

Dialogue Protocols for Formal Fallacies

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Published online: 15 August 2014

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Abstract This paper presents a dialogue system called Lorenzen–Hamblin Natural Dialogue (LHND), in which participants can commit formal fallacies and have a method of both identifying and withdrawing formal fallacies. It therefore provides a tool for the dialectical evaluation of force of argument when players advance reasons which are deductively incorrect. The system is inspired by Hamblin’s formal dialectic and Lorenzen’s dialogical logic. It offers uniform protocols for Hamblin’s and Lorenzen’s dialogues and adds a protocol for embedding them. This unification required a reformulation of the original description of Lorenzen’s system to distinguish “between different stances that a person might take in the discussion”, as suggested by Hodges. The LHND system is compared to Walton and Krabbe’s Complex Persuasion Dialogue using an example of a dialogue.

Keywords Formal fallacy · Natural dialogue · Dialectical force of argument · Formal dialectic · Dialogical logic · Dialogue protocol

1 Introduction

Argumentation is present in natural dialogues, but some of the justifications used are incorrect. Arguments which are invalid according to the rules of some logical account are called *formal fallacies*. In this paper we consider formal fallacies which violate the

A comment to this article is available at doi:[10.1007/s10503-014-9326-2](https://doi.org/10.1007/s10503-014-9326-2).

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rules of classical propositional logic. For example, the argument, “If Tom is a banker, then he is a rich person. Tom is a banker. Therefore, he is a rich person”, is logically correct because it is based on the *modus ponens* rule. In contrast, the following argumentation is identified as a formal fallacy: “If Tom is a banker, then he is a rich person. Tom is not a banker. Therefore, he is not a rich person”. This reasoning, i.e. denying the antecedent, is represented by the propositional formula $((A \rightarrow B) \wedge \neg A) \rightarrow \neg B$. It is not difficult to prove that this formula is invalid.

Real-life arguments can be interpreted not only from the perspective of deductive validity. For example, if someone reasons according to the pattern “if *A* then *B*, *B* therefore *A*”, he does not necessarily commit a formal fallacy, as long as he does not believe that he is performing deductive reasoning (e.g. he may be performing a correct abduction). Generally, a valid argument is an argument where it is impossible for the premises all to be true and the conclusion false. Thereby, a valid argument can be based on a scheme which does not correspond to valid inference rule of the underlying logic (Mackenzie 1991, Massey 1981, Sorensen 1991). Since our paper is dedicated to formal fallacies we are restricting our study to argumentations which are assumed to be deductive and we focus only on arguments which are logically true sentences, i.e. sentences whose schemes are valid formulas of the assumed logic (in our paper classical propositional logic). In other words, we challenge the formal validity of argument *A* used by player *P* only in the case when player *P* argues that *A* is valid because it corresponds to some tautology of propositional logic.

The need to perceive formal fallacies in natural language communication was recognized in pragma-dialectics, developed by van Eemeren and Grootendorst. They specified an ideal model for argumentative discourse which provides a set of norms that form the basis for critical discussion. Pragma-dialectical rule 7 (see van Eemeren et al. 1996, p. 284) states that resolution of a conflict of opinion is possible only if the protagonist and antagonist have a method of testing whether the arguments used are sound. Rule 8 (see van Eemeren et al. 1996, p. 284) adds that argumentation leads to the resolution of a conflict if a conclusion follows logically from the premises used in the argumentation. Pragma-dialectics emphasizes that participants in a dialogue should have a method of verifying that arguments are correct, e.g. by applying the logical rules of the Erlangen School (van Eemeren and Grootendorst 2004, p. 148), i.e. Lorenzen’s dialogical logic.

Dialogical logic (Keiff 2011, Lorenz and Lorenzen 1978, Rahman and Tulenheimo 2006) is the pioneer system for formal dialogues. This system provides a dialogue game for arguing whether or not a propositional formula is a tautology. Lorenzen proposes a set of rules which determine the dialogical definition of logical constants (connectives and quantifiers) and describe the ways they are used in a dispute between two people who disagree about something. We use this system to test whether the inference on which a player’s argumentation is based corresponds to some propositional tautology, i.e., whether or not it is a formal fallacy.

Hodges’ comment (Hodges 2013), however, suggests that the application of Lorenzen’s system for studying natural argumentation is not trivial and straightforward. Specifically, it would first require the expression of different types of communicative intentions that a player can adopt during a dialogue game, such as *stating (claiming)*, *conceding*, or *querying (questioning)*:

“To return for a moment to Lorenzen: he failed to distinguish between different stances that a person might take in an argument: stating, assuming, conceding, querying, attacking, committing oneself. Whether it is really possible to define all these notions without presupposing some logic is a moot point. But never mind that; a refinement of Lorenzen’s games along these lines could serve as an approach to informal logic, and especially to the research that aims to systematise the possible structures of sound informal argument.”

The aim of our paper is to present a dialogue system which enables the identification and withdrawal of formal fallacies in natural dialogues. To this end, Lorenzen’s system is reformulated in the paper to account for different stances that a player might take in an argument. Then this dialogical system is combined with the formal dialectic of (Hamblin 1970, see also Mackenzie 2014), which provides rules for natural dialogues without fallacies. In this approach, fallacies are understood as violations of some rules. Participants in a dialogue who conform to the rules cannot perform fallacious moves. For example, if player *A* challenges player *B*’s statement *S* by asking “Why *S*?”, player *B* can offer the arguments “*T*” and “ $T \rightarrow S$ ”. Since this inference is based on *modus ponens*, player *B* has not committed a formal fallacy. We use formal dialectic as a framework for modelling natural communication. However, to reach our goal, i.e., to analyse dialogues containing formal fallacies, we need to modify Hamblin’s rules to allow players to use incorrect inferences as well.

Our contribution is a description of both Hamblin’s and Lorenzen’s systems using locution, protocol and effect rules commonly used for specification of persuasion dialogue games (Prakken 2006). The result is a unified framework in which Hamblin’s and Lorenzen’s dialogues can be performed with the possibility of expressing different stances during verification of an argument’s validity, as per Hodges’ suggestion. Furthermore, we propose new rules which allow a dialogue in which participants play Lorenzen’s game to be embedded into a natural dialogue game, to implement the pragma-dialectical suggestions. The result is a system called Lorenzen–Hamblin Natural Dialogue (LHND). The goal of the LHND system is to allow a player to (1) use an argument based on a specific formula which in his opinion is a tautology, (2) say explicitly what formula he has applied, (3) challenge this formula, i.e. challenge whether it is a tautology, and finally (4) provide in the course of the dialogue a proof that the formula under question is or is not a tautology. In this way, we provide a tool for the dialectical evaluation of force of argument and “give substance to the modern argumentation theory” by “concentrating on the reasonableness of argumentation” as was pointed out by van Eemeren in (van Eemeren 2013).

The first framework to link dialogical logic with formal dialectic was given by Walton and Krabbe in (Walton and Krabbe 1995). They proposed two dialogical systems: Permissive Persuasion Dialogue (PPD), which describes natural persuasion dialogues, and Rigorous Persuasion Dialogue (RPD), which describes formal dialogues in the style of dialogical logic. They combined these systems into one—Complex Persuasion Dialogue (CPD). The goal of Walton and Krabbe’s system differs from that of our approach. CPD aims to help disputants to infer a

conclusion from previously assumed premises, whereas LHND is intended to provide a game for eliminating formal fallacies within a dialogue. The differences between CPD and LHND are analysed in detail in Sect. 7.2.

Hamblin initiated a formal-dialectical approach to argumentation, which was later continued by Barth and Krabbe (see Barth and Krabbe 1982). Formal accounts of dialogues have also been studied in much of the contemporary work on computational argumentation. For example, (Visser et al. 2011) presents the dialogue rules of pragma-dialectics. The problem of embedding different dialogues is analysed in (Parsons et al. 2004). The formal specification of the Hamblin and Lorenzen dialogue systems by means of Dialogue Game Description Language is described in (Wells and Reed 2012). The issue of logical modelling of communication in AI, especially in teamwork, is studied in (Dunin-Kępicz and Verbrugge 2010). An implementation of speech acts in a paraconsistent framework is shown in (Dunin-Kępicz et al. 2012). In AI, specification of speech acts is closely related to dynamical character of systems in which dialogues are performed. Thereby, participants of dialogues decide which speech acts use based on reasoning about changes, often under incomplete information (see Skowron et al. 2012, Gomolinska 2010 for rough set and Kacprzak et al. 2013 for fuzzy view on this problem).

The novelty of our work is that we explicitly focus on reasoning with propositional tautologies and provide a tool for identification and elimination of formal fallacies with respect to these tautologies. Our aim in this paper is to combine the Hamblin and Lorenzen systems to show how to include analysis of formal fallacies in dialogue systems whose rules were originally established to make such fallacies impossible.

The paper is organized as follows. First, in Sect. 2, a running example is given. Section 3 is devoted to the general specification of persuasion dialogue games. In Sects. 4 and 5, the Lorenzen and Hamblin Natural Dialogues are presented. In Sect. 6, we introduce Lorenzen–Hamblin Natural Dialogue (LHND), which embeds Hamblin Natural Dialogue in Lorenzen Natural Dialogue. In Sect. 7, we discuss the differences between the proposed LHND system and Walton-Krabbe Complex Persuasion Dialogue system. Section 8, offers some concluding remarks and a note on further research.

2 Running Example

To illustrate our ideas, we present a dialogue below written in quasi-natural language. We will refer to this example in subsequent sections. It is a modification of the persuasion dialogue given in (Prakken 2005), in which Paul and Olga discuss whether or not a car with an airbag is safe. Paul justifies his position by making a fallacious move. Olga identifies this and questions Paul's move. Then Paul starts a Lorenzen game to prove that his reasoning is valid. Here we focus on the reasons for the formal fallacy and not on how it can be eliminated. Therefore, the part of the dialogue where Olga and Paul play the Lorenzen game is omitted. The complete dialogue is given in Sect. 6.2.

1. **Paul:** My car has an airbag. (stating a claim)
2. **Olga:** That is true. (conceding the claim)
3. **Paul:** If a car does not have an airbag then it is not safe. (stating a claim)
4. **Olga:** That is also true. (conceding the claim)
5. **Paul:** My car is safe. (making a claim)
6. **Olga:** Why is your car safe? (asking grounds for the claim)
7. **Paul:** My car has an airbag. If a car does not have an airbag then it isn't safe. So, my car is safe. This reasoning is correct since the scheme: "airbag \wedge (\neg airbag $\rightarrow \neg$ safe) \rightarrow safe" is a tautology. (making an argument)
8. **Olga:** Why is this scheme a tautology? (asking grounds for the argument)
- ⋮
18. **Paul:** OK, you are right. This scheme is not a tautology. (making a claim)
19. **Olga:** Now, you are in conflict. You are saying that this scheme is a tautology and is not a tautology at the same time. (asking for resolution of an incoherence)
20. **Paul:** I was wrong that it is a tautology. (withdrawal of the claim made in move 7)

In move 7, Paul commits the formal fallacy of denying the antecedent. Olga recognizes this and challenges the validity of Paul's argumentation in move 8. Next, in moves 9–17 (omitted in the example), they perform a Lorenzen-style game to examine the scheme of argumentation applied by Paul. During the game, Paul and Olga verify whether the scheme is based on a propositional tautology. After the game, in move 18, Paul presents a different position regarding the scheme on which he had based his argument, and in move 20 he admits that this scheme is not valid. In this paper we propose a dialogue system which allows for modelling dialogues such as the above, i.e., in which the inference used can be challenged and tested.

3 General Specification of Dialogue Systems

The aim of this paper is to introduce a framework which include analysis of formal fallacies in systems for natural dialogues. To this purpose both natural and formal dialogues were described using one language. The purpose of the game is to recognize and verify formal fallacies committed during natural dialogue. To this end, two dialogue systems are used: formal dialectic (Hamblin 1970) and dialogical logic (Lorenz and Lorenzen 1978). The main difficulty in combining these two approaches is that they have different objectives and structures. For example, in Hamblin's system players can use speech acts such as "statement", "no commitment", "question", and "why", while in Lorenzen's games they can only attack and defend formulas. The proposed solution to this problem is to express Hamblin's and Lorenzen's games in the language of the general specification of persuasion dialogues described by Prakken in (Prakken 2005). To be precise, we use Prakken's notation and the main ideas of his specification rather than the entire

system (c.f. Prakken 2010). We summarize the key elements of this specification below.

Every dialogue system has a *dialogue purpose*, a set A of *participants* and a set R of *roles* which participants can adopt during a game (c.f. Debowska-Kozłowska 2014). At the beginning of a dialogue, to every player s there is assigned a (possibly empty) set of *commitments* C_s which usually changes during the dialogue. The dialogue system consists of several sets of rules. First, the communication language L_c defines **locution rules** describing what type of speech acts players can execute during a dialogue. The most common of these include *claim* φ for asserting proposition φ ; *concede* φ for agreeing with the opponent about φ ; *retract* φ for withdrawing φ ; *why* φ for challenging φ ; φ *since* Ψ for supporting the conclusion φ with the premise Ψ ; and *question* φ for asking whether the opponent accepts that φ holds. The central element of a dialogue system is its **protocol**, i.e. a set of rules which determine the interaction between locutions. In other words, the protocol specifies which locution can be performed as a reply to another locution. The last set consists of the **effect rules**, which specify the effect of each locution on the set of commitments of the participant s . The function C_s for a sequence of moves returns a set of commitments. For example, the sequence of moves ending with the performance of *claim* φ by agent s results in the addition of the proposition φ to s 's commitment base. In some dialogue systems, the protocol is enriched with rules regulating turntaking, and the termination and outcome of a dialogue. Turntaking rules determine the maximum number of moves player can make at each turn, while termination rules determine the cases where no move is legal. Outcome rules define the outcome of a dialogue, i.e. who wins and who loses.

4 Lorenzen-style Natural Dialogue

Lorenzen-style Natural Dialogue (LND), introduced in (Yaskorska et al. 2013), is a system which provides a method for testing propositional tautologies. This game is based on Lorenzen's dialogical logic (DL) (see Keiff 2011, Lorenz and Lorenzen 1978, Rahman and Tulenheimo 2006). Specifically, the rules of DL, which enable verification of propositional logic formulas, were expressed in the language of the general specification. As a result, in LND it is possible to express and distinguish "between different stances that person might take in an argument" (Hodges 2013) such as stating: *claim* φ , conceding: *concede* φ , or querying: *question* φ . LND can be embedded in any dialogue which is also expressed in the language described by Prakken. In this section, we give a short overview of the main elements of dialogical logic and then explain the reconstruction of DL into LND. The full LND system with its protocol is presented in Appendix in "Dialogical Logic: Structural Rules" section.

Dialogical logic proposes a model of a dialogue game involving two players: a *proponent* (**P**) of a formula and an *opponent* (**O**). During the game both the proponent and opponent make use of two types of moves: they *attack* or *defend* some formula. A *dialogue* for a formula A , denoted by $\mathbf{D}(A)$, is a set of dialogue games consisting of sequences of moves. Dialogical logic is specified by two kinds

of rules: *particle rules* describing the way a formula can be attacked and defended depending on its main connective and *structural rules* determining the general organization of the game. Particle rules for basic propositional language are presented in Table 1. In this table, A and B denote formulas of propositional logic; a question mark “?” denotes an attack on a disjunction, i.e. a question about the entire formula being attacked; and the expression $X?$ denotes an attack on a conjunction in the form of a question about one of its conjuncts X . For example, if a player wants to attack the conjunction $A \wedge B$, he can ask about A by stating 1? or he can ask about B by stating 2? (see: rule **PR-2a**); if a player wants to attack the negation $\neg A$, he must state the contradictory formula A (see: rule **PR-1a**); to defend the disjunction $A \vee B$, the player must state one of its elements, formula A or formula B (see: rule **PR-3d**).

Structural rules determine the general course of the game. They are listed in Appendix in “[Dialogical Logic: Structural Rules](#)” section.

In order to design a system which allows for formal dialogues in a natural context, we model attacks and defences of formulas using the terminology of the locution rules from Prakken’s specification, and propose a Lorenzen-style natural dialogue consistent with the rules of dialogical logic. Below, we show the reconstruction procedure using examples of the translation of selected particle and structural rules into the language of locution, protocol, and effect rules. The result of this reconstruction is the LND system presented in Appendix in “[Lorenzen-style Natural Dialogue](#)” section.

In the first step, we have to determine which speech acts can be used during an LND game. For example, consider particle rule **PR-2a** of DL (see Table 1), which says that an attack on conjunction $A \wedge B$ can be performed via a question about one of its conjuncts. In Prakken’s language such an action can be modelled by the locution *question* φ , where φ is the sentence A or the sentence B . In consequence, an attack on the conjunction is modelled by rule **L5**: “A question *question* φ is performed when a player attacks $A \wedge B$; then φ is formula A or formula B ” (see Appendix, “[Lorenzen-style Natural Dialogue](#)” section). According to particle rule **PR-2d**, a player can defend conjunction $A \wedge B$ by stating the formula which was questioned during the attack. In Prakken’s language such a locution can be modelled by the speech act *claim* φ , where φ is sentence A or sentence B . On the other hand, a structural rule (**SR-5**) of DL states that a proponent cannot introduce an atomic formula, but can only repeat it after it has been stated by the opponent. Such a move is modelled by the locution *concede* φ (via which a player admits some sentence),

Table 1 Particle rules for the basic propositional language

			Attack (a)	Defence (d)
PR-1	Negation	$\neg A$	A	—
PR-2	Conjunction	$A \wedge B$	1?	A
			2?	B
PR-3	Disjunction	$A \vee B$?	A
				B
PR-4	Implication	$A \rightarrow B$	A	B

where φ is the sentence A or the sentence B . Accordingly, to this information we can model the defence of a conjunction by locution rule **L1.1**: “A claim *claim* φ is performed when a player defends $A \wedge B$; then φ is formula A or formula B ,” and locution rule **L2.2**, “A concession *concede* φ is performed when φ is an atomic formula and the performer is the proponent **P** who defends $A \wedge B$; then φ is formula A or formula B ”. According to the full set of locution rules **L1–L5** in the LND system, a player can perform: *claim*, *concede*, *since*, *why*, and *question*. Note that the only locution included by Prakken which is not allowed in the game is *retract*.

In the second step, we define the protocol rules, which determine all possible responses for every locution. Consider again particle rule **PR-2a**, which describes the interaction between the attack on and defence of a conjunction. According to this rule, after an attack on a conjunction a player can defend the conjunction. Taking into account the locution rules presented above according to which players can perform this attack and defence, we can define protocol rule **P7.1**, which expresses this interaction: “After *question* φ a player can perform *claim* φ ” (see Appendix, “[Lorenzen-style Natural Dialogue](#)” section). Let us now turn back to structural rule **SR-5**, which is a restriction on the proponent, who can not introduce an atomic formula. According to this rule, when an opponent attacks a conjunction $A \wedge B$ by asking about, for example, the atomic formula A , then the proponent can defend this conjunction only if the opponent has previously stated the validity of A . In this situation the proponent has to perform *concede* φ , where φ means A . This is expressed by protocol rule **P7.2**, “After *question* φ a player can perform *concede* φ , if the player is **P** and φ is a proposition”, with the restriction contained in LND protocol rule **P2**: “A player **P** (...) can state that φ is true by executing *concede* φ but this move can be performed only if **O** has claimed φ in some previous move”.

In the third step we determine the effect rules. Note that there is no description of commitment sets in the original dialogical logic. In LND we assume a *hypothetical commitment base* for each player, which is used during the formal dialogue. This base contains all formulas which have been stated by the player during the formal dialogue, even contradictory ones. It is denoted as C'_s , where s is the proponent or opponent. During the LND-game, new formulas are added to this base. What is more, no formulas are deleted since in this system players are not allowed to retract. The effects of performing each locution allowed in LND are defined according to the language of the general specification. For example, after the locution *claim* φ performed in the move m_n of a dialogue $m_0, m_1, \dots, m_{n-1}, m_n$, the formula φ is added to the hypothetical commitment base of the performer of this locution. This is expressed by LND effect rule **E1**: “if $s(m_n) = \textit{claim } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$ ”.

5 Hamblin-style Natural Dialogue

In this section, we introduce Hamblin-style Natural Dialogue, HND, which is a formal system for natural dialogues. This system was defined by the reconstruction of Hamblin’s formal dialectic into the language of Prakken’s general specification.

Formal dialectic, FD, was presented by Hamblin in (Hamblin 1970). The main goal of his work was to provide rules according to which natural dialogues without fallacies can be constructed. Formal dialectical models were constructed primarily to give a satisfactory account of fallacies. Hamblin proposes a set of discretionary rules. If participants conform to the rules, then their behaviour is non-fallacious. Violation of a rule is equivalent to committing a fallacy. This means that fallacies, including formal fallacies, do not appear in Hamblin's dialogue, because fallacious moves are prohibited. Our proposition is to include formal fallacies in FD analysis by allowing participants to commit formal fallacies and providing a method for recognizing formal fallacies and withdrawing them.

In Hamblin's game, there are two participants, Black and White, who make moves alternately. Players can perform one of the following locutions: (1) "Statement S " or in certain special cases "Statement S, T "; (2) "No commitment S, T, \dots, X " for any number of statements S, T, \dots, X (one or more); (3) "Question S, T, \dots, X ", for any number of statements (one or more); (4) "Why S ?" for any statement S other than a substitution-instance of an axiom; or (5) "Resolve S ". The performance of these locutions is regulated by syntactical rules which prescribe the possible responses to the questions "Question S, T, \dots, X ", "Why S ?" and "Resolve S ". For example, after "Resolve S " the answerer can perform "No commitment S " or "No commitment $\neg S$ " (Hamblin 1970, p. 265). There is also a set of effect rules defined in FD which describe the effect of the performance of each locution at a given stage of the game, e.g. "Statement S " places S in the speaker's commitment store except when it is already there, as well as in the hearer's commitment store unless his next move is "Statement $\neg S$ " or "No commitment S " [...] (Hamblin 1970, p. 226).

To unify the two dialogue systems, Hamblin's game was also described using the terminology of Prakken's general specification. The two approaches appear to be similar, e.g. in both systems players can assert a sentence, challenge it, or retract it. Nevertheless, Hamblin and Prakken define the rules of their system in different ways, so we need to reconstruct the rules of the FD system in order to describe it with the language of the general specification. To give an idea of the methodology of the reconstruction, we analyse selected rules. The entire HND system is presented in Appendix in "[Hamblin-style Natural Dialogue](#)" section.

First, we need to reformulate the locutions permitted in Hamblin's system in order to describe them using the terminology of Prakken's specification, in which players will perform their dialogue games. For example, in FD a player can perform "Statement S " and in some cases "Statement S, T " (see Hamblin 1970). When a player performs "Statement S " and his antagonist does not have the proposition S in his commitment store, he introduces a new formula, and this move could be modelled in HND by the speech act *claim* φ , where φ is the sentence S (see Appendix, "[Hamblin-style Natural Dialogue](#)" section, rule **HL1**). If a player performs "Statement S " when S is already in his antagonist's commitment store, he admits a sentence which was stated before, and this move could be modelled in HND by the speech act *concede* φ , where φ is the sentence S (see Appendix, "[Hamblin-style Natural Dialogue](#)" section, rule **HL2**). According to the rules of formal dialectic, a player can assert only one sentence during each move. The only

exception is when a player wants to justify a sentence (say Q). In this case, he can perform “Statement S, T ”, where one of the sentences (say S) is a premise and the other (say T) is the implication $S \rightarrow Q$, i.e., the player makes an argument based on the *modus ponens* rule. Such moves are modelled in Prakken’s specification by the locution φ since Ψ , where φ is a sentence Q and $\Psi = \{S, T\}$ (see Appendix, “Hamblin-style Natural Dialogue” section, rule **HL3**).

Secondly, after the locution rules of the FD system have been reformulated into Prakken’s language and the locution rules of the HND have been described, we need to model the legal interaction between them. To this end we express Hamblin’s structural rules in terms of new locutions. For example, according to the structural rules of formal dialectic, one of possible replies to the locution “Why Q ” is “Statement $\neg Q$ ”, which in the LND system is modelled either by *claim* $\neg\varphi$ or *concede* $\neg\varphi$ for $\varphi = Q$. This is expressed by HND protocol rule **HP 3.1**: “After why φ a player can perform (a) *claim* $\neg\varphi$, or (b) *concede* $\neg\varphi$ ” (see Appendix, “Hamblin-style Natural Dialogue” section).

In this paper we present a formal system for natural dialogues based on Hamblin’s approach. Nevertheless, our goal is to provide rules according to which players can *identify* and afterwards eliminate formal fallacies committed during a dialogue. Therefore, we modify Hamblin’s system to allow participants in a dialogue to use argumentation schemes which are not based on tautologies of classical propositional logic, and then to recognize such argumentations. To achieve this goal, we need to add the following sentence to the topic language: “The formula θ is a propositional tautology”. This sentence is used in the rules of the Hamblin-style system. For convenience, we introduce the following abbreviations. Let *Taut* (θ) be short for “ θ is a propositional tautology”. This sentence may be true or false. We do not state here that θ is actually a tautology. Let us turn to the question “Why Q ?”. One possible answer to this locution is “Statement S, T ”, where T means “ S implies Q ”. In the LND, the equivalent of such an answer is modelled by φ since $\{\Psi, \text{Taut}(\Psi \rightarrow \varphi)\}$ for $\varphi = Q$ and $\Psi = S$. This restriction is expressed by HND protocol rule **HP3.4**: “After why φ a player can perform φ since $\{\Psi_1, \dots, \Psi_n, \text{Taut}(\Psi_1 \wedge \dots \wedge \Psi_n \rightarrow \varphi)\}$ (justification for φ by the inference rule in which Ψ_1, \dots, Ψ_n are premises and φ is a conclusion; the player states that this inference is based on a tautology, i.e. that the formula $\Psi_1, \dots, \Psi_n \rightarrow \varphi$ is a tautology)”.

The final step is to reconstruct the effect of the performance of each locution at a given stage of the game. In FD, the performance of almost all moves changes both the sender’s and the receiver’s commitment store; the exception is the move “No commitment”. Therefore, we assume that a player s can play the role of the sender S or the receiver R , $s(m)$ denotes a move by the player s , and C_S and C_R denote the commitment stores of S and R , respectively. For example, if in the sequence m_0, m_1, \dots, m_n , the last locution performed by player s is $s(m_n) = \text{claim } \varphi$, then the contents of the commitment stores of R and S are described by the effect rule **HE1**: “If $s(m_n) = \text{claim } \varphi$, then: (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$; (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$ if the player **R** does not perform *claim* $\neg\varphi$, *concede* φ or *why* φ during the m_{n+1} move.” Intuitively, this means that the formula φ is added to the commitment bases of both the sender and the receiver. The exception is the situation in which the receiver in move m_{n+1} performs one of

the locutions *claim* $\neg\varphi$, *concede* φ or *why* φ . In this case, the formula φ is not added to the set C_R .

6 Lorenzen–Hamblin Natural Dialogue

This section specifies how the protocols for Lorenzen-style and Hamblin-style Natural Dialogues are combined into one Lorenzen–Hamblin Natural Dialogue, LHND. Note that moves 1–8 and 18–20 of (...) of the running example from Sect. 2 are sentences expressed in quasi-natural dialogue and can be modelled in the HND system. The missing part of this dialogue (indicated by dots) is a Lorenzen game which can be modelled in the LND system. To combine these two dialogues we need to define new locution, protocol, and effect rules.

6.1 Embedding Rules

The following new rules are defined in order to embed the LND protocol into the HND protocol.

Locution rules. To interrupt the HND game and then resume it when the embedded LND game is finished, two new locutions are introduced:

EL1 Initialization The locution *InitLor* (φ) stops the HND dialogue and initializes the LND dialogue for formula φ . The player who performs *InitLor* (φ) becomes the proponent of φ in the embedded LND dialogue.

EL2 Ending The locution *EndLor* (φ) ends the LND dialogue for φ and resumes the interrupted HND dialogue.

Protocol rules. A Lorenzen-style dialogue for a formula φ begins when one of the players challenges this formula or states that it is not a tautology. Then, the players examine φ in accordance with the rules for LND games. The protocol rules for embedding LND into HND are described below:

EP1 The locution *InitLor* (φ) can be performed as a reply to the locution: *why*($\text{Taut}(\varphi)$), or the locution *claim*($\neg \text{Taut}(\varphi)$), executed in HND;

EP2 After the locution *InitLor* (φ), players can perform the same actions that may be executed after *claim* (φ) according to rules **P1–P8** of LND (see Appendix, “[Lorenzen-style Natural Dialogue](#)” section);

EP3 The locution *EndLor* (φ) can be performed by a player **X** if **X** has no legal move according to dialogue rules **P1–P8** of LND (see Appendix, “[Lorenzen-style Natural Dialogue](#)” section);

EP4 After the locution *EndLor* (φ), (1) if **P** is the performer then **P** can execute one of the two locutions *retract* ($\text{Taut}(\varphi)$) or *claim* ($\neg \text{Taut}(\varphi)$) in the interrupted HND dialogue; (2) if **O** is the performer then **O** executes *concede* ($\text{Taut}(\varphi)$) in the interrupted HND dialogue.

Effect rules. When a player starts a Lorenzen game by performing *InitLor* (φ), he creates a new commitment store, called *hypothetical commitment base* C' , and adds

to it a formula φ . The hypothetical commitment base changes during the game according to rules **E1–E5** of LND (see Appendix, “Lorenzen-style Natural Dialogue” section). The locution *EndLor* (φ) does not change the hypothetical commitment base at all. Formally, if $\Delta = m_0, m_1, \dots, m_n$ is a Lorenzen game, the rules for hypothetical commitment base C'_s of a player $s \in \{\mathbf{O}, \mathbf{P}\}$ are specified below, where $s(m)$ denotes a move by player s and φ, Ψ are propositional formulas:

- EE1** If $s(m_0) = \text{InitLor}(\varphi)$ then $C'_s(m_0) = \{\varphi\}$;
EE2 If $s(m_n) = \text{EndLor}(\varphi)$ then $C'_s(m_0, \dots, m_n) = C'_s(m_0, \dots, m_{n-1})$ for $n > 0$.

6.2 Example of Embedding Dialogues

To illustrate application of the embedding rules, the running example from Sect. 2 is written in the LHND system. The sentence “A car has an airbag” is denoted briefly by “airbag”, and the sentence “The car is safe” is denoted by “safe”.

- P**₀: *claim* (airbag)
O₂: *concede* (airbag)
P₃: *claim* (\neg airbag \rightarrow \neg safe)
O₄: *concede* (\neg airbag \rightarrow \neg safe)
P₅: *claim* (safe)
O₆: *why* (safe)
P₇: *safe since* {airbag; \neg airbag \rightarrow \neg safe; $\text{Taut}((\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe})$ }
O₈: *why* ($\text{Taut}(\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe}$)
P₉: *InitLor* ($\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe}) \rightarrow \text{safe}$)
O₁₀: *claim* ($\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})$)
P₁₁: *question* (airbag)
O₁₂: *claim* (airbag)
P₁₃: *question* (\neg airbag \rightarrow \neg safe)
O₁₄: *claim* (\neg airbag \rightarrow \neg safe)
P₁₅: *claim* (\neg airbag)
O₁₆: *claim* (\neg safe)
P₁₇: *EndLor* ($\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe}) \rightarrow \text{safe}$)
P₁₈: *claim* ($\neg \text{Taut}(\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe}$)
O₁₉: *question* ($\text{Taut}(\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe}$), *question* ($\neg \text{Taut}(\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe}$)
P₂₀: *retract* ($\text{Taut}(\text{airbag} \wedge (\neg \text{airbag} \rightarrow \neg \text{safe})) \rightarrow \text{safe}$)

In this dialogue, in move 8 Olga asks for reasons why the formula given is a tautology. In move 9 Paul starts an LND game according to embedding rule **EP1**. In moves 10–16 Olga and Paul follow embedding rule **EP2** and the protocol rules of LND. In move 16 Olga claims “ \neg safe”. Paul has no legal response to this move and according to rule **EP3** ends the Lorenzen game in move 17. In move 18, according to rule **EP4**, he resumes the interrupted HND game, claiming that the formula at issue is not a tautology. In move 19, Olga asks for a resolution of the conflict

between the statements from moves 7 and 18, and finally, in move 20, Paul retracts the assertion that the formula under consideration is a tautology.

7 Comparison LHND and Complex Persuasion Dialogue

Complex Persuasion Dialogue (Walton and Krabbe 1995) was introduced by Walton and Krabbe. It combines two kinds of persuasion dialogues, Permissive Persuasion Dialogue (PPD) and Rigorous Persuasion Dialogue (RPD), by defining five rules needed to embed RPD into PPD. Permissive Persuasion Dialogue is inspired by Hamblin's model. PPD is flexible in the sense that disputants can choose different kinds of moves as responses to previous moves and have quite a lot of freedom in their selection. The course of PPD depends on the cooperativeness of the participants and non-explicitly expressed commitments called *dark-side commitments*. During a PPD dialogue players can improve their arguments or construct new ones, and retract their assertions and concessions.

Rigorous Persuasion Dialogue is inspired by Lorenzen's game and is much simpler and more rigorous than PPD. In this dialogue, retraction of commitments is not allowed. The aim of an RPD dialogue is not to introduce new arguments or claims but to verify whether the proponent's previous commitments are sufficient to defend his thesis T.

The idea of CPD is that participants play the game according to PPD rules, and at some point the proponent of some thesis T may start an RPD dialogue to show that T also results from commitments made by T's opponent. If the opponent loses the RPD game, the PPD discussion is resumed and the opponent must concede T. In the next section we show how the running example from Sect. 2 can be rewritten using the language and rules of CPD.

7.1 Running Example in CPD

Let us return to the dialogue in which Paul and Olga discuss whether a car with an airbag is safe. This dialogue is modelled below using CPD terminology. The dialogue begins with the PPD part. In PPD there are two parties who move alternately. The locutions permitted are of four types: statements (assertions, concessions), elementary arguments, questions (requests, extractors, confronters, challenges), and retractions (of commitment and of strong commitment). A participant may perform more than one locution in each move. The dialogue begins when the initial conflict is described, i.e., when participants make their initial assertions. In the running dialogue, in move 0, Paul asserts "safe" and Olga asserts " \neg safe":

P₀: $a(\text{safe})$

O₀: $a(\neg\text{safe})$

Next, in move 1, Paul challenges Olga's initial assertion " \neg safe" and asks about two propositions, "airbag" and " \neg airbag \rightarrow \neg safe":

P₁: $\neg\text{safe}??, \text{con}(\text{airbag})??, \text{con}(\neg \text{airbag} \rightarrow \neg \text{safe})??$

In move 2, Olga concedes "airbag" and " \neg airbag \rightarrow \neg safe" and challenges Paul's initial assertion "safe":

O₂: $c(\text{airbag}), c(\neg\text{airbag} \rightarrow \neg \text{safe}), \text{safe}??$

At this point, Paul believes that Olga's concessions imply the thesis "safe", and interrupts the PPD dialogue using the locution:

P₃: *Your position implies: safe*

This locution initiates an RPD game in which Paul plays the role of the proponent of the thesis "safe" and Olga plays the role its opponent. All the concessions which Olga has made up to that point are now initial concessions in the RPD game. Paul's initial thesis in PPD becomes the initial thesis in RPD.

RPD is asymmetric in that the players are allowed to perform different kinds of moves depending on the role they play in the dialogue. The opponent can make the moves concession, challenge, concession and challenge, and final remark, while the proponent can make the moves assertion, question, assertion and question, and final remark. In the running example, the initial move in the RPD is made by Olga, who challenges Paul's thesis "safe":

O₄: ??

In move 5, Paul questions Olga's concession "¬airbag":

P₅: (?) ¬ airbag

Olga defends this concession stating that it is true:

O₆: ¬ safe

In move 7, Paul attacks the negation from move 6:

P₇: (?) safe

Now, Olga's only possible move is

O₈: ⊥

which expresses the claim that Paul's position is absurd or inconsistent. In move 9, Paul asks a free question:

P₉: airbag (?)

In move 10, Olga answers:

O₁₀: airbag

Now, Paul does not have any legal move since atomic sentences cannot be questioned. He loses the game making the final remark:

P₁₁: *I give up!*

Next, the PPD dialogue is resumed by Paul's retraction from the thesis "safe":

P₁₂: $nc(\text{safe})$

7.2 Main Differences Between LHND and CPD

Complex Persuasion Dialogue and Lorenzen–Hamblin Natural Dialogue differ in their motivations. The aim of CPD is to combine PPD and RPD models in order to help disputants to infer a conclusion from assumed premises, whereas LHND is intended to provide a game for recognizing and removing formal fallacies. This difference is clearly visible in the examples considered in Sects. 6.2 and 7.1. In the LHND dialogue (see Sect. 6.2), Paul claims two statements: "airbag" and "¬airbag → ¬safe" (moves 1 and 3). Next, he explicitly gives the inference which he uses to justify the statement "safe" (move 7). Olga challenges this inference (move 8) and Paul defends it by starting a Lorenzen-style game (move 9). He loses this game and must retract the inference, conceding that it is incorrect, i.e., it does

not correspond to a propositional tautology (move 20). In LHND Paul commits a formal fallacy, Olga recognizes this, and after a Lorenzen-style game the fallacy is eliminated.

In CPD (see Sect. 7.1), Paul asks Olga about two propositions: “airbag” and “ \neg airbag \rightarrow \neg safe” (move 1). Olga concedes that they are true (move 2). Then, Paul starts an RPD game to help Olga to infer “safe” (move 3). Since he loses the game (move 11), he must retract the proposition “safe” (move 12). In this dialogue, the inference Paul uses implicitly is not stated explicitly at all. If this inference was correct, Olga would have to concede the proposition “safe”. Thus, CPD rules give a player the opportunity to force the opponent to accept a conclusion that results from the premises he committed himself to earlier.

Another difference between LHND and CPD is apparent from what players learn during these dialogues. Explicitly pronounced inferences in LHND can be tested and divided into two groups: correct and incorrect. This allows participants to gather information about which arguments violate the rules of propositional logic and which do not. In further argumentation, correct inferences can be used again and incorrect inferences avoided. This is not possible in CPD, where the RPD game starts every time the proponent wants to convince his opponent of some thesis, even if the proponent repeatedly tries to use the same incorrect inference. This is because the proponent does not record any conclusions resulting from the losing game.

CPD eliminates formal fallacies in that it prevents players from using arguments which do not correspond to the rules of the logic being used. LHND does not eliminate formal fallacies in the same sense. It allows players to commit formal fallacies but it also provides a method for identifying and eliminating them. This approach is closer to modelling real dialogues, in which participants make diverse mistakes, including formal ones, as we have shown in the introduction. LHND implements a pragma-dialectic postulate stating that one of the conditions for a discussion which results in the resolution of a conflict of opinion is the use of arguments in which the conclusions follow logically from the premises. Furthermore, the disputants should have a method for verifying the correctness of the arguments in terms of their formal correctness. LHND meets both of these requirements.

8 Conclusions

In this paper, we have introduced a dialogue system for removing formal fallacies from natural dialogues (as suggested by pragma-dialectics). To this purpose, we have reconstructed and unified Lorenzen’s dialogical logic (as suggested by Hodges) and Hamblin’s formal dialectic and we have proposed two coherent dialogue protocols using the tradition of persuasion dialogue games as specified by Prakken. These protocols are combined by means of specific embedding rules. The result is a new dialogue system called Lorenzen–Hamblin Natural Dialogue. In this system, (1) players can commit formal fallacies, i.e., can use incorrect schemes of argumentation; (2) parties can challenge not only the content of arguments but also the correctness of the inference applied; (3) a formal fallacy can be recognized; and

(4) a player has the chance to withdraw the incorrect argumentation. The next steps of our research will be to implement the system designed so that it can be used in computational systems (Reed and Wells 2007), and develop software which will allow LHND games to be played online.

Hamblin's formal dialectic offers a formal approach to diverse groups of fallacies, also strictly dialectical such as *petitio principii*: “ p because p ”, which is built on the propositional tautology “ $p \rightarrow p$ ” (see e.g. Walton 1980, Walton 1991 for the overview, see also Budzynska 2013 for its specific, ethotic version). Our reconstruction of formal dialectics takes into account only its basic rules, but not the rules introduced additionally in the original Hamblin's system for the prevention of fallacies. For example, the rules **W** and **R1** preventing *petitio principii* have not been reconstructed and included into our system, so that a player can commit this fallacy. In our future work, we plan to study this issue and extend LHND to make it suitable for recognition and elimination of fallacies such as *petitio principii* within a dialogue.

Acknowledgments Special thanks are due to Dr hab. Katarzyna Budzynska, who contributed to this paper by sharing her knowledge and valuable comments. We gratefully acknowledge the support of the Polish National Science Centre under Grant 2011/03/B/HS1/04559. We also thank the Polish Ministry of Science and Higher Education at the Bialystok University of Technology under Grant S/WI/1/2011.

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Appendix

Dialogical Logic: Structural Rules

SR-0: Starting Rule. For any $\Delta \in \mathbf{D}(A)$, the thesis has position 0. At even positions **P** makes a move, and at odd positions it is **O** who moves. **SR-1_c:** Classical Round Closure Rule. Whenever player **X** is to play, he can attack any move by **Y** insofar as the other rules allow him to do so, or defend against any attack by **Y**. **SR-2:** Branching Rule For Dialogical Games. Any game situation where **O** is to play and has to choose between several moves will generate a distinct game for every *propositional choice* available to **O** (for more details see Keiff 2011, Rahman and Tulenheimo 2006).¹ **SR-3:** Winning Rule For Dialogical Games. A dialogical game $\Delta \in \mathbf{D}(A)$ is said to be closed iff there is some atomic formula which has been played by both players. A dialogue game is finished iff it is closed or the rules do not allow any further move by the player who has to move. Let Δ be a finished game. If Δ is closed, **P** wins it; otherwise, he loses it. **SR-4:** Shifting Rule. **O** cannot switch to another game before the game he is playing is closed. **SR-5:** Formal Use of Atomic Formulas. An atomic formula is

¹ A propositional choice for **O** is when he creates distinct games in order to: (1) defend a disjunction, (2) attack a conjunction, or (3) react to an attack against an implication.

introduced by a move if it has not been played in a previous move in the game. **P** cannot introduce atomic formulas (i.e. he can use an atomic formula iff **O** has introduced it in a previous move). Atomic formulas cannot be attacked. **SR-6_c**: Classical No-Delaying-Tactics Rule. No strict repetition is allowed (for more details see Keiff 2011, Rahman and Tulenheimo 2006).

Lorenzen-style Natural Dialogue

Locution rules. **L1:** A claim *claim* φ is performed when a player does one of the following: (1) attacks $\neg A$; then φ is formula A ; (2) defends $A \wedge B$; then φ is formula A or formula B ; (3) attacks $A \rightarrow B$; then φ is formula A ; or (4) defends $A \rightarrow B$, then φ is formula B . A concession *concede* φ is performed when φ is an atomic formula and the performer is the proponent **P** who does one of the following: (1) attacks $\neg A$; then φ is formula A ; (2) defends $A \wedge B$; then φ is formula A or formula B ; (3) attacks $A \rightarrow B$; then φ is formula A ; or (4) defends $A \rightarrow B$, then φ is formula B . **L3:** An argumentation *since* Ψ is performed when a player defends $A \vee B$; then φ is the formula $A \vee B$ and Ψ is a set which includes formula A or formula B . **L4:** A challenge *why* φ is performed when a player attacks $A \vee B$; then φ is the formula $A \vee B$. **L5:** A question *question* φ is performed when a player attacks $A \wedge B$, then φ is formula A or formula B .

Protocol. Let $D'(A)$ be a DL-style dialogue for A , i.e. a set of DL-style games for A . **P1:** In the first move **P** performs *claim* φ where φ is the topic A , then the players perform one locution at each turn. **P2:** A player **P** has following limitations in stating an atomic formula φ : (1) **P** can not perform *claim* φ where φ is a proposition, he can state that φ is true executing *concede* φ ; (2) **P** can not perform Ψ since φ before φ was introduced by **O**; these moves can be performed only if **O** has claimed φ in some previous move. **P3** After *claim* φ a player can perform one of the following: (1) *claim* Ψ , if (a) φ is the negation of a formula and Ψ is the negation of φ , (b) φ is an implication and Ψ is the antecedent of φ , or (c) φ is an antecedent of the implication under the attack and Ψ is a consequent of this implication (**P** has to abide by the restriction described in P2.1); (2) *concede* Ψ , if the player is **P** and Ψ is a proposition, and (a) φ is the negation of a formula and Ψ is the negation of φ , (b) φ is an implication and Ψ is the antecedent of φ , or (c) φ is an antecedent of the implication under the attack and Ψ is a consequent of this implication; (3) *question* Ψ , if φ is a conjunction and Ψ is one of its operands, (4) *why* φ , if φ is a disjunction; (5) an attack on or defence of any formula which was uttered before and was not attacked or defended yet, if a player is **P**; (6). no move, if (a) *claim* φ is an attack on a negation and φ is a proposition, or (b) *claim* φ is a defence executed by **P**, and **O** has attacked this defence before. **P4** After *concede* φ has been performed by a proponent, where φ is a proposition, a player can perform one of the following: (1) *claim* Ψ , if *concede* φ is an attack on an implication, Ψ is the consequent of the implication and *claim* Ψ is performed by the opponent; (2) no move, if (a) *concede* φ is an attack on a negation and φ is a proposition, or (b) *concede* φ is a defence executed by a proponent and the opponent has attacked this defence before. **P5** After *since* Ψ , where $\Psi = \{\Psi\}$, a player can perform one of the following: (1)

claim ϕ , if (a) Ψ is the negation of a formula and ϕ is the negation of Ψ , (b) if Ψ is an implication and ϕ is its antecedent (P has to abide by the restriction described in P2.1); (2) *concede* ϕ , if the player is P and ϕ is a proposition, and (a) Ψ is a negation of a formula and ϕ is the negation of Ψ , or (b) if Ψ is the implication and ϕ is its antecedent; (3) *question* ϕ , if Ψ is a conjunction and ϕ is one of its operands; (4) *why* Ψ , if Ψ is a disjunction; (5) an attack on or defence of any formula which was uttered before and was not attacked or defended yet, if a player is P; (6) no move, if ϕ *since* Ψ is a defence executed by P, and O has attacked this defence before. **P6** After *why* ϕ a player can perform one of the following: (1) ϕ *since* Ψ (P has to abide by the restriction described in P2.2); (2) an attack on or defence of any formula which was uttered before and was not attacked or defended yet, if a player is P. **P7** After *question* ϕ a player can perform one of the following: (1) *claim* ϕ (P has to abide by the restriction described in P2.1); (2) *concede* ϕ , if the player is P and ϕ is a proposition; (3) an attack on or defence of any formula which was uttered before and was not attacked or defended yet, if a player is P. **P8:** If O loses a game Δ which involves a *propositional choice* made by O (see DL-rule SR-2), then O can start a sub-game Δ' . There are three possible types of sub-games Δ' : (1) Assume that P executes *claim* ϕ in Δ , where ϕ is $\Psi \wedge \Psi'$, and O attacks the conjunction by stating *question* Ψ (the *propositional choice* step). If they continue to play the game Δ according to the LND rules and P makes the last available move, then O can extend Δ with a sub-game Δ' by attacking the conjunction one more time using the locution *question* Ψ' . (2) Assume that O executes *claim* ϕ in Δ , where ϕ is $\Psi \vee \Psi'$. In the next moves, P attacks the disjunction by stating *why* ϕ , and O defends it by stating ϕ *since* Ψ (the *propositional choice* step). If they continue to play the game Δ according to the LND rules and P makes the last available move, then O can extend Δ with a sub-game Δ' by defending the disjunction one more time with the locution ϕ *since* Ψ' . (3) Assume that in a game Δ O executes *claim* ϕ , where ϕ is $\Psi \rightarrow \Psi'$, and P attacks the implication by stating *claim* Ψ . There are two possible sub-cases: (1) let O respond to this attack by defending the implication, i.e., he performs *claim* Ψ' (the *propositional choice* step). If they continue to play the game Δ according to the LND rules and P makes the last available move, then O can extend Δ with a sub-game Δ' by responding to P's attack one more time and attacking the propositional content of P's attack, Ψ , according to its logical form. (2) Let O respond to P's attack by attacking its content, Ψ , according to its logical form (the *propositional choice* step). If they continue to play the game Δ according to the LND rules and P makes the last available move, then O can extend Δ with a sub-game Δ' by responding to P's attack one more time and defend the implication using the locution *claim* Ψ' . In all cases P8.1-P8.3, during Δ' the players may use all the LND rules, with the limitation on rule P2 that P cannot perform *concede* ϕ if O did not introduce a proposition ϕ in Δ before the propositional choice step and did not introduce a proposition ϕ in Δ' .

Effect rules. For a formal game $\Delta = m_0, m_1, \dots, m_n \in \mathbf{D}'(A)$, the rules for the hypothetical commitment base C'_s of a player $s \in \{\mathbf{O}, \mathbf{P}\}$ are specified below, where $s(m)$ denotes a move by a player s and $\phi, \Psi \in L_\tau$ are propositional formulas: **E1:** If

$s(m_n) = \textit{claim } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$, i.e. after *claim* φ the formula φ is added to the hypothetical commitment base. **E2:** If $s(m_n) = \textit{why } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1})$. **E3:** If $s(m_n) = \textit{concede } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$. **E4:** If $s(m_n) = (\varphi \vee \Psi) \textit{ since } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$, i.e. after $(\varphi \vee \Psi) \textit{ since } \varphi$ the formula φ is added to s 's hypothetical commitment base. **E5:** If $s(m_n) = \textit{question } \varphi$ then $C'_s(m_0, m_1, \dots, m_n) = C'_s(m_0, m_1, \dots, m_{n-1})$.

Termination and outcome rules. Termination rule: a game finishes if (1) there is no legal move to perform for **O** or **P**, and (2) **O** cannot extend the game with a sub-game. Outcome rule: **P** wins the game if (1) the game is finished, and (2) in the game and in all its sub-games **P** has performed the locution *concede*.

Hamblin-style Natural Dialogue

Locution rules. **HL1:** A claim *claim* φ is performed when a player asserts that a sentence φ is true and his antagonist does not have this sentence in his commitment base. **HL2:** A concession *concede* φ is performed when a player asserts (concedes) that sentence φ is true and his antagonist has this sentence in his commitment base. **HL3:** An argumentation *since* Ψ is performed when a player justifies statement φ with a set of sentences Ψ only with *modus ponens*. **HL4:** A retraction *retract* $\varphi_1 \wedge \varphi_2 \wedge \dots \wedge \varphi_k$ for $k \in N$ is performed when a player withdraws the statement that sentences $\varphi_1 \wedge \varphi_2 \wedge \dots \wedge \varphi_k$ are true. **HL5:** A challenge *why* φ is performed when a player asks for some proof of φ . **HL6:** A question *question* $\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k$ for $k \in N$ is performed when a player asks his antagonist whether one of the formulas $\varphi_1, \varphi_2, \dots, \varphi_k$ is true. **HL7:** A complex question *question* φ , *question* $\neg\varphi$ is performed when a player wants his antagonist to resolve which of φ or $\neg\varphi$ is true.

Protocol. **HP1:** Each participant makes one locution at each turn, with the following exceptions: (1) *retract* φ , which can be followed by *why* φ ; (2) the complex question *question* φ , *question* $\neg\varphi$. **HP2:** After *question* $(\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k)$ a player can perform one of the following: (1) (a) *claim* $\neg(\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k)$, or (b) *concede* $\neg(\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k)$, (2) *retract* $(\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k)$, (3) (a) *claim* φ_1 or *claim* φ_2 or ... or *claim* φ_k , or (b) *concede* φ_1 or *concede* φ_2 or ... or *concede* φ_k ; (4) *retract* $(\varphi_1 \wedge \varphi_2 \wedge \dots \wedge \varphi_k)$. **HP3:** After *why* φ a player can perform one of the following: (1) (a) *claim* $\neg\varphi$, or (b) *concede* $\neg\varphi$; (2) *retract* φ ; (3) a statement of some sentence Ψ which is equivalent to φ by the primitive definition (a) *claim* Ψ , or (b) *concede* Ψ ; (4) $\varphi \textit{ since } \{\Psi_1, \dots, \Psi_n, \text{Taut}(\Psi_1 \wedge \dots \wedge \Psi_n \rightarrow \varphi)\}$ (justification for φ by the inference rule in which Ψ_1, \dots, Ψ_n are premises and φ is a conclusion; the player states that this inference is based on a tautology, i.e. that the formula $\Psi_1, \dots, \Psi_n \rightarrow \varphi$ is a tautology). **HP4:** After *question* φ , *question* $\neg\varphi$ a player can perform (1) *retract* φ or (2) *retract* $\neg\varphi$.

Effect rules. If $s \in \{S, R\}$, where S denotes the sender and R denotes the receiver, and $s(m)$ denotes a move by the player s , then the effect rules of the formal dialectic can be described as follows: **HE1:** If $s(m_n) = \textit{claim } \varphi$, then: (1)

$C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$ if the player R does not perform *claim* $\neg\varphi$, *concede* φ or *why* φ during the m_{n+1} move. **HE2:** If $s(m_n) = \textit{concede } \varphi$, then (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1})$. **HE3:** If $s(m_n) = \varphi$ since $\{\Psi_1, \dots, \Psi_n\}$, then (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) \cup \{\Psi_1, \dots, \Psi_n\}$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1}) \cup A$, where $\Psi' \in A$ iff $\Psi' \in \Psi$ and in the move m_{n+1} the player R does not perform: *claim* $\neg\Psi'$, *concede* $\neg\Psi'$, or *why* Ψ' . **HE4:** If $s(m_n) = \textit{retract } \varphi_1 \wedge \varphi_2 \wedge \dots \wedge \varphi_k$, then (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) - \{\varphi_1, \varphi_2, \dots, \varphi_k\}$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1})$. **HE5:** If $s(m_n) = \textit{question } \varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k$, then (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k\}$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi_1 \vee \varphi_2 \vee \dots \vee \varphi_k\}$ if R does not perform *claim* $\neg(\varphi_1, \varphi_2, \dots, \varphi_k)$ or *concede* $\neg(\varphi_1, \varphi_2, \dots, \varphi_k)$ during the m_{n+1} move. **HE6:** If $s(m_n) = \textit{why } \varphi$, then (1) $C_S(m_0, m_1, \dots, m_n) = C_S(m_0, m_1, \dots, m_{n-1})$, and (2) $C_R(m_0, m_1, \dots, m_n) = C_R(m_0, m_1, \dots, m_{n-1}) \cup \{\varphi\}$ if the player R does not perform *claim* $\neg\varphi$, *concede* φ or *why* φ during the m_{n+1} move.

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