A LINGUISTIC ANALYSIS OF REPAIR SIGNALS IN CO-OPERATIVE SPOKEN DIALOGUES

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ABSTRACT

This paper presents results of a corpus-based analysis of speech repairs, investigating repair signals which mark the existence of possible repairs. Dividing speech repairs into three parts: erroneous part, editing term and correction, this paper provides empirical evidence which supports the notion that speech repairs are produced in a rather regular syntactic pattern. Phrases seem to play a particular role in the production of speech repairs, as phrasal boundaries frequently correspond to boundaries within or around repairs. Related acoustic-prosodic features highlighting the internal structure of repairs including F_0, duration and tonal patterns are also examined and discussed with respect to specific syntactic patterns.

1. INTRODUCTION

Regardless of the type of dialogues, human-human or human-machine dialogue systems, the capability of language understanding systems to recognise and correct speech repairs is indispensable. Due to the fact that human beings easily and frequently make errors, they need to correct their erroneous or inappropriate speech in order to deliver the intended information. The phenomenon of repair signals should be made clear by means of empirical observations and examinations, concerning the detection and correction of speech repairs of human beings or machines.

This paper aims, by carrying out a corpus analysis, at systematising different types of repair signalling at syntactic and prosodic levels. Recent work on speech repairs, in both the psycholinguistic field and in natural language processing, has more or less focused on the immediate problem-solving of speech repairs themselves, without explicitly examining repair signals. Not only syntactic-structural cues can help listeners follow the interrupted and re-initiated speech flow. Prosodic cues which are especially effective in spoken language in expressing particular emotion and intention serve the purpose of signalling the occurrence of speech repairs as well. Thus, this paper intends to find and explore possible syntactic and prosodic cues signalling speech repairs and to investigate their relationship. Other factors such as gestures or pragmatic cues which are also often used to signal speech repairs will not be taken into account.

Firstly, research results related to speech repairs are summarised. Following an introduction to the data used for the study, syntactic and prosodic cues signalling speech repairs are presented. The relationship between syntactic and prosodic repair signalling is subsequently discussed.

2. RELATED WORK

Psycholinguistic studies have paid great attention to description/classification and possible interpretation associated with why and how repairs are produced [5], [6] and [7]. The segmentation - *reparandum, editing term* and *repair* - is the most widespread notation for repair structure. Reparandum is the *erroneous part* which is to be corrected. Editing terms are usually produced after the reparandum and indicate that there is something wrong with the speech flow. Repair represents then the *correction* of the erroneous part. Research in natural language processing has also noticed the necessity of dealing with speech repairs. Some have explored and dealt with disfluencies such as pauses/filled pauses, repetitions and restarts in automatic speech recognition [10], [11], while others have worked on the detection and correction of irregular, in other words, ungrammatical strings referred to a given grammar or model [1], [3], [4] and [8].

Recent approaches proposed for detecting and correcting speech repairs can be distinguished according to the information types on which the approaches base:

- *editing term,*
- *pattern matching,*
- *acoustic/prosodic cues* and
- *syntactic/semantic knowledge.*

Hindle [4] and Nakatani *et al.* [9] explicitly or implicitly used editing terms in their detection mechanism. Hindle [4] used copy editor to detect repair structure on

the both sides of editing terms. The string on the left hand side is removed after the parser recognises a repair structure. Repair Interval Model (RIM) in [8] made use of temporal information about the intervals: reparandum, disfluency and repair. The intervals were measured and used for identifying cues of offset of reparandum and onset of repairs. Bear *et al.* [1] applied the method of pattern matching without presupposing the existence of editing term and repair structure is not specifically classified, whereas Heeman *et al.* [3] used a POS-based language model, in which they classified three types of repair structure besides their POS-tagging: *modification repairs, fresh starts* and *abridged repairs*. Moreover, Heeman *et al.* [2] used acoustic cues such as silence in addition to their repair-tagging to combine recognition of speech repairs and identification of intonational boundaries. Nakatani *et al.* [9] investigated possible acoustic-prosodic features of repair cues, but concentrating more or less on interruption sites. Syntactic and semantic information resources have been applied by Bear *et al.* [1] to differentiate repairs from false positives, whereas in Hindle's approach [4] syntactic categories are more explicitly used to detect repairs.

It will be shown that these four types of information resources concerning repair structure can be re-found in a rather integrative way by focusing on syntactic and prosodic peculiarities of speech repairs which signal the existence of speech repairs.

3. REPAIR SIGNALS

It is proposed in this paper that syntactic and prosodic features are two important information resources which can provide information about the occurrence of speech repairs to both human beings and language understanding systems. Furthermore, there is a close relationship between syntax and prosody, focusing on the realisation and structuring of speech repairs. Syntactic distribution no doubt plays a role, since in the case of speech repairs the surface structure of utterances no longer fits the structure prescribed by a grammar for written language. More specifically, syntactic attributes such as parts of speech and phrasal boundaries do influence the production of speech repairs explicitly. Similar to characteristics at the syntactic level, prosodic marking of speech repairs is also likely to be used to indicate disfluent or irregular speech flow. It is taken for granted that prosody plays an important role in spoken language, but the correlation of prosody, syntax and the production of speech repairs has not yet been explicitly discussed.

Figure 1 shows that there are two levels of signalling: syntactic patterns and their associated prosodic markings. The hypothesis is that there exist *syntactic patterns* in which speech repairs are most likely to be produced and
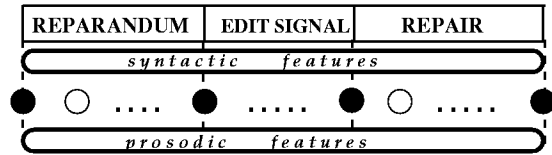

Figure 1: Syntactic and Prosodic Repair Signals

there exist particular syntactic locations where the speech flow is more frequently interrupted and repairs are more likely to be initiated than elsewhere. The segmentation - *reparandum, editing term* and *repair* - is more than a functional division, indicating to-be-repaired, editing and been-repaired, as at the onset and offset of each segment, cues marking the boundaries can be found. Furthermore, as in spoken language, prosodic cues can support or compensate for other linguistic means, the *effect of prosody* is assumed to be observable during the production of speech repairs, in addition to syntactic realisation. These two tiers, which are supposed to function in parallel in the production of speech repairs: *syntactic* and *prosodic*, present the main signalling groups of speech repairs under preliminary consideration of the surface structure.

4. CORPUS AND DATA

The BAUFIX-corpus consists of 22 digitally recorded German human-human dialogues. 44 participants cooperated in pairs as instructor and constructor, aiming to build a toy-plane. Because of the limited visual contact between dialogue partners in some given cases, subjects had to rely on their verbal communication to a great extent. This corpus setting was especially suited to force subjects to repair their speech errors, after they have made them. The objects and movements must be described as clearly as possible so that the tasks can be understood properly and carried out accordingly by the constructors.

For the specific purpose, the corpus analysis is merely concerned with immediate self-repairs. They were identified and hand-annotated by the author. Totally 420 speech repairs were classified according to their syntactic attributes such as categories and parts of speech. They were subsequently analysed with respect to the location of interruption and their repair structure. Selected data produced by a chosen female subject were furthermore prosodically annotated and acoustical features such as fundamental frequency (F_0) and duration within speech repairs were accordingly measured and analysed by *esps* (Entropic Signal Processing System).

5. PHRASED-BASED PATTERNS

The empirical examination, focusing on the syntactic characteristics of repair structure, shows several noticeable results which support the hypothesis that syntactic features are directly related to the production of speech repairs. Syntactic patterns can therefore signal likely distinctiveness of speech repairs from well-formed speech.

5.1. Syntactic Categories

When speech repairs are produced to make correct speech, it is very often the case that they are located within noun (NP) or prepositional phrases (PP). Certainly, this result is closely related to the setting of corpus. Subjects usually use simple sentence construction and realise a great number of NPs and PPs to describe objects and tasks. But since more than 70% of speech repairs are realised within NPs and PPs, this result nevertheless indicates a higher possibility of detecting speech repairs within NPs and PPs than in other phrases.

5.2. Location of Interruption

Cues around interruption sites often have been investigated [9], [10], because the location of interruption is a conspicuous signal of speech repairs. However, the issue, in which syntactic context interruptions occur more frequently, has been seldom examined by means of empirical studies. Results show that there are positions, dependent on the syntactic category, where the speakers interrupt more frequently than elsewhere. In particular, the position after determiners is important. In both NPs and PPs, interruptions take place significantly more frequently after determiners than at other positions. Interruptions occur after determiners in 65% of speech repairs in NPs and 46% in PPs. Another relevant location of interruption in PPs is after prepositions, about 27%. This fact to some extent suggests similar functional characteristics between NPs and noun phrases within PPs.

5.3. Phrasal Boundaries

Within NPs and PPs, syntactic patterns can be found, based on the position of onset and offset of reparandum and repair. The onset of repair is located in most of the cases in phrasal-initial position, whereas the offset of repair is often phrasal-final. Among the identified repairs, 86% match the pattern, (*erroneous phrase, editing term, corrected phrase*). Levelt [5] has mentioned the tendency of speakers to retrace back to phrasal boundaries to initiate speech repairs. This hypothesis can be supported by this empirical evidence. Moreover, speakers tend to complete the phrasal construction, even when more information is not necessary. Phrasal boundaries therefore correspond mostly to boundaries which are relevant to the internal construction of speech repairs. In other words, if these relevant sites can be
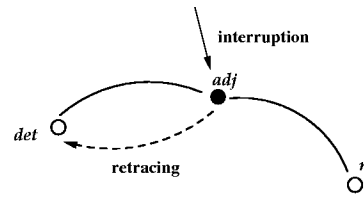
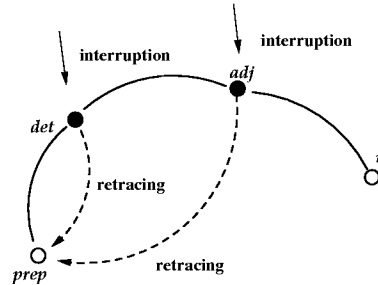

Figure 2: Phrase-Based Repair Structure in NPs

Figure 3: Phrase-Based Repair Structure in PPs

identified, the task of detecting and correcting speech repairs could be facilitated more easily.

5.4. Phrase-Based Production

Similar results are obtained with respect to the location of interruption and the syntactic patterns of repair structure in NPs and PPs. It is seldom the case that speakers interrupt the speech flow within the preposition or determiner in the German corpus. As shown in figure 2 and 3, the positions after determiner, both in NPs and PPs and after the preposition in PPs are highly relevant to the realisation of speech repairs in German. As the internal construction of speech repairs produced within NPs and PPs can be similarly modelled, it strongly supports the pattern-matching approach. This regularity nevertheless suggests that syntactic information should be more explicitly used to search for patterns of speech repairs.

6. PROSODIC STRUCTURING

Parallel to syntactic patterns, prosodic markedness is examined by means of an acoustic-prosodic analysis. Results show that syntactically crucial sites within speech repairs are also prosodically marked in most of the cases.

6.1. Intonational Restart

Speakers tend to re-start their previous phrase prosodically, in the way that they initiate the correction in similar intonational pattern as the erroneous or inappropriate parts. In the utterances examined, no significant difference could be found in F_0 between the onset of the

reparandum and the repair, nor between the accentuated vowel of the first word in the reparandum and the repair. Though this can not empirically prove the existence of F_0-resetting at the initial site of repair, it nevertheless indirectly supports its existence.

6.2. Temporally Marked Repeating

As mentioned above, the location of the repair onset is often phrasal-initial, in many cases there are repeated words. They are words which have already been realised in the reparandum and are repeated in the repair. Those words are usually spoken more quickly than their counterparts in the reparandum. The first repeated word in repair is spoken more quickly, where statistical significance has been found, $\alpha = .05$ and $p = .009$. The phenomenon, repeating within speech repairs, is therefore temporally marked and serves the purpose as repair signal as well.

6.3. Tonally Emphasised Correcting

There exists a difference between so-called overt repairs and covert repairs in which they are prosodically marked or unmarked. When contrast tone patterns are produced it tends to be the case that a correction rather than a simple repetition takes place. The corrected word is marked prosodically, whereby a high tone is realised to contrast with the low tone in the reparandum or vice versa. Correlation between similar/contrast tonal patterns and repeated/corrected items in speech repairs is statistically significant, $\alpha = .05$ and $p = .03$.

7. DISCUSSION

By means of this empirical study, it has been shown that syntactic and prosodic information can be integrated to more specifically model repair signals. Interruption sites and acoustic-prosodic cues help identify certain syntactic sites which build the structural pattern of repairs, as shown in figure 4. Speech repairs which occur within NPs and PPs are more frequent than in other syntactic categories. In particular, the phenomenon of retracing mentioned in [5] is empirically clarified that phrasal boundaries are explicitly relevant to the realisation of repairs. Thus specific syntactic pattern is a clear signal of speech repairs. In parallel, prosodic marking also signals possible existence of speech repairs, in which the repair structure is emphasised by temporal and tonal contrasts.

8. CONCLUSION

The results presented in this paper provide empirical support of a parallel relation of the function of syntax and prosody in the production of speech repairs. Further investigation into additional cues to the functional
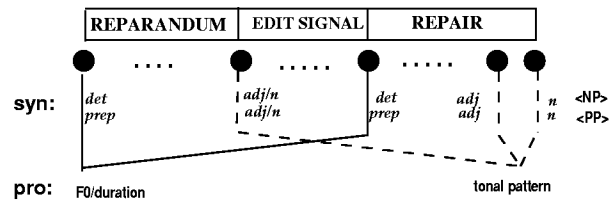

Figure 4: Repair Signalling: Syntactic and Prosodic

correlation of syntactic and prosodic means with respect to the *irregular* strings in spoken language is in progress.

9. REFERENCES

1. Bear, J., Dowding, /J., and Shriberg, E. "Integrating Multiple Knowledge Sources for Detection and Correction of Repairs in Human-Computer Dialog," *ACL*, 56-63, 1992.

2. Heeman, P., and Allen, J. "Intonational Boundaries, Speech Repairs, and Discourse Markers: Modeling Spoken Dialog," *ACL*, 1997.

3. Heeman, P., Loken-Kim. K, and Allen, J. "Combining the Detection and Correction of Speech Repairs," *ICSLP*, 1996.

4. Hindle, D. "Deterministic Parsing of Syntactic Nonfluencies," *ACL*, 123-128, 1983.

5. Levelt, W. "Monitoring and Self-Repair in Speech," *Cognition, 14: 41-104*, 1983.

6. Levelt, W., and Cutler, A. "Prosodic marking in Speech Repair," *Journal of Semantics, 2(2): 205-217*, 1983.

7. Lickley, R.J., Shillcock, R.C., and Bard, E.G. "Processing Disfluent Speech: How and When are Disfluencies Found?," *Eurospeech 91*, 1499-1502, 1991.

8. Nakatani, C., and Hirschberg, J. "A Speech-First Model for Repair Detection and Correction," *ACL*, 46-53, 1993.

9. Nakatani, C., and Hirschberg, J. "A Corpus-Based Study of Repair Cues in Spontaneous Speech," *Journal of the Acoustical Society of America, 95: 1603-1616*, 1994.

10. O'Shaughnessy. "Recognition of Hesitations in Spontaneous Speech," *ICASSP*, 521-524, 1992.

11. Shriberg, E. "Acoustic Properties of Disfluent Repetitions," *Proc. of the International Congress of Phonetic Sciences*, Stockholm, 1995