An Analysis of the Dialogic Complexities in Designing a Question/Answering Based Conversational Agent for Preschoolers

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Abstract. Parents are well aware that pre-school children are incessantly inquisitive, and the high ratio of questions to statements suggests that questions are a primary method utilized by children for language acquisition, cognitive development, and formulating knowledge structures. Question-asking is furthermore a comfortable medium for a child to stay engaged in natural discourse and the activity at hand. To take advantage of the naturalness and learning benefits of question-answer exchanges, there could be intelligent agents that can engage a child in activities while setting children in the mood to ask meaningful, information-seeking questions. There are currently multiple intelligent agents that can interact with older children and adults to promote literacy or teach topics in specific domains. This paper thus focuses on the complexities of designing an intelligent agent for younger children, by collecting and analyzing data and categorizing children's questions, which are often ill-formed.

Keywords: Question-Answering Agent, Pedagogical Agent, Conversational Agent, Discourse Analysis, Language Learning.

1 Introduction

A large body of research has shown that the "literacy gap" between children is well-established before formal schooling begins, that it is enormous, and that it predicts academic performance throughout primary, middle and secondary school. Indeed rather than closing this gap, there is much evidence that formal schooling exacerbates it: once behind in reading and vocabulary, children read with lower comprehension, learn more slowly and have lower motivation than their more language-able peers. Many national organizations recognize the essential role of early literacy in a child's later educational and life opportunities [5],[3],[4]. Hart and Risley [2] report a factor of two difference in the working vocabularies of high vs. low-SES (Socio-Economic Status) three-year-olds. The average low-SES child has heard 30 million fewer words than a high-SES child by this age. However, they also observed that SES alone is not a predictor of cognitive development at the pre-school stage. "The richness of nouns, modifiers, and past-tense verbs in their parents' utterances, their parents' high propensity to ask yes/no questions, especially auxiliary-fronted yes/no questions; and their parents' low propensity to initiate and use imperatives and prohibitions were more strongly predictive of the children's

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performance on the Stanford-Binet IQ test battery than was the family SES." Hart and Risley note that to close this gap is an enormous challenge and will require lengthy and regular language experiences for the child. As noted in the above studies, the greatest impact on child literacy will come from intervention at pre-school ages.

While it is becoming increasingly clear that conversations and language interactions serve as an important tool in the child's cognitive process, a growing body of research is also suggesting that pre-school children are voracious inquisitors. One recent study found that preschoolers ask approximately 80 questions/hour [1] which constitutes more than one-fourth of their utterances. These questions are an essential part of language development: they provide primary experience with question construction, statement construction, explanation construction, complex tenses etc. The child question-asker is primed for an answer. Unlike other forms of interaction (reading, games) no external influence is needed to garner the child's interest or build motivation. The questions reflect the child's current state of knowledge and should take them just beyond it. In other words, child-initiated questions are naturally in the child's Zone of Proximal Development (ZPD). Question-asking, not surprisingly, goes beyond literacy and is an integral part of children's cognitive development [1].

It is safe to assume that parents are the primary teachers for preschool children, but many interventions directed at parents reproduce the gap. Educational interventions for children involving parents appear to be dependent on the parent's educational level, so literacy differences persist across generations. For instance, dialogic reading (defined later) interventions involving high-SES parents were far more effective than with low-SES parents [17]. Children evidently need some form of linguistic engagement for many hours a week, with a language-able partner who can engage with them in age-appropriate language-learning activities. Since research in early child development suggests that for pre-school children question-answering serves as a frequent and heavily-utilized medium of synchronizing mental models with adult-like understanding of the world, this linguistic engagement can come in form of interactive question-answering systems. Since children spend a significant amount of time playing alone, or out of home, there might be instances when they don't find an adult around to answer their questions. There might also be times when the adult doesn't have sufficient information at hand to answer a child's question. This explains the need for expert interactive systems that can work as engaging question-answering agents. However, before any type of technology push, we want to establish a theoretical framework in which such interventions can be based. Therefore, this paper outlines the dialogic complexities involved in designing a Q/A system for preschoolers, by analysis of transcripts from the CHILDES database [14].

2 Related Works and Background

Child development research has shown that children rapidly acquire knowledge of new words starting at 18 months of age. According to Jean Piaget's theory of development, it is during the pre-operational period (ages 2-7) during which children become able to represent ideas through language and mental imagery [18]. Vocabulary size more than doubles between 18-21 months and again between 21-24 months of age, and a typical

child understands at least 10,000 words by first grade. These patterns suggest a high propensity for children to acquire vocabulary at a very young age, and that preschool age is likely an appropriate time to engage children in language learning [21]. Moreover, scaffolded linguistic interactions with adults significantly advance children's learning. For example, toddlers whose mothers follow their attention by labeling objects of joint attention tend to have larger vocabularies later on [21]. Adult grammar provides semantic clues that aid children in deciphering the meaning of words, and social cues also help children develop competency through the corrective feedback that adults give when children use words incorrectly.

According to psychologist Lev Vygotsky, such interactions are not merely external forces that provoke internal change in an individual, but rather integral to the very mechanism of cognitive development [23]. Because childhood word learning both increases rapidly at an early age and demands support from adult modeling, it is valuable to examine ways in which adult-child interactions at the preschool age can be modeled through software interfaces. It is common knowledge that young children ask a considerable number of questions, but to correlate children's inherent motivation to develop theories about the world with their question asking, the amount, content, and responses to adult's answers have been analyzed. In a longitudinal study of transcripts involving four children, ages 2.5-4, 71% of the questions were information-seeking questions, and of these, 75% were fact-seeking and 25% were explanation seeking questions [7]. Noninformation-seeking questions ranged from seeking attention, clarification, action, permission, play, towards a child or animal, or were unknown [7].

Based on questions with young children, such as asking the children for sentence completions, Piaget concluded that young children had very primitive notions of causality under 5 or 6 years old [18]. However, recent works are re-examining Piaget's claims. Shultz performed an experiment, where children of ages 3, 5, 7, and 9, were shown three pairs of two objects, where one object was the cause of an effect, and asked to identify the object which created the effect. Children of all ages were able to correctly link the causes and effects using attributes of the source or result. Hood and Bloom [9] find that children make causal statements and responses to causal questions by adults from at least age 24 months, and by 30 months, they can ask causal questions productively. Furthermore, these causal questions are oftentimes more sophisticated than one word questions such as "why" and "how" that are meaningful in the context of specific domains such as natural phenomena, biological phenomena, physical mechanisms, motivation/behavior, and cultural conventions. In a study by Callanan and Oakes [7], parents of children ages 3, 4, and 5 were asked to record forms for children's questions, with special focus on causal questions for two weeks. At age 3, 20% of "why" questions were simply "why?" at age 4, 10% were "why?" and at age 5, 4% were "why?". This demonstrates that age plays a major role in the kind of questions that children ask. Frazier et al. [8] performed a laboratory experiment where investigators engaged children in conversation about a set of unusual toys and alternated between providing explanatory versus non-explanatory answers to the children's questions. Shultz's experiments provide evidence that children can judge causality by using their knowledge of object attributes, or by generative transmission, rather than on attributes such as spatial or temporal contiguity [20].

Many recent research papers have focused on categories of children's questions through manual coding. These studies generally perform diary studies, or perform laboratory experiments observing the question/answering dynamic for young children. Questions can be coded along several dimensions: information-seeking versus non information-seeking, response desired, content, response type, and information given in the response [1]. The response desired can be a fact or explanation if the question is information-seeking, or it can be attention, clarification, etc. if the question is non information seeking [1]. Content can range from the label, appearance, property, etc. of the questions' subjects [1]. Callanan and Oakes also derived the statistics of the ratio of causal question types, the situations in which they emerge, and their content through a diary study of 30 preschool children [7]. Frazier et al. derived the statistics of parent's responses to children's causal questions and children's responses to different responses by their parents by examining longitudinal studies from CHILDES and through laboratory experiments with 42 preschool children [8].

3 Children's Questions in Various Activities

There are several components requiring research from various fields that are necessary to construct any technology that promotes question asking by pre-school aged children. The conversation dynamics between children and adults have their own structures and processes, with complex rules of turn-taking. In this domain, we are primarily interested in how to best encourage a child to ask meaningful, instructional questions while keeping them engaged. To anticipate and correctly answer the questions that children may ask, it is necessary to properly identify and group the questions with the type of response needed. Determining the types and levels of engagement children have during specific activities in their daily lives will guide us in designing technology that promotes their question asking.

3.1 Materials

The focus of our question categorization is to investigate how engagement differs with interaction. For our analysis, we had to choose between labeling dialogs of spontaneous child play or dialogs of children with controlled play activities in a laboratory setting. For spontaneous child play, the dialogs would have to be coded for the activity type, and there would be variation within groups of interaction types, such as the type of toys a child had access to in a game of pretend. Furthermore, the transcripts of child and parent interaction lack any details regarding the surrounding objects, simultaneous events, and other extraneous circumstances, making them difficult to code for interaction type and difficult to annotate for disturbances. For controlled play activity, there are always pitfalls related to the naturalness of interaction in an unfamiliar setting with new objects. The observer's paradox is an additional concern, which affects both child and parent, since cameras and investigators easily distract the children, while parents are concerned with their appearance as guardians [11].

After preliminary analysis of both types of datasets within the CHILDES database, the spontaneous child play was determined to be very difficult to annotate in a consistent manner, and a laboratory study of adult with child interactions was chosen. The

Gleason database includes transcripts of 24 different children- 12 boys and 12 girls-in various activities with their father and mother separately. In the lab, the child and parent engaged in three activities: playing with a toy auto, reading a picture book, and playing store (also referred to as "pretend"). The parents were encouraged to divide the time evenly among the activities, and the activity order and parent order were randomized [16]. Since there are laboratory studies of the child with the Mother and Father separately and the studies are spaced out, we only analyze the transcripts of children who are between the ages 3-4 for both visits. This left 6 children, ages 3;1.04[1], 3;7.01, 3;2.21, 3;2.12, 3;2.03, and 3;7 during the Father's visit and ages 3;0.20, 3;6.07, 3;2.02, 3;3.16, 3;2.21, and 3;7.25 during the Mother's visit.

3.2 Procedure

Since we are interested in building an interactive interface for addressing children's questions, we code the questions in the Gleason study across various dimensions of question types. The first dimension chosen was **questions of causality**. The causal categories were chosen from the Callanan and Oakes [7] study as a comprehensive overview of children's causal questions, and no other causal question types were found during coding. The second category was the **response type expected**. If a child's question is in a causal category, then the question requires an explanation. If a child's question does not fit in a causal category, but is still information seeking, then the response needed is a fact. This includes clarification of a previous statement, confirmation that a belief or answer is correct, or any other question that seeks information. If the child asks a question for attention, to direct the conversation to a different topic, to direct attention of the adult to an object, to request something, or to signify interest or impatience, then the question is non-information-seeking. Of the information seeking questions (fact-seeking and explanation-seeking), the question can be directed completely towards the activity at hand and provide the child with no new information of the world. These questions are labeled "within scope". Questions that are "outside scope" can still be about the current toys the child is interacting with; however, it should add to the child's knowledge base of object names, properties, or mechanisms in the world. Lastly, the adult prompts many of the questions that children ask. To engage a child, adults will often ask the child a question. When the child repeats the question, the question is not the result of the child's inherent interest, but of the adult's mode of interaction, and is thus coded.

3.3 Discussion

The Gleason dataset was relatively simple to divide into the three activities, since the parents were encouraged to split time between the activities evenly across their half hour in the lab. There was a section at the end where the investigators holding the study gave the children a gift: this section was not included in the category analyses. There were also instances where the children noticed a camera in the room and conversed about the

[1] Ages are represented with year;month.day, where day is optional. For example, 1;5.10 is a child that is 1 year, 5 months, and 10 days old.

camera: this section was also removed in category analyses. Lastly, there was overlap between activities. When fully engaged in an activity, the child would stay focused on the task at hand; however, between activities, it would take several turns of persuasion by the parent to continue with the next task. A new task is considered started when the parent or child suggests the activity, and there is no further debate after that line of starting the new activity.

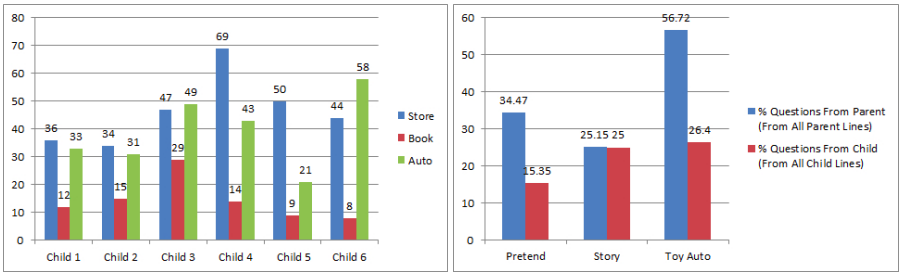

Fig. 1. Left: Ratio of conversational turns by parents and children percentages in various activities. **Right:** Percentage of questions by parents and children in various activities. Y-axis denotes percentages in both graphs.

Play Encourages Questioning: The type of role children take based on activity can be inferred by the ratio of child statements to questions and the number of child turns to adult, as they vary greatly between activities. Figure 1 presents these ratios. For example, in the game of pretend, children took up relatively more turns in the conversional exchange, but asked fewer questions relative to their increased speech. From the transcripts, it is clear that children are more interested in the role-playing aspect of pretend, than asking questions about familiar objects. Thus, they direct the conversation towards the make-believe world they wish to enact, while asking questions only when they are uncertain what a toy prop is. In contrast, children on average took a more passive role in interpreting the picture book. In general, the parents made up the story for the child, and most children took the role of listener, with varying degrees of participation in story-making.

When constructing the toy auto, parents tended to take a more verbally active, tutorial role, answering questions, giving suggestions in both statements and questions-and giving and asking for additional information about the different components of the car. This is reflected in the relatively high ratio of questions to statements by parents. These numbers hold across all children, and Figure 2 presents the percentage of child-initiated questions asked per child per activity, out of all questions asked in the activity by the child and adult. From this figure, it is more apparent that in the story activity, parents ask many more questions than children. Overall, children were more active when playing store or playing with the auto. When reading the story with their parents, however, the amount of child-initiated questions varied greatly. It should be noted that this cannot be seen as a result of just the child. There are two sides to the conversation, and the variance in child-initiated questions may also be due to the specific dynamics between the parent and child. The percentage of child-initiated questions is presented in Figure 2.

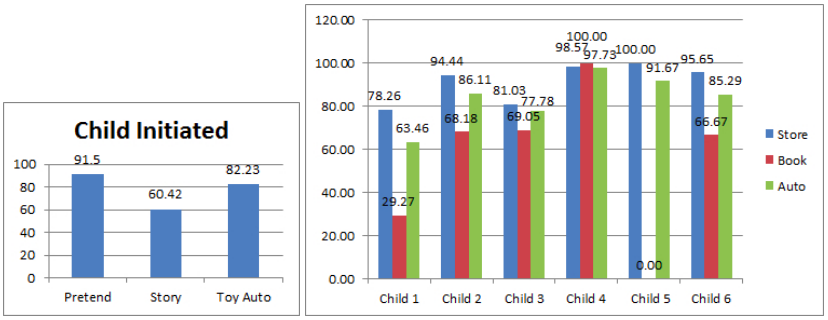

Fig. 2. Left: Percentage of questions initiated by children across activities out of all questions asked by children in an activity. **Right:** Percentage of questions initiated by each child across activities out of all questions asked by a child in an activity.

Children's Questions Are Grounded in Scope: For our study, a question is considered "outside scope" if a response would either help categorize an object, describe properties of an object, or explain how an event, such as how to connect an engine to a car, would take place. In this case, unlike Chouinard's definition [1] of information-seeking questions, "outside scope" can include clarifications of what an adult said. At the same time "outside scope" is also much more conservative. Fact-seeking questions such as "where is it?" are considered within scope because they only pertain to the activity at hand.

Since most of the questions children asked while reading the picture book involved what explicitly was transpiring on the pages, children could ask few "outside scope" questions during this activity. On the other hand, since the toy auto activity was focused primarily on constructing the auto, the child could ask many questions on the mechanisms, pieces, and properties of the car. There were quite a few "outside scope" questions in the game of pretend as well, since even though children were involved in role-playing, the children were unfamiliar with many props and asked for their labels. As a note, there were few "outside scope" questions during reading, most likely resulting from the fictional nature of the story and the listener-role adopted by the child. If the book were non-fiction, the results might be very different. The percentages of child questions that are outside scope are presented in Table 1.

Table 1. Percentage of questions that are outside scope across activities

Activity	Outside scope questions
Pretend	28%
Story	13%
Toy Auto	40%

Negatively Phrased Statements Lead to Followup Questioning: It was observed that the number of "why?" questions increase following a negatively phrased statement by an adult. Since we are interested in promoting meaningful questions from children, we

examined the ratio of "why" questions following negative phrased statements versus other question types.

Since children ask questions to solidify their understanding of the world, it should be expected that questions contradicting children's current beliefs should prompt them to ask more "why" questions. In the Callanan and Oakes [7] study, this was coded for by checking for "why" questions which contain negative words and phrases, such as "not" and "can't", and they found that the proportion of "why" questions with negative words and phrases to be low overall. As we are interested in ways to promote meaningful question asking in children, we decided to approach this from a different angle. Instead of looking at "why" with negative words or phrases, we look at the number of "why" questions as a result of an adult making a statement in a negative way. The percent of "why" statements following adults that use any of the words "not", "no", "neither", or "never", including contractions, was compared with the percent of other questions following the negative words. For this study, we use all free-interaction studies for the age range 3-4 ([6], [10], [14], [19], [22]). The results are available in Table 2.

Table 2. Number and percentage of why questions and all questions following a negatively phrased statement

	#	%
"Why" Questions Following Negative Statement	175	14.31(from "why" questions)
Total Why Questions	1223	
Questions Following Negative Statement	799	6.41 (from all questions)
Total Questions	12474	

Without further analysis, we can only make hypotheses for the greater percentage of "why" questions following negative statements. Children could, as mentioned above, be asking "why" questions because their expectations of the world were violated. Other possibilities include conversation formalities, greater comfort with the language structure of "why", increasing the likelihood of being granted permission to do something that was originally forbidden, etc. In conversation formalities the child may ask "why", as a way to express interest, which is an important for maintaining conversational discourse. There are many studies on children repeating statements by parents, so there is also support for children using "why", because repeating a commonly used phrase can be related to repeating a previously said line. Asking "why" to persuade adults for granting permission is a probable hypothesis as children often ask "why" when denied permission; however, more often than not parents will still deny the child's request after being asked "why" which reduces the plausibility of children asking "why" to be given permission. Regardless, the significantly higher percentage of "why" questions following negative statements suggests that using negative statements in a conversation can be a useful technique for prompting children to ask "why".

4 Conclusion

Overall, we have shown that children tend to take on a more conversational role and ask questions more frequently when involved in play-like activity. In storytelling activities,

they tend to take a more passive role while the parents take the lead. Moreover, children tend not to ask "outside scope" questions; their questions most often remain grounded in the activity at hand. In particular, ambiguity in the activity, such as in a storybook reading, tend to prompt "why" questions whereas activities requiring joint attention on a constructive task are more likely to prompt "how" questions. Negative responses from an adult may also be more likely to elicit questions from children; however, care should be taken to ensure that the negative responses are not harsh, but rather meant to encourage inquisitiveness and metacognition. Such findings suggest that conversational Q/A agents may be more effective in keeping the child verbally engaged if they have built-in activities that require joint attention on a creative task or puzzle, as well as mild negative responses which may pique a child's interest in asking further questions.

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