarrow B)$, that is, it would be a function whose domain is all the objects of type A such that for each object in the domain it returns an object of type B. The existence of such a function gives us a license to conclude that B is true (that is, that there is something of type B) if A is true. Notice that the characterisation of the inferential act that you are able to perform given the function (or inference rule) is distinct from the function (or inference rule) itself. It belongs to a theory of inferential acts, normally tacitly assumed in the characterisation of a logic. This distinction becomes important in our adaptation of the idea of using functions to model inference rules to defeasible inference.

For a defeasible inference (such as an enthymeme or topos) from A to B clearly a function of type $(A \rightarrow B)$ would be incorrect since the existence of such a function would guarantee that B is true if A is true. Instead we will say that the inference rule is modelled by a function that takes any object of type A to the type B itself, not an object of type B. Thus the inference rule as such does not tell you whether or not B is true if A is true. It rather associates the type B with any object of type A and it is the theory of inferential acts which controls what you might do with B. For instance you might use it to argue (defeasibly) that B is true or you might take it as a license to create something new (like an event) of type B (for discussion of type acts see Cooper, 2014).

Suppose that we want to model the topos τ_{cure} given in (20). We will use the record type in (22) to correspond to $\mathrm{cure\_cancer}(x)$.

(22) $$\begin{bmatrix} \mathrm{x} & : & \mathit{Ind} \\ \mathrm{e} & : & \mathrm{cure\_cancer(x)} \end{bmatrix}$$

Record types are sets of fields (that is, the order of the fields in the notation does not make a difference). This record type has two fields labelled by 'x' and 'e' respectively. The fields contain types (e.g. *Ind* is the type of individuals). A record will be of this type if it is a set of fields of the form in (23a) and meets the conditions in (23b).

(23) a. $\left[\begin{array}{lcl} \text{x} & = & a \\ \text{e} & = & s \\ \vdots & & \end{array}\right]$

b. a : *Ind*
s : $\text{cure\_cancer}(a)$

That is, the record has to have fields with the same labels as those in the type (and may have additional fields). The objects in the record have to have the type indicated in the type field with the same label. The type in some fields depends on the object in another field of the record. Thus 'cure_cancer(x)' in the case of (23a) will correspond to 'cure_cancer(a)' since a is the object that occurs in the 'x'-field of the record we are checking (for a detailed account of records and record types see Cooper, 2012, in prep). If r is a record containing label ℓ then $r.\ell$ represents the object in the ℓ-field of r. Thus if r is (23a), then r.x is a. Now we can model τ_{cure} as the function in (24).

(24) $\lambda r{:}\left[\begin{array}{l}\text{x:}\mathit{Ind}\\ \text{e:cure\_cancer(x)}\end{array}\right] . \left[\begin{array}{lcl}\text{e} & : & \text{should\_be\_saved}(r\text{.x})\end{array}\right]$

Intuitively, (24) is a function which for any situation where there is an individual who can cure cancer will return the *type* of situations where that individual should be saved. We can then construct an enthymeme based on (24) where it is the doctor, d, who should be saved if he can cure cancer. We do this by restricting the domain type of the function so that instead of *Ind* we have the singleton type Ind_d. In TTR singleton types are constructed as indicated in (25).

(25) a. If T is a type and a is an object of any type, then T_a is a type

b. $b : T_a$ iff $b : T$ and $b = a$

The consequence of the definition in (25) is that T_a is the type whose only witness is a if $a : T$ and otherwise T_a is empty (that is, there is nothing of the type). Now we can formulate the corresponding enthymeme which references the doctor as (26).

(26) $\lambda r{:}\left[\begin{array}{l}\text{x:}\mathit{Ind}_d\\ \text{e:cure\_cancer(x)}\end{array}\right] . \left[\begin{array}{lcl}\text{e} & : & \text{should\_be\_saved}(r\text{.x})\end{array}\right]$

For reasons of readability, since in many cases what corresponds to 'd' might be a complex expression, we normally write this employing a *manifest field*, [x=d:*Ind*], as in (27).

(27) $\lambda r{:}\left[\begin{array}{l}\text{x=}d\text{:}\mathit{Ind}\\ \text{e:cure\_cancer(x)}\end{array}\right] . \left[\begin{array}{lcl}\text{e} & : & \text{should\_be\_saved}(r\text{.x})\end{array}\right]$

Intuitively, we can think of a manifest field in a record type as not only specifying the type of an object in the corresponding field of a record of this type but in addition specifying exactly which object should occur in the record field. In this way we can have types where some fields are specified in this way and others are not. This facilitates, for example, incremental specification of a record type as new information is processed. This makes record types suitable for modelling dialogue gameboards which we think of as types of information states, building on the use of TTR for gameboards in Ginzburg (2012).

Our focus here is particularly on how agents draw on individual (and sometimes distinct) resources in the shape of sets of topoi. We will therefore use separate gameboards for each agent, representing their respective information states. This is crucial for being able to account for potentially diverging takes on the state of the dialogue. This allows us to capture misunderstandings between interlocutors in general, and is also particularly relevant when dealing with discourse involving patients with schizophrenia (see for example Rebuschi et al., 2014).

Let us now consider a simple dialogue gameboard. What is required for present purposes is a field tracking the enthymematic arguments which have been made explicit in the discourse, which we refer to as *enthymemes under discussion* (eud), a field to track the topoi which are considered shared by the dialogue participant, and a field to keep track of the latest utterance. In (28) we see the type of A's shared information state after u_1 in (12).

(28) $$\begin{bmatrix} \text{eud}=[\varepsilon_{\text{cure\_everyone}}]\text{:list}(\textit{Enthymeme}) \\ \text{topoi}=[\tau_{\text{not\_to\_be\_trusted}}]\text{:list}(\textit{Topos}) \\ \text{LU}=u_1\text{:}T^{A,u_1} \end{bmatrix}$$

The type of the eud is list(*Enthymeme*), that is the type of lists of objects of type *Enthymeme*, and that of the topoi, list(*Topos*). Technically, however, we treat *Enthymeme* and *Topos* as the same type: the type of functions from records of some particular type to record types. We will not go into detail here about the construction of the type *Enthymeme*/*Topos* as that would involve the discussion of technical details beyond the scope of this paper. The field LU ("latest utterance") is restricted to contain the latest speech event, u_1 and to be of some type, T^{A,u_1}, representing the type that A has assigned to u_1 as a result of linguistic processing. Let us now consider the information state of dialogue participant B at this point in the sequence. In (29) we see the type of her information state before she has integrated any topos. This does not correspond to what is given in (12), where the topos is already taken to be integrated.

(29) $$\begin{bmatrix} \text{eud}=[\varepsilon_{\text{cure\_everyone}}]\text{:list}(\textit{Enthymeme}) \\ \text{topoi}=[]\text{:list}(\textit{Topos}) \\ \text{LU}=e_1\text{:}T^{B,e_1} \end{bmatrix}$$

In order to accommodate a topos B looks to the set of available topoi or *rhetorical resources* (Breitholtz and Cooper, 2011), to find a topos that could underpin the presented enthymematic argument $\varepsilon_{\text{cure\_everyone}}$.

For a topos to work as underpinning for an enthymeme, the enthymeme has to be recognised as an instantiation of the topos. Which enthymemes can be seen as instantiations of particular general principles for reasoning is an empirical question, but one requirement is for it to be a *specification* of the topos. This means that the antecedent of the enthymeme, that is the type of situation that is being reasoned from, is a subtype of the antecedent of the topos, and that the result of applying the enthymeme function to a record (representing a situation, event, etc.) is a subtype of applying the topos function to the same record, see (30). We say that type T_1 is a *subtype* of T_2 ($T_1 \sqsubseteq T_2$) just in case anything of type T_1 has to be of type T_2 (for a formal characterisation of subtype see Cooper, 2012, in prep).

(30) Definition of specification:
$\tau = \lambda r{:}\mathrm{T}_1 \cdot T_2$
$\varepsilon = \lambda r{:}\mathrm{T}_3 \cdot T_4$
The domain type of τ is T_1, and the domain type of ε is T_3
specification(ε,τ) is witnessed iff
$T_3 \sqsubseteq T_1$ and
for any r, $\varepsilon(r) \sqsubseteq \tau(r)$

If we compare the enthymeme in (8), $\varepsilon_{\text{cure\_everyone}}$, with $\tau_{\text{one\_of\_many}}$ in (9) in a recasting of them in TTR, we can ensure that $\varepsilon_{\text{cure\_everyone}}$ qualifies as a specification of $\tau_{\text{one\_of\_many}}$. To obtain B's updated information state, we apply the update function $\mathcal{F}_{\text{integrate\_shared\_topos}}$ in (31).

(31) $\mathcal{F}_{\text{integrate\_shared\_topos}}$ =

$$\lambda r{:}\left[\text{shared:}\begin{bmatrix}\text{eud:list}(\textit{Enthymeme})\\ \text{topoi:list}(\textit{Topos})\end{bmatrix}\right] . \quad \lambda e{:}\begin{bmatrix}\text{t:}\textit{Topos}\\ \text{c}_1\text{:in(t, resources)}\\ \text{c}_2\text{:specification(fst(}r\text{.shared.eud), t))}\end{bmatrix} . \quad \left[\text{shared:}\left[\text{topoi=}[e\text{.t} \mid r\text{.shared.topoi]:list}(\textit{Topos})\right]\right]$$

This function says that if there is a topos in your resources which is a specification of the first enthymeme on eud, that topos goes first on the list of shared topoi. B's updated information state is seen in (32).

(32) $$T_{IS_{B2}} = \begin{bmatrix}\text{eud=}[\varepsilon_{\text{cure\_everyone}}]\text{:list}(\textit{Enthymeme})\\ \text{topoi=}[\tau_{\text{one\_of\_many}}]\text{:list}(\textit{Topos})\\ \text{LU:}T_{u_1}\end{bmatrix}$$

6 Conclusions

We have sketched methods for analysing reasoning in dialogue which can account for situations where dialogue participants can be employing different non-logical inference patterns expressed in terms of enthymemes and topoi. This can lead to misunderstandings which have to be repaired by the accommodation of new topoi based on the contributions of the interlocutor. We have considered how an interlocutor can prevent misunderstandings – or fix potential misunderstandings before evidence of misunderstanding has occurred – by specifying an enthymeme in order to minimise the set of topoi that interlocutors are likely to draw on to interpret it. We have also considered how the ranking of topoi plays a part in an account of reasoning in dialogue. It is not surprising that dialogue participants may rank topoi differently, nor is it surprising that this ranking often does not correspond to the temporal order in which topoi are accommodated. However, in dialogues that are mainly focused on transferring information, rather than argumentation, this difference might be less pronounced. We conclude that accounting for preferences and acceptance in dialogue requires us to develop the dialogue game board to include one or more additional fields tracking preference order. Breitholtz and Cooper (2018) discuss argument preferences as components of *social meaning* (Eckert and Labov, 2017) in dialogue, where techniques from game theory can be used to shape enthymemes based on previous argumentative behaviour of the interlocutor, similar to Burnett's (2017) account of context dependent socio-phonetic variation in one individual.

This raises the following questions in the context of our corpus:

1. do patients rank topoi differently to non-patients?
2. do patients signal to a lesser extent which topoi they intend to evoke and how they rank them?
3. do patients accommodate topoi and update ranking of topoi in the same way as non-patients?
4. if patient behaviour differs from non-patient behaviour, does this have an effect on the non-patient contributions to the dialogue?

Our preliminary results suggest that patients do tend to rank topoi differently to non-patients and do not accommodate or update rankings in the same way as non-patients and that this does have an effect on the contributions to the dialogue by non-patients. Our current annotation of topoi as part of the DRiPS project will enable us to establish whether this is in fact a general pattern.

In this corpus participants also rated their experience of rapport with each of their interacting partners. Patients received poorer rapport ratings from their partners, compared to non-patients, in either the control or patient groups. Our hypothesis is that this may be related to the lack of social signalling from patients and the extra work required by patients' partners to compensate for this. This will be explored in future analysis.

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