Analyzing the structure of parent-moderated narratives from children with ASD using an entity-based approach

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Abstract

Storytelling is a commonly used technique for rating linguistic and communicative abilities of children with Autism Spectrum Disorders (ASD). It highlights their language use beyond sentence-level production, and their ability to cohesively link events into a plot, including incorporating social context. A key scenario of interest we consider is spoken narrative creation in interactive settings, where confederates such as parents can offer scaffolding to their children's narratives by eliciting answers with appropriate questions, shaping the structure of the resulting narrative. We analyze the structure of children's stories narrated with the help of their parents using entity-based feature-level patterns in order to see how there are influenced by the parents' narrative elicitation techniques. The frequency distribution and evolution of entities -meaning the co-referent people, objects and ideas- can capture the main axis of the story plot. Our results indicate that the type of questions the parents ask can be reflected in the entity-based features of a narrative, affecting its underlying structure and coherence.

Index Terms: Narrative Structure, Coherence, Text Entities, Autism Spectrum Disorders

1. Introduction

One of the key aspects in rating communication skills of children with Autism Spectrum Disorders (ASD) is their ability to report events in a comprehensible fashion that takes into account sequential descriptions and causal dependencies [1]. A commonly used technique for analyzing such communication and language skills is storytelling. Children with ASD are likely to produce less coherent narratives [2] than their typically developing peers. They are also reported to demonstrate poor building of causal events and weak emotional understanding within a story [3]. Behavioral Signal Processing (BSP) [4] can help in modeling and understanding these linguistic and cognitive atypicalities with quantifiable measures and insights.

Storytelling can be elicited in an interactive manner such as with the support of parents. Parental elicitation strategies affect the content and structure of children's narratives. Children whose parents focus more on event elaboration rather than context description are more likely to produce better structural organization of their stories [5]. Also better quality narratives result from children whose parents prompt more questions and explanations [6]. Especially for children with ASD, parental clarifications of affect during narratives influence the children's understanding of implicit human behavior, feelings and thoughts [7]. Our goal is to understand the link between the parental narrative style and the resulting structure of the children's story.

In this paper we study the structure, i.e. the internal organization, of narratives elicited from children with ASD with the help of their parents during storytelling. We hypothesize that the way parents scaffold the story, and specifically their types of questions, affects the overall narrative coherence, meaning the logical flow and integration of the story's individual events. Out of the possible techniques which parents can use, we focus on the type of questions they ask, studied in detail [5, 6], since these provide a framework for the child to elaborate on. Specifically we differentiate between context and action questions. The first ones are oriented toward the description of specific people and objects, while the second focus on events constituting the plot evolution. Action-oriented questions are more likely to provide a more structured story [5] resulting in more cohesive narratives, as previously found [8, 9]. Analyzing the response of children with ASD to their parent's stimuli and the resulting narrative coherence might afford us new insights into understanding their cognitive mechanisms and impairments.

Toward this goal, we designed features of narrative coherence that model the frequency and evolution of entities, meaning the co-referent noun-phrases that represent the main characters, objects and ideas in the story. Previous studies have measured text-coherence using local sentence text-relatedness features that track the transitioning of entities with respect to their grammatical roles [10]. Semantic [11] and syntactic [12] similarity between adjacent sentences have been also used towards this goal. Our features capture the distribution of entity frequencies using decaying probabilistic distributions, which can indicate the portion of most frequent entities in the plot [13]. We model the transitioning of dominant entities across sentences as a Markov Chain, the evolution of entities in the narrative with step sequences and the entities interactions using "directed" normalized distance measures. These features enable us to represent the underlying narrative structure and coherence, affected from the sort of questions parents provide.

We consider three types of narratives: context-, action- and context/action-oriented, characterized based on whether the parents ask respectively more, less or equal amount of context compared to action questions during the task. We hypothesize that these three narrative groups demonstrate differences in their structure and coherence. We validate our approach by analyzing our entity-based feature descriptors with respect to the three narrative types. We further conduct classification experiments to discriminate between the three narrative groups based on these features. Our results indicate the presence of specific patterns both in the frequency distributions and the evolution of entities that can distinguish between the prevailing type of questions that are being asked and can implicate the existence of coherence in the story.

2. Data Description

Our data come from the "USC Rachel ECA interaction Corpus" [14], containing interactions of children with ASD with

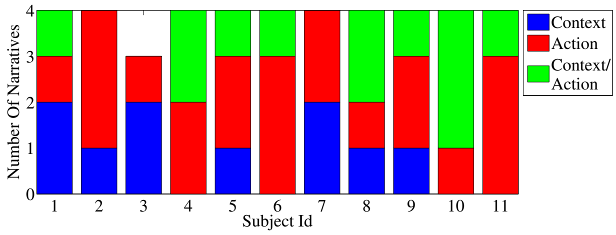


Figure 1: *Distribution of context, action and context/action narratives within each subject.*

an Embodied Conversational Agent (ECA), named Rachel, and their parents. For the purpose of this study we analyzed the data recorded from the child-parent interaction portion, during which the child and the caregiver narrate a story based on a picture-book. The ECA does not take part in this task. We have previously modeled the behavior of the child with and without the ECA [15] and the triadic ECA-child-parent interaction [16].

This paper includes data from 11 verbally fluent subjects with ASD, 9 boys and 2 girls, aged between 6 and 12 years. Each child participates into 4 storytelling tasks with his/her parent, each narrated on a separate session. There was one child who did not provide a narrative during one of its sessions, resulting in a total of 43 narratives for our analysis. For the purpose of this study, we used human-derived transcripts.

3. Context and Action Questions

We manually tagged the questions asked by the parents during the storytelling task as context or action questions. Context questions seek information about people, as for example "How does he look?", objects, such as "Is that grass?", or places, like "Where is that?". Action questions on the other hand can ask for general information, like "What's going on?", or for specific prompts, as for example "What's Henry doing here?".

In total there are 10 narratives with more context than action questions (referred as "context narratives"), 21 narratives with more action than context questions ("action narratives"), and 12 narratives with equal context and action questions ("context/action narratives"). The distribution of the types of narratives is not uniform across children, as shown in Figure 1. There are subjects, like 6 and 11, whose narratives tend to be dominated by action questions and others, such as 10, with equal number of context and action questions during most narratives.

4. Narrative Structure Features

As shown in previous studies [10], in order to model the structure and coherence of narratives, it is important to efficiently capture the evolution and interaction of the main characters presented in the story. In this paper we model the frequency and evolution of the main entities and analyze the way these are related to context and action narratives and in extension, to the structure and coherence of the story. In order to do this, we found the entities of a narrative using the ARKref noun-phrase coreference system [17]. Based on these, we computed general descriptors of the entity frequency distributions and features capturing the evolution of entities across sentences. In an effort to highlight the differences between context and action narratives, the feature analysis of this section refers only to those two types, and not the context/action narrative, for which it is more difficult to provide characterizations.

4.1. Entity Frequency Descriptors

We computed features that describe the frequency of entities within a narrative (referred as "EntityFreqCounts"). These include the number of unique entities within a narrative and the percentage of unique entities with frequency larger than $5, 10, 15, 20\%$. The number of unique entities can give us an estimate of the number of characters, objects or ideas, while the most frequent entities represent the main objects of interest, as also mentioned in [13]. Most of these measures tend to have larger values for action compared to context narratives, indicating that action narratives are centered around several entities which are frequently mentioned throughout the story, as we also find in Sections 4.2-4.4. Due to their simplicity, we have set these features as our baseline for our experiments (Section 5).

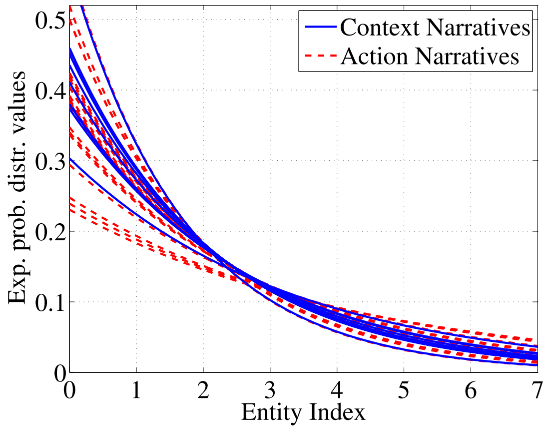


Figure 2: *Exponential entity frequency distributions for context and action narratives. The x-axis represents the index of entities sorted by descending frequency in the story.*

4.2. Entity Frequency Distribution Parameters

Motived by previous studies [13] and inspired by the inherent decreasing shape of entity frequency distributions, we modeled these with decaying probabilistic distributions, specifically the exponential and the Generalized Pareto (GP).

According to the Kolmogorov-Smirnov goodness of fit test, 41 out of the 43 narratives had an entity frequency distribution significantly fitting ($p < 0.05$) to an exponential. The two narratives with no significant fit, belonging to different subjects and sessions, had two or three dominant entities with high frequency, therefore lacking the steep decreasing shape in their distributions. All narratives gave a significant fit ($p < 0.05$) to the GP distribution. Using the Maximum Likelihood Estimate (MLE) we computed the rate of the exponential distribution and the scale and shape of the GP. This 3-dimensional feature vector, referred as "EntityFreqFit", gives an estimate of the curvature, steepness and flatness of the entity frequency distribution.

A steep curve, having low rate and shape values for the exponential and GP distributions respectively, reflects the presence of few important but commonly repeated entities. In contrast, a flat distribution indicates that the narrator refers to many entities without emphasizing a dominant one. As shown in Figure 2, there exist some action narratives distinguishing from all others, in that they have very steep or very flat entity distributions. The first could suggest the presence of few primary characters in the action narratives around which the plot evolves, and the second the existence of many interchanging characters participating in the plot. These observations do not seem to happen in context narratives with frequency distributions in the middle.

4.3. Narrative Transitions between Entities

The entities within a narrative can be viewed as states between which the narrator transitions in order to describe the plot of the story. If we hypothesize that the current state depends only on the previous one, we can model the transition of entities as a Markov Chain. We assume that transitioning happens between consecutive sentences. In case of multiple entities in a sentence,

Table 1: *One-sided Wilcoxon rank sum test comparing the medians of EntityTransition features between context and action narratives(† : $p < 0.1$, ∗ : $p < 0.05$). The null hypothesis supports that data from two narratives have equal medians, while the alternative that action narrative features have higher medians than context narrative ones.*

EntityTransition Feature	Median Feature Values		P-value
	Context Narratives	Action Narratives	
$\mathbf{r}$	0.15	0.20	0.06†
$\mathbf{r_p}$	0.49	0.58	0.26
$\mathbf{r_s}$	0.24	0.44	0.03*
$\mathbf{n_{pf}}$	0.37	0.43	0.10
$\mathbf{n_{pt}}$	0.42	0.43	0.36
$\mathbf{n_{sf}}$	0.18	0.25	0.08†
$\mathbf{n_{st}}$	0.16	0.27	0.01*

the sentence is represented by the most frequent one, referred as the "dominant entity". On average there were 1.7 unique entities per sentence. The most frequent entity over the whole narrative will be referred as "primary", the second most frequent as "secondary" and the third as "tertiary". If no entities are present in a sentence, the latter is omitted from the sequence.

In order to describe the transitions between sentences, we compute the stochastic matrix $P = [p_{ij}]$ of the Markov Chain, where element p_{ij} denotes the probability of transitioning from state i to state j, i.e. between two consecutive sentences the most dominant entity changes from entity i to entity j. Let N be the dimensionality of the stochastic matrix. N is the total number of narrative states, i.e. the total unique dominant entities in our setup. The entities appear in the stochastic matrix in decreasing frequency order, meaning that the first row/column represents transitions from/to the primary entity, the second row/column transitions from/to the secondary entity, etc.

The mean probability of dominant entities remaining the same over two consecutive sentences is $r = \frac{1}{N}\sum_{i=1}^{N} p_{ii}$ and the probabilities of the primary and a secondary entities remaining dominant over a transition are $r_p = p_{11}$ and $r_s = p_{22}$.

A coherent story is centered around a common axis or reference point [18], property which benefited other domains, such as essay scoring [19]. This could be achieved by frequently mentioning or interchanging the common entities in a narrative. To capture this, we compute the percentage of entities that are reached from (n_{pf}) and reach to (n_{pt}) the primary entity. These are the percentage of non-zero elements of first the row and column of P and are respectively given by the equations:

$$n_{pf} = \frac{1}{N-1}\sum_{i\neq 1} \mathbf{1}_{(\mathbf{0},+\infty)}\left(p_{1i}\right)$$
$$n_{pt} = \frac{1}{N-1}\sum_{i\neq 1} \mathbf{1}_{(\mathbf{0},+\infty)}\left(p_{i1}\right)$$

Function $\mathbf{1}_{(\mathbf{0},+\infty)}(x)$, $x \geq 0$, checks for positive/zero input:

$$\mathbf{1}_{(\mathbf{0},+\infty)}\left(x\right) = \begin{cases} 1 & \text{if } x \geq 0 \\ 0 & \text{if } x = 0 \end{cases}$$

We find the same measures for the secondary entity as:

$$n_{sf} = \frac{1}{N-1}\sum_{i\neq 2} \mathbf{1}_{(\mathbf{0},+\infty)}\left(p_{2i}\right)$$
$$n_{st} = \frac{1}{N-1}\sum_{i\neq 2} \mathbf{1}_{(\mathbf{0},+\infty)}\left(p_{i2}\right)$$

The higher these quantities are, the more the primary and secondary entities are involved in the plot. Tertiary entity measures were not included so as not to increase the dimensionality of the feature space and since they did not seem to benefit our setup.

The features extracted based on the Markov Chain transitions, 7 in total, are referred as "EntityTransition".

We compared the median values of EntityTransition features between context and action narratives with a Wilcoxon rank sum test (Table 1), chosen because the data samples do not follow the normal distribution. The results show that in action narratives, primary and secondary entities tend to dominate the plot more than in context ones, since the probabilities of remaining at the primary/secondary entity (r_p and r_s) are higher for action narratives. Similar findings are reflected on the n_{pf}, n_{pt}, n_{sf}, n_{st} values, suggesting that the transitioning from/to primary and secondary entities is more frequent for action compared to context narratives and implying that action narratives are likely to evolve around a set of dominant characters with the presence of others supporting the plot. Secondary entity measures tend to be more distinct between the two types of narratives than primary ones. This could suggest that while primary entities tend to be active in most stories, secondary entities might capture more attention during action narratives.

4.4. Evolution and Interaction of Entities

Until now we have described a general trend on how dominant entities transition between sentences without getting an insight into the entities evolution and their interactions. Toward this direction, we model the entity evolution as a path of successive steps, each corresponding to a sentence, increasing when an entity is present in a sentence and decreasing otherwise. A sequence with much higher values than the others suggests the presence of an active entity which favors coherence [18].

Let $\{X_{nk}\}$, $n = 1, \ldots, N$, $k = 1, \ldots, K$, be the k^{th} step of the n^{th} entity sequence, where N is the total number of entities (as in Section 4.3) and K the total number of steps, i.e. the total number of sentences in a narrative. If entity n is present in sentence k, then $X_{nk} = X_{n,k-1} + 1$, else $X_{nk} = X_{n,k-1} - 1$ ($k > 1$, $X_{n1} = 0$). In this way, sequence $\{X_{nk}\}$ can represent the evolution of the n^{th} entity within a narrative.

In Figure 3 there are examples of entity sequences based on which we motivated our approach. As we have noticed, in action narratives a primary entity dominates the story with the possible presence of interchanging entities supporting the plot. This is not the case for context narratives, in which the primary entity is not as prevailing. As shown in Figure 3a of an action narrative, the primary entity (solid blue line) receives a lot of attention, reflected in its higher position and large distance from the other entities. In Figure 3b the three most frequent entities of the action narrative (solid blue, dashed red and "circled" green lines respectively) "compete" for the focus of attention. The plot's attention in the beginning is centered to the tertiary entity, whose distance from the others is large. Similar observation occurs for the primary entity in the end of the story. In the context narrative however (Figure 3c), the curves of the most frequent entities are not separated by large distances, suggesting that none of them appears to dominate the story.

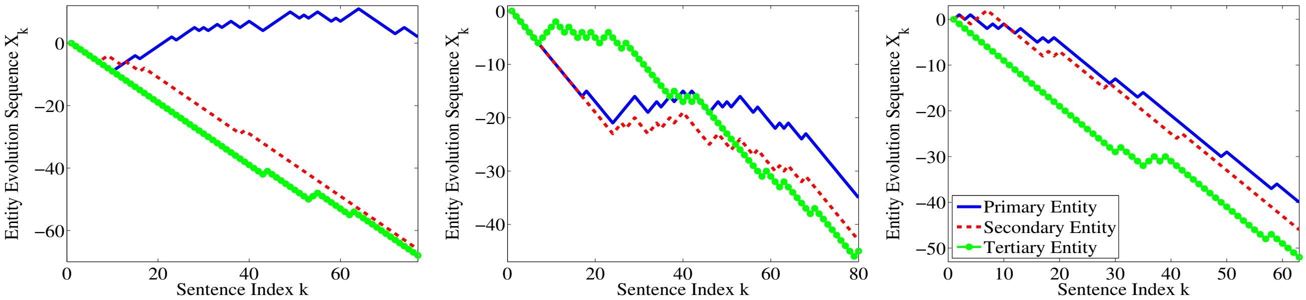
We computed the "directional" distances between the sequences $\{X_{nk}\}$ and $\{X_{mk}\}$ of the n^{th} and m^{th} entity respectively. Let $S_h = \{k \in [1, \ldots, K] : X_{nk} > X_{mk}\}$ and $S_l = \{k \in [1, \ldots, K] : X_{nk} < X_{mk}\}$ be the sets of indices in which the n^{th} entity sequence has respectively higher or lower values than the m^{th} one. The normalized distances between two sequences over the regions that one exceeds the other are:

$$d_{nm} = \mathcal{E}_{k\in S_h}\left(X_{nk} - X_{mk}\right)$$

$$d_{mn} = \mathcal{E}_{k\in S_l}\left(X_{mk} - X_{nk}\right)$$

where $\mathcal{E}$ is the average function defined over a set S with cardinality $|S|$ defined as $\mathcal{E}_{k\in S}\left(d_k\right) = \frac{1}{|S|}\sum_{k\in S} d_k$.

These distances were computed between the three most frequent entities ($n, m = 1, 2, 3$, $n \neq m$) resulting in 6 features. Including more entities did not benefit our setup. These features, referred as "EntityEvolInter", tend to be greater for action than context narratives, enhancing our observations from Figure 3 and indicating the presence of interchanging dominant entities in action narratives that contribute to story coherence.



(a) *1st Example of Action Narrative* **(b)** *2nd Example of Action Narrative* **(c)** *Example of Context Narrative*

Figure 3: *Schematic representation of the evolution of the three most frequent entities ("primary", "secondary", "tertiary" in order of decreasing frequency) for two examples of action and one example of context narrative. The legend is common for all subfigures.*

5. Experiments

We provide our experimental setup for classifying the three types of narratives (context, action, context-action) based on the narrative structure features. Our classification results, reaching 62.88% unweighted accuracy, indicate that the parental scaffolding affects the narrative structure and coherence, as manifested with the entity-based features.

5.1. Methods

We performed feature selection using Fisher Discriminant Ratio (FDR) [20]. Features with FDR greater than the p^{th} percentile of the maximum FDR value of the total feature set were maintained. To further increase class separation, we performed Linear Discriminant Analysis (LDA) over the remaining features. Since we have 3 classes and LDA results in one fewer dimension than the total classes [20], we get a 2-dimensional feature.

Classification was performed with a K-Nearest Neighbor (K-NN) classifier, suitable for our small-size low-dimensional data. Results are reported based on a leave-one-speaker-out cross-validation scheme. In each fold data from one speaker were assigned to the test, from the next speaker to the dev, and the remaining to the train. Subjects were ordered based on their first recording date and we have no reason to assume this introduces any bias. The dev set was used to optimize the number of nearest neighbors of K-NN ($K = 3, 5, 7$) and the p^{th} percentile FDR threshold ($p = 15 - 80\%$ with step 5). Feature selection was done on the train and then applied on the dev and test sets.

5.2. Results

Significance of the results compared to the EntitFreqCounts baseline was tested using the one-sided Fisher's Exact Test for categorical variables, matching our small sample size. According to this, each of the 43 total narrative-instances was given a label based on whether it was correctly classified or not. The null hypothesis that the correct proportion of narrative-instances for the baseline and the proposed features are equal, is compared to the alternative that the correct proportion achieved by the proposed features is greater than the baseline's.

EntityTransition feature is the only one outperforming the baseline EntitFreqCounts (Table 2) indicating its importance for our task. Combinations of EntityFreqCounts+EntityTransition and EntityFreqCounts+EntityEvolInter (at the feature level) provide significantly better results than our baseline, suggesting that the transition and evolutional interaction of entities in a narrative have information complementary to the entity distribution. Combining different or more features than the ones we report was not beneficial to the performance.

6. Discussion

In this study we found that action narratives tend to focus on few dominant entities, while this is not as apparent in context ones. This was captured by modeling the frequency and evolution of entities in the story. The distribution of entity space in stories has been the focus of many domains, such as narrative theory of literature [21], research on children's literacy [22, 23] and education [19]. The comparison between topic centered narratives, with a dominant entity receiving most attention, and associative ones, containing loosely coupled interactions of many entities, is a central issue. Quantitative measures, like the ones we described, could help differentiating between the various narrative types and provide reliable estimates of the underlying structure.

Table 2: *Unweighted classification accuracy (%) of the three narrative types (context, action and context-action) based on narrative structure features. (* : significant over the EntityFreqCounts baseline, $p < 0.05$, according to Fisher's Exact Test)*

Feature Group	Unweighted Accuracy (%)
EntityFreqCounts	52.27
EntityFreqFit	36.51
EntityTransition	**59.85**
EntityEvolInter	44.70
EntityFreqCounts + EntityFreqFit	51.52
EntityFreqCounts + EntityTransition	**61.36***
EntityFreqCounts + EntityEvolInter	**62.88***

Our results also indicate that during interactional narratives, children's interlocutors, such as parents, can influence the story structure by prompting specific types of responses. This could be used in a child-computer interaction scenario, in which appropriate personalized scaffolding from the ECA can help eliciting and shaping stories. Many studies have addressed the importance of a virtual agent for practicing imagination [24] and building coherence of children's narratives [25]. The Rachel ECA system [14], part of which is the child-parent interaction data analyzed here, elicits similar storytelling data with the help of the ECA. In our future work, we plan to compare structure and coherence between ECA- and parent-moderated narratives to spot possible differences in the elicitation techniques and analyze the aspects in which one could outmatch the other.

7. Conclusions and Future Work

In this paper we analyzed the structure of children's narratives with respect to the stimuli of the caregiver. We found that story structure, modeled with features capturing the entities frequency, transitioning and evolution, differs between narratives with more/less/equal context compared to action questions.

In our future work, we plan to expand these entity-based features to integrate their semantic and syntactic information. We will also examine possible effects of other kinds of stimuli in the narrative coherence, such as open/closed-questions, statements and prompts. Finally, we intend to expand those ideas for modeling dialog coherence of the child's various interactions.

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