Exploration of Human Repair Initiation in Task-oriented Dialogue : A Linguistic Feature-based Approach

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Abstract

In daily conversations, people often encounter problems prompting conversational repair to enhance mutual understanding. By employing an automatic coreference solver, alongside examining repetition, we identify various linguistic features that distinguish turns when the addressee initiates repair from those when they do not. Our findings reveal distinct patterns that characterize the repair sequence and each type of other-repair initiation.

1 Introduction

Human language complexities often expose flaws such as misunderstandings, misinterpretations, speech impediments, or social norm violations. Strategies people use in conversations to identify and address these problems, fostering mutual understanding, are called repair (Schegloff, 2007). Schegloff, 2007 distinguishes repair types based on who initiates and who provides the solution between the speaker and the addressee. This paper focuses on Other-initiated Self-repair, also called Other-initiated repair (OIR), where the addressee initiates repair for the speaker corrects, as highlighted by Dingemanse and Enfield, 2024 as foundational for human language resilience, complexity, and flexibility.

Recent studies emphasize the need for Conversational Agents (CAs) to have repair mechanisms. Gehle et al., 2014 show that museum guide robots failing to promptly address issues led to visitor disengagement and conversation breakdowns, suggesting the importance of multimodal repair strategies. van Arkel et al., 2020 find that simple OIR mechanisms in agents improve communicative success and reduce computational and interaction costs for disambiguation in communication compared to pragmatic reasoning (interlocutors reason each other). Efforts to detect OIR in the literature are narrow. Purver et al., 2018 trained a supervised classifier on four different datasets using turn-level features extracted from transcription, such as numbers of wh-words and fillers. The results indicate that challenging repairs are more common in task-oriented datasets. Besides, research on integrating OIR in CAs is limited and primarily relies on rule-based systems. For instance, Höhn, 2017 developed a rule-based chatbot with repair capabilities that recognize repair initiation in messaging conversations using conversational analysis rules, such as repetition, determiner and pronoun usage, and adjacent position.

Example 1. Sample of OIR sequence, annotated based on Dingemanse and Enfield, 2015's coding schema. Data is in Dutch, English translation provided by DeepL[1].

TS SPEAKER: en ik zie een uh ovaalvormig ding op het kopje (T-1)
(and I see a uh oval-shaped thing on the cup)
REPAIR INITIATOR: op het platte kopje daarboven hè? (T0)
(on the flat head up there huh?)
TS SPEAKER: ja (T+1)
(yes)

A minimal OIR sequence comprises three components: trouble source (TS) turn (T-1), repair initiation (T0), and repair solution (T+1), depicted in Example 1. T-1 is where a potential communication problem arises, T0 is where the addressee signals a problem, and T+1 is where the speaker resolves the problem, completing the repair sequence. In addition, Dingemanse and Enfield, 2015 categorized repair initiation into three types: *Open Request* (the least specific, no TS specified in T-1), *Restricted Request* (implying the TS location), and *Restricted Offer* (the most specific, proposing a candidate understanding). Our research aims to develop a CA

[1]https://www.deepl.com/

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system that can detect human repair initiation (T0) based on verbal and non-verbal cues and generate an appropriate repair solution (T+1). This work examines dialogue transcripts to identify linguistic features that distinguish OIR sequences from non-repair sequences and differentiate among the three types of OIR in task-oriented dialogues. Previous studies have identified various OIR practices, for instance, Schegloff et al., 1977 described five OIR formats in their study of American English conversation, while Dingemanse et al., 2014 find similarities in OIR formats across ten languages, such as question word "what?" or interjection "huh." The contributions of this paper are as follows: First, unlike previous studies that focused solely on references to trouble sources (TS), this work expands further by examining the acceptance of repair initiation by subsequent turn. Second, in addition to repetition, we incorporate an automatic coreference solver to see if repair initiators refer back to the TS and if the response acknowledges the repair initiation. Results show significant coreference involvement in *restricted request* and *restricted offer*.

2 Dataset

As repair occurs more often in task-oriented dialogue and is generally unaffected by familiarity or interaction mode (Colman and Healey, 2011), we employ dialogue transcripts from a Dutch multimodal task-oriented corpus (Rasenberg et al., 2022) within project CABB (Eijk et al., 2022), involving 20 dyads performing referential communication tasks to locate 16 stimulated geometrical objects called Fribbles. The data collection setup corresponds to the CABB dataset, described in (Eijk et al., 2022). Participants alternated between Director and Matcher roles to communicate and locate specified objects. Each participant's speech was segmented into Turn Constructional Units (TCUs) and then orthographically transcribed based on standard spelling conventions of Dutch. The repair sequences were annotated following Dingemanse and Enfield, 2015's coding schema, resulting in: 20 (*open request*), 32 (*restricted request*), and 255 (*restricted offer*) sequences, respectively.

We examine the interaction differences after a potential issue (turn labeled as TS) to compare instances when a person initiates repair versus when they do not identify trouble and request repair immediately. To do this, we selected all turns between T-1 and the repair initiation in T0, identifying 91 non-repair sequences. Appendix A provides sample data for each OIR type and details the non-repair selection method.

3 Feature Extraction

Based on the OIR coding schema (Example 1), T0 is considered a repair initiation if it (1) treats the prior turn containing trouble and (2) the subsequent turn T+1 acknowledges and responds to this request. To determine (1), we analyze the syntactic structure of the repair initiation turn (T0) regarding the potential TS in T-1 via coreferences. For (2), we examine how the TS speaker acknowledges the repair initiation by analyzing coreferences in T+1 that refer to the entity mentioned in T0 and the TS speaker's self-repetition.

3.1 Feature extraction for repair initiation (T0) concerning prior turn (T-1)

Part-of-Speech (POS) tagging and Lemmatization. To investigate T0's linguistic patterns across three OIR types compared to T0 in non-repair sequences, we leverage Stanza[2], a multilingual NLP toolkit, for POS tagging and lemmatization. It enables us to comprehend the overall grammatical structure of the OIR turn and identify the most frequently used word types and their corresponding most common lemmas. The performance of Stanza's pretrained model on Dutch is 94.97% for POS tagging and 95.33% for lemmatization. See Appendix C for the list of POS tags in Dutch.

Coreference. Coreference, a linguistic phenomenon in dialogue, involves referring to entities across turns using pronouns, demonstratives, or other expressions linked to previously mentioned nouns or concepts. Analyzing coreference patterns offers insights into the relationships between turns. By examining coreferences used by the repair initiator in T0, we investigate if T0 refers to an entity in T-1, potentially the TS. We utilized the coreference resolution model from the UTD_NLP team (Li et al., 2022), which achieved the best performance at CODI-CRAC 2022 (Yu et al., 2022), with an average CONLL F1 score of 75.04 in resolving anaphora in dialogue. The coreference chain sample produced by the model is included in the Appendix B.

To analyze repair initiation structure and its grammatical ties to prior turns via coreferences,

[2] https://stanfordnlp.github.io/stanza/

we used Seq2Pat[3], a sequence-pattern-generation library (Kadıoğlu et al., 2023). Each turn T0 after tokenization and POS tagging was fed into Seq2Pat to obtain a list of the most frequent sequential patterns. The instances of the coreference chain are tagged by [COREF]. Due to data imbalance among OIR types, different min_frequency thresholds were set to each: min_frequency = [5, 5, 30, 10] for *open request*, *restricted request*, *restricted offer*, and non-repair, respectively.

3.2 Feature extraction for repair acknowledgment in subsequent turn (T+1)

To determine if the TS speaker's response in T+1 addresses the request made by the repair initiator in T0, we analyzed the coreferences initiated in T0 and used in T+1. We also examined the TS speaker's self-repetition behavior when providing a repair solution, as these repetitions suggest the TS speaker's language consistency and alignment with the trouble in T-1. To identify self-repetition, we used dialign[4], a tool for measuring lexical alignment in human-agent interaction (Dubuisson Duplessis et al., 2017) (example in Appendix B).

4 Results and Discussion

4.1 Does T0 consider the prior turn T-1 as source of trouble?

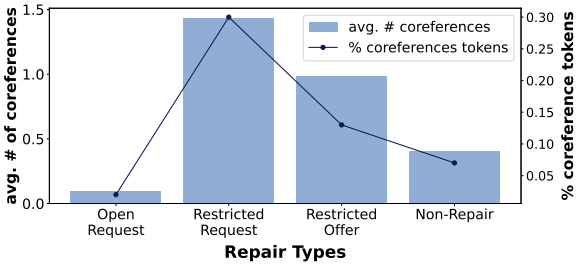

Figure 1: T0's average number of coreferences and coreferences tokens proportion

Figure 1 shows the average number of coreferences in T0 (initiated in T-1) and the percentage of T0 tokens that are coreferences. *Restricted request* has the highest coreference usage (about 1.5 coreferences per T0, comprising approximately 30% of tokens), followed by *restricted offer* (around one coreference per T0, accounting for approximately 13% of tokens). Non-repair and *open request* show minimal coreference use, with about 0.5 coreferences (7% of tokens) and 0.1 coreferences (2% of tokens) per T0, respectively. Both *restricted request* and *restricted offer* signal trouble in T-1, likely indicating dependence on coreferences for previously mentioned ambiguous entities. However, *restricted offer*, potentially introducing new entities and a longer T0 turn to propose candidate understanding, explains the lower coreference usage and proportion of coreference tokens compared to *restricted request*.

Figure 2 describes the most common sequential POS tag patterns for T0 across three OIR types and non-repair sequences. These patterns, displayed as bi-grams ["1st POS tag", "2nd POS-tag", frequency], are visualized on the y-axis, x-axis, and heatmap values, respectively. Additionally, Figure 3 depicts the top five most frequent POS tags and their corresponding lemmas.

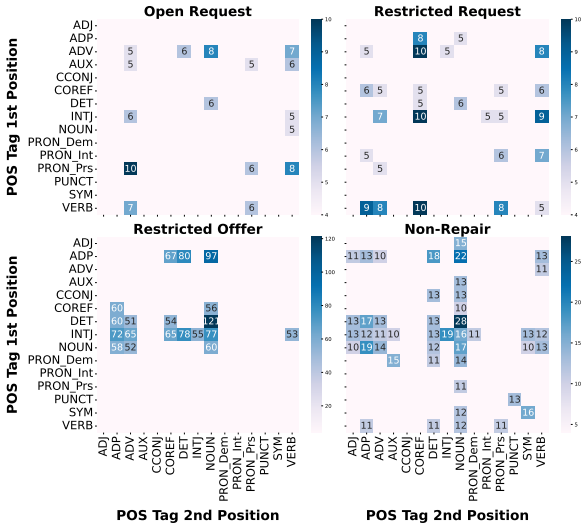

Figure 2: T0 utterances POS tags Sequential Patterns

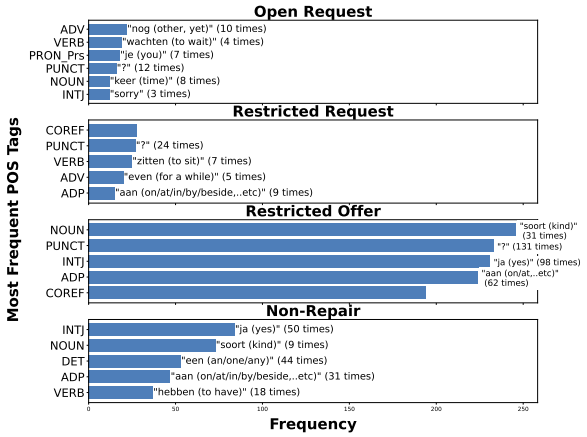

Figure 3: T0's most frequent POS tags and its corresponding most frequent lemma

Regarding *open request*, frequent patterns in-

[3] https://github.com/fidelity/seq2pat
[4] https://github.com/GuillaumeDD/dialign

volve adverbs preceded by personal pronouns (10 times), verbs (7 times), interjections (6 times), and auxiliaries (5 times). The most common adverb lemma is "nog" (*yet*) expressing negation, while the personal pronoun "je" (*you*) suggests a request towards the prior turn's speaker. Compared to the other OIR types, *open request* uniquely involve auxiliaries, with the modal verb "kunnen" (*be able to/can/may*) being the most frequent, indicating the request for action from the prior speaker. Notably, verbs frequently found in these patterns, with the most common lemma being "wachten" (*to wait*), may indicate a request to slow down due to issues in the previous turn.

In *restricted request*, the notable correlation between coreferences and other word forms like verbs (16 times), adverbs (15 times), and prepositions (14 times) indicates heavy reliance on referring back to previously mentioned entities. Using interrogative pronouns (PRON_Int) is a distinctive feature in this type, often followed by verbs (7 times, most frequently "zitten" (*to sit*)), prepositions (5 times, most commonly "aan" - equivalent to multiple English prepositions like *on, at, in, by, beside*), and personal pronouns (6 times, most frequently "je" (*you*)). Its most common lemma, "wat" (*what, which, any*), is used for asking questions, indicating a demand for clarification from the current speaker regarding what the prior speaker mentioned (potentially TS).

Considering *restricted offer*, the most frequent sequential patterns involve determiners followed by nouns (121 times) and coreferences (54 times). The sequences combining prepositions preceded or followed by determiners (60 or 80 times, respectively), nouns (58 or 97 times, respectively), or coreferences (60 or 67 times, respectively) are also common patterns. These patterns emphasize the scenario where the repair initiator is likely presenting or describing specific objects to offer the candidate understanding.

Non-repair sequences' T0 share similarities to *restricted offer* regarding the usage of noun phrases, determiners, and prepositions. However, the presence of adjectives sets it apart from all three OIR types, implying a focus on descriptive presentation. Especially in non-repair, there is a high occurrence of the combination of demonstrative pronouns with auxiliaries, determiners, and nouns, emphasizing the introduction of new entities, clarification, or stating existence rather than extensive reference back. Unlike *open request*, the auxiliary verb "zijn" (*to be*) is the most frequent in non-repair sequences, often employed for demonstration.

Unique sequential POS tag patterns and particular behaviors in employing coreference chains to refer to entities from the preceding turn reveal that each OIR type initiates repair requests differently, setting them apart from non-repair sequences. Utilizing these extracted patterns could assist in creating a repair initiation detector for CA.

4.2 Does subsequent turn T+1 acknowledge T0's request as repair initiation?

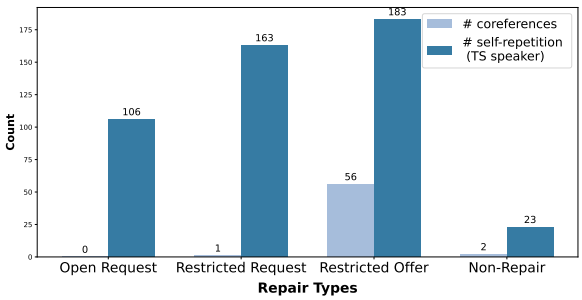

Figure 4: Distribution of Coreference (initiated in T0) and TS Speaker Self-repetition in T+1

Figure 4 examines T+1's acceptance of repair initiation from T0, showing the number of coreferences (initiated in T0) used in T+1 and the TS speaker's self-repetition (verb and noun) from T-1 to T+1. Regarding coreference, only in *restricted offer*, the TS speaker in T+1 uses several coreferences to refer to the entities initiated by the repair initiator in T0, unlike *open request* and *restricted request* where coreferences are rare. Since the *restricted offer* is the most specific repair initiation, it potentially prompts the TS speaker to use coreferences for confirming the proposed candidate.

In contrast, the high self-repetition across all OIR types suggests the TS speaker often repeats themselves (from T-1) to address the repair initiation request. Despite occasional similarities with repair initiation or a format resembling OIR, the infrequent use of coreferences and self-repetition in non-repair sequences suggests that the TS speaker potentially progressed the conversation without acknowledging it as a request for repair.

These patterns, particularly in *restricted offer*, could enhance repair solution generation models in CA by incorporating them with repair initiation sequential patterns.

5 Conclusion and Future Work

Utilizing Natural Language Processing approaches on dialogue transcripts, we identified linguistic and sequential patterns characterizing three types of OIR and non-repair sequences. The coreference chains used in T0 combined with sequential patterns of OIR structure are typical across OIR types and non-repair sequences, which reveal the grammatical structure of T0 and whether T0 treats the prior turn T-1 as containing trouble. Besides, the TS speaker's self-repetition and coreference chains (initiated by the repair initiator) used in T+1 show the behavior of the TS speaker in acceptance of the repair initiation from T0. Our future work will explore multimodalities like prosodic, facial and bodily cues, to develop a computational model for repair initiation detection and repair solution generation in the Conversational Agent.

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A Sample Data

Example 2. Open request OIR sample

TS SPEAKER: op dat driehoek (T-1)
(on that triangle)
REPAIR INITIATOR: wat zei je? (T0)
(what did you say?)
TS SPEAKER: op die driehoek (T+1)
(on that triangle)

Example 3. Restricted request OIR sample

TS SPEAKER: deze heeft twee oren die aan de onderkant breder worden en een soort hanekam op zijn hoofd een kleintje (T-1)
(this one has two ears that widen at the bottom and a sort of cock's comb on its head a little one)
REPAIR INITIATOR: maar wat zei wat zei je in het begin? (T0)
(but what did you say at the beginning?)
TS SPEAKER: een soort oren die aan de onderkant breder worden (T+1)
(a kind of ears that widen at the bottom)

Example 4. Restricted offer OIR sample

TS SPEAKER: waarbij je dus op de bovenkant zo'n zo'n mini uh kegeltje hebt (T-1)
(where you have one of those mini uh cones on the top)
REPAIR INITIATOR: oh ja die zo scheef naar achter staat? (T0)
(oh yes which is so slanted backwards?)
TS SPEAKER: ja precies (T+1)
(yes exactly)

Example 5. Non-repair sequence selection example.

TS SPEAKER: het is een een een een een kopje en aan de onderkant zit een uh ovale standaard zeg maar het kopje staat daarop -> **TS**
(it's a a a a a little cup and at the bottom there's an uh oval stand, let's say, the cup stands on it)
REPAIR INITIATOR: zit er een driehoek op? -> **Non-repair**
(is there a triangle on it?)
TS SPEAKER: nee er zit geen driehoek op -> **Non-repair**
(no there is no triangle on it)
REPAIR INITIATOR: en het staat zeg maar op zo'n ovale ding ja zo'n pilvorm is het -> **OIR**
(and it stands on such an oval thing, yes such a pill shape is it)
TS SPEAKER: ja het belangrijkste is dat het een soort van houder heeft waar het op staat zeg maar -> **Repair solution**
(yes the most important thing is that it has some kind of holder that it stands on, let's say)

Example 6. Non-repair sequence sample (2). The second turn resembles an OIR format with the repair initiator repeating "drie bolletjes" (three balls). However, it is not considered OIR because the TS speaker continues with new information in the subsequent turn, indicating they saw it as acknowledgment rather than a repair request.

TS SPEAKER: oh ja deze heeft uh drie bolletjes telkens als armen
(oh yes this one has uh three balls each as arms)
REPAIR INITIATOR: drie bolletjes
(three balls)
TS SPEAKER: en staat op een groot vierkant
(and stands on a large square)

B Coreference Chain and Self-repetition Samples

Example 7. Coreference used by Repair Initiator in T0, initiated by TS Speaker in T-1

TS SPEAKER: um dit is de hoofdvorm met die ronde staaf aan de linkerkant die uitgesneden is met **die punt** erin (T-1)
(um this is the main shape with that round bar on the left cut out with that point in it)
REPAIR INITIATOR: um je bedoelt met **die schuine punt** zo naar beneden? (T0)
(um you mean with that slant point so down?)
TS SPEAKER: ja (T+1)
(yes)

Example 8. Coreference used by TS Speaker in T+1, initiated by Repair Initiator in T0

TS SPEAKER: soort plakseltjes ofzo (T-1)
(kind of sticky or something)
REPAIR INITIATOR: ja lijkt een beetje op **een stopcontact** zou kunnen zo'n stekker? (T0)
(yes looks a bit like a socket could be such a plug?)
TS SPEAKER: ja je zou het in **een stopcontact** kunnen zetten (T+1)
(yes you could put it in a socket)

Example 9. Sample of TS speaker's **self-repetition**

TS SPEAKER: dit is **de hoofdvorm** waarbij een **yoghurtbakje** **links** aan **de hoofdvorm** vastzit soort van klein staafje rechts en dan bovenop een rechthoekige staaf (T-1)
(this is the main form where a yoghurt container on the left is attached to the main form kind of small bar on the right and then on top a rectangular bar)
REPAIR INITIATOR: yoghurtbakje was? (T0)
(yoghurt container was?)
TS SPEAKER: ja **yoghurtbakje** op de kop **links** van **de hoofdvorm** zit er aan vastgeplakt (T+1)
(yes yoghurt tray on the head left of the main form is stuck to it)

C POS tags List

- ADJ - adjectives
- ADP - prepositions and postpositions
- ADV - adverbs
- AUX - auxiliaries, including
  - perfect tense auxiliaries "hebben" (*to have*), "zijn" (*to be*)
  - passive tense auxiliaries "worden" (*to become*), "zijn" (*to be*), "krijgen" (*to get*)
  - modal verbs "kunnen" (*to be able, can*), "zullen" (*shall*), "moeten" (*must*), "mogen" (*to be allow*)
- CCONJ - coordinating conjunctions "en" (*and*), "of" (*or*)
- DET - deteminers
- INTJ - interjection
- NOUN - noun
- PRON_Dem - demonstrative pronouns
- PRON_Int - interrogative pronouns
- PRON_Prs - personal pronouns
- PUNCT - punctuations
- SYM - symbols
- VERB - verbs