From annotation to analysis: Exploring conversational dynamics with rezonateR

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Abstract

This paper demonstrates the use of `rezonateR`, an R package processing data from the annotation program Rezonator for research in discourse and grammar, Conversation Analysis, and beyond. Distilling information from complex annotations in Rezonator's native format (including span, chain, segmentation, and dependency tree annotations), `rezonateR` produces tabular data for statistical analysis, modelling and visualisation. As demonstrated in this paper, the package supports research on a wide variety of interlocked topics, including turn-taking, dialogic resonance, and the pragmatics of reference tracking and argument structure.

1 Introduction

Discourse-oriented linguists and conversation analysists have closely studied naturally occurring spontaneous conversation for decades. Though such research traditionally focus on fine-grained qualitative analysis or small-scale quantitative analysis with few variables, recent years have seen a massive explosion in interest in larger-scale quantitative, computational and data visualisation methods to uncover the underlying patterns of coherence and engagement in interaction (e.g. Stivers et al. 2019, Rühlemann 2020, Dingemanse & Liesenfeld 2022).

Nevertheless, flexible and accessible tools for carrying out necessary steps of such studies, eg. (semi-)automatic annotation, feature engineering, and abstract visualisation of annotations across conversations, remain scarce. Traditionally, analysts of natural conversation rely on plaintext transcripts, which can be searched with regular expressions (Rühlemann 2020); often, data must then be coded manually (e.g. counting preceding mentions of a referent by hand), which takes time and does not allow for easy feature engineering. On the other hand, modern multilayer annotated corpus formats (e.g. Widlöcher & Mathet 2012, Krause & Zeldes 2016) are structured based on complex data models like graph structures, and require specialised programming knowledge to transform into a tabular format most analyses need. Moreover, while numerous tools exist for analysing corpora, most focus on written or monologic texts (e.g. Amorim et al. 2021), or are general-purpose (e.g. Benoit et al. 2018); few are geared specifically towards questions specific to dialogue. Indeed, even most of the conversational visualisation systems reviewed by Kim et al. (2021) handle general linguistic and textual issues like lexical coherence.

In response to these challenges, I have been actively developing `rezonateR`, a software package containing an extensive set of functions for analysing conversational discourse phenomena. It is written for R (R Core Team 2022) users, given the availability of abundant resources in linguistics (e.g. Levshina 2015, Gries 2017) and familiar packages like `lme4` (Bates et al. 2015) in R. It resembles `qdap` (Rinker 2013), but instead of raw transcripts, mainly works with annotated data from the visual annotation environment Rezonator (DuBois 2019, DuBois et al. 2020) (some functions apply to other, similarly-formatted data). It aids in investigating a variety of interlinked phenomena, particularly referent accessibility and referential choice (Gundel et al. 1993, Ariel 2001), turn organization (Schegloff 1996), dialogic syntax (DuBois 2014), and associated issues. It can automate aspects of corpus annotation and transform complex annotations (e.g. text segmentation, coreference and resonance chains, and dependency trees) into a tabular format familiar to R users, which can then be easily passed on to standard visualisation, statistical modelling and machine learning environments.

The package is designed to be usable to users of both base R and `tidyverse` (Wickham et al. 2019), including a series of functions acting as drop-in replacements for `tidyverse` functions. Section 2 will introduce the workflow, data format, and basic data wrangling features. Section 3 illustrates the use of these basic features together with specialised features for three concrete lines of research, followed by a brief conclusion and future directions in Section 4.

2 Workflow, data format and wrangling

2.1 Workflow and I/O

The basic workflow of `rezonateR` is illustrated in Figure 1. A user wishing to analyse data in `rezonateR` will first import the transcript (or other supported import formats like CoNLL-U files and tab-separated files output from ELAN) into Rezonator, where various annotations can be added. Rezonator stores these annotations in its native JSON-style `.rez` format, which can then be imported into `rezonateR` with the `importRez()` function, creating an object called a `rezrObj` containing a series of data frames called `rezrDF` along with a `nodeMap` object (see Section 2.2). The `rezrObj` can be saved with `save_rez()` as an `.Rdata` file and loaded back in R again with `load_rez()`.

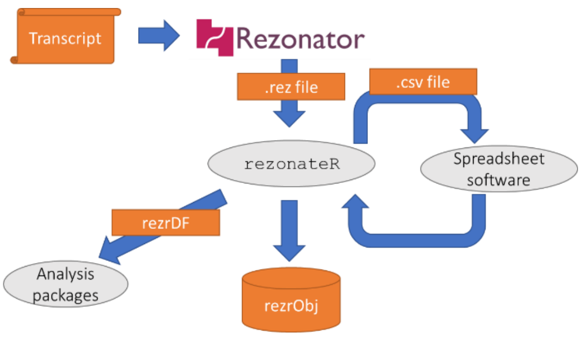


Figure 1: Workflow of working with `rezonateR`.

The user may then produce additional automatic annotations from currently existing manual ones (e.g. from a set of rules or statistical models), export part of the annotations in a `.csv` file to manually correct them, and then import them back into R to be integrated with the `rezrObj`, similar to what is implemented in the LaBB-CAT annotation software (Fromont & Hay 2012). The whole process is facilitated by three functions `rez_read_csv()`, `rez_write_csv()`, `updateFromDF()` to prevent errors common in such operations, e.g. by ensuring that the data formats of columns of the imported `.csv` file match those in the `rezrObj`.

2.2 Data format

Rezonator (DuBois et al. 2020) represents transcriptions and annotations as a graph format known as a *node map* consisting of interlinked nodes, objects representing different aspects of transcriptions and annotations. Each node is connected to other related nodes in the JSON representation, for example, a trail (coreference chain) to its tracks (mentions), and contains other information such as user-defined tags (e.g. entity type of a trail). Some of the names are non-standard in linguistics, but chosen for brevity and abstraction, since they may map to different linguistic constructs for users with different needs. The most important nodes are shown in Table 1.

Token	A token in the transcription, for example words or morphemes, punctuation and transcription symbols.
Unit	A line of dialogue, typically an intonation unit, utterance, or similar-sized unit.
Entry	A part of a unit corresponding to a token.
Chunk	A span of tokens functioning as a unit, for example noun phrase or (when tokens correspond to morphemes) verb.
Stack	A flexible structure for segments comprising of multiple lines, e.g. turns or turn-constructional units.
Card	A part of a stack corresponding to a unit.
Reso-nance	A chain of rezzes that belong in a single column of a diagraph (Du Bois 2014).
Rez	An entry of a resonance, corresponding to a token or chunk.
Clique	A set of units linked through resonance.
Trail	A coreference chain.
Track	An entry of a coreference chain (for reference **track**ing), corresponding to a token or chunk.
Tree entry	Terminal nodes of dependency trees, corresponding to a collection of tokens.
Tree	A dependency tree.

Table 1: Common node types in Rezonator. Most will be elaborated on below.

The rezrObj contains two representations of these nodes. The first is the nodeMap object, which includes most information in the original JSON .rez file; it is organised as a list of lists, each of which contains all nodes of a specific type (thus there is a token list, a unit list and so on).

The second is a series of rezrDF objects, structured like a relational database, each of which again corresponds to a node type, but dispenses of information less amenable to a tabular format (e.g. a single field with multiple values) or largely irrelevant to the analyst (e.g. colours of objects or creation time metadata), and appends additional useful information, e.g. the positions of the starting and ending tokens of stacks and chunks in the conversation. These data frames inherit from tidyverse's tibble object, and thus can be manipulated using relevant functions. In the event where there are multiple layers of objects (as in the case of *stackings*; see Section 3.1), each rezrDF corresponds to a single layer. In the rezrDF, each row corresponds to a node (e.g. a token or a trail), and each column corresponds to a field storing properties of the nodes (e.g. the text of a token). This tabular format makes rezrDF well-suited for use in standard visualisation, statistical and machine learning packages taking input where each line is a data point.

Each field in a rezrDF has a field type: key, core, flex, auto, foreign. key and core fields are not to be modified, flex fields can be freely updated, and auto and foreign fields are automatically updated using a function stored with the rezrDF upon creation. This allows for automatic generation of features from manually-coded ones. For example, when working on coreference, suppose that one has, in Rezonator, classified tracks into fined-grained entity types (person, organisation, animal, … e.g. Zaenen 2004). Ti extract a binary animate-inanimate distinction from these tags, one may add an auto field such that if the fine-grained entity type values change, the reload() function can automatically update the binary animacy value.

2.3 Data manipulation

There are two suites of data manipulation functions for rezrDF objects. The first, EasyEdit, has four core functions for adding and changing fields (columns): addFieldLocal(), changeFieldLocal(), addFieldForeign(),changeFieldForeign(). The 'local' functions create new fields based on information from the same rezrDF; the 'foreign' functions create new fields with reference to information in other rezrDF objects in the same rezrObj. The second suite, TidyRez, builds on tidyverse functions like mutate() and left_join() for use with rezrDFs without affecting rezonateR features like reloading. The two perform similar functions of combining information from different nodes to create predictors (exemplified below), but for different audiences (base R vs tidyverse).

3 Linguistic phenomena that can be investigated through rezonateR

This section will show how rezonateR pools together information from different nodes (including user-defined tags) and derives useful predictors from linguistic annotations to create data in a tabular format suitable for analysis, visualisation, and modelling. The three subsections will discuss discourse and prosodic units, dialogic resonance, and referent tracking.

The conversation used to illustrate all three sections will come from SBC007 'A Tree's Life', a conversation from the Santa Barbara Corpus of Spoken American English (DuBois et al. 2000). A late-night conversation between two sisters from Montana, it shifts in topic between discussing relationships with roommates, car troubles, and family, and illustrates different aspects of conversational dynamics, as seen below.

3.1 Discourse and prosodic units using units and stacks

Conversational interactions are organised into various segments, including prosodic segments like the intonation unit (IU) (Chafe 1994, DuBois et al. 1993), as well as discourse segments like the turn and turn-constructional unit (TCU) (Sacks, Schegloff & Jefferson 1978). Examining the distribution of these units across time and among participants can be highly revealing of the genre and interactional style and dynamics of the conversation, and the distribution of linguistic forms within these units can also illuminate their textual and interactional functions. Rezonator and rezonateR provide extensive tools to study such segments, which can be represented by units and stacks in Rezonator. Stacks of different natures (e.g. turns and TCUs in the SBC007 file in our example) are stored in different *stackings*, which represent different segmentations of the same text.

(a) (b)

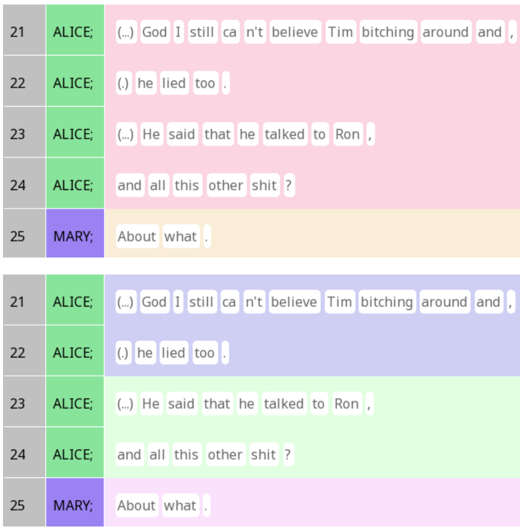


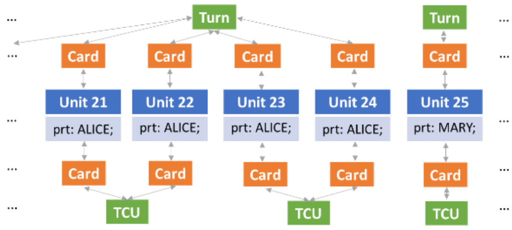
Figure 2: Segmentation of SBC007 into (a) turns and (b) TCUs. Alice's and Mary's lines each belong to one turn, but Alice's include four IUs and two TCUs, and Mary's only one IU and TCU.

Figure 2 shows two segmentations of SBC007 inside Rezonator, manually corrected after running Rezonator's automatic stack creator. Each unit (represented by a line on the screen) corresponds to one IU. In (a), the stacks (indicated by background colour shading) represent turns, whereas in (b), the stacks represent TCUs.

Suppose one aims to explore the dynamics of shifts in speaker dominance and participant framework in conversation, for example the distinction between *tellings* where one speaker dominates and others take the recipient role and more interactive 'chat' segments (Schegloff 1982, Goodwin 1995, Gilmartin et al. 2018). These phenomena can be efficiently represented by Gantt charts (Dingemanse & Liesenfeld 2022). Here, we will generate Gantt charts corresponding to turns and TCUs, with the x-axis (time) measured in intonation units.

Recall that in `rezonateR`, stacks of each stacking have their own `rezrDF`, so there is a table corresponding to turns and another to TCUs. They serve as input to `ggplot2` (Wickham 2016). By default, `rezonateR` adds information about the first and last units of a stack to these tables, and the `EasyEdit` function `addField-Foreign()` can add participant names as well, as shown in Figure 3. This information can then be passed to `ggplot2` to produce Figure 4.

(a)



(b)

name	unitSeqFirst	unitSeqLast	prt	…
Turn 10	19	24	ALICE;	…
Turn 11	25	25	MARY;	…
…	…	…	…	…

Figure 3: (a) Representation of units, cards and turns in Rezonator's internal node map and (b) part of the `rezrDF` for turns in `rezonateR` (derived from (a)), which is then used for visualisation. The variable `participant` is shortened to `prt`.

(a) (b)

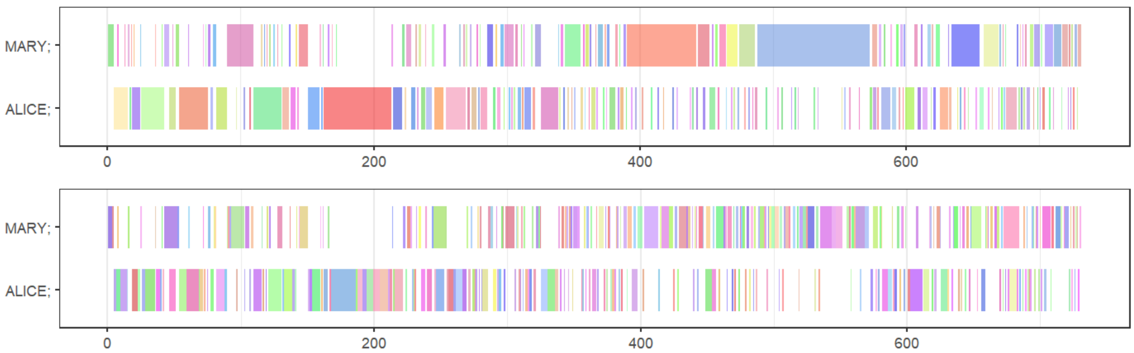


Figure 4: Gantt charts showing (a) turns and (b) turn-constructional units in SBC007 over time (measured in IUs). Colours follow those used in the Rezonator stacks. (a) shows that the start of the conversation was largely dominated by Alice in the teller role with Mary producing backchannels and other minimal utterances, but also some substantive contributions. Sometime around the 300th IU, the conversation became chat-like, followed by a transition to Mary in the teller role shortly before the 400th IU, before transitioning again to a chat before the 600th IU. (b) shows that most of the long, multi-IU turns in (a) are also multi-TCU turns, though very long TCUs are occasionally found.

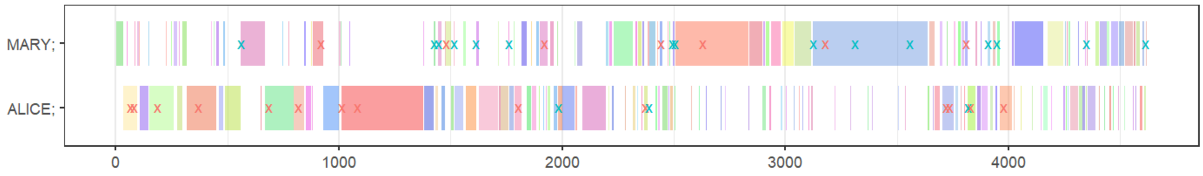


Figure 5: Gantt charts showing the positions of the discourse markers *oh* (blue) and *like* (red) within turns, (with time measured by token sequence). *Oh* typically appears at left edges (turn starts), especially within chat segments (and one of the exceptions is within a constructed dialogue). *Like* typically appears turn-medially, and is common in both chat segments and tellings.

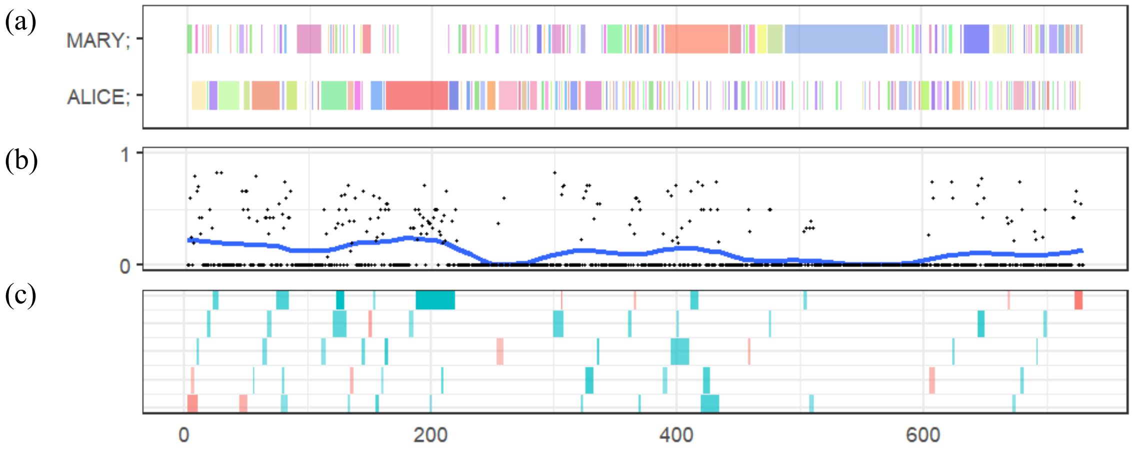


Figure 6: Diagram showing (a) the Gantt chart for turns from Figure 4 (again with time measured in IUs), (b) normalised resonance level with a LOESS smooth ($\alpha = .2$) and (c) all the cliques in the conversation. In (c), red corresponds to cliques that exhibit other-resonance, and blue means the clique contains only self-resonance. The darker the colour, the higher the number of resonances (chains) in the clique.

Since the distribution of linguistic forms like discourse markers in different units often corresponds to linguistic function (e.g. Chan 2010, Fuentes-Rodríguez et al. 2016), it is instructive to examine such distributions graphically too. Figure 5 shows the distribution of *oh* and *like* within turns, revealing that *oh* typically appears at turn-initial positions and during interactive chat segments, consistent with standard literature arguing that *oh* indicates change in state and often prefaces turns (e.g. Heritage 1984). Likewise, *like* typically appears turn-medially, consistent with its functions as a preposition, conjunction, and free direct speech marker (e.g. Romaine & Lange 1991), all of which project later content in the turn.

If a user wishes to distill these patterns into quantitative summaries, `rezonateR` additionally provides the function `stackToToken()`, which pushes stack information to the token data frame. The function `getOrderFromSeq()` can then calculate the positions of tokens within turns, such as the position of each token of *oh* and *like*. Figure 7 uses this information to show that *oh* is overwhelmingly turn-initial.

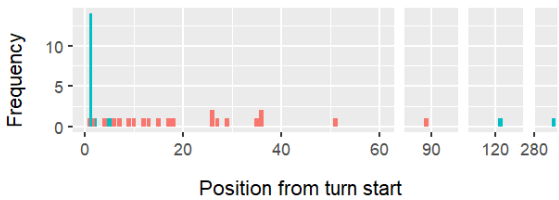


Figure 7: A barplot of the positions of *oh* (blue) and *like* (red) within the turn, using `ggbreak` (Xu et al. 2021). *Oh*, but not *like*, is overwhelmingly turn-initial, other than a few outliers on the right.

3.2 Investigating resonance and cliques

Dialogic syntax (DuBois 2014) investigates the selective reproduction of linguistic resources within a conversation, as well as the meaning created by such reproduction. Though resonance-related work was initially focused on qualitative analyses, some analysts have also turned towards large-scale quantitative analysis, particularly in specific types of social actions such as (dis)agreements (e.g. Põldvere et al. 2021, Tantucci & Wang 2021). As the first software package for quantitative analysis of dialogic resonance, `rezonateR` is uniquely positioned to support this burgeoning line of research.

In Rezonator, structurally similar lines are annotated for resonance by linking up their corresponding tokens or chunks (i.e. small spans of tokens). Each chain of resonance links is called a *resonance*, and a group of units linked together is called a *clique*, which can be seen as a segment of conversation that displays high structural and semantic affinity between intonation units. One example of a clique is shown in Figure 8.

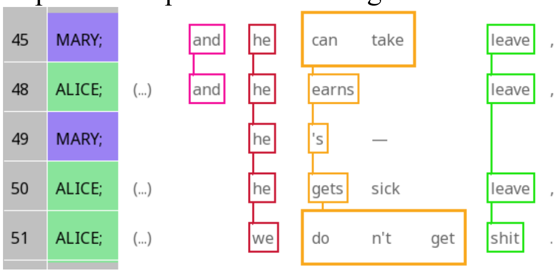


Figure 8: A clique with four resonances where Alice and Mary repeatedly produce similar clausal structures, contrasting the privileges enjoyed by a roommate to their less fortunate situation. Here, *can take* and *don't get* are multi-token chunks.

As an example, `rezonateR` can help locate and visualize moments of high resonance in an abstracted representation of a conversation – a.k.a. the 'dialogic moment' (DuBois 2014, Oropeza Escobar 2011). By default, `rezonateR` already imports from Rezonator measures of resonance strength, e.g. the number of units (lines) and resonances (chains) inside a clique. The `augmentRezInfo()` function augments the `rezrDF`s for units (i.e. IUs) and cliques to contain additional information, including a unit's level of resonance (both the raw number of resonances – similar to Tantucci & Wang's (2021) syntactic resonance level – and normalised by the number of tokens in the unit), as well as whether a clique contains other-resonance (resonance between two or more participants) or only contains self-resonance (resonance within a participant) (Lei 2020). Figure 6 draws from this data to map out the dynamics of resonance in SBC007.

As one can see from Figure 6, 'chat' segments, like the portion around the 300th IU or near the end, often contain substantial resonance, and the latter part of Mary's telling segment had very little resonance. However, the densest resonance is found within Alice's initial telling between the 150th and 250th IUs, including a substantial amount of self-resonance. All in all, self-resonance is dominant, which is expected of conversations mostly consisting of tellings.

3.3 Using trails, trees and EasyTrack to study referential forms

Rezonator also contains tools for relatively standard corpus annotations, including dependency structures and coreference. These annotations are useful for studying phenomena central to linguistic discourse analysis, such as referent accessibility and the choice of referential forms (e.g. Gundel et al. 1993, Ariel 2001, Arnold 2010) and preferred argument structure (DuBois et al. 2003), which studies how the discourse status of referents (e.g. activation level) affects their distribution within argument structures.

Compared to the two previous topics, the quantitative study of (co)reference has a long history (e.g. Givón 1983) and many recent large-scale quantitative studies exist (e.g. Kibrik et al. 2016, Same & van Deemter 2020). Nevertheless, despite reference being a collaborative process (Clark 1986), most large-scale studies focus on written or monologic texts, with some exceptions (e.g. Helasvuo & Kyröläinen 2016, Torres Cacoullos & Travis 2019). One common line of research predicts the choice of referential form, given predictors about discourse context, the referents' semantics, and syntax and semantics of the current clause. `rezonateR` has built-in tools for exploring many of the standard predictors, drawing from Rezonator annotations.

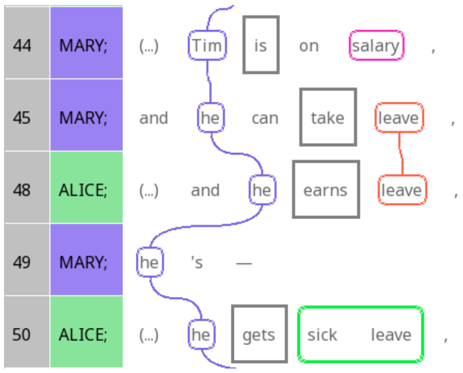


Figure 9: Sample coreference chains in SBC007. There are four coreference chains shown here, including Tim, salary, leave, and sick leave (considered a subset of leave). Verbs are marked as chunks in grey.

Rezonator represents coreference chains similar to other annotation environments, but refers to coreference chains as *trails* and mentions inside them as *tracks*. The verbal complex is marked up using *chunks*, represented by grey rectangles spanning one or more tokens. Examples of tracks, trails and chunks are shown in Figure 9.

Rezonator also allows the creation of dependency trees on units or stacks. Nodes in the tree are called tree entries, and can consist of contiguous collections of tokens. This allows for more laconic representations of argument structure, instead of fully elaborated dependency trees. An example is shown in Figure 10.

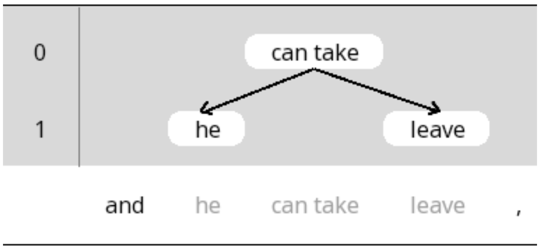


Figure 10: Sample dependency tree of line 45, connecting three tree entries he, can take and leave. Tree links are represented by straight edges (e.g. Osborne & Groß, 2012), unlike curved arcs standard in computational linguistics.

`rezonateR` taps into these annotations their tags to generate to rapidly generate predictors of referential choice (or features for similar tasks like coreference resolution). Firstly, the `EasyTrack` suite of functions creates predictors based on the location and tags of other mentions in the surrounding context, such as distance to the previous mention. These functions are highly customizable; for example, users can set what kind of token should be counted in measures of distance (excluding e.g. punctuation and representations of zero anaphora), how cases of zero anaphora should be treated when speaking of their 'locations', and so on. Some commonly-used functions in this suite are shown in Table 2. These functions can also be used on non-Rezonator data as long as the user transforms it to a format suitable for these functions.

Secondly, because Rezonator does not automatically link tree entries to tokens, chunks or tracks, `rezonateR` also provides the function `getAllTreeCorrespondences()` which attaches information from tree entries (including tags attached to their link to their parent) to the `rezrDF`s for tokens, chunks and tracks. The latter can then be used by `EasyTrack`.

Finally, many properties of referential expressions can benefit from automatic annotations which are then manually corrected. Using the workflow mentioned in Section 2.1, this can be done by exporting part of the `rezrDF` for tracks as a `.csv` file, then importing it back to R.

As an example, the initial portion of Alice's telling (up to line 162), about Alice's roommates, was annotated for coreference and basic argument structure. Mentions (tracks) were then divided into three types – zero anaphora, pronominal, and lexical – first using automatic rules with `TidyRez` (together with standard `tidyverse` functions like `case_when()` and `str_detect()`) then manual correcting the annotations.

To visualise patterns as to how the three forms tend to be used, one can chart the change in form choice over time. Figure 12 does this for the four longest coreference chains other than those referring to Alice and Mary themselves. A common pattern is that after a period of not being mentioned, a referent will be referred to first using a lexical form before switching over to pronominal or zero, as expected from the literature (e.g. Ariel 2001, Givón 1983). One exception in the Tim + Mandy chain, involving a change from pronominal to lexical form even when there is no large gap between the two mentions, coincides with a speaker transition.

`unitsToLastMention()`, `tokensToLastMention()`	Distance to the previous mention of the referent, measured in units and tokens.
`unitsToLastBridge()`, `tokensToLastBridge()`	Distance to the previous bridging mention.
`countPrevMentions()`	Number of previous mentions within a specific window size.
`countPrevMentionsIf()`	Similar to `countPrevMentions()` but imposes a condition on an entity being counted (e.g. being the subject)
`countPrevMentionsMatch()`	Similar to `countPrevMentions()` but checks whether the current and previous mention have a specified common property (e.g. both matching in semantic role).
`getPrevMentionField()`	Retrieve a property of the previous mention.
`countCompetitors()`, `countCompetitorsMatch()`	Count the number of competitors.

Table 2: A selection of common `EasyTrack` functions. Functions concerning previous mentions also have equivalents for following mentions.

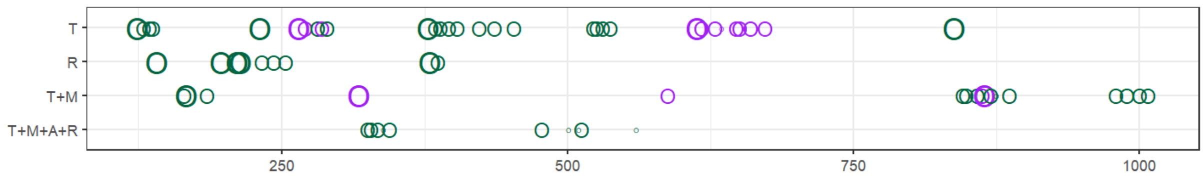


Figure 11: A chart of the four longest coreference chains (other than first-/second-person singular referents) in the first part of SBC007, including Tim (T), Ron (R), Tim and Mandy (T+M), and Tim, Mandy, Alice and Ron (T+M+A+R). The x-axis represents tokens; mentions are represented by circles placed at the position of the first token of the referential expression. Green circles represent forms produced by Alice, and purple circles represent those produced by Mary. Circle size represents the weight of the referential expression: The largest circles are lexical forms, the smallest ones represent zero anaphora, and the remainder are pronominal.

For this preliminary exploration, three predictors frequently found to affect referential choice were chosen for detailed study: animacy, subjecthood, and density of recent mentions. Trails were tagged for the animacy of the referent inside Rezonator, tree links were tagged for whether it was a subject-verb relation (also in Rezonator `rezonateR`), and `countPrevMentions()` in was used to find the number of mentions of the same referent within a 10-IU window. These patterns are summarised in Figure 12.

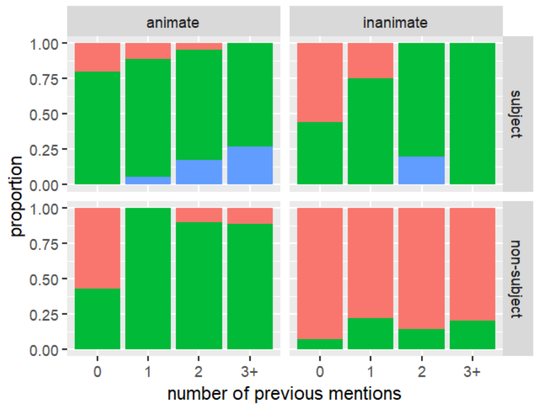


Figure 12: Proportion of lexical (red), pronominal (green) and zero (blue) mentions by animacy, subjecthood, and number of previous mentions in a 10-IU window. Inanimate non-subjects are overwhelmingly lexical, while others, especially animate subjects, are overwhelmingly pronominal. The greater the number of previous mentions, the larger the likelihood of a heavier expression and vice versa.

Clearly, animacy, subjecthood, and recency all contribute to a referent being mentioned using a more attenuated form (e.g. zero or pronominal) over a heavier form (e.g. a fully lexical expression), consistent with general observations that we prefer lighter forms for more cognitively accessible referents (e.g. Ariel 2001). Perhaps since this is an intimate conversation between two family members with much common shared knowledge, there are few lexical forms used outside of inanimate non-subjects.

4 Conclusion and future directions

In this paper, I introduced `rezonateR`, an R package for turning complex corpus annotations from Rezonator into tabulated data with features that can be readily used for visualization and modelling. After briefly introducing the basic workflow, data format, and data manipulation features, I showed how a single conversation from the Santa Barbara Corpus can be analysed from multiple perspectives – turn-taking, dialogic resonance, and referent tracking – using the package's functionalities, facilitating future research on these topics, which have seen a recent increase in large-scale quantitative research. By transforming complex annotation graphs into a relational database structure and providing simple functions for generating features geared towards specific research questions, `rezonateR` bridges the gap between visual qualitative analysis of conversations in Rezonator (with an underlyingly complex data structure) and quantitative analysis.

As the package is under active current development, it will continue to be updated with new capabilities and bug fixes in coming years. Future directions including directly building visualisation capability, such as those in this paper, into `rezonateR`, providing accessible visualisation methods to those unfamiliar with `ggplot2`. Another direction is to enhance the capacity of the package to handle multiple `.rez` files, for instance in the context of evaluating inter-annotator agreement. Lai, Li & Zhang (2023) has integrated `rezonateR`'s import function to compare the segmentation of conversations into units; similar features may be implemented for stacks and other Rezonator annotations. Finally, the package may be extended to convert Rezonator formats to and from Salt (Zipser & Florian 2010), in order to interface with a wider variety of data from other visual annotation environments.

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