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Introduction to the Special Issue on Incremental Processing in Dialogue

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1 Introduction

The topic of this special issue is "incremental processing in dialogue", by which we mean, very broadly, the successive processing of input (or generation of output) in increments smaller than whole utterances, as it can be observed in natural dialogue. Due to idealisation assumptions in linguistics and philosophy subscribed to by many scholars since Frege and Saussure, incrementality became only a topic of research not very long ago. Setting philologies and hermeneutic's programs (Heidegger, Gadamer) aside, the first researchers who systematically dealt with the incrementality of language production and understanding were those working in ethno-methodology and in a field to become conversation analysis (CA) later on. This can be seen from the early papers of Jefferson (1972, 1974), the famous Sacks, Schegloff, and Jefferson articles (1974, 1977) and especially from work of Schegloff building on these attempts (1979, 1982). These scholars were interested in the contributions-within-conversation perspective not restricted to dialogue proper, so their focus was on large increments and their regular distribution, for example on the allocation of turns or on the placing of repairs. A CA perspective complemented by an experimental one is here implemented in the paper *On Incrementality in Dialogue: Evidence from Compound Contributions* by Chr. Howes, M. Purver, P.G.T. Healey, G.J. Mills, and E. Gregoromichelaki.

Simultaneously with CA research, scholars working on the psychology of language processing considered small increments such as phonemes and clusters of them in words (Marslen-Wilson 1973), without however, taking extra-word units into account; something that can perhaps be attributed to the experimental methodology they used at that time.

The incremental perspective gained popularity by research taking up the conversation analysis tradition and combining it with the paradigms of experimental psycholinguistics. This is the hallmark of work done by H. Clark and his collaborators (Clark and Marshall 1981, Clark and Wilkes-Gibbs 1986), which *inter alia* was concerned with incrementality in syntax production and reference resolution, *i.e.* with in-turn regularities. In addition, Clark's notion of grounding tried to shed light on the fine-grained structure of speakers' successive contributions in dialogue (Clark and Schaefer 1989). As can be seen from current literature (e.g., Roque and Traum 2008, Poesio and Rieser 2010), interest in grounding matters and their fine-grained reconstruction is still continuing.

In the 1980s and 90s, the increasing availability of two different experimental techniques gave researchers access to fine-grained temporal information about the comprehension process without interfering with it. Eye-trackers provide a "window to the mind", through which the current focus of attention is to be tracked, be that words during reading (see Rayner 2009 for an introduction) or potential referents of expressions (as in the "visual world paradigm", e.g. Trueswell and Tanenhaus Eds. 2005). This research tradition is also reflected in the present volume: Ilkin and Sturt's article *Active Prediction of Syntactic Information During Sentence Processing* uses eye-tracking during reading to show that certain kinds of phrases were often skipped in contexts that make them predictable, hence demonstrating the role that prediction plays in incremental processing; Vasishth and Drenhaus' *Locality Effects in German* uses eye-tracking (among other methods) to argue that processing load increases with distance in sentence processing. Brown-Schmidt and Hanna in *Talking in Another Person's Shoes: Incremental Perspective-Taking in Language Processing* review experiments from the visual world paradigm to argue for a constraint-based view of perspective taking in dialogue. Incrementality modelling based on corpus investigation and experimental evidence coming especially from the visual world paradigm can be found in Poesio and Rieser's *An Incremental Model of Anaphora and Reference Resolution Based on Resource Situations*.

To continue with the main incrementality research line, the recording of Event-Related brain Potentials, and especially the N400 associated with semantic mismatches, provides another way to gain insights in the interplay of information sources during language comprehension (e.g., van Berkum *et al.* 1999).

Changing to language processing and syntax, the paradigm most frequently associated with an incrementality perspective is Dynamic Syntax (DS; Kempson, Meyer-Viol, Gabbay 2001, Cann, Kempson, Marten 2005), but some attempts at devising theories of incremental processing were already made earlier on, for example, in research undertaken by Neumann (1994, 1998) and Wirén (1992, 1994) at Linköping, Sweden, and at the DFKI Saarbrücken, Germany. Unfortunately, awareness of this latter research tradition has been nearly lost. Two papers of the present collection use DS modelling among a lot of other things, Andrew Gargett's *Incrementality and the Dynamics of Routines in Dialogue* and the paper *Incrementality and Intention-recognition in Utterance Processing* by Gregoromichelaki, Kempson, Purver, Mills, Cann, Meyer-Viol and Healey.

Turning to dialogue theory proper, perhaps the most decisively incremental approach was suggested with PTT, where incrementality is essentially based on Poesio's notion of Micro-conversational Events (MCEs, Poesio 1995). The question of options concerning incremental units such as MCEs is discussed in Schlangen and Skantze's *A General, Abstract Model of Incremental Dialogue Processing* (their *IU*s, see below). MCEs have since 1995 become part and parcel of standard PTT models (Poesio and Traum 1997) and later PTT versions using LTAG and Compositional DRT (e.g. Poesio and Rieser 2010). PTT is a good example of how concurrent developments in syntax (tree grammars, LTAG) and dynamic semantics (DRT variants) boosted the development of incrementality approaches. In the same vein, a link between DS and dialogue theory was established in Purver and Kempson (2004) and papers based on that. The present stage of this development in DS can be seen from Gargett's and Gregoromichelaki *et al.*'s papers.

For some time, the contact between research on fine-grained incrementality on the phonological and prosodic level and the investigation of sequences of larger structures in discourse seemed to have been neglected. However, recent computational work (e.g., Skantze and Schlangen 2009, Edlund *et al.* 2008) shows that there now is renewed interest in combining "high" level and "low" level incrementality. There is a good chance that yet another one of H. Clark's assumptions – namely that providing and monitoring feedback is a process that continuously accompanies all contributions – can be reconstructed and simulated. We find fine-grained incrementality detailed in this volume in the paper *Evaluation and Optimisation of Incremental Processors* by Timo Baumann, Okko Buß and David Schlangen and a more global and abstract perspective on incremental goings-on in David Schlangen and

Gabriel Skantze's contribution *A General, Abstract Model of Incremental Dialogue Processing*, as well as in the contribution by DeVault, Sagae and Traum, *Incremental Interpretation and Prediction of Utterance Meaning for Interactive Dialogue.*

The papers collected in this volume are either by founders or later proponents of the incrementality research movement. From the references quoted therein one can gather that they have maintained this research line for many years. All of the papers originate from a workshop on "Incrementality in Verbal Interaction" hosted from the 8th to the 10th of June, 2009 by the ZiF, the Interdisciplinary Research Centre of the University of Bielefeld. The workshop was organised by Ruth Kempson (King's College London), Hannes Rieser, Petra Wagner (both Bielefeld University) and David Schlangen (then University of Potsdam) and financed by the Collaborative Research Centre "Alignment in Communication", which is funded by the German Research Foundation. The workshop's invited speakers were:

Atterer, Michaela (University of Potsdam, Germany)
Baumann, Timo (University of Potsdam, Germany)
Buss, Okko (University of Potsdam, Germany)
De Vault, David (ICT / USC Los Angeles, USA)
Dubey, Amit (University of Edinburgh, UK)
Edlund, Jens (KTH, Sweden)
Gregoromichelaki, Eleni (King's College London, UK)
Hanna, Joy (Oberlin College, USA)
Harbusch, Karin (University of Koblenz-Landau, Germany)
Healey, Pat (Queen Mary University of London, UK)
Kempson, Ruth (King's College London, UK)
Knoeferle, Pia (CITEC, Bielefeld University, Germany)
Kruijff, Geert-Jan M.(DFKI, Language Technology Lab, Saarbrücken, Germany)
Poesio, Massimo (University of Trento, Italy / University of Essex, UK)
Purver, Matthew (Queen Mary University of London, UK)
Rieser, Hannes (Bielefeld University)
Sato, Yo (University of Hertfordshire, Hatfield, UK)
Schlangen, David (University of Potsdam, Germany)
Schuler, William (University of Minnesota, USA)
Skantze, Gabriel (KTH, Stockholm, Sweden)
Sturt, Patrick (University of Edinburgh, UK)
van Berkum, Jos (MPI Psycholinguistics Nijmegen, The Netherlands)
Vasishth, Shravan (University of Potsdam, Germany)
Wagner, Petra (Bielefeld University)

At the workshop the following talks were given in the order indicated:

Jos J.A. Van Berkum
Incrementality and beyond: What ERPs tell us about utterance comprehension

Shravan Vasishth
On anticipation and integration processes

Patrick Sturt
The dynamics of long distance dependency formation: pre-verb structural integration in a head-initial language

Pia Knoeferle
Variation in the time course of visual context effects on sentence comprehension

Christine Howes
Some empirical observations on split utterances

Massimo Poesio and Hannes Rieser
Incremental anaphoric interpretation with Micro Conversational Events

Eleni Gregoromichelaki
Mechanistic accounts of dialogue and split utterances: probing the limits of grammar

Ruth Kempson
Incremental growth of interpretation as natural language syntax

David Schlangen
A general, abstract model of incremental dialogue processing

Gabriel Skantze
Incremental processing in human-computer number dictation

Michaela Atterer, Okko Buss and Timo Baumann
Incremental ASR, NLU and dialogue management in the Potsdam InPro P2 system

David DeVault
Incremental understanding in virtual human dialogue systems

Joy E. Hanna
Incremental perspective-taking in conversation: Putting language processing in context and context in language processing

Amit Dubey
An incremental syntax/semantics interface for psycholinguistic modelling

William Schuler
Simple computational model of interactive language comprehension

Pierre Lison
Incremental processing of spoken dialogue for human-robot interaction

Pat Healey
Incremental processing in collaborative interactions

Jens Edlund
Tread carefully – collaboration in small steps

Karin Harbusch
Incremental sentence production inhibits clausal coordinate ellipsis: A comparison of spoken and written language

Yo Sato
Incrementality, bi-directionality and grammar learning

Discussion about talks and submitted papers continued among the speakers and their reviewers throughout 2010-2011. We here subsume the papers ultimately included in this volume under the systematic fields they prototypically belong to.

2 Experimental Work

The issue opens with a review article by Sarah Brown-Schmidt and Joy E. Hanna, *Talking in Another Person's Shoes: Incremental Perspective-Taking in Language Processing.* In this paper, the authors review psycholinguistic evidence for incrementality in language processing, focussing on the role of perspective taking. Taking sides in the ongoing debate on how to interpret the experimental results, the authors argue that a constraint-based account in which perspective is one of many constraints that guides language processing decisions best fits the data.

The article by Zeynep Ilkin and Patrick Sturt, *Active Prediction of Syntactic Information During Sentence Processing*, presents an experiment that shows that during reading, and measured by eye-tracking, plural noun phrases were skipped more often than singular noun phrases, in contexts where there was a high expectation for a plural.

Shravan Vasishth and Heiner Drenhaus present in their article *Locality Effects in German* a collection of experiments, using different paradigms, which show that in relative clauses, increasing the distance between the relativized noun and the relative-clause verb makes it more difficult to process the verb in the relative clause; this, they argue, supports a view where dependency-resolution cost is responsible together with expectation-based facilitation for determining processing cost.

3 Abstract Models

Frequently, the solution of selected problems, say parsing of a string or setting up a semantic representation concurrently, is fairly clear and can be done in a locally consistent way, given specific idealizing assumptions. However, what one would need to know more about is the global embedding of the local problem in an incremental model and the interaction of its components with various other modules. Knowledge concerning these matters comes from David Schlangen's and Gabriel Skantze's contribution *A General, Abstract Model of Incremental Dialogue Processing*. They specify a general framework to set up architectures for incremental processing in dialogue systems. Their focus is on the options available to system designers interested in handling data such as sub-utterance edits, feed-back phenomena or split utterances. The authors' aim is to specify necessary components of such a system thereby delineating a large class 'from non-incremental pipelines to fully incremental, asynchronous, parallel, predictive systems'. Having introduced the advantages of incremental processing and a description of the modular structure of their system, the authors explain the setup of the network topology and the different types of information flow used. The structure of the modules and module behaviour is presented. The question which type of *incremental units (IUs)* can be used and which relations between them have to be assumed is given detailed consideration. The system also allows for revisions of output. In the end we are provided with some example specifications showing how the conceptual classification can be applied to existing implementations. This indicates not only that the abstract model can be used in meta-theoretical work, *i.e.* classifying and comparing implemented incremental approaches, but also that the model can be used for theories and descriptions of ongoing information processes not directly tied to computational linguistics or AI.

4 Practical Computational Models

Incremental processing of spoken language poses special problems to the components designed to achieve this task. The development of such components, called incremental processors subsequently, and their evaluation is discussed in the paper *Evaluation and Optimisation of Incremental Processors* by Timo Baumann, Okko Buß and David Schlangen. The special task incremental processors have to meet is as follows: They must be able to produce partial albeit growing output given the partial input they are fed with by other

components of the system in question, components, perhaps also working in an incremental fashion. In addition, inputs can be revised in the course of later processing. In this paper incremental processors designed for this task are specified and evaluated. Evaluation meets special challenges since interim outputs have to be considered in addition to final ones.

Based on their previous practical work, Baumann, Buß and Schlangen lay down requirements for individual incremental processors and derive from these general description metrics for the evaluation of their performance. The chosen representation format for the outputs enables them to define metrics encompassing the quality of results, the times of their formation and alternative hypotheses, if any, entertained by the system. Evaluation amounts to comparing actual outputs with idealised ones, called "gold standards", and the development of metrics. Of these we are given similarity metrics, timing metrics and diachronic ones, measuring incrementality in terms of pace, fit and persistence, respectively. Baumann *et al.*'s specification of an evaluation framework should prove a valuable general contribution to the growing field of incremental spoken dialogue systems.

David DeVault, Kenji Sagae and David Traum present in the paper *Interpretation and Prediction of Utterance Meaning for Interactive Dialogue* techniques for building one such module for incremental dialogue systems, namely for the component that does interpretation. In their setup, incremental interpretation is done via *prediction* of the meaning that the ongoing utterance will ultimately have, once it is completed. They show how such a component can be used in a system to initiate completions of user utterances.

5 From Grammar to Dialogue

Among formal grammars Dynamic Syntax (DS) was one of the first incrementally working algorithms. Until around 2000 DS focused on single propositions; it has been extended since to the reconstruction of particular dialogue phenomena such as split utterances. Andrew Gargett's contribution *Incrementality and the Dynamics of Routines in Dialogue* extends DS in various ways. Responding to the on-going discussion in Cognitive Psychology on linguistic routinisation, his main interest is in developing a dual processing model of linguistic routinisation ranging from fixed idioms to looser collocational constructions. His main interest is to capture routinised and non-routinised language in one comprehensive theory based on incrementality: non-routinised language use is modelled *via* the rule-based account of DS whereas for formulaic language memory-based processes operating as larger stable patterns are introduced. By way of example, in conversations one observes the emergence of routines out of initially regular wordings, that is the emergence of 'constants' with a fixed interpretation out of compositionally set up material. This has been shown in several studies of e.g. H. Clark (see the contributions in Clark, Ed. 1992) or of S. Garrod and co-workers. In Gargett's words, there is a move from initially rule-based production to a subsequent memory-based one. Basing on this insight, he gives special attention to the interaction of both types of devices. In order to model routines the lexical architecture of DS, up until now working with lexical actions, *i.e.* rules introducing words, is extended with patterns of 'stable' semantic output, a sort of "frozen semantics". A dual model allows for competition between rule-based procedures and interpretation via stored semantic input. Seen from the DS development perspective, the account adds dynamicity to the lexicon which had been missing so far.

The paper *Incrementality and Intention-recognition in Utterance Processing* by Gregoromichelaki, Kempson, Purver, Mills, Cann, Meyer-Viol and Healey discusses at the outset the role of higher order ("Gricean") intentions in communication and argues for the development of alternative models which might be more plausible given the psychological restrictions of humans. The intention topic is fused with the incrementality assumption on the theoretical and the empirical side. Concerning the empirical side, the focus is on split utterances which are a prototypical incrementality paradigm involving switches of speakers. On the theoretical side incremental Dynamic Syntax (DS) is used in a version going back to

work of Purver and Kempson (Purver and Kempson 2004) implementing the notion of a bi-directional DS. The bi-directional version of DS allows for a regular switch from parsing to generation using partial information on the generation side. All of that is embedded in a broad discussion of variants of intentionalism and challenges to these, the challenges coming from philosophy (cf. MacDonald and Papineau Eds. 2006) and experimental psychology (e.g. Pickering and Garrod 2004). Similarly, detailed attention is given to the problem of incrementality in speech production and understanding winding up to the claim that co-operative processes operate on propositional and sub-propositional levels. Assuming this to be plausible, a grammar model dealing with sub-sentential contributions of different speakers is required. This is developed after discussing intention-based approaches which are dismissed as a generally valid tool. Against initially given intentions as usually assumed in models based on dialogue acts, the preferred route is to implement coordination on a sub-intentional, "low-level" basis. This does not imply that intentions are discarded once and for all, on the one hand, so the argument goes, one might need them in particular settings, where there is common information for speaker and hearer, on the other hand, it is shown resorting to experiments that the assumption of emerging (*i.e.* not "pre-fabricated") intentions is a plausible one. So, the opposition set up in the end is "initially given" *vs.* stepwise emerging intentions. The whole discussion serves as a methodological preparation to the introduction of DS as the main tool to incrementally represent split utterances, the principal DS feature in this context being the parsing-grammar coordination. Finally, we get the modelling of split utterances in DS and a concluding chapter bringing together the different strands of argumentation.

Situation-sensitive resolution of anaphora in the PTT dialogue paradigm is the subject of Poesio's and Rieser's paper *An Incremental Model of Anaphora and Reference Resolution Based on Resource Situations*. They start from the observation familiar from work on corpora such as TRAINS (cf. Allen *et al.* 1995) or the Bielefeld corpora SAGA (cf. Lücking *et al.* 2010) that utterances in general and anaphora in particular are interpreted incrementally. What the increments are can often be seen from repairs, clarification requests, interruptions by other or acknowledgements. Data like these provide an indication of how processes of understanding work, thus complementing findings from experimental paradigms like the visual world paradigm. Anaphora can occur in the guise of pronouns or definite NPs. The theory of referring expressions developed in the paper integrates several accounts: Löbner's functional approach (Löbner 1987) and a theory of anaphoric accessibility using resource situations (the situations one gets suitable antecedents from) as developed in Situation Semantics and in previous work of Poesio (1995) as well as findings in experimental psychology about incrementality and reference resolution. Observations from corpora and experimental evidence are bound together in a unified theory of the semantics and the pragmatics of referring (anaphoric) expressions. This in turn is reconstructed in an updated version of PTT. In particular, incrementality is modelled through micro-conversational events, defaults and a parallelism constraint. Anaphora resolution uses resource situations, visual scenes, shifts over referential domains and a host of parsing rules. Finally, it is shown how the theory's predictions fare with respect to the results of experimental psychology, pointing out shortcomings on both sides.

6 Corpus Studies and Experimental Work

Investigations of incremental processes in dialogue have often been bound to the study of so-called completions or "split utterances" across agents' different turns in dialogue (for earlier work cf. H. Clark 1996, Skuplik 1999, Rieser and Skuplik 2000, Poncin and Rieser 2006). Completions (subsequently *Compound Contributions*, *CC*s) are the topic of the study *On Incrementality in Dialogue: Evidence from Compound Contributions* by Chr. Howes, M. Purver, P.G.T. Healey, G.J. Mills, and E. Gregoromichelaki. They provide two approaches to CCs in this paper, a standard one, namely a corpus investigation showing that CCs are indeed

central for coordination in dialogue and a newly and specially designed experimental study showing the on-line effects of "artificially" introduced CCs. At the start we get a useful clarification of CA notions subsequently used such as *turn* or *contribution*. The *Related Work* section provides a useful overview of approaches to CCs ranging from CA to current dialogue theory. Their list of research questions to be treated, for example investigation of split point occurrences, shows the study to be perhaps the first one looking for dialogue effects of CCs. The corpus study investigates types of CCs, one result being that same person CCs are more frequent than more spectacular cross-agent ones. In addition, parameters of CCs are considered which have already been suggested in previous studies, for example where split points can occur in contributions or the grammatical completeness of the constituents making up CCs. Howes *et al.* also indicate which effects their findings might have on the development of grammars/parsers for CCs, e.g. with respect to back-tracking procedures to be set off. The experimental manipulation in the second study using a chat-based tool was carried out to show what the 'effect of CCs on the dynamics of a conversation' is. Despite their different format, the results of the two studies yield similar results, for example, that there are syntactic constraints on where split points usually appear.

The issue closes with a paper by Karin Harbusch, *Incremental Sentence Production and Clausal Coordinate Ellipsis*, which presents a treebank study of clausal coordination in spoken Dutch and German. This study shows that clausal coordinate ellipsis (CCE) occurs much more frequently in written than in spoken language, with a particular pattern when different types of CCE are studied in detail. The author argues that the pattern cannot be accounted for in terms of audience design but rather needs an explanation that assumes that the grammatical planning of spontaneous speech is restricted to a single finite clause.

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