# Cumulativeness in Dialectical Games

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**Abstract**

There are many dialectical games and correspondingly there are many dialogical situations in which the games can be deployed. These situations include a range of differing dialogue types and social circumstances in which a dialogue may occur. This paper investigates the ways that cumulativeness is exhibited in a range of formal dialectic games and how the notion of cumulativeness can be applied to the *classification problem*; determining which groups of dialectical games are most suitably applied to a given dialogical situation. Building on the features identified in the extant games analysis, some elements of a theory of cumulativeness are identified and presented in the context of a computational framework for dialectical game implementation called the Architecture for Argumentation. Finally a number of problems are identified to which the class of cumulative dialectical games could be usefully applied.

## 1   Introduction

Many dialectical games have been proposed and applied to a range of problems. There is also much ongoing work into how dialectical games are represented; how dialectical games are classified and described in terms of their identifiable features; how the dialogues produced according to a given game are analysed; and how games are specified to regulate particular types of dialogue in specific situations. This paper is based on research into computational dialectics, the use of formal dialectical models of argumentative dialogue in computational systems, and some problems that have been identified during the implementation of such systems. It is concerned with a feature of dialectical games that has been studied in explaining certain fallacies and proposes that this feature can be used to classify and group extant games, as a contributory factor in the formulation of rules to regulate production of dialogue during a dialectical game, and as an explanatory element during the analysis of produced dialogue. This feature is cumulativeness, the notion that once something is established in a dialogue it remains so established until the end of the dialogue.

Given the large number of dialectical games, and the large number of dialogical situations to which they can be applied it is hard to determine which games are most suited for application to a particular situation. There are currently no comprehensive classifications for different types of dialectical game nor for the types of dialogue, notwithstanding the influential typology of Walton and Krabbe [16] to which a game could be applied. In addition there are no comprehensive schemes to classify the differing social situations in which a dialogue of any given type could occur. This *classification problem* could be tackled

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by taking a feature of dialectical games such as cumulativeness, determining which games exhibit this feature and which do not, and identifying particular dialogical situations to which a game exhibiting the feature is more suited than a game that does not.

The remainder of this paper is structured as follows; section 2 introduces dialectical games and the notion of cumulativeness; section 3 examines the extant dialectical games in the context of cumulativeness to determine how it is exhibited in those systems and the nature of the rules that facillitate this; section 4 analyses cumulativeness in dialectical games in the context of the Architecture for Argumentation (A4A) which is a software framework for rapidly developing and deploying computational dialectics; finally section 5 looks at some problems in dialogue and how their analysis and modelling could be benefited by the explicit adoption of cumulative concepts.

## 2   Dialectical Games and Cumulativeness

Dialogue games have been proposed as a means to model the interactions between participants during argumentative dialogues. One branch of dialogue game research is into the dialectical games [5] of Hamblin. Dialectical games are a way to extend formal logic to account for the dialectical contexts in which arguments are put forward, and to enable the analysis of fallacies using an approach different to that used in formal logic. Dialogical investigations utilising dialectical games can be carried out in either a descriptive or a formal fashion, descriptive if the aim is to identify the underlying rules and conventions which can be used to describe certain features of the dialogue, and formal if the aim is to begin with a set of rules and conventions and to produce dialogue in accordance with the rules and thereby demonstrate and explain how certain features of dialogue actually occur. It is dialectical games in the formal sense that this paper is concerned with.

Formal dialectical games can be simply defined as two-player, turn-taking games in the traditional ludic sense. In such a dialectical game the moves available to the players represent the locutional acts and utterances made by the participants in the dialogue. The rules of the game specify the points at which particular moves can be legally played and the resultant effects upon the components of the game of actually playing the move. Rules dealing with legality requirements are generally specified in terms of earlier moves that must have occured, the state of the games components, and the particular form of the locution expressed by the move. Rules dealing with resultant effects generally specify the set of legal responses and the updates that must be applied to the dialogue's components.

Many dialectical games have been proposed based on the characterisation of a range of dialogical situations. A small sample of extant games includes Hamblin's "*Why-Because-System-With-Questions*" [5], also referred to as "H" , and Mackenzie's "DC" [8] both of which are targeted towards fallacy research, whilst Walton and Krabbe's game $PPD_0$ [16] examines the interactions between parties during persuasion dialogues. Girle introduces a number of games which are aimed at modelling belief revision in A.I. systems [2, 3, 4]. McBurney and Parsons specify some games for use in communication between agents in multiagent systems [9]. Bench-Capon *et al.* introduce the Toulmin Dialogue Game which they claim is particularly suited to modelling legal argument [1] and that is based upon the argument schema of Toulmin [11].

Computational implementations of dialectical games are also well-favoured in the domains of computer-based learning, multiagent systems and artificial intelligence. Current research into agent communication has yielded the Architecture for Argumentation (A4A) [17], a unified framework for representing disparated dialectical games that enables games to be rapidly implemented. As a result of this activity there are a plethora of games looking at individual problems in disparate domains but comparatively little work into classifying and grouping individual games based upon the features of either the games rules or the resultant dialogues. What little work does exist identifies a number of desiderata of games [10, 18] but stops short of classifying extant games according to those desiderata. This could be termed the classification problem, having an abundance of sets of game rules but comparatively little evaluation of those rule sets especially in terms of distinguishing which games, or classes of games, are best applied to particular problems.

One way to tackle the classification problem is to take an identifiable feature of the game rules and group individual games accordingly. In their examination of the role of Hamblin's rules H+(W)+(R1) in prohibiting the *petitio*, Woods and Walton [19] describe an attribute of dialectical games which they identify as a critical factor in those games which prohibit the *petitio* and which could be used to tackle the classification problem, this attribute they name cumulativeness. Cumulativeness is identified by Woods and Walton in terms of commient store contents at discrete points in the game. A game is cumulative with respect to commitments if once that commitment is incurred and added to the player's commitment store it cannot be subsequently retracted and removed from the store. Woods and Walton define a general notion of cumulativeness in terms of a a set of points $w_i \in W$, an ordering relation $<$ on the members of $w_i$, a language $L$ containing statements of propositions A, B, C,..., and a function $f$ that maps a pair $<w_i, A>$ onto a set $<1,0>$. A game is thus defined as cumulative if and only if for any two points $w_i$ and $w_j \in W$, and for any proposition A, if A has a given value, 1 or 0, at $w_i$ then A has the same value at $w_j$ if $w_i < w_j$. Practically this means that for a dialectical game consisting of a sequence of turns, $T_n$, the game is cumulative with respect to any given component if the status of that component as established at $T_x$ is the same at $T_y$: $y > 0$. Woods and Walton thus identify that whether or not a *petitio* is committed in a given dialectical game depends on whether that game is cumulative with respect to certain values ascribed to particular elements of $L$ at various points during a play of the game.

Given the identifiable dialectical game attribute cumulativeness, the extant games can be surveyed to determine how they exhibit this attribute. Such a survey would aim to shed light on underlying theoretical aspects of cumulativeness in dialectical games and could be extended to find particular problems, the analysis of which would correspond naturally to games classified in a particular group.

## 3 Exhibition in Extant Dialectical Games

To gain an understanding for how cumulativeness actually occurs in extant dialectical games it is necessary to examine how each game exhibit cumulativeness. This section surveys a range of games in terms of cumulativess. The survey is used to demonstrate how various disparate games can be grouped according to their exhibition of cumulativeness. A

summary of the survey is presented in table 1. This table records for each type of commitment that can be added to the players commitment stores whether the game is cumulative with respect to that commitment.

| Game | Cumulative Elements |
|---|---|
| Hamblin's Formulation of rules for the Obligation Game [5, pp. 260-263] | Cumulative with respect to statements |
| H [5, pp. 265-267] | Non-cumulative with respect to statements |
| DC [8, pp. 118-121] | Cumulative with respect to challenge locutions<br>Non-cumulative with respect to statements |
| DD [8] | Non-cumulative with respect to challenge locutions<br>Non-cumulative with respect to statements |
| CB [12] | Non-cumulative with respect to statements |
| CB+ [12] | Non-cumulative with respect to statements |
| CBV [12] | Non-cumulative with respect to statements |
| CBZ [12] | Non-cumulative with respect to statements |
| DL [2] | Cumulative with respect to challenges<br>Non-cumulative with respect to statements |
| DL2 [3] | Cumulative with respect to withdrawals<br>Cumulative with respect to challenges<br>Cumulative with respect to wh-questions<br>Non-cumulative with respect to statements<br>Non-cumulative with respect to defenses |
| DL3 [4] | Cumulative with respect to withdrawals<br>Non-cumulative with respect to statements<br>Non-cumulative with respect to wh-questions<br>Non-cumulative with respect to challenges<br>Non-cumulative with respect to justification sequences |
| $PPD_0$ [16] | Non-cumulative with respect to light-side assertions<br>Non-cumulative with respect to light-side concessions<br>Cumulative with respect to dark-side commitments |
| TDG [1] | Non-cumulative with respect to commitments<br>Non-cumulative with respect to claims |

Table 1: The exhibition of cumulativeness for a range of dialectical games

It should be noted that merely identifying whether a game is or is not cumulative with respect to a given component does not give the full picture with respect to cumulative effect in that game. Cumulativeness appears to be intimately entangled with the notion of retraction as noted by Walton [14, pp.767] for where a game may not strictly be cumulative with respect to a given element insofar as the game incorporates rules allowing retraction of that element, the actual formulation of rules may specify sufficient conditions as to make it very difficult to retract a commitment once incurred. This aspect of cumulative effect is not studied in any more depth here.

In Hamblin's formulation of rules for the Obligation Game [5, pp. 260-263] only the respondent possesses a commitment store. This is cumulative with respect to the answers uttered by the respondent and the *positum* which is a part of the initial statement made by the opponent at the beginning the game. All of the statements that the respondent makes during their turn are in response to the contributions of the opponent in the previous turn. An answer-rule is formulated to determine whether the respondent's answers are correct or incorrect. The aim is for the opponent to ask questions of the respondent with the aim of forcing the respondent to answers such that they lead to inconsistency in the respondents commitment store. The Obligation Game is the only extant game which is cumulative with respect to the statements uttered although other games exhibit cumulativeness with respect to a number of other feature such as particular locutions.

The rules of H only allow commitment to be incurred with respect to the statements uttered as the content part of a locution. Any commitment that is incurred within either player's commitment store can also potentially be retracted at some subsequent point dependent upon the state of the game and the locutions played. DC is similar to H in its treatment of commitments, allowing commitment with respect to statements to be both incurred and retracted. In addition DC allows commitments to be incurred with respect to particular locutions, hence DC is cumulative with respect to challenges. Each time a challenge is made the challenge locution is incurred in the speaker's commitment store but there is no corresponding move to allow a player to remove a challenge from their commitment store.

Walton's CB-based family of games do not add anything new with respect to cumulativeness and act similarly to H, both games are non-cumulative with respect to the statement content of their respective locutions and neither game accumulates any other element within their commitment stores. Girle's DL game is also very similar to DC in terms of cumulativeness, both games are cumulative with respect to challenge locutions and non-cumulative with respect to the statement content of particular locutions.

DL2 is non-cumulative with respect to the statement content of it's locutions but the commitment stores record retraction of a commitment such that after a withdrawal of a statement "P" the player's commitment store records "minus P" in place of the original "P". In this way the commitment stores of DL2 are cumulative with respect their constituent commitments. Once a commitment is established in the commitment store it remains in the store although the form of the commitment may change to reflect the effects of subsequent moves. DL2 is cumulative with respect to questions, challenges and withdrawals all of which can be incurred in a player's commitment stores and for which there are no means to remove the commitent. DL2 is however non-cumulative with respect to both statements and defenses, both of which can be removed from a player's commitment store through use of the withdrawal locution.

DL3 is cumulative only with respect to withdrawals and is non-cumulative with respect to the other commitent types that players can incur in this game. These commitment types include statements, questions, challenges, and justification sequences. DL3 introduces the notion of a commitment complex which Girle names a justification sequence. This is a

structure built from a number of atomic commitments which are incurred during a particular dialectical sequence. Girle's stated intention is to allows commitment stores to record the sequence of locutions that lead to a particular commitment being established as grounds for another after a challenge-defense exchange between the participants.

Although the dark-side commitment store is introduced in CBV in the guise of the *veiled* commitment store it is merely a private commitment store in which the commitments are added prior to the dialogue and the contents of which are removed during play according to the rules. It is not until the dark-side stores of $PPD_0$ are utilised that a special form of commitment store can be identified. These stores are cumulative with respect to their contents because there are no moves which allow commitments to be removed from them but they are also static insofar as there are also no moves to allows new commitments to be incurred within them. The contents of dark-side commitment stores are established prior to and remain static throughout the dialogue.

TDG is non-cumulative with respect to the statement contents of locutions and does not allow any other components of the game to be incurred as commitments. However TDG introduces a new kind of store which is public and accessibly by all participants but which tracks the claims made during the dialogue. This store, known as the *claim stack*, is non-cumulative with respect to claims because TDG has rules to allow claims to be pushed onto and popped from the stack as a result of certain moves being played. Internally the claim stack is a standard last-in-first-out data structure [6].

A number of groupings of dialectical games can be identified based on the information in table 1. These include the groups of games that are cumulative or non-cumulative with respect to the statement content of locutions or with respect to particular locutions, e.g. commitment with respect to challenge-locutions. A summary of groupings of dialectical games organised according to each games exhibition of cumulativeness can be found in table 2. It should be noted that similarly to the analysis of cumulativeness found in table 1 games are only grouped according to the elements that are accumulated during play. A game is only considered as cumulative with respect to a given element if it accumulates elements but offers no way to remove the accumulated element. Similarly a game is considered non-cumulative if it accumulates particular elements but allows a way to remove those elements from the accumulation during play.

In summary this section has presented the results of a survey of the nature and extent of cumulativeness exhibited in extant dialectical games together with a number of groupings of such games with respect to the nature of each games cumulativeness.

## 4  Towards a Theory of Cumulativeness in Dialectical Games

Three questions can be asked regarding a theory of cumulativeness in dialectical games; what would such a theory look like?, why would such a theory be required?, and assuming such a theory is required how would such a theory be attained? It is not clear at this point what a theory of cumulativeness in dialectical games would look like yet some elements of such a theory may be sketched out based upon the features identified earlier. Given that

| Grouping | Member Games |
|---|---|
| **Cumulative with respect to:** | |
| Statement Content of Locutions | The Obligation Game |
| Challenge Locutions | DC, DL, DL2 |
| Withdrawal Locutions | DL2, DL3 |
| Wh-Question Locutions | DL2 |
| Dark-side Commitments | $PPD_0$ |
| **Non-cumulative with respect to:** | |
| Statement Content of Locutions | H, DC, DD, CB, CB+, CBV, CBZ, DL, DL2, DL3, TDG |
| Justification Sequences | DL3 |
| Light-side Assertions | $PPD_0$ |
| Light-side Concessions | $PPD_0$ |
| Challenge Locutions | DD |
| Defense Locutions | DL2 |
| Question Locutions | DL3 |
| Wh-Question Locutions | DL3 |
| Claim Locutions | TDG |
| Dark-side Commitments | $PPD_0$ |

Table 2: The grouping of dialectical games based upon exhibition of cumulativeness

there are a number of problems to which cumulative dialectical games are well suited to modelling, a theory of cumulativeness would shed light on why certain games are particularly suited to these problems as well as contributing to the understanding of retraction of commitment in dialectical games. The remainder of this section presents these elements in the context of the A4A schema, a unified format for representing dialectical games which is implemented as a part of the Architecture for Argumentation (A4A).

The A4A schema was developed to tackle an implementational problem which asked that given the wide range of dialectical games which game should be implemented to support communication between autonomous software agents? The most efficient approach is to build a common system that supports all of the extant systems. To achieve this an analysis of existing games was undertaken with the aim of identifying the common featyres of such games. A unified representation format called the A4A schema was developed that enabled arbitrary dialectical games to be specified in terms of the common features identifiable in the extant dialectical games.

A dialectical game is laid out according to the following schema consisting of three sections, the game, structure, and moves sections;

**Game**
    **Name** *Unique System Label*
    **Turns** *⟨Progression, Size⟩*
    **Stores**: *⟨Name, Owner, Content, Structure, Visibility⟩*

**Structure**
    **Rule Name**
    **Requirements**:

Ø  
**Effects:**  
Ø  

**Moves**  
⟨**Performative, (Content)**⟩  
**Requirements:**  
Ø  
**Effects:**  
Ø  

The first section enables the specific components required by a particular instance of a dialectical game to be specified. These components are manipulated by the rules of the game. In ludic theoretic terms, the game section specifies the boards that the game is played on and the way that the turns are structured. The second section is a formulation of rules for regulating the structure of the dialectical game such as those rules which govern how a game starts and finishes, or whether an embedding or a shift to a sub-game is legal. The third element is a formulation of rules which govern how the players can legally interact with and directly manipulate the components of the game, these rules specify the moves of the game. The formulation of contents fo both the structural rules and the moves relies on being able to identify particular states of game components and being able to manipulate those states. The range of component states and manipulations will not be detailed here but is sufficient to allow the H, DC, DD, CB, CB+, CBV, CBZ, DL, DL2, DL3, $PPD_0$, and TDG games to be specified as well as a range of hybrid games.

By identifying the range of boards that a game can be played on and the range of tokens that the boards can hold, an abstract model of dialectical games can be constructed. All dialogues have a transcript detailing the utterances made. Likewise all dialectical games have a transcript object which holds the sequence of utterances that the players of the game make. The transcript is usually implicit in the extant games but is explicitly represented in the A4A schema. This enables the rules of games expressed in the schema to be formulated in terms of earlier utterances. The transcript is the only board that a game must include however most dialectical games also specify a number of other boards which are the games commitment stores. The tokens are the statement-variables, locutions, and commitments which are established and manipulated during dialogues. Tokens are manipulated by the players when they play a move. This is accomplished by the participant playing a move during their turn. During any given turn, the playing of a move may manipulate tokens onto various boards and thereby establish the corresponding artifacts in the specified artifact stores. How any given move manipulates tokens betweens boards is regulated by the rules of the game.

Two notions of cumulativeness can be identified from the extant games, the first is essential cumulativeness with respect to the transcript of a dialogue, the record of all utterances that the players make during a game; the second is cumulativeness with respect to the commitments of the players.

Real-world dialogues are essentially cumulative with respect to their component utterances such that once something is said it cannot be subsequently unsaid. Similarly all extant dialectical games are essentially cumulative insofar as all the moves that a player makes within a game cannot be subsequently unplayed. Once each move is played that move is recorded in the dialogue transcript. It should be noted that although many game rules are framed in terms of previous utterances of a given player the transcript itself is not explicitly represented as a component of a game in the same way that commitment stores are. The transcript is a useful source of infomation about the current game and rules can be formulated which lay out the legality conditions for each move of a game in terms of previous dialogue utterances. To determine whether a move, specified in such terms, can be legally played depends upon examination of the transcript to check for the specified condition. For example, in $PPD_0$ [16] the retraction "nc" can only be played if the preceding move contained either the request "con(P)?" or the extractor "serious(P)?". These legality conditions do not rely on the commitment state of the game but on the state of the dialogue's transcript. There is no way to remove an utterance from the transcript in any of the extant dialectical games, hence they are essentially cumulative with respect to utterances stored in the transcript.

Cumulativeness of commitment is intimately connected with how a game allows retraction to occur. Retraction is described by Walton [14, pp.767] as a vexing problem when constructing formal dialectical games to represent rational argumentation. The issue lies in the fact that the suitability of a given retraction rule, and how therefore a player can retract commitment, depends upon the type of dialogue that the players are engaged in and is a central theme of Walton and Krabbe's analysis of commitment in dialogue [16]. When a player incurs a commitment it is placed in their commitment store and, if the rules allow, when a player retracts a commitment it is removed from their commitment store. The formulation of rules, commonly termed commitment store rules, which regulate how commitment is incurred or retracted during a game set out how each legal move affects the commitment state of the game. The rules pertaining to each move may also set additional conditions which must be met for the commitment effect to occur. Each move may, by specifying alternate sets of legality conditions and resultant effects, possess a different commitment effect dependent upon the current state of the game when the move is played and also upon the listeners response.

Due to the granularity of the survey of extant games the requirements of a unified schema to represent cumulativeness of commitment requires the following basic capabilities;

1. if a game is cumulative with respect to a given artifact type and store then it requires at least one move which can manipulate the artifact into the requisite store.

2. if a game is non-cumulative with respect to a given artifact type and store then it requires that if there is at least one move which can manipulate the artifact into the store then there must be at least one corresponding move which can remove the artifact from the store.

A more complete approach to the construction of a theory of cumulativeness in dialectical games requires at least the following, the development of a model of dialogical situation

and the analysis of the space of rules that can be used to specify a dialectical game. Dialogical situation,the utilisation of a given dialogue type in particular social circumstances, is required because, as Walton and Krabbe recognise [16, pp.67], dialogue types coincide with particular dialectical games. Analysis of the space of rules is required because as stated earlier, a non-cumulative game may because of the strictness of its retraction rules be cumulative in practise even if it is not cumulative by definition.

## 5   The Varied Roles of Cumulativeness

Dialectical games have been formulated as tools to aid in the exploration of a range of problems in argumentative dialogue. Such problems fall into a number of non-exhaustive groups which include the investigation of those fallacies described by Aristotle as fallacies outside of language, the formulation of rules of dialectical procedure to guide the production of dialogue, and the investigation of the conventions and rules under which either particular types of dialogue or dialogues occuring in particular circumstances can be modelled. One area where cumulative dialectical games have demonstrated their utility is in modelling the *petitio* [19, 20, 8]. This section examines inquiry-type dialogues and dialogues that incorporate the argument from expert-opinion scheme. It is proposed that certain dialogue types and situations, by virtue of their structure, aims and goals are more suited to being modelled using cumulative dialectical games than non-cumulative dialectical games.

The purpose of an inquiry type dialogue according to Walton [13, pp.24] is to either prove a proposition or demonstrate that it cannot be proved with the current level of knowledge. Walton identifies the kind of reasoning that occurs in an inquiry as a cumulative increment of verified and established propositions [13, pp.1944] that yields an argument with a tree-like structure. It naturally follows that a dialectical game targeted towards the inquiry-type dialogue should be cumulative with respect to certain dialogue artifacts which correspond to verified and established propositions.

A commonly occuring argumentation scheme is the appeal to expert opinion [15, pp.84], the notion that for a given knowledge domain there are certain sources which can be cited for information. Such arguments from expert opinion are presumptive and defeasible, just because the source is an expert does not mean that they are necessarily correct or telling the truth and there are several critical questions associated with the scheme, yet expert opinion is common in legal argument. For example during a Scottish court case involving fingerprint evidence an expert from the Scottish Fingerprint Service will be called to court to testify in relation to the fingerprint evidence. Dialectical games have been used to model legal argument [7] in which the participants try to justify statements by convincing an audience. Cumulative dialectical games are particularly suited to modelling the type of dialogue that occurs during witness testimony, particularly where the witness is acting in the capacity of an expert witness. Onee goal of the participant in the interrogative role in such a game would be to demonstrate the existance of inconsistencies in the witnesses testimony with the aim of convincing the jury that the witness could not be relied upon. Conversely the goal of the witness is to convince the jury to accept their testimony as fact. If a game is cumulative with respect to the statements of the witness then the witness is more likely to maintain a consistent account of events if they are reliable. If the witness is not

wholly reliable then the accumulated commitments of the witness will contain inconsistencies. These inconsistencies are valuable as they are a public record of how the testimony of the witness has evolved under cross examination, and given the jury some measure of the reliability of the testimony.

# 6   Conclusion

This paper has examined cumulativeness in dialectical games and the role that cumulativeness can take as a classification attribute to identify groups of dialectical games. The utility of identifying such groups rests on the notion that dialectical games from certain groups are more suited to modelling certaing dialogical situations. The proposal was made that certaing situations such as legal testimony by an expert witness or inquiry-type dialogues are best tackled using cumulative dialectical games.

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