Empirical and theoretical constraints on dialogue act combinations

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Abstract

This paper presents an empirical study and analytical examination of the actual and possible co-occurrence of dialogue acts in dialogue units of various sorts. We formulate semantic and pragmatic constraints on dialogue act combinations for various types of dialogue unit.

1 Introduction

One of the reasons why people can communicate efficiently is because they use linguistic and nonverbal means to address several aspects of the communication at the same time. Consider, for example, the following dialogue fragment[1]:

(1) *U1: What is RSI?*
S1: RSI stands for Repetitive Strain Injury
U2: Yes but what is it?
S2: Repetitive Strain Injury is an infliction where...

Utterance (U2) in 1 indicates that (1) the user interpreted the system's previous utterance (S1) successfully (signalled by 'Yes'); (2) the system did not interpret utterance (U1) as intended (signalled by 'but'); and (3) the user requests information about the task domain. If the system does not recognize all three functions, it will most likely resolve the anaphoric pronoun 'it' as coreferential with 'RSI' and interpret (U2) as a repetition of (U1), and thus not be able to react properly.

This example shows that the multifunctionality of utterances must be taken into account in order to avoid errors and misunderstandings, and to support a dialogue that is effective and efficient.

While the multifunctionality of dialogue utterances has been widely recognised (Allwood, 2000; Bunt, 2000; Popescu-Belis, 2005), computationally oriented approaches to dialogue generally see multifunctionality as a problem, both for the development of annotation schemes and for the design of dialogue systems (Traum, 2000). Information that may be obtained through a multifunctional analysis is often sacrificed for simplicity in computational modelling. As a consequence, the actual multifunctionality of dialogue utterances are still understudied (though see Bunt, 2010).

The present study is concerned with the forms of multifunctionality that occur in natural dialogue and the relations between the communicative functions of a multifunctional dialogue units (Section 3). In Section 4 we formulate the semantic and pragmatic constraints on the multifunctionality of dialogue units. Section 5 ends with conclusions and prospects for future research.

2 Semantic framework

We used the semantic framework of Dynamic Interpretation Theory (DIT, Bunt, 2000), which takes a multidimensional view on dialogue in the sense that participation in a dialogue is viewed as performing several activities in parallel, such as pursuing the dialogue task, providing and eliciting feedback, and taking turns. The activities in these various 'dimensions' are called *dialogue acts* and are formally interpreted as update operations on the information states of the dialogue participants and have two main components: a *semantic content* which is to be inserted into, to be extracted from, or to be checked against the current information state; and a *communicative function*, which specifies more precisely how an addressee updates his information state with the semantic content when he understands the corresponding aspect of the meaning of a dialogue utterance.

A communicative function captures beliefs and intentions of the speaker. For instance, the preconditions to perform an Answer are: (1) Speaker (S) believes that Addressee (A) wants to have some information, and (2) S believes that the informa-

[1] From a dialogue with the IMIX system translated from Dutch - see (Keizer & Bunt, 2007).

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tion is true. Applying this to a particular semantic content type, e.g. Auto-Feedback, gives the following: (1) S believes that A wants to know about S's processing state, and (2) S believes that the information about S's processing state is true.

The DIT taxonomy of communicative functions distinguishes 10 dimensions, addressing information about the task or domain (*Task*), speaker's processing of the previous utterance(s) (*Auto-feedback*) or this of the addressee (*Allo-feedback*), difficulties in the speaker's contributions (*Own-Communication Management - OCM*) or those of the addressee (*Partner Communication Management- PCM*), the speaker's need for time (*Time Management*), maintaining contact (*Contact Management*), allocation of speaker role (*Turn Management*), future structure of dialogue (*Dialogue Structuring - DS*), and social constraints (*Social Obligations Management- SOM*).

Some communicative functions can be combined with only one particular type of information, such as Turn Grabbing, which is concerned with the allocation of the speaker role. Being specific for a particular dimension, these functions are called *dimension-specific*. Other functions are not specifically related to any dimension, e.g. one can request the performance of any type of action (such as 'Please close the door' or 'Could you please repeat that'). Question, Answer, Request, Offer, Inform, and many other 'classical' functions are applicable to a wide range of semantic content types. These communicative functions are called *general-purpose* functions.

3 Forms of multifunctionality

To examine the forms of multifunctionality that occur in natural dialogue we performed a corpus analysis, using human-human multi-party interactions (AMI-meetings[2]). Three scenario-based meetings were selected containing 17335 words. Dialogue contributions were segmented at turn level (776 turns); at utterance level (2,620 utterances); and at the finer level of functional segments (see below; 3,897 functional segments). The data was annotated according to the DIT dialogue annotation scheme (DIT^{++} tagset[3]).

[2]Augmented Multi-party Interaction (`http://www.amiproject.org/`).

[3]For more information about the tagset, please visit: `http://dit.uvt.nl/`

3.1 Relations between communicative functions

The DIT^{++} tagset has been designed in such a way that two communicative functions which can be applied in the same dimension either (1) are *mutually exclusive*, or (2) one *entails* the other. Consider, for example, the Time Management dimension. The speaker may suspend the dialogue for one of several reasons and signal that he is going to resume it after a minor or a prolonged delay (Stalling or Pause, respectively). Evidently, stalling and pausing acts are mutually exclusive: they both cannot apply to one and the same segment. In the case of an entailment relation, a functional segment has a communicative function, characterized by a set of preconditions which logically imply those of a dialogue act with the same semantic content and with the entailed communicative function. For instance, more specific functions entail less specific ones, such as Agreement, Disagreement entailing Inform, and Confirm and Disconfirm entailing Propositional Answer. This intra-dimensional entailment relation is called *functional subsumption* (Bunt, 2010).

A communicative function in one dimension may also entail a function in another dimension. This inter-dimensional entailment relation occurs between responsive acts in non-feedback dimensions on the one hand and auto- and allo-feedback acts on the other. For example, accepting or rejecting an offer, suggestion, invitation or request, answering a question, responding to a greeting and accepting apology entail positive Auto-Feedback.

A functional segment may have multiple functions by virtue of its observable surface features (called *independent* multifunctionality), like wording, prosodic and acoustic features or accompanying nonverbal signals. For example, 'yes' and 'okay', said with an intonation that first falls and subsequently rises, express positive feedback and give the turn back to the previous speaker.

A functional segment may also have multiple communicative functions due to the occurrence of conversational implicatures. *Implicated* functions correspond semantically to an additional context update operation and are an important source of multifunctionality. For example, a shift to a relevant new discussion topic implicates positive feedback about the preceding discussion. In DIT^{++}, five processing levels in Auto- and Allo-Feedback also have logical relations that turn up as impli-

Table 1: *Co-occurrences of communicative functions across dimensions in one functional segment, expressed in relative frequency in %, implied functions (implicated and entailed) excluded and included.*

segments in / *have function in*	form	Task	Auto-F.	Allo-F.	Turn M.	Time M.	DS	Contact M.	OCM	PCM	SOM
Task	independent	0	1.1	0	2.2	0.1	19.6	0	3.8	0	0
	implied	49.8	47.9	24.9	97.5	2.4	31.5	0.4	69.6	0.1	0.7
Auto-F.	independent	0.7	0	0	11.0	0.6	1.9	11.1	0.8	0	0
	implied	38.9	100	0	88.7	11.4	11.2	20.2	11.7	65.0	8.7
Allo-F.	independent	0	0	0	0.1	0	0	0	0	0	0
	implied	24.9	0	100	94.8	35.7	2.1	1.2	7.9	0.7	0.3
Turn M.	independent	3.4	26.9	6.7	0	28.6	12.4	7.4	4.8	18.2	6.7
	implied	76.0	66.2	19.4	0	42.9	14.6	13.8	99.6	27.3	10.5
Time M.	independent	0.1	0.7	0	44.9	0	4.7	0	1.3	0	0
	implied	28.2	11.3	7.8	98.6	0	1.7	0	83.2	0.5	0
DS	independent	0.1	0.4	0	0.3	0	0	0.9	0	0	6.7
	implied	3.2	58.3	29.1	87.5	4.9	4.6	25.0	3.7	0	12.5
Contact M.	independent	1.7	0.3	0	3.6	0.5	3.7	0	0	0	1.3
	implied	2.4	97.1	1.6	98.8	0.5	2.4	0	0.3	0	3.7
OCM	independent	1.2	0.4	0	2.8	0.5	0	0	0	0	6.7
	implied	82.2	2.8	2.5	96.9	7.8	3.9	13.5	0	0.9	7.6
PCM	independent	0	0	0	0.3	0	0	0	0	0	0
	implied	11.8	65.0	11.8	79.1	12.2	0	0	0	0	0
SOM	independent	0	0	0	0.2	0	0	2.7	0.3	0	0
	implied	0.7	80.0	10.0	90.0	0	30.0	3.9	2.0	0	0

cations between feedback acts at different levels:

(2) *attention* $<$ *perception* $<$ *understanding* $<$ *evaluation* $<$ *execution*

The implication relations between feedback at different levels are either entailments or implicatures. In the case of positive feedback, an act at level L_i *entails* positive feedback at all levels L_j where $i > j$; positive feedback at execution level therefore entails positive feedback at all other levels. Positive feedback at level L_i *implicates* negative feedback at all levels L_j where $i < j$; for instance, a signal of successful perception implicates negative understanding. This is, however, not a logical necessity, but rather a pragmatic matter. For negative feedback the entailment relations work in the opposite direction. For allo-feedback the same relations hold as for auto-feedback.

3.2 Relations between dialogue units

Dialogues can be decomposed into *turns*, defined as stretches of speech produced by one speaker, bounded by periods of silence of that speaker. Turns consist of one or more *utterances*, linguistically defined stretches of communicative behaviour that have a communicative function. The stretches of behaviour that are relevant for interpretation as dialogue acts often coincide with utterances in this sense, but they may be discontinuous, may overlap, and may even contain parts of more than one turn. They therefore do not always correspond to utterances, which is why we have introduced the notion of a *functional segment* as a minimal stretch of communicative behaviour that has a communicative function (and possibly more than one)[4]. Thus, the units of dialogue that our analysis will be concerned with, are turns and functional segments.

There are different forms of multifunctionality. Allwood in (1992) claims that if an utterance is multifunctional, 'its multifunctionality can be sequential and simultaneous'. Bunt (2010) examines this claim using empirical data from several dialogue annotation experiments and concludes that sequential multifunctionality disappears if we take sufficiently fine-grained dialogue units into account ('functional segments' rather than turns). It was shown that even if we consider fine-grained units of communicative behaviour we do not get rid of simultaneous multifunctionality. The minimum number of functions that one segment has in dialogue is 1.3 on average and this number increases when entailed and implicated functions are taken into account.

3.2.1 Multifunctionality in segments

Our observations show that different functions in different dimensions may address the same span in the communicative channel. This what is called *simultaneous* multifunctionality. Segments may have two or more communicative functions in different dimensions. For example:

(3) *B1: Any of you anything to add to that at all?*
A1: No
D1: I'll add it later in my presentation

[4]These stretches are 'minimal' in sense of not being unnecessarily long.

Table 2: *Co-occurrences of communicative functions across dimensions in overlapping segments, expressed in relative frequency in %.*

have function in \ *segments in*	Task	Auto-F.	Allo-F.	Turn M.	Time M.	Contact M.	DS	OCM	PCM	SOM
Task	0	40.8	23.4	42.4	38.2	0	28.2	65.4	22.9	18.2
Auto-F.	10.5	6.7	16.9	16.9	19.1	18.8	19.1	14.2	54.8	9.5
Allo-F.	1.5	4.2	1.3	4.3	12.1	18.8	12.1	5.4	16.2	9.1
TurnM.	14.1	31.4	45.9	0	14.6	25.0	14.6	76.0	25.8	4.9
TimeM.	2.9	7.7	20.2	12.8	0	0	0.8	3.4	16.1	3.2
ContactM.	0.3	0.2	1.8	0.1	0	0	5.6	0	0	2.9
DS	2.1	6.9	11.4	0.2	3.9	37.5	0	5.6	0	8.2
OCM	4.6	3.8	5.8	4.4	2.3	0	2.2	0	0	1.6
PCM	0	0.9	0.9	1.2	0.7	0	0.7	0	0	0
SOM	0	0.1	1.3	2.1	0.3	23.3	0.3	0.2	0	0

In utterance B1 the speaker's intention is to elicit feedback, and the utterance also has an explicitly expressed ('any of you') turn releasing function. In utterance A1 the speaker provides an answer to B1. The speaker in utterance D1 gives no answer to B1, instead he indicates that he will provide the requested information later in the dialogue (negative Auto-Feedback act combined with Discourse Structuring act). A segment may have one or more functions by virtue of its observable features and one or more functions by implication. For example:

(4) *B1: Just to wrap up the meeting*
D1: Can we just go over the functionality again?

Utterance D1 in (3) is a request to shift the topic back to what was already discussed before. This utterance by implication has a function of negative feedback about B1, disagreeing to close dialogue as announced in B1.

Table 1 gives an overview of co-occurrences of communicative functions across dimensions for one and the same stretch of communicative behaviour simultaneously as observed in features of this behaviour, and when entailed or implicated functions occur[5]. It can be observed that functions which address the same dimension never co-occur, except for Auto- and Allo-Feedback where functions are not mutually exclusive but entail or implicate each other, and some general-purpose functions addressing different dimensions (in our data Task and Discourse Structuring) that are not mutually exclusive but a specialization of the other as discussed in Section 3.1.

Some combinations of functions are relatively frequent, e.g. time- and turn management acts often co-occur. A speaker who wants to win some time to gather his thoughts and wants to continue in the sender role, may intend his stalling behaviour to signal the latter as well (i.e., to be interpreted as a Turn Keeping act). But stalling behaviour does not *always* have that function; especially an extensive amount of stallings accompanied by relatively long pauses may be intended to elicit support for completing an utterance.

Co-occurrence scores are higher when entailed and implicated functions are taken into account (see also Bunt, 2010). An *implicated* function is for instance the positive feedback (on understanding and evaluating the preceding addressee's utterance(s)) that is implicated by an expression of thanks; examples of *entailed* functions are the positive feedback on the preceding utterance that is implied by answering a question or by accepting an invitation. Questions, which mostly belong to the Task dimension, much of the time have an accompanying Turn Management function, either releasing the turn or assigning it to another participant, allowing the question to be answered. This implicature, however, may be cancelled or suspended when the speaker does not stop speaking after asking a question. Similarly, when accepting a request the speaker needs to have the turn, so communicative functions like Accept Request will often be accompanied by function like Turn Accept. Such cases contribute to the co-occurrence score between the Turn Management and other dimensions.

3.2.2 Multifunctionality in segment sequences

Participants do not limit their dialogue contributions to functional segments; their goal is to produce coherent utterances. Utterances may be *discontinuous*, where smaller segments can be inside larger functional segments. For example, the speaker of the utterance in (5) interrupts his Inform with a Set-Question:

[5]Tables 1, 2 and 3 should be read as follows: from all identified segments addressing dimension in column, these segments have also a communicative function in dimension listed in rows.

Table 3: *Co-occurrences of communicative functions across dimensions in a sequence of two functional segments in one turn, expressed in relative frequency in %.*

segments in / *have function in*	Task	Auto-F.	Allo-F.	Turn M.	Time M.	DS	Contact M.	OCM	PCM	SOM
Task	26.5	36.5	33.3	33.5	42.4	0	15.4	21.6	20.0	46.7
Auto-F.	15.9	24.8	9.9	16.7	17.2	33.3	19.2	8.0	30.0	13.3
Allo-F.	0.4	1.1	6.6	0.6	0.6	0	0	0.5	0	0
TurnM.	59.7	38.1	36.7	53.0	44.2	15.3	61.5	69.9	50.0	33.3
TimeM.	27.9	20.4	20.0	30.9	18.8	0	15.4	55.4	0	26.7
ContactM.	0	0.1	0	0.1	0	34.2	0	0	0	54.6
DS	0.5	1.2	0	0.6	0.6	15.0	7.6	0.5	0	0
OCM	9.9	8.0	6.7	11.3	13.9	0	7.7	9.5	0	0
PCM	0.4	0.42	0	0.1	0.1	0	0	0.3	0	0
SOM	0.2	0.6	0	0.3	0.1	33.3	0	0.5	0	6.7

(5) *Twenty five Euros for a remote... **how much is that locally in pounds?** is too much to buy a new one*

Segments with different functions may *overlap* (see Table 2). For example:

(6) *B1: I think we're aiming for the under sixty five*
*D1: **Under sixty five** is a good constraint*

Utterance D1 is positive feedback about B1 at the level of evaluation, whereas the bold marked part is an explicit feedback signal at the level of perception. Such a co-occurrence is possible because higher levels of positive feedback entail lower levels of positive feedback.

The most important sources of overlapping multifunctionality are entailed functions, but here they are expressed explicitly by means of certain utterance features. For instance, as mentioned above answers entail that the previous question was successfully processed. Answers often overlap with explicitly expressed positive feedback, e.g. when the speaker repeats (positive perception) or paraphrases the partner's previous (part of) utterance (positive interpretation) in a segment within his utterance. Discourse markers may also be used for this purpose signalling that higher processing levels are reached (i.e. evaluation or execution). For example:

(7) *D1: Which is the clunky one on the left or on the right?*
*C1: **The clunky one** is the one on the right*

The speaker of C1 could have said *'on the right'* which would be a perfectly acceptable answer to the question D1. Instead, he repeats part of the question and thereby signals that his perception was successful. In the same way, Accept and Reject Offer, Suggestion and Request, but in fact any responsive, which entail positive auto-feedback, may overlap with such segments.

Another source of overlapping is pragmatic implicatures. It is often possible to add explicitly what is implicated without being redundant. For example, positive feedback implicated by shifting to a new topic, related to the previous one, may be expressed explicitly and happens very often by means of discourse markers, such as 'and then', 'okay then', 'next', etc. (see Petukhova&Bunt, 2009). More generally, any relevant continuation of the dialogue implicates positive feedback, such as question that moves the dialogue forward. But this may also be expressed by repeating or paraphrasing parts of previous utterances, or using discourse markers like 'then'. For example:

(8) *D1: This idea focuses on the twenty five age group*
*B1: Are we aiming at **a fairly young market then**?*

Functional segments following each other within a turn give rise to *sequential* multifunctionality at turn level. We analysed sequences of a length of 2 functional segments for the most frequently occurring patterns of communicative function combinations (see Table 3). It was observed that the co-occurrence scores for Turn Management, Task and Auto-Feedback with other dimensions are relatively high. This means that Task functional segments are frequently preceded or followed by Turn Management or Auto-Feedback segments or segments that have functions in these two dimensions simultaneously. For instance, a frequent pattern for constructing a turn is first performing a turn-initial act (e.g. Turn Take, Accept or Grab) combined with or followed by an Auto-Feedback act and one or more segments in another dimension, and closing up the turn with a turn-final act. This pattern occurs in about 49.9% of all turns. For example:

(9) *B1: well (Neg.Auto-Feedback Evaluation + Turn Take)*
B2: Twenty five euro is about eighteen pounds, isn't it? (Auto-Feedback Check Question)
D1: um (Turn Take+Stalling)
D2: Yep (Allo-Feedback Confirm)

Dialogue participants make their contributions consistent. To perform a task act and then to ex-

plicitly take the turn would not be a logical thing to do, because by starting speaking one already implicitly indicates that one wants to occupy the sender role. Similarly, to reject a request and then to accept it would be very unfortunate, unless the first act is performed by mistake or the speaker changes his mind and withdraws the first act.

We often observed sequences where the speaker performed a certain act and subsequently tried to justify this by elaborating or explaining what he just said. For example:

(10) *A1: it ties you on in terms of the technologies*
A2: ***like for example*** *voice recognition*
A3: ***because*** *you need to power a microphone*
A4: ***so*** *thats one constraint there*

In example (10) discourse markers are used by the speaker to indicate the steps in a sequence of arguments: he makes a statement (Inform); then provides an example for this statement (Inform Exemplify); justifies his choice (Inform Justification); and draws a conclusion (Inform Conclude).

4 Constraints on dialogue act combinations

A good understanding of the nature of the relations among the various multiple functions that a segment may have, and how these segments relate to other units in dialogue, opens the way for defining a computational update semantics for the interpretation and generation of dialogue utterances. In order to develop such a semantics, it is necessary to investigate forms of multifunctionality that occur in natural dialogue and the relations between the communicative functions of a multifunctional utterance. Moreover, no corpus is big enough to examine all possible function co-occurrences; corpus-based observations call for an additional analytical examination of the conditions for performing a certain dialogue act.

The DIT^{++} set of 10 dimensions is *orthogonal* (see Petukhova & Bunt (2009)), thus, theoretically it is possible that a segment has a communicative function in each dimension (thus, 10 tags per segment). There are, however, certain constraints on the use of functions within a dimension. The following should be taken into account: (1) that there's at most one (most specific) applicable function per dimension, and (2) the total number of functions available per dimension. DIT^{++} tagset has 44 general-purpose functions and 56 dimension specific functions. Distribution of function across dimensions is, therefore, as follows: Task dimension has 44 functions; Auto-Feedback - 54; Allo-Feedback - 59; Turn Management - 50; Time Management - 46; Contact Management - 46; DS - 50; OCM - 47; PCM - 46; and SOM - 54. A function, however, can be assigned not in each dimension. The total number of possible combinations is the sum of the possible number of 10 tags, the number of 9 tags, the number of 8 tags, ... the number of single tags. The number of possible combinations of 10 tags is $44 \times 54 \times 59 \times 50 \times 46 \times 46 \times 50 \times 47 \times 46 \times 54 = 8.66 \times 10^{16}$; adding the number of possible combinations of nine tags or less gives a total of 8.82×10^{16}.

In practice, it has been shown that 2 functions per segment is a realistic number when we count functions expressed by virtue of utterance features and implicated functions (see Bunt, 2010). This gives us $(D_1 \times D_2 + D_1 \times D_3 + D_1 \times D_4 + ...) = 110,605$ possible dialogue act combinations.

We analysed these function combinations and determine whether there are additional constraints on their combinations and what nature they have: do they have a logical or a pragmatic origin. For each dialogue act we calculated logical entailments and generated dialogue act pairs, in search of logical conflicts between them. Entailments between dialogue acts are defined by logical implications between their preconditions. Calculating the entailment relations among dialogue acts through their preconditions ensures completeness in the sense of finding all entailments between dialogue acts. While entailments depend solely on the definitions of communicative functions in terms of their preconditions, implicatures are pragmatic relations between a dialogue act and a condition that may be a precondition of another dialogue act, as will be illustrated below, and are a matter of empirical observation.

4.1 Logical constraints

From a logical point of view, two communicative functions cannot be applied to one and the same semantic content if they have logical conflicts in their preconditions or/and entailments. We analysed functional consistency pairwise between (1) preconditions of F_1 and F_2; (2) entailments of F_1 and F_2; (3) entailments of F_1 and preconditions of F_2 and vice versa.

The use of two functions (F_1 and F_2) applied to the same semantic content p is logically inconsis-

tent if there is a proposition q which can be derived from the set of preconditions P_1 of F_1, while $\neg q$ can be derived from the preconditions P_2 of F_2. This is for instance the case when we deal with alternative end-nodes in the tagset hierarchy. For example, one cannot accept and reject an offer in one functional segment: Accept Offer requires that $believes(S, will\_do\_action(A,a))$; $believes(S, can\_do(A,a))$; $believes(S, wants(A, believes(S, will\_do\_action(A,a))))$ and $wants(S, plan\_do\_action(A,p))$; for Reject Offer the same preconditions hold except for the last one which is $\neg wants(S, plan\_do\_action(A,a))$.

Similarly, F_1 and F_2 applied to the same semantic content p are logically conflicting if F_1 has an entailed condition q and F_2 has the entailment $\neg A$. For example, the entailments of an answer to a question expressed by utterance u ($wants(S, knows(A, Interpreted(S,u)))$) are in conflict with entailments of negative Auto-Feedback at the level of perception and lower (e.g. $wants(S, knows(A, \neg Perceived(S,u)))$ entails $wants(S, knows(A, \neg Interpreted(S,u)))$).

Two acts are also in conflict if the entailments of one are in logical conflict with preconditions of the other. The most obvious case is that of responsive dialogue acts and negative Auto-Feedback at all processing levels. For example, in order to provide a correction the speaker needs to have paid attention, perceived and understood the relevant previous utterance.

Note that the combination of two acts in one functional segment that share the same semantic content are not necessarily in conflict if they refer to different segments or acts in the previous discourse, i.e. if they have different *functional* or *feedback dependency relations*, see Bunt (2010).

4.2 Pragmatic constraints

Pragmatically speaking, two acts A_1 and A_2 are inconsistent in the following to cases:

(11) (1) an implicated condition q_1 of A_1 blocks the performance of A_2;
(2) an implicated condition q_1 of A_1 is in conflict with implicated condition q_2 of A_2.

An example of the first type of pragmatic inconsistency is the combination of direct and conditional (indirect) variants of the same act. For instance, a direct request like *Please tell me where Harry's office is* has the precondition that the addressee is able to perform the requested action: $believes(S, can\_do\_action(A,a))$, whereas a conditional request (like *Can you tell me where Harry's office is?*) does not have this preconditions; instead, it implicates that the speaker wants to know whether the addressee is able to perform the action ($wants(S, knowsif(S, can\_do\_action(A,a)))$).

Similarly, questions and requests implicate that the speaker wants the addressee to have the next turn, hence the speaker does not want to have the next turn himself: ($\neg wants(S, Turn\_Allocation(S))$), whereas such acts as Stallings or Pausing, but also acts like Self-Correction, Error Signalling and Retraction, implicate that the speaker wants to keep the turn himself: ($wants(S, Turn\_Allocation(S))$).

Two dialogue acts cannot be combined in one segment if an implicature of one act makes the performance of another act impossible. For example, positive auto-feedback acts at the level of perception and lower do not satisfy the conditions for the speaker to be able, for example, to assist the addressee by providing a completion or a correction of the addressee's mistakes, because for being able to offer a completion or a correction it is not sufficient to pay attention and hear what was said, but understanding and evaluation are required, and positive perception implicates negative feedback at these higher processing levels.

As noted in (11), two acts cannot be combined in one segment if implicatures of one are in conflict with implicatures of another. For instance, Contact Check carries an implicature of negative perception of partner's linguistic or non-verbal behaviour, whereas, for example, Opening carries an implicature of positive perception of partner's behaviour. Similarly, Partner Communication Management acts are pragmatically inconsistent with dialogue acts like Opening, Self-Introduction, Greeting or Contact Check, because PCM acts are performed in reaction to certain linguistic behaviour of the dialogue partner, and therefore implicate higher levels of successful processing of such behaviour, whereas dialogue initiating acts implicate lower processing levels like attention or perception, or elicit them. PCM acts can be combined with responsive acts in these dimensions although we do not find examples of this in our corpus data.

4.3 Constraints for segment sequences

We discussed above logical and pragmatic constraints for simultaneous multifunctionality. Since overlapping multifunctionality is a special case

of simultaneous multifunctionality; the constraints discussed above apply in this case as well.

For sequential multifunctionality within turns there are fewer and softer constraints on dialogue act combinations than for simultaneous multifunctionality. For example, the combination of two mutually exclusive acts in a sequence is in principle possible. A speaker who wants to constructed turn coherent and logically consistent turns should not combine logically or pragmatically conflicting dialogue acts associated with segments within the same turn. However, such combinations cannot be excluded entirely, since a speaker can perform a dialogue act by mistake and subsequently correct himself. Hence we may expect sequences of the following kind:

(12) 1. dialogue act A_1
2. retraction of A_1
3. dialogue act A_2

where A_1 and A_2 are conflicting.

5 Discussion and conclusions

The main conclusion from this study is that in order to define a multidimensional computational update semantics for dialogue interpretation it is important to understand the nature of the relations among the various multiple functions that a segment may have and how these segments relate to other units in dialogue. We investigated the forms of multifunctionality that occur in natural dialogue and analysed the obtained functions co-occurrence matrices across dimensions. Additionally, analytical examination of act preconditions, entailments implication relations was performed. General constraints on the use of dialogue act combinations were formulated. These constraints are also general in a sense that they are not only applicable when using the DIT^{++} dialogue act set but also other multidimensional tagsets such as DAMSL (Allen and Core, 1997), MRDA (Dhillon et al., 2004) and Coconut (Di Eugenio et al., 1998). These constraints are important for efficient computational modelling of dialogue and dialogue context, as well as for automatic dialogue act tagging, in that it could facilitate the effective computations and reduce the search space significantly.

The results of this study do not only have consequences for the semantic interpretation of dialogue contributions, but also for their generation. Our future work will be concerned with the automatic generation of sets of dialogue acts for contribution planning; the formulation of rules assigning priorities among alternative admissible dialogue acts; and formulating linguistic constraints on possible combinations of dialogue acts in a segment, an utterance, and a turn.

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References

Allen, J., Core, M. 1997. *Draft of DAMSL: Dialog Act Markup in Several Layers*.

Jens Allwood. 1992. *On dialogue cohesion*. Gothenburg Papers in Theoretical Linguistics 65. Gothenburg University.

Jens Allwood. 2000. *An activity-based approach to pragmatics*. In H. Bunt and W. Black (eds.), Abduction, Belief and Context in Dialogue. Amsterdam: Benjamin, pp. 47-81.

Harry Bunt. 2000. *Dialogue pragmatics and context specification*. H. Bunt and W. Black (eds.), Abduction, Belief and Context in Dialogue. Amsterdam: Benjamins, pp.81-150.

Harry Bunt. forthcoming 2010. *Multifunctionality in dialogue*. Computer, Speech and Language, Special issue on dialogue modeling.

Rajdip Dhillon, Sonali Bhagat, Hannah Carvey, and Elizabeth Schriberg. 2004. *Meeting recorder project: dialogue labelling guide*. ICSI Technical Report TR-04-002.

Barbara Di Eugenio, Pamela W. Jordan, and Liina Pylkkaenen. 1998. *The COCONUT project: dialogue annotation manual*. ISP Technical Report 98-1.

Simon Keizer and Harry Bunt. 2007. *Evaluating combinations of dialogue acts for generation*. In: Proceedings of the 8th SIGdial Workshop on Discourse and Dialogue, Antwerp, pp. 158-165.

Volha Petukhova and Harry Bunt. 2009. *The independence of dimensions in multidimensional dialogue act annotation*. Proceedings NAACL HLT Conference, Boulder, Colorado.

Andrei Popescu-Belis. 2005. *Dialogue Acts: One or More Dimensions?* ISSCO Working Paper 62, ISSCO, Geneva.

David Traum. 2000. *20 questions on dialogue act taxonomies*. Journal of Semantics, 17(1): 7-30.