Qualitative versus Quantitative Notions of Speaker and Hearer Belief: Implementation and Theoretical Extensions

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Abstract
This paper investigates the notion of the Stalnakerian acceptance in relation to common ground, exploring alternative contexts where the Stalnakerian view of acceptance is insufficient (2002). Thus, this paper extends the Stalnakerian notion of acceptance through the introduction of qualitative as well as quantitative notions of beliefs into Discourse Representation Theory (DRT), corresponding to a weaker degree of belief than contexts requiring a stronger commitment beliefwise on the hearer’s part. In addition, emphasis is placed on viewing presuppositions through agents’ beliefs instead of the vague notion of common ground. These qualitative and quantitative notions of beliefs are then implemented as part of a speaker/ hearer model of dialogue.¹

1. Introduction
The terms ‘common ground’ and ‘belief’ have been used interchangeably in literature on beliefs. Traditional views of common ground and Dynamic Semantics (part of which is DRT) share the position that the context for presupposition (given information) is equal to common ground. The common ground has been used synonymously with mutual or common belief (Traum 1994). Zeevat equates the set containing common ground with the set containing the beliefs of agents (Zeevat 1997). It is important, however, to distinguish belief, which has an individual basis, from common ground.

Moreover, this paper argues that different contexts give rise to two notions of belief, belief (strong belief) and acceptance, one form of which is weak belief (cf. section 3). Belief is understood in relation to the agent, i.e. what the agent takes to be true. Example (1) which takes place between a father and his teenage daughter demonstrates a weak form of belief.

(1) S1: Fairuz is singing at the Helix this weekend.
H1: That’s nice.

In H1, the father interprets S1’s utterance as informative not requiring any ‘commitment’ on his part (Geurts 1996). The father merely ‘goes along with’, another meaning of acceptance (in the Stalnakerian sense), the information provided in S1 (Stalnaker 2002). However, going along with what the speaker says is not always sufficient in all contexts. In some contexts, agents attribute a stronger degree of belief to the propositions and to other agents’ beliefs about the propositions. Compare this example to example (2), where the father has to act on the information provided by the daughter.

(2) S1: Fairuz is singing at the Helix this weekend.
H1: That’s nice.
S2: You should get tickets for your wedding anniversary.
H2: Did you say it was this weekend?
S3: Good grief dad, yes, I’ve been talking about this all week.
H3: Oh alright then.

In this example, the father is asked to commit to a course of action, i.e. buy tickets for his wedding anniversary. The degree to which he believes ‘Fairuz is singing at the Helix this weekend’ becomes more significant than merely going along with what his daughter is saying.

In addition to these two proposed notions of beliefs, the paper proposes dividing Stalnaker’s notion of acceptance into qualitative and quantitative notions of belief. Section 3 presents this proposal. Before explaining these extensions to Stalnakerian acceptance, section 2 outlines the Stalnakerian notions relevant to this paper’s argument.

2. Common Ground
The common ground approach was advocated by Stalnaker
Stalnaker views presupposition as a reflection of the speaker’s beliefs about common ground. “[W]hat a speaker presupposes could be identified with the speaker’s beliefs about common ground” (Stalnaker 2002: 715), where common ground is understood as ‘the mutually recognized shared information in which an act of trying to communicate takes place’ (Stalnaker 2002: 704). Indeed, ‘[t]o believe P to be common ground is to presuppose in Stalnaker’s sense’ (Simons 2003: 19).

In certain situations an utterance may presuppose information which is not already known to the hearer. This has been termed ‘informative presupposition’ (Stalnaker 2002), where the speaker, unknowingly, introduces new information to the hearer. This involves one agent assuming that a presupposition P is part of common ground for another agent. When P does not constitute common ground to the hearer, the hearer has to ‘accommodate’. Stalnaker (1999) views accommodation not as ‘context fixing’, or a repair mechanism, but as a mechanism by which agents in a conversation coordinate their presuppositions. However, these are surely grounds for arguing that accommodation can be a mechanism for adjusting the context or repairing the context in the case of presupposing something out of the ordinary. Generally, when the hearer does not share P with the speaker, there are three choices: reject P as false, add P to the set of common ground, or to go along with the speaker by accepting P to be in common but not necessarily believing it.

However, the speaker does not always make presuppositions based on common ground. An informative presupposition may take place when a speaker utters P knowing that P is not part of common ground. The speaker pretends that P is part of common ground, when, in fact, it is not. This may lead to successful accommodation. Work on presupposition in corpora has shown that presupposition does not always communicate shared information (Spenader 2002). Furthermore, Stalnaker seems to be suggesting that regardless of whether the speaker knows or does not know that P is not common ground, successful accommodation can be achieved. This is dependent on whether P is remarkable, odd or unusual, or unremarkable, which influences the ease or the difficulty of accommodating P (Geurts 1996).

This paper sees presupposition (and assertion –new information) in terms of the individual beliefs of each agent in the dialogue rather than through common ground. Beliefs are necessary to have a full account of presupposition. Equally, beliefs can be extracted from utterances and their presuppositions, as Csiger and Poole (1989) point out. This paper views common ground as broad enough to include any facts about the world including mutual beliefs about the dialogue. Indeed, common ground can be anything from world knowledge, contextual information, to domain knowledge. World knowledge includes domain knowledge. Domain knowledge specifies the domain or topic of the dialogue. Agents can entertain beliefs about what they think is in common between them, i.e. their understanding of what forms mutual belief. To demonstrate,

(3) My brother loves eating noodles.

‘My brother’ shows that the speaker believes she has a brother. This belief may or may not be part of common ground (Grice 1989). It also may or may not be a mutual belief among the agents that the speaker has a brother, i.e. it is possible the hearer knows that the speaker has a brother but the speaker does not know the hearer knows this.

Common ground as this paper sees it is the commonly accepted, non-controversial information that may not yet have acquired the status of belief or non-belief. Common ground is a term that is general enough to include mutual belief between two agents. Common ground envelops the following: (a) accepted information (cf. section 3), (b) the beliefs of agents, (c) world knowledge of agents which may not be equivalent (this includes domain knowledge (of the type of dialogue such as task-oriented dialogues; social interaction; etc. in which agents in dialogue are engaged), (d) background knowledge related to the dialogue, and (e) mutual beliefs.

3. Qualitative versus Quantitative Belief

As section 1 and the current section suggest, there is a need for the representation of different notions of belief. The treatment of acceptance presented here differs in some respects from that outlined by Stalnaker (1999). Stalnaker introduces his own notion of acceptance to deal with presupposition. He redefines the notion of common ground through acceptance. For a presupposition, P, to be common ground, the agents have to ‘accept’ P and believe that all ‘accept’ P and that everyone believes that everyone ‘accepts’ P. The concept of acceptance, as used in this paper, is not restricted to the treatment of presupposition. Acceptance, as defined here, is associated with uttering new information whether as an assertion or an informative presupposition. Additionally, unlike Stalnaker, acceptance is not necessarily mutual acceptance, i.e. an agent can accept a proposition whether or not she accepts that other agents in the dialogue accept that proposition or not.
Qualitative Belief

In discussing acceptance, one must distinguish between two meanings of acceptance, quantitative and qualitative. Both meanings are real. One meaning entailed by acceptance is illustrated by example (1). This is the qualitative meaning of acceptance. This distinction between acceptance and belief is shared with Stalnaker’s treatment of acceptance. To Stalnaker, a hearer goes along with, i.e. ‘accepts’, a new presupposition introduced by a speaker to be in common ground without necessarily believing it. A similar notion of acceptance is also found in Clark and Schaefer (1989). The hearer can ‘go along with’ a proposition without necessarily having to strongly believe it just yet. Acceptance represents the grey area where information is put on hold, not yet strongly believed, but neither rejected.

In a dialogue, the hearer decides to accept some of the things the speaker says for the purposes of the conversation. This form of weak belief is just as viable as strong belief, introduced in section 1. For instance, the speaker may describe a hypothesis, possibly in a conditional sentence. The hearer accepts certain propositions. If the hearer does not know if it is raining outside (perhaps the windows and curtains are closed) the hearer sets up a mini–context, accepting the proposition that it is raining is true and discussing what would be the case if it were raining. As long as the hearer is in a hypothetical context, his degree of belief is fairly low. Thus, the hearer’s beliefs and beliefs about the speaker’s beliefs are represented as weak belief, and are, therefore, represented in the hearer’s acceptance Discourse Representation Structure, (cf. figure 1). This is a qualitative, not a quantitative meaning of acceptance. At some point, the hearer may leave that context, because the hearer has to act in the real world and not just the hypothetical world (Stalnaker 1999), in which case we are entering into another type of acceptance. Another example is when listening to fairy tales or discussing them. Consider example (4):

(4)  A: Snow White was turned evil by her stepmother.
B: No, Snow White was never evil. She is a good person.

The agents in this mini dialogue do not believe that there exists such a person as Snow White. However, they accept that she exists only for the purposes of the dialogue and can talk about Snow White and disagree about what happened to her. The agents keep the pretense that they do accept her existence, even though they do not believe that she actually exists. Figure 1 demonstrates B’s utterance in example (4). An acceptance DRS, referred to by drs2 and ‘attitude(i, ‘ACCEPT’, drs2)’ is introduced into DRT to represent B’s (weak) beliefs, drs2, and B’s beliefs about A’s weak beliefs, drs3. Outside the context of this dialogue, i.e. in real life, the agents give up that acceptance. In this sense, a qualitative description of beliefs is more appropriate.

Figure 1: Snow White Example: B’s utterance

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Quantitative Belief

The quantitative meaning of acceptance becomes more relevant when shifting between contexts. When talking amongst each other, we cooperate. Therefore, we accept, or go along with, what the other person is saying. However, when we have to act upon the accepted information, we move to a different kind of context. This is when how reliable this information is becomes crucial.

This brings us to the other meaning of acceptance, which is a quantitative meaning, believing to some degree. Acceptance, in the sense, is one form of belief, albeit a weaker form. Acceptance is a weak form of belief, which applies to both speaker and hearer and to both presupposition and assertion. The agent can trust her beliefs to a certain degree. This meaning of acceptance is not covered by Stalnaker. If we put example (5) in a real life context, the quantitative distinction between beliefs becomes important.

(5) A: Snow White is coming to the party.

Let us assume that the hearer of example (5) did not know about Snow White. She may or may not exist. The hearer comes to speculate about her and her relationship with the dwarfs. If the hearer has to act upon it, the fact that he only weakly believes in her existence becomes relevant. The hearer is then left with the decision of whether to believe this information and go to the party, or not to go. The hearer then has to decide whether to put on a suit, because whether the hearer acts upon this information is dependant on how much strength the hearer attaches to it. The hearer might not have a suit and might have to buy one, and so on.

This paper argues that there is a need in DRT for both meanings of acceptance. In some cases, the quantitative meaning of acceptance is more relevant than the qualitative meaning. In other hypothetical or fairy tales situations, the qualitative meaning is more of an issue. The argument is that while Stalnaker’s notion of acceptance is not erroneous, it is, nonetheless, not sufficient in examples where the hearer is making a commitment based on information obtained from the speaker. In such cases, it is important how strong the hearer’s beliefs about this information are. If it is clear to both the speaker and the hearer that they are exchanging information about the real world, then the quantitative meaning of acceptance becomes important, because the information is supposed to be reliable and reflect the world as it is. These are ordinary cases, which are not covered by Stalnaker’s concept of acceptance.

4. Implementing Belief Complexes in DRT

Lee and Wilks maintain that ‘belief modelling is the development of techniques to represent the mental attitudes of a dialogue participant’ (Lee and Wilks 1996:1). However, Ballim and Wilks see that the fundamental notion of representing beliefs involves being able to represent nested beliefs and different beliefs of more than one agent. They further claim that although a lot of work has been done on beliefs, belief spaces and belief revision, very little has been done on beliefs, meta-beliefs and the ascription of beliefs (Ballim and Wilks 1991: 122-124). What differentiates the implementation described in this paper is the representation of the private beliefs and weak beliefs of both speaker and hearer and not just common or mutual belief. Additionally, in this implementation presupposition is not represented as being equal to common ground.

This section implements the extensions made to DRT in the previous sections in order to represent agents’ attitudes and computationally draw the distinction between qualitative and quantitative belief. The following set of predicates or operations concern DRSs which can represent different attitudes. Three ‘Attitude DRSs’, belief, acceptance, and intention, are introduced into the implementation for both agents in order to represent this distinction. An Attitude DRS representing beliefs contains an agent’s beliefs as well as the agent’s beliefs about the other agent’s beliefs. On the other hand, an Acceptance DRS contains weaker beliefs of the agent and those weaker beliefs of the other agent. The first operation, genDRSLabel, generates a unique DRS label, e.g. drs1. This is used inside other operations so that when some changes are made to a DRS, the emerging DRS has a different and unique label to differentiate the new from the old (cf. DRS labels in Figure 1). When attempting to generate a new attitude, two operations are needed, one to create a DRS with an attitude (e.g. attitude(i,’BEL’, drs4)) and an attitude mode in it and one operation to select the appropriate mode: mode(‘BEL’), mode(‘INT’), mode(‘ACCEPT’). The modes, BEL, INT and ACCEPT are used inside an attitude in order to refer to belief, intention and acceptance respectively.

To make changes to an Attitude DRS, we need means by which we can extract Attitude DRSs. Therefore, an operation is defined to check if a DRS has an attitude in it without specifying the type of attitude mode to minimize processing. To be more specific, two operations to detect acceptance, ‘ACCEPT’, and belief, ‘BEL’, attitudes are needed. Two operations are further employed to extract an attitude from a DRS and a DRS containing an attitude
separately. `getAttitudeDRS` searches the DRS for an attitude, then it searches for the DRS with the label used in the attitude and returns the Attitude DRS. To specify which Attitude DRS is required, the parameter `BEL` is used to get the belief DRS, whereas the parameter `ACCEPT` is used to get the acceptance DRS. Figure 2 demonstrates how we can extract an agent’s belief DRS from an agent’s cognitive state.

The following sets of operations are used to add or merge two DRSs together. The first, `addSimpleAttitudeDRS`, adds a ‘simple’ Attitude DRS to a DRS to create a New DRS. Another way to add to a DRS is to embed another DRS into it. The operation `embedSimpleAttitudeDRS` embeds a simple Attitude DRS into another simple DRS to create a New DRS. Such an operation is most useful when an agent comes to believe something about another agent’s belief. Figure 3 represents an agent’s cognitive state, where a new belief, ‘male(x)’, about the other agent’s belief is added to her belief DRS.

```
drs1:drs([x, z],
    attitude(i, ‘BEL’, drs2),
    drs2:drs([x],
        [bl: male(x)],
        attitude(you, ‘BEL’, drs3),
        drs3:drs([z],
            [b2: female(z)]))),
    attitude(i, ‘ACCEPT’, drs4),
    drs4:drs([ ],
        attitude(you, ‘ACCEPT’, drs5),
        drs5:drs([ ],
            [cl: singer(z)]))).
```

Figure 2: Extracting Attitude DRSs

Additionally, operations are also required in order to revise, alter, or delete embedded agents’ attitude. For example, out of the speaker’s attitude DRS, we can extract the speaker’s belief attitude about the hearer’s belief attitude. In Figure 5, we can separately extract the agent’s embedded attitude as well as the agent’s embedded Attitude DRS.

```
drs1:drs([ ],
    attitude(i, ‘BEL’, drs2),
    drs2:drs([y],
        [b2: female(y)]))).
```

```
drs3:drs([ ],
    attitude(you, ‘BEL’, drs4),
    drs4:drs([x],
        [bl: male(x)]))).
```

produce

```
drs1:drs([ ],
    attitude(i, ‘BEL’, drs2),
    drs2:drs([y],
        [b2: female(y)],
        attitude(you, ‘BEL’, drs3),
        drs3:drs([x],
            [bl: male(x)]))).
```

Figure 3: Adopting a New Belief

If the agent comes to modify or change her beliefs, the belief or weak belief is removed from the agent’s Attitude DRS. Figure 4 removes the belief ‘dance(y)’ from the agent’s belief DRS.

```
drs3:drs([y],
    [mia(y)],
    attitude(i, ‘BEL’, drs4),
    drs4:drs([ ],
        [dance(y)])).
```

we get

```
drs3:drs([y],
    [mia(y)],
    attitude(i, ‘BEL’, drs4),
    drs4:drs([ ], [ ])).
```

Figure 4: Removing beliefs

Other operations on embedded attitudes allow the specification of the attitude parameter, for example ‘BEL’ in order to specifically search and find agents’ embedded beliefs. Here, we can search a specific embedded attitude DRS, e.g. other agent’s acceptance DRS embedded inside the agent’s DRS, for a specific proposition to check whether the other agent accepts or not. Figure 6 searches for the proposition ‘singer(z)’ in the other agent’s embedded acceptance DRS. In the first DRS, the
proposition is found, thus, the operation returns true, whereas in the second DRS, the operation returns false as no match is found.

\[
\text{drs1:drs([], attitude(i, 'BEL', drs2), drs2:drs([ ]), [b1: male(x)], attitude(you, 'BEL', drs3), drs3:drs([ ]), [b1: male(x)])])].
\]

we get the following attitude

\[
\text{attitude(you, 'BEL', drs3)}
\]

and the following embedded Attitude DRS

\[
\text{drs3:drs([], [b1: male(x)])])}. \text{Figure 5: Extracting Embedded Attitudes and Attitude DRSs}
\]

Using the previous attitude operations, it is now possible to implement attitude modes and their DRSs in DRT format. Example (6) is represented in Figure 7.

\[
\text{(6) Walter has a rabbit. It is white.}
\]

These attitude operations allow us to represent qualitative and quantitative beliefs for both the speaker and the hearer and their embedded beliefs and accepted propositions. They also allow us to add more information to agents' cognitive states, remove or strengthen beliefs when enough evidence is established to warrant stronger belief. In example (2), the speaker infers a weaker form of belief after hearing H1 than when hearing H3. In H3, the speaker attributes more strength to the hearer's beliefs by virtue of the hearer committing to performing an action related to the proposition in question, i.e. buying tickets for Fairuz's concert at the Helix. In order to implement this change in the speaker's beliefs about the hearer's beliefs, we employ the operations introduced above to remove the belief propositions from the hearer's acceptance DRS embedded inside the speaker's acceptance DRS and add them to the speaker's beliefs about the hearer's beliefs. Another application of this attitude implementation is checking whether a speaker believes a proposition, X, and the hearer does not believe or accept X, the speaker can move on to make the utterance.

\[
\text{drs1:drs([x, z], [walter(x), vincent(z), attitude(i, 'BEL', drs2), drs2:drs([ ], [b1: dancer(x)], attitude(you, 'BEL', drs3), drs3:drs([ ], [b2: male(x)])]), attitude(i, 'ACCEPT', drs4), drs4:drs([ ], attitude(you, 'ACCEPT', drs5), drs5:drs([ ], [c1: singer(z)])])].}
\]

\text{returns true.}

\[
\text{drs1:drs([x, z], [walter(x), vincent(z), attitude(i, 'BEL', drs2), drs2:drs([ ], [attitude(you, 'BEL', drs3), drs3:drs([ ], [b1: singer(x)])]), attitude(i, 'ACCEPT', drs4), drs4:drs([ ], [c1: dancer(z)], attitude(you, 'ACCEPT', drs5), drs5:drs([ ], []))])].}
\]

\text{returns false.}

\text{Figure 6: Proposition Checking}

\section{5. Implementation of Speaker, Hearer Dialogue Process}

This section describes a dialogue process that incorporates the pragmatic extensions to DRT in Al-Raheb (2005) as well as the attitude representation and manipulation operations described in the previous section. Each agent has his or her own dialogue process. The operation for the speaker is \text{speakerDialogueProcess} and the hearer's is \text{hearerDialogueProcess}. We begin with the dialogue process from the speaker's perspective when making an utterance and move on to the effects of the speaker's utterance on the hearer's cognitive state. Figure 8 shows the cyclical dialogue process as a whole employing both the speaker's and the hearer's processes.
To start this cyclical dialogue process, the operation starts initializes the implementation which becomes ready to process a given dialogue. start obtains the inputted utterance and parses it. It then creates the initial world of two agents and their initial states of beliefs. Each agent’s initial state is represented in a separate DRS with the three Attitude DRSs, belief, acceptance and intention, embedded inside the agent’s DRS representing his or her cognitive state. With each example dialogue, the operation createInitialState can be modified to accommodate the beliefs of different agents and different dialogue topics. Finally, start begins the speaker’s dialogue process by calling speakerDialogueProcess.

After that, the processor moves to the dialogue act of the utterance. parseDialogAct identifies the dialogue acts expressed by the utterance. Then, the dialogue processor goes through the ‘information checks’ to check whether the speaker is being clear, consistent and informative (cf. Al-Rahbah 2005), again employing the attitude operations in section 4. After which the inputted utterance is used to create the intention space in the speaker’s DRS, createIntentionSpace and update the speaker’s DRS through the operation updateState. createIntentionSpace uses labels for the inputted presupposition and assertion to create the intention space. The new intention space is then added to the speaker DRS, using the attitude merging operations described in section 4. The speaker can now make the utterance for the hearer to ‘hear’. Once the speaker makes an utterance, utter works to link the intention space from the speaker’s DRS with the hearer’s DRS, producing a new state for the hearer containing the speaker’s recognized intention. This moves us to hearerDialogueProcess.

The hearer’s dialogue process first calls hear which extracts the presuppositions and assertions from the speaker’s intention space to be used in the hearer’s intention space. It then gets the DRS of the hearer, getDRSofAgent and removes the hearer’s previous intention space in preparation for representing the inferred intentions of the current utterance. Next, the beliefs and information checks are initiated for both the presupposition and the assertion using the attitude operations introduced in section 4 to check the hearer’s beliefs against the presupposition and the assertion of the current utterance. The dialogue acts of the utterance are then added to the new intention space. Where there are dialogue acts that require a response, for example, an offer requires

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3 The three operations, parsePresuppositions, parseAssertions, and parseDialogAct are used instead of a parser. It is hoped that the present implementation will inspire future work on integrating this paper’s approach with a robust parser, containing detailed grammar and lexicon.
acceptance or rejection, the next hearer state represents that response in the hearer’s intention space. With this done, the hearer’s state is then updated using `updateState` and the new hearer state is written out, `writeState`. The effects the current utterance has had on the hearer’s beliefs are displayed in the new hearer state. The hearer can now move on to become the speaker and the `speakerDialogueProcess` is started again. These two dialogue processes continue to alternate until one agent ends the dialogue.

6. Conclusion and Future Work

This paper extended the notion of belief into strong belief and acceptance. Acceptance is divided into quantitative acceptance, a weaker form of belief, rather than the ‘suspension of belief’, qualitative acceptance. There is no account in standard DRT that accommodates these notions of belief. This paper has addressed this omission and suggested a modified notion of common ground in order to make a distinction between what agents strongly or weakly believe and what the common ground is. Furthermore, these two notions of beliefs have been employed in an extended DRT model of dialogue and have been implemented as part of a dialogue process involving two agents in dialogue.

References


