

New Types of Inter-agent Dialogues*

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Abstract. Much work in the area of argumentation-based dialogues between agents has been based on the influential taxonomy of dialogue types developed by Walton and Krabbe. In this paper we re-examine the Walton and Krabbe framework, concentrating on the preconditions for different types of dialogue and analyzing them in a systematic way. Doing so identifies a number of new kinds of dialogue missing from the framework. We discuss some of the more interesting of these and develop protocols for them.

1 Introduction

Sycara [26, 27] has reasonable claim to be the first to suggest the use of *argumentation* in inter-agent dialogues, that is: the exchange of reasons in favor of and against the assertions of dialogue participants. There has been increasing interest in, and work on, the use of argumentation-based techniques. An important influence on this work was a paper by Reed [24] which introduced the work of the philosophers Walton and Krabbe [28] to researchers interested in this form of dialogue. Walton and Krabbe distinguish six basic forms of dialogue :

Information seeking: one participant seeks the answer to some question(s) from another participant, who is believed by the first to know the answer(s).

Inquiry: participants collaborate to answer some question(s) whose answer(s) are not known to any one participant.

Persuasion: one participant seeks to persuade the other participant to adopt a belief or point-of-view that the second does not currently hold.

Negotiation: participants bargain over the division of some scarce resource.

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Deliberation: participants collaborate to decide what course of action to take.

Eristic: participants quarrel verbally as a substitute for physical fighting.

A number of authors have taken Walton and Krabbe's framework as a starting point for discussing various kinds of inter-agent dialogue. For example, [4, 12, 23] have discussed *persuasion*, [17] considered *inquiry*, [16, 19] looked at *negotiation*, and [15] examined *information seeking*. [20, 21], defined simple protocols for, and investigated the properties of, persuasion, information seeking, and inquiry dialogues. Others, [6, 11, 25, 29] for example, investigated types of dialogue that are not covered by Walton and Krabbe (who make no claims of comprehensiveness).

Our long term aim is to identify and formalize a set of dialogue types that will support a wide range of agent interactions. Along with the dialogue types, we seek protocols that agents can follow to engage in these dialogues. Towards this aim, in this paper we take a systematic approach to analyzing dialogue preconditions, and identify a set of new dialogue types. This moves us some way towards a comprehensive classification that will allow agents to select from a broad range of dialogue types to best suit their dialogical needs.

2 Background

2.1 Argumentation

We start with the formal system of [20, 21], which we present very briefly and informally. A full, formal description is in [20, 21]. That system also deals with preferences between arguments, which, for simplicity, we ignore here.

Each agent involved in a dialogue has a knowledge base which contains formulas of a propositional language \mathcal{L} . \vdash stands for classical inference and \equiv for logical equivalence. An *argument* is a pair $A = (S, p)$ where p is a formula of \mathcal{L} and S a consistent subset of the knowledge base such that $S \vdash p$ and no proper subset of S does so. S is called the *support* of A , written $S = \text{Support}(A)$, and p is the *conclusion* of A , written $p = \text{Conclusion}(A)$.

Two arguments may conflict. More precisely, arguments may *undercut* one another, where argument A_1 undercuts A_2 iff $\exists p \in \text{Support}(A_2)$ such that $\neg p \equiv \text{Conclusion}(A_1)$. In other words, an argument is undercut if and only if there is another argument which has as its conclusion the negation of an element of the support for the first argument. There are, of course, other ways to define a system of argumentation. This is just one approach, based on [1, 2], which itself is based on [7], and which our experience suggests is an adequate framework for handling agent communication.

Now, a set of arguments \mathcal{S} *defends* an argument A iff for each argument B that undercuts A , there is an argument in \mathcal{S} that undercuts B . From this notion we can develop the important idea of an *acceptable* argument. An acceptable argument A is one that is not undercut, or for which there is an acceptable argument that undercuts each of the arguments that undercut A . An acceptable argument is one which is, in some sense, proven since all the arguments which might undermine it are themselves undermined. However, this status can be revoked following the discovery of a new argument (possibly as the result of the communication of some new information from another agent).

Table 1. Notation

$CS(X)$	the commitments made by the agent during the current dialogue
$B_X p$	p is the conclusion of an acceptable argument
$I_X p$	$p \in INT(X)$ (Intentions)
$W_X p$	$B_X p \vee B_X \neg p$ (Whether)
$A_{X,Y} p$	$(B_X p \wedge B_Y p) \vee (B_X \neg p \wedge B_Y \neg p)$ (Agree)

2.2 Agents and Dialogue

We build a model of dialogue on top of this system of argumentation. Dialogues take place between two agents. Each agent X has a private knowledge base. One part of this, the belief base $BEL(X)$, contains the agent's beliefs. In addition, each agent has a set of obligations, intentions and desires, denoted by $OBL(X)$, $INT(X)$ and $DES(X)$ respectively, which are modeled as a multi-context system as in [19]. Such a system can take care of nested modalities and the necessary constraints between modalities, as described in [19]. Our agents are BOID agents in the sense of [5] — though we don't *require* obligations or desires for the work described here, we keep them in the model for continuity with our other work. We write $I_X p$ to denote $p \in INT(X)$ and $B_X p$ to denote that p is the conclusion of an acceptable argument¹. Each agent's commitment store, $CS(X)$, contains the commitments made by the agent during the current dialogue. Following Hamblin [14] we take commitments to be propositions that an agent is prepared to defend. Each agent in a dialogue has access to its own private knowledge base and both commitment stores. The union of the commitment stores can be viewed as the public state of the dialogue at any given time.

We further define two notions:

- $W_X p$ (X knows whether or not p) which denotes $B_X p \vee B_X \neg p$.
- $A_{X,Y} p$ (X and Y agree about p) which denotes $(B_X p \wedge B_Y p) \vee (B_X \neg p \wedge B_Y \neg p)$.

Table 1 summarizes the notation used in this paper.

2.3 Locutions

The following locutions (moves in the dialogue game) are available to the agents. Some of the moves we use here were first introduced in [20] and modified in [22]. Each locution has a rule describing how to update the commitment store after the move. For all moves, player G addresses the i th move of the dialogue to player H , p is a proposition, and S is a set of propositions. The special character \mathcal{U} may also be asserted. It indicates that G cannot give an answer. As soon as \mathcal{U} is asserted, the dialogue terminates.

The first two moves allow propositions to be asserted. An agent uses these locutions to state propositions that it wishes to place “on the record” in the dialogue. Typically these are ones that it wishes the other agent in the dialogue to accept. The next two moves respond to assertions, taking the propositions that another agent has asserted and moving them into the speaker's commitment store. The *question* locution can be used to ask the other player about the truth of any proposition. Since a question makes no

¹ Any proposition p in \mathcal{L} is the conclusion of an argument $(\{p\}, p)$.

commitment, the CS remains unchanged. Finally, *challenge* is a means of asking the other player to state the support of an argument for a proposition.

$assert(p)$	$CS_i(G) = CS_{i-1}(G) \cup \{p\}$
$assert(S)$	$CS_i(G) = CS_{i-1}(G) \cup S$
$accept(p)$	$CS_i(G) = CS_{i-1}(G) \cup \{p\}$
$accept(S)$	$CS_i(G) = CS_{i-1}(G) \cup S$
$question(p)$	$CS_i(G) = CS_{i-1}(G)$
$challenge(p)$	$CS_i(G) = CS_{i-1}(G)$

The preconditions for the locutions are determined by what has previously been called the *attitude* of an agent and the content of the agent's knowledge base. While a range of such attitudes are explored in [22], here we restrict ourselves to considering what [22] call a thoughtful/skeptical agent; that is, one who is allowed to *assert* and *accept* only propositions for which it has an acceptable (in the sense defined above) argument. Such preconditions do not uniquely define which locutions an agent can use at a particular point in time. Additional constraints are provided by a protocol. Examples of the kind of protocol that we are interested in are given in [20].

2.4 Dialogue Protocols

As mentioned above, [20] introduced some simple dialogue protocols. In order to contrast those with the ones we introduce here, we restate the protocols from [20]. In addition, we formalize the preconditions that [20] states informally.

Before giving these protocols, however, we first define a macro $CD(X, Y, p)$ for a common set of locutions used in the “challenge and defense” of a proposition. Suppose agent X has asserted a proposition p for which agent Y has no acceptable argument. Agent Y then challenges p . Agent X attempts to defend p by providing the support of an argument for p . Y may then (when necessary) challenge each element of the defense. If Y accepts the elements of the defense and they do indeed form the support of an acceptable argument for p , then Y can accept p .

$CD(X, Y, p)$

1. Y challenges p
2. $\begin{cases} X \text{ asserts } S, \text{ the support of an argument for } p & \text{if allowed by its attitude,} \\ \text{the dialogue terminates} & \text{otherwise.} \end{cases}$
3. for each $s \in S$ $\begin{cases} Y \text{ accepts } s & \text{if allowed by its attitude,} \\ CD(X, Y, s) & \text{otherwise.} \end{cases}$
4. $\begin{cases} Y \text{ accepts } p & \text{if allowed by its attitude,} \\ \text{the dialogue terminates} & \text{otherwise.} \end{cases}$

We now give the protocols from [20] using $CD(X, Y, p)$. The preconditions are drawn up from the perspective of G , the agent that utters the first locution in any dialogue using the protocols.

Information seek(G, H, p)

preconditions:

- $\neg W_G p$
- $I_G W_G p$
- $\neg B_G \neg W_H p$

locutions:

1. G *questions*(p)
 - $\left\{ \begin{array}{ll} H \text{ asserts } p & \text{if allowed,} \\ H \text{ asserts } \neg p & \text{if allowed,} \\ H \text{ asserts } \mathcal{U} & \text{otherwise.} \end{array} \right.$
2. $\left\{ \begin{array}{ll} H \text{ asserts } p & \text{if allowed,} \\ H \text{ asserts } \neg p & \text{if allowed,} \\ H \text{ asserts } \mathcal{U} & \text{otherwise.} \end{array} \right.$
3. $\left\{ \begin{array}{ll} G \text{ accepts } H\text{'s response} & \text{if allowed,} \\ CD(H, G, H\text{'s response}) & \text{otherwise.} \end{array} \right.$

Inquiry(G, H, p)

preconditions:

- $\neg W_G p$
- $I_G A_{G,H} p$
- $B_G \neg W_H p$
- $B_G I_H A_{G,H} p$

locutions:

1. G asserts $q \rightarrow p$ for some q , or \mathcal{U} .
2. $\left\{ \begin{array}{ll} H \text{ accepts } q \rightarrow p & \text{if allowed,} \\ CD(G, H, q \rightarrow p) & \text{otherwise} \end{array} \right.$
3. H asserts q , or $r \rightarrow q$ for some r , or \mathcal{U} .
4. $\left\{ \begin{array}{ll} G \text{ accepts } H\text{'s assertion} & \text{if allowed,} \\ CD(H, G, H\text{'s assertion}) & \text{otherwise} \end{array} \right.$
5. If $\mathcal{A}(CS(G) \cup CS(H))$ (the set of arguments that can be made from $CS(G) \cup CS(H)$) includes an argument for p which is acceptable to both agents, then first G and then H accepts p and the dialogue terminates successfully.
6. Go to 3, reversing the roles of G and H and substituting r for q and some t for r .

Persuade(G, H, p)

preconditions:

- $B_G p$
- $B_G \neg B_H p$
- $I_G B_H p$

locutions:

1. G asserts p
2. $\begin{cases} H \text{ accepts } p & \text{if allowed,} \\ H \text{ asserts } \neg p & \text{if allowed,} \\ CD(G, H, p) & \text{otherwise.} \end{cases}$
3. If H asserts $\neg p$, then go to 2 with the roles reversed and $\neg p$ instead of p .

We now turn to the main contribution of this paper: by examining the preconditions of dialogues, we identify new kinds of dialogue and specify protocols for them.

3 Preconditions for Dialogue

We summarize Walton and Krabbe's [28, pages 65–85] descriptions of the three dialogue types that deal with beliefs (which will be our focus here) as:

Information Seeking Dialogues: One participant has some information, or is in a position to know it, and the other both does not have the information and needs it. Both participants share the goal of spreading knowledge.

Inquiry Dialogues: The participants collaborate to answer some question(s) whose answer(s) are not known to any one participant. Both parties are initially ignorant about the answer(s), but are committed to resolving the question(s).

Persuasion Dialogues: These dialogues begin with one participant supporting a particular statement which the other participant does not hold, and the first seeks to resolve the conflict by convincing the second to adopt the proposition. The second party shares the objective of resolving the conflict, but may try to do this by convincing the other to change his or her mind.

One way to interpret Walton and Krabbe's descriptions is in terms of the conditions that hold at the beginning and end of a specific kind of dialogue. In the literature this has typically been done in the sense of defining the initial conditions that any dialogue protocol must cope with, and the final conditions it must bring about to be successful (for example as in [3]). Thus, since an inquiry dialogue starts with no one participant knowing whether or not the proposition in question is true, and will end successfully with a proof of the proposition or its negation, the minimum requirement for an inquiry dialogue is that it must be able to construct a proof where the various components are distributed among the participants, exactly as in the Inquiry protocol given above.

Another approach, and the one we pursue here, is to consider the preconditions as a guide to the participants as to what kind of dialogue is appropriate. Thus if Shimon doesn't know *whether* p and needs to know, then if Piotr knows *whether* p , it makes sense for Shimon to engage Piotr in an information seeking dialogue, but if Piotr does not know *whether* p , then it makes sense for Shimon to engage him in an inquiry into p . From this perspective, we can think of Table 2 (which is taken from [13] and modified to mesh with our notation) as specifying which dialogue is appropriate under which conditions. Here, as for all the tables in this paper, the preconditions are laid out along

Table 2. Preconditions from Walton and Krabbe [13, 28]

	$B_H p$	$B_H \neg p$	$\neg W_H p$
$B_G p$		Persuasion	InfoSeek
$B_G \neg p$	Persuasion		InfoSeek
$\neg W_G p$	InfoSeek	InfoSeek	Inquiry

Table 3. Modified preconditions from Walton and Krabbe

	$B_G B_H \neg p$	$B_G I_H A_{G,H} p$	$B_G \neg W_H p$	$B_G I_H A_{G,H} p$	$B_G W_H p$
$B_G p$	$I_G A_{G,H} p$	Persuasion			
$\neg W_G p$	$I_G A_{G,H} p$			Inquiry	InfoSeek

both axes and the cell contains the relevant dialogues. If the dialogue is successful, the intention(s) of the participants will be fulfilled. A space indicates that there is no dialogue that applies. For example, in Table 2 there is no dialogue when both agents agree on the truth of a proposition.

However, though this characterization is neat and apparently faithful to what Walton and Krabbe intended, it is no use to Shimon in his efforts to determine what kind of dialogue is appropriate in determining the truth of p . Why not? Because he will not generally know the truth of $B_{Piotr} p$. He can determine only if $B_{Shimon} B_{Piotr} p$ — and must use this to make his decision about the most appropriate dialogue.

Furthermore, the goal (or, as we model it here, the intention) of the participants comes into play. It is not just their mutual ignorance about p that suggests Shimon should engage Piotr in an inquiry, but the fact that Shimon intends to know whether p is true or not, and believes that Piotr does the same. These considerations suggest that Table 3 rather than Table 2 is what Shimon should use to determine what kind of dialogue is most appropriate. It takes the goals of the dialogue, as stated in [28] and restates them as preconditions.

Note that Table 3 deals only with the conditions from G 's perspective (in other words in terms of G 's beliefs). Like the remainder of the tables in this paper, it presents the perspective of the initiator of the dialogue. It also exploits the symmetry in p and $\neg p$. Were we to distinguish p and $\neg p$ in G 's beliefs we would get an expanded version. We could further add a similar set of results for H and get a table that includes all the entries in Table 2. We leave these additional entries out here and for the remainder of the paper because they are redundant.

The table does more than tell Shimon what dialogues are appropriate in different situations: it identifies some suggestive gaps. For example, under Walton and Krabbe's definition, it isn't possible for G to engage H in a persuasion unless H wants to resolve the inconsistency. If H doesn't care, then the dialogue cannot be a persuasion. We argue that this is unnecessarily restrictive. We have all been party to persuasions where we didn't want to resolve the issue but were forced into the dialogue by some convention (reluctant encounters with authority for example, or not wishing to give too much offence to doorstopping evangelists) and from the point of view of formalization, actively requiring both participants to want to resolve the situation isn't necessary.

Table 4. Modified preconditions from Parsons, Wooldridge and Amgoud [22]

		$B_G B_{HP}$	$B_G B_H \neg p$	$B_G \neg W_{HP}$ $B_G I_H A_{G,HP}$	$B_G \neg W_{HP}$	$B_G W_{HP}$
$B_G p$	$I_G B_{HP}$		Persuasion	Persuasion	Persuasion	
$\neg W_{GP}$	$I_G A_{G,HP}$	InfoSeek	InfoSeek	Inquiry		InfoSeek

Provided that H is at least *cooperative*, in the sense of not actively trying to derail or prolong the dialogue², then G may rationally initiate a persuasion.

Examining the protocols given above reveals that it is possible to relax the preconditions for persuasion and information seeking. In particular, $I_G A_{G,HP} \wedge B_G I_H A_{G,HP}$ (a requirement in [20]) is not required for G to initiate a persuasion. Under the interpretation we favor, a sufficient condition for G to start a persuasion is that $I_G B_{HP}$, G wants H to believe p . Indeed, the protocol for persuasion given above also works when $B_G \neg W_{HP}$, that is whether or not H believes anything about p .

For an information seeking dialogue, we suggest that the preconditions should allow G to start a dialogue whether or not G believes it knows H 's position on p , as long as $\neg W_{GP}$ (G doesn't currently have a position on p). Once again, the protocol works under these conditions, and it seems a sensible relaxation. Some information seeking dialogues make sense under such conditions. For example, when Shimon is hopelessly lost, he might randomly ask people in the street for directions. He doesn't know whether they know the place to which he is headed, but he might still want to ask them.

With these new preconditions, Table 3 expands to become Table 4. Note that the preconditions given are not those as stated in [20], but are consistent with the dialogues given there.

4 New Dialogues and Protocols

Despite this relaxation of the initial conditions, there remain several situations in which it seems natural to engage in dialogues, but to which the basic Walton and Krabbe dialogue types do not apply. In this section we identify some of these situations and give protocols that capture them, extending the set of protocols given in [20]. Note that we are not claiming to identify all possible dialogues here (one could, of course, continue modifying preconditions more or less forever). Rather, by carefully considering the preconditions, we can identify some useful kinds of dialogue that are apparently not included in the Walton and Krabbe classification (dialogues, therefore, that couldn't take place under a strict implementation of the Walton and Krabbe typology).

To start with, we note that, as things stand, an agent is allowed to engage in information seeking and inquiry dialogues only if it is ignorant (to use Walton and Krabbe's [28, page 66] terminology) about the subject of the dialogue. The only kind of dialogue about p in which one can engage when one knows p , according to Walton and Krabbe,

² [8, 9, 10] give examples of cases where one would not want to be so cooperative, for example when engaged in a dialogue with law enforcement officers who wish to persuade one to confess to a crime.

is persuasion. However, there are cases in which it is natural to have other kinds of dialogue about some p that one believes to be true.

Consider that Shimon believes some proposition p to be true (p might be the proposition that “According to Walton and Krabbe, both participants in a persuasion dialogue have to start the dialogue with opinions about the subject of the dialogue”), but wants to check whether he is correct by asking Piotr if he thinks this is the case. This would be an information seeking dialogue if Shimon didn’t already have an opinion about p . Since the initial conditions differ from an information seeking dialogue, we require a new dialogue type and a new protocol. We call this kind of dialogue a *verification* dialogue.

4.1 Verification Dialogue

In a verification dialogue, agent G seeks the answer to some question from agent H . The proposition with which the dialogue is concerned is p . Unlike information seeking, verification no longer requires that G doesn’t know p ($\neg W_G p$). It requires only that G wants to see if H thinks p is true ($I_G B_G B_H p$), and we don’t have any condition on what H believes or on what G believes that H believes (we are all familiar with dialogues in which we ask, for instance, “Do you want that last piece of cake?”, thinking the answer will be “yes”, but hoping it will be “no” and these seem to be verification dialogues just as much as the previous example). One possible protocol for conducting a verification dialogue about p is the following. Note that all the protocols given in this paper, like those in [20], are the minimal protocol we can imagine for the task at hand.

$Verify(G, H, p)$

preconditions:

- $I_G B_G B_H p$

locutions:

1. G questions p
2. $\left\{ \begin{array}{ll} H \text{ asserts } p & \text{if allowed,} \\ \text{dialogue terminates unsuccessfully} & \text{otherwise.} \end{array} \right.$

If H asserts p , the dialogue was successful.

If the dialogue fails and G wants to continue the discussion about p , G must initiate another dialogue. For example, G might then proceed to *persuade* H . Since a verification dialogue is narrowly focused on the question of whether H believes p or not, it is even simpler than an information seeking dialogue (which requires that G be sure to check the grounds of H ’s argument for p in order to know whether it can accept p). But a verification dialogue won’t help G if it wants to know the *reason* that H believes p .

Knowing the reason may be irrelevant — as when Shimon just wants to check his facts about Walton and Krabbe. However, knowing the reason may be important. Shimon may have an argument for “It is important to attend AAMAS this year” based on the fact that his friends will be there, but want to come up with a stronger one if possible (say, to convince the chairman of his department to pay for the trip). As a result Shimon may want to find out Evelyn’s reason for the importance of AAMAS, in case it is a

better argument. Similarly, Shimon may be about to engage Piotr in a persuasion about p (“Shimon deserves to be the lead author of the paper Shimon and Piotr are writing”), and might think his chances of convincing Piotr are improved if he first learns Piotr’s reasons for Piotr’s position. (Shimon can then construct an argument that is less likely to be undercut.) In either case, we need a form of dialogue which focuses on the argument rather than the subject itself. We call this kind of dialogue a *query*, and describe it in detail next.

Another common example, as suggested in [25], which distinguishes between *verify* and *query* is that of a teacher who asks a student a question to which the teacher already knows the answer. The teacher is looking to *verify* that the student knows the answer as well. If the teacher wants the student to defend his position, it becomes a *query*.

4.2 Query Dialogues

The query dialogue arises in a situation where G will *always challenge* after H *asserts* its answer about p because G isn’t interested only in whether or not H believes p , but rather in H ’s argument for p . This marks a shift from the underlying assumptions used in introducing the protocols in [20], where agents always *accepted* whenever their attitude allowed. For a query, agents always *challenge*. A simple protocol for a query dialogue is as follows:

$Query(G, H, p)$

preconditions:

- $I_G W_G p$
- $\neg B_G \neg W_H p$

locutions:

1. G *questions* p
2. $\left\{ \begin{array}{l} H \text{ *asserts* } p \\ \text{dialogue terminates unsuccessfully} \end{array} \right. \begin{array}{l} \text{if allowed,} \\ \text{otherwise.} \end{array}$
3. $CD(H, G, p)$

A dialogue under the Query protocol³ succeeds when H offers an argument for p that is acceptable to G . Note again that we don’t require G to be ignorant about p before undertaking the dialogue.

We consider that the dialogue has failed if G doesn’t find H ’s argument acceptable since it has failed in its objective of discovering an argument. G ’s perspective is the only one that counts here because G initiated the dialogue. However, this does not mean that the dialogue need have been a waste of time for G . At the very least G may have obtained some new information (some of H ’s grounds) that G can use to construct a

³ We will follow the convention of referring to a dialogue under a specific protocol by the name of the protocol, so that a Query dialogue is one under the Query protocol, and is distinct from a “query dialogue”, which is any dialogue in the general class in which one agent is interested in the argument another has for a proposition.

different, new argument. Furthermore, if G started the query to discover H 's argument prior to a persuasion, then a failure might be more helpful to G than a success.

This completes our discussion of Query dialogues, but there is another kind of dialogue that stands in the same relation to those generated by the Query protocol as inquiry does to information seeking. Under the conditions proposed by Walton and Krabbe, an inquiry can take place only when both agents don't know whether or not p is true, and both intend to resolve the matter. There is another kind of query, a mutual query, in which G and H work together to establish a mutually acceptable argument for p , but from a position that either or both of them already have an opinion about the truth of p . Such a dialogue has some elements of persuasion and inquiry as defined by Walton and Krabbe, but we believe it to be subtly different enough to be a separate class of dialogue.

An example here is when Shimon and Evelyn get together to discuss their ideas for a paper on new kinds of dialogue. Evelyn believes that they have a new classification of dialogue types and wants to check that Shimon agrees. Now, because this isn't something that Shimon has necessarily thought about prior to the meeting, Evelyn can't just *question* and launch into a query dialogue. In addition, Evelyn can't use an inquiry, since that requires her to not believe she has a classification before the dialogue commences. Furthermore, it isn't a persuasion because what is important is not Evelyn convincing Shimon to agree, but seeing whether they can *jointly* build a case. Instead, what is required is a dialogue in which the two of them jointly construct the case for writing the paper, arguing out the truth of each step along the way, while allowing Evelyn to have a position on the subject of the dialogue before the dialogue commences.

To cover this case we introduce a *Query2* dialogue which does exactly this. One possible protocol for it is:

$Query2(G, H, p)$

preconditions:

- $I_G W_G p$
- $B_G \neg W_H p$

locutions:

The protocol then proceeds as for Inquiry (Sect. 2.4).

This completes our discussion of *Query2*, but there is yet another kind of query dialogue that we can imagine.

Going back to the case of Shimon and Evelyn's discussion about writing a paper which motivated the *Query2* protocol, we recall that it started from the position that Evelyn wanted to discuss *whether* they had a new classification of dialogue types. We can easily imagine a situation in which Evelyn hopes that Shimon and Evelyn together might produce an acceptable argument *for* p (in other words an argument that proves p is true), rather than aiming to know the truth of p .

Thus Evelyn may initiate this dialogue irrespective of either participant's current position on p . In fact, it even makes sense to initiate this kind of dialogue when either or both participants believe the proposition to be false. Although Evelyn and/or Shimon

might initially believe that there isn't a paper to be written, the discussion might end up constructing an argument for the proposition that there is one.

This seems to us to be a new kind of query dialogue, one we will call *Query3*, and a protocol for such a dialogue is:

$Query3(G, H, p)$

preconditions:

- $I_G B_G p$

locutions:

The protocol then proceeds as for Inquiry (Sect. 2.4).

An interesting kind of dialogue that is close to *Query3* is one in which a criminal lawyer and a defendant jointly seek arguments to prove that the defendant is innocent, whether or not they individually believe this to be the case. The lawyer's job in such a case is not to determine whether or not his client committed the crime but to produce a good case for the defense. He wants the dialogue to produce an argument to convince the jury that the defendant didn't commit the crime.

This completes our discussion of new dialogue types.

4.3 A New Classification

With these new kinds of dialogue, we can fill in the gaps in Table 4. In fact, we do more than that: we cover interactions which (in terms of their preconditions) were obscured in the previous tables, identifying new goals that *G* might have for engaging in a dialogue. The result is Table 5.

Furthermore, Table 5 reflects some subtle changes to inquiry and persuasion dialogues as well. In persuasion dialogues, we weaken the condition on *G*'s beliefs about *H*'s beliefs about *p* so that *G* can engage *H* in a persuasion without even knowing that *H* doesn't agree about *p* (on top of the previous relaxation that *G* no longer had to know that *H* disagrees). Now the key thing is that *G* believes *p* and wants *H* to believe it too — that, to us, seems the essence of persuasion. The change allows persuasion to encompass situations where the dialogue is “evangelical” — where *G* wants to get other agents to agree with it because it feels so strongly that *p* is true and wants to broadcast the fact — as well as the situations that [20, 28] consider persuasions. Once again, the existing persuasion protocol from [20] will handle this weakening without alteration.

Table 5. An intermediate set of preconditions. $X \equiv B_G W_{Hp} \wedge \neg B_G B_{Hp} \wedge \neg B_G B_{H\neg p}$

		$B_G B_{Hp}$	$B_G B_{H\neg p}$	$B_G \neg W_{Hp}$	$B_G \neg W_{H\neg p}$	X
		$B_G I_H A_{G,Hp}$				
$B_G p$	$I_G B_{Hp}$		Persuasion	Persuasion	Persuasion	Persuasion
$\neg W_{Gp}$	$I_G W_{Gp}$	InfoSeek	InfoSeek	Inquiry	Inquiry	InfoSeek
	$I_G W_{G\neg p}$	Query	Query	Query2	Query2	Query
	$I_G B_{Gp}$	Query3	Query3	Query3	Query3	Query3
	$I_G B_G B_{Hp}$	Verify	Verify	Verify	Verify	Verify

Table 6. Our preconditions. $X \equiv B_G W_{HP} \wedge \neg B_G B_{HP} \wedge \neg B_G B_H \neg p$

		$B_G B_{HP}$	$B_G B_H \neg p$	$B_G \neg W_{HP}$	X
B_{GP}	$I_G B_{HP}$		Persuasion	Persuasion	Persuasion
$\neg W_{GP}$	$I_G W_{GP}$	InfoSeek	InfoSeek	Inquiry	InfoSeek
	$I_G W_{GP}$	Query	Query	Query2	Query
	$I_G B_{GP}$	Query3	Query3	Query3	Query3
	$I_G B_G B_{HP}$	Verify	Verify	Verify	Verify

In inquiry dialogues, it does not seem necessary for H to have the goal of establishing the truth of p . So long as one participant in an inquiry sets it off, all that is required of the other participant is that it respond truthfully and cooperatively during its turn, filling in missing pieces of the proof to the best of its ability. As a result, we drop the requirement $I_H A_{G,HP}$. The protocol for inquiry given above will work under this alteration to the preconditions since it makes no assumptions about H 's goals.

Finally, from the perspective of G trying to decide what dialogues they can engage in under specific conditions, this considerably eases G 's job since it no longer has to figure out what H 's intentions are. The third and fourth columns of Table 5 thus collapse, and we are left with Table 6.

5 Conclusion and Future Work

This paper has considered dialogues about beliefs — that is dialogues akin to the ones that Walton and Krabbe [28] called information seeking, inquiry and persuasion — and, in particular, has systematically considered the preconditions for such dialogues. Doing so has exposed a need for a number of new kinds of dialogue (Verify, Query, Query2 and Query3), and we have given protocols for these. Of course there is no more reason to think that this set of dialogues is complete, than there was any reason to suspect that the set originally identified by Walton and Krabbe was complete — the dialogues we have listed here, and the preconditions for them, just represent our current understanding.

It is useful to have identified these additional kinds of dialogues, which seem distinct from those proposed by Walton and Krabbe and commonly discussed in the literature. While the philosophical distinctions between these new types and the familiar ones — information seek, inquiry, and persuasion — are perhaps minor, the practical importance is major. These new dialogues are themselves useful — we started on this line of work because we identified the need for the Verify dialogue in the context of work on delegation — and if we are going to build agents that engage in these dialogues we need to identify protocols for them.

The desire to build agents that can engage in dialogue also explains why we have bothered to tease out the preconditions in such detail. As we have stressed throughout the paper, identifying which preconditions go with which dialogue (and hence with which protocol) is important so that an agent can choose which protocol it should make use of depending on what it knows about the agent with which it proposes to converse. Thus we see the preconditions as a necessary step towards operationalizing dialogue, and the statement of the preconditions in terms of mental notions (which Walton and Krabbe were largely careful to skirt) is a necessary step in doing this.

Having identified these new forms of dialogue, we need to examine their properties, just as [22] did for persuasion, information seeking and inquiry dialogues. We also plan to continue our analysis of dialogues about actions, that is, to expand into the territory of the kinds of dialogue that Walton and Krabbe called deliberation and negotiation.

As the different forms of dialogue multiply, it seems increasingly likely that we will not directly program agents with a range of different protocols of the kind described in this paper. Instead, we will program agents with the kinds of *atomic* protocols discussed in [18] — sub-protocols from which more complex protocols can be constructed. These atomic protocols will then be used to construct the kinds of protocol described here, enabling agents to verify, query, persuade, inquire, and information seek. However, in order to do this, we need to develop rules for composing atomic protocols to build up a range of complex interactions, and how to do this is a topic of our ongoing work.

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