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Parents modify their prosody when asking questions with pedagogical intent

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Abstract

Although children are on the receiving end of pedagogical questions (asked with an intent to teach) and information-seeking questions (asked with an intent to seek information), little is known about how children differentiate between the two types of questions. Here, we tested if parents spontaneously modulate their prosody when asking pedagogical as opposed to information- seeking questions. To test this, we asked 35 parent- child pairs to engage in a learning game where parents were asking questions while being in the role of a teacher (pedagogical) or in the role of a student (information- seeking). Next, 128 naïve listeners judged the questions produced by parents. We found that naïve listeners could reliably differentiate the two types of questions on the basis of prosody alone. This finding highlights the importance of prosody as a mechanism for communicating pedagogical intent in parent-child interactions.

Keywords: parent-child interaction; prosody; pedagogical and information-seeking questions

Introduction

At least since the writings of the Ancient Greeks, it has been recognized that asking questions in the context of a Socratic dialogue can guide learners to discovery and learning (Plato, ca 387 B.C.E.). Questions, like the ones asked in a Socratic dialogue, where the intention is to teach, are called pedagogical questions. Pedagogical questions are contrasted with information-seeking questions, where the asker does not know the answer and seeks to learn the answer (Yu, Landrum, Bonawitz, & Shafto, 2018). Not only are pedagogical questions highlighted in philosophical writings, but they are prevalent in everyday experience. Indeed, the hypothesis that questions may be used for teaching and learning seems to be part of our intuitive theories about teaching and learning. In a school context, children hear approximately 300 to 400 questions per day (Leven & Long, 1981). Presumably, the majority of those questions are pedagogical. Furthermore, at least in Western cultures, parents begin directing questions to their infants as early as 5 months of age (Bornstein et al., 1992), and almost half of the utterances directed to 12- to 27-month-olds are questions (Newport, Gleitman, & Gleitman, 1977). In all likelihood, many of those questions are with an intention to teach or to draw the infant's attention to an important aspect of the world. Provided that there are at least two importantly different types of questions, namely pedagogical and information-seeking, raises the issue of how parents communicate to their children that they are asking a pedagogical, as opposed to an information-seeking question.

Whether the question is interpreted as pedagogical or information-seeking by the child, has important consequences for learning. When children are unambiguously and explicitly told that the asker knows the answer to the question, as contrasted with conditions when the asker does not know the answer to the question, they show superior learning patterns (Jean, Daubert, Yu, Shafto, & Bonawitz, 2019; Yu, et al., 2018).

However, it is unlikely that outside psychological laboratories, parents unambiguously and explicitly tell their children that they know the answer to the question when the question's intent is pedagogical. Thus, the issue of how parents communicate their pedagogical intent to children is still open. One possibility is that children make inferences about the question's intent by relying on the content and context of the question. For example, a question about biology asked by an expert in biology is most likely, but not certainly, a pedagogical question, simply because the expert probably knows the answer to the question. Along the same vein, a parent's question directed to a child is also likely, but not certainly, a pedagogical question, because parents are more knowledgeable than children, and they often engage in informal teaching. Similarly, a question asked by a teacher in an educational context is also most likely, but not certainly, a pedagogical question. However, as these few examples illustrate, both the content and the context of the question are ambiguous. That is, experts, parents, and teachers do not know the answers to all questions, and they frequently ask information-seeking questions in various contexts, including educational ones. Given that content and context are inherently ambiguous suggests that additional cues are necessary in order to communicate the intent of questions reliably and unambiguously.

One plausible cue that may differentiate pedagogical from information-seeking questions is the prosody of speech. Unlike other cues, prosody is a reliable signal that is always present in speech, and although there is a great redundancy between context, content, and prosody, prosody seems to carry information over and above the content of utterances and the context in which they are produced (Wolf et al., 2023). Furthermore, prosody can carry information about intent (e.g., Trott et al., 2023), and it can seamlessly change as the intent changes, even in a single communicative episode. Finally, it has been well-documented that even very young children are sensitive to different registers of speech, such as child-directed speech (Saint-Georges et al., 2013). Taken together, it is plausible to hypothesize that when talking to their children, parents modify the prosody of questions when asking questions with pedagogical intent.

As is well-documented, parents modify their prosody when talking to their children as opposed to when they are talking

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to adults. That is, when talking to infants or young children, adults typically produce short, syntactically simplified, and repetitive utterances with a unique prosody that is different from the prosody of adult-directed speech. The phenomenon has been documented in many different cultures and languages (e.g., Chew, 1969; Ferguson, 1964; Meegaskumbura, 1980), and it has been proposed that the tendency to use child-directed prosody when talking to children is universal (Grieser & Kuhl, 1988; Fernald, 1992; however, see Lieven, 1994). As children get older, the acoustic profile of child-directed speech undergoes change (Amano, Nakatani, & Kondo, 2006; Garnica, 1977; Kitamura & Burnham, 2003; Liu, Tsao, & Kuhl, 2009; Stern, Spieker, Barnett, & Mackain, 1982), and it is detectable at least by the time the child is age 5 (Liu, et al., 2009).

Child-directed speech, however, cannot serve as a reliable signal of pedagogical questions for at least two principled reasons. First, child-directed speech is used in a variety of contexts, including ones that are not pedagogical (e.g., modulating the infant's emotions) (Falk, 2004). Second, as noted above, parents stop using child-directed prosody by the time children are age 5 (Liu et al., 2009). Presumably, however, parents continue directing pedagogical questions to their children even when they are no longer deploying child-directed speech. Furthermore, pedagogical questions directed to adults are unlikely to be marked with child-directed prosodic cues.

Consistent with the above stated hypotheses, prior studies have shown that the prosodic cues marking pedagogical questions are indeed somewhat independent from those marking child-directed speech. For example, Bascandziev, Shafto, & Bonawitz (2021) showed that deliberately produced pedagogical and information-seeking questions can be differentiated by naïve adult listeners both when the questions are spoken with child-directed and adult-directed prosody. In other words, there is a specific set of prosodic cues that mark pedagogical questions both when talking to children and when talking to adults. In a different study, Bascandziev, Shafto, & Bonawitz (2022) showed that 5- and 6-year-old children can differentiate pedagogical from information-seeking questions when all questions are spoken with child-directed prosody. In sum, a specific set of prosodic cues differentiate pedagogical from information-seeking questions both within adult-directed and child-directed speech.

The prior studies, however, investigated questions that were produced deliberately as opposed to spontaneously. Thus, it is unclear whether the prosody of pedagogical and information-seeking questions documented in prior research also occurs in *spontaneous* speech. Here, we test the hypothesis that parents spontaneously modify the prosody of pedagogical questions, as contrasted with information-seeking questions, while talking to their child. To test this, we used questions produced by parents in two different learning games: i) parent as a teacher game, where the parent knows the answer to a question and asks it in order to teach about the answer; and ii) child as a teacher game, where the child is a teacher, and the parent asks a question about a fact they don't know about. The questions produced by parents were then given to a sample of naïve listeners who were asked to judge which questions were pedagogical and which were information-seeking.

In addition, we sought to begin mapping some of the prosodic cues that systematically differ between pedagogical and information-seeking questions. We note that the present study was not designed to document all specific prosodic features of pedagogical and information-seeking questions, nor it was designed to specify the acoustic features that influence the listeners' classification decisions. Nevertheless, we report two prosodic features, namely duration and the pitch contour at the end of the utterance. Bascandziev et al. (2021) reported that adults who deliberately asked pedagogical and information-seeking questions showed longer duration for pedagogical questions both within adult-directed and child-directed speech. In addition, Bascandziev at al. (2021) reported that wh- pedagogical questions end with a rising pitch compared to information-seeking questions. This is consistent with other research reporting that wh-questions for which the asker has partial knowledge of the answer, have non-canonical pitch contour, characterized with a rising rather than falling pitch at the end of the utterance (Hedberg & Sosa, 2011).

Method

The present study included two phases, a generative and an evaluative phase. In the first generative phase, in order to produce spontaneously generated pedagogical and information-seeking questions asked by parents, we recruited parent-child pairs to participate in a learning game. The audio produced during the game was used to construct the stimuli. Next, in the second evaluative phase, we recruited an independent sample of adult participants on Mechanical Turk to whom we presented the stimuli constructed in the first generative phase of the study. That is, the MTurk participants were asked to evaluate the intent of the questions produced by the parents in the parent-child pairs. We first describe the participants and procedures of the generative parent-child study, and then the evaluative Mechanical Turk study. The study was pre-registered at:
https://aspredicted.org/LCZ_WT7

Participants (Generative Phase)

A total of 35 parent-child pairs participated in synchronous sessions on Zoom. Five parent-child pairs were excluded and replaced. Three of them were excluded because the parent's first language was not English and two were excluded because of technical difficulties and ambient noise (both criteria were listed in the pre-registration). Due to experimenter error, we did not record the age of two children. The age of the remaining 33 children was $M = 95.39$ months, $SD = 14.27$ months, range = 74 to 119 months. The age range was deliberately chosen to fall outside the range when parents use child-directed speech.

Procedure (Generative Phase)

The parent-child pairs were invited to play two different games: i) a parent-teacher game where the parent was going to be the teacher and ii) a child-teacher game where the child was going to be a teacher. This study had a within-subjects design, and so the parent-child pairs played both games. The order of the games was counterbalanced across participants. Importantly, the participants in this study were *not* familiar with the goal of the experiment. They were invited to play a learning game and they did not know that the goal of the study was to investigate the prosody of questions. The goal was revealed only at the very end of the experiment, during debriefing.

In both games, the person whose assigned role was a "teacher," used headphones to hear about some obscure fun facts. The fun facts were told to the "teacher" (i.e., either the child or the parent) by the experimenter. At the beginning of each trial, the experimenter projected a picture of the entity relevant to the fun fact (see Figure 1 for an example) and told the "teacher" what the fun fact was about. An example fun fact is the answer to the question: "Where are the ears of a cricket?" The answer: on their legs.

There was a total of 10 fun facts (5 presented within each game). The fun facts were organized in two blocks of 5. The order in which the blocks of fun facts were presented was counterbalanced across participants and across games.

Figure 1: An example of a picture accompanying a fun fact presented to "teachers" (Fun fact: the ears of a cricket are on its legs)

Parent as Teacher Game. In the parent-as-teacher game, the parent was invited to put on headphones, so that only the parent could hear about the 5 fun facts. After this, the parent removed the headphones, and the experimenter said: "So now, on the screen I'll show questions that your parent can read and ask you like teachers ask questions, and then after they ask you, you can answer, and then your parent will teach you what the answer is. So, [name of parent], you should now know the answers to these questions. Please read each question to yourself first (silently), and then turn to your child and ask the question out loud so that you can teach your child the information that follows." Provided that for these questions, the parent knew what the answer was, and the

question was asked with the intent to teach something, we considered these questions to be *pedagogical questions*.

Child as Teacher Game. In the child-as-teacher game, the child was invited to put on headphones, so that only the child could hear about the 5 fun facts. After this, the child removed the headphones, and the experimenter said: "So now, on the screen I'll show questions that your parent can read and ask you, and after they ask you, you can teach your parent what the correct answer is. Okay? So, [name of parent], you will probably not know the answers to these questions. Please read each question to yourself first silently, and then turn to your child and ask the question out loud so that your child can teach you." Provided that for these questions, the parent did not know what the answer was, and the question was asked with the intent to learn something, we considered these questions to be *information-seeking questions*.

In the pre-registration, we noted that we will exclude questions that would be classified as information-seeking questions (according to the criterion outlined above), if the parents knew the answer to the question. This is so because a person who is asking a question to which they know the answer to is (by definition) not an information-seeking question. In addition, recordings where there was an ambient noise or technical interruptions were also excluded. During pre-processing, of the 350 questions recorded in the study, 58 were excluded. Thus, 292 audio recordings were generated in this study.

Participants (Evaluative Phase)

The participants in the evaluative phase of the study who rated the audio recordings produced during the generative phase of the study, were 128 adults who were recruited on Mechanical Turk. The average age was 39.89 years (range 20 – 74; SD = 13.01). Seventy-five participants identified as men, fifty-two as women, and one participant identified as non-binary. Fifty-three participants identified as parents and twenty-eight said that they had worked with children in some professional capacity (e.g., a teacher, a nanny, or similar).

Stimuli

Because 292 audio recordings is a large number to be given to participants to rate, we randomly divided the 292 questions into 4 sets, with each set containing 73 audio recordings of pedagogical and information-seeking questions. Each of these sets was then presented to 32 participants on Mechanical Turk, which yielded a total sample size of 128 (4 sets x 32 participants).

Procedure (Evaluative Phase)

After answering the demographic questions, participants read a description of what a pedagogical and information-seeking question is. Next, participants were tasked with listening to the audio clips and answering the following question about each audio clip: Is the question you heard: a) A pedagogical question; b) An information-seeking question. The order in

which the two alternative answers appeared after each audio clip were counterbalanced.

Results

We first present the results of the ratings provided by naïve listeners on Mechanical Turk ratings. Next, we present the prosodic analyses of the stimuli generated by the parents during the parent child interactions.

Naïve listeners' ratings

On average, the naïve listeners were able to accurately discriminate between pedagogical and information-seeking questions as defined by the context in which they were generated during the parent-child interaction game. Collapsing across the two orders (parent as teacher first and child as teacher first), we found that the average accuracy score was $M = .53$, which is significantly different from chance performance ($t(127) = 4.95$, p < .001, d = .44). However, the accuracy was not unform across the two orders for the two types of questions. Inspection of Table 1 shows that participants, on average, accurately rated *pedagogical* questions regardless of the order (i.e., parent as teacher first or child as teacher first). A paired t-test confirmed that the accuracy at identifying pedagogical questions was comparable across the two orders ($M_{PARENT\_FIRST} = .54$ and $M_{CHILD\_FIRST} = .54$; $t(127) = .02$, $p = .98$). A departure from the predicted results, however, was observed for the information-seeking questions in the child as teacher first order. A paired t-test showed that the accuracy at identifying information-seeking questions was significantly higher in the parent as teacher first order ($M_{PARENT\_FIRST} = .56$) than in the child as teacher first order ($M_{CHILD\_FIRST} = .47$) ($t(127) = 5.27$, $p < .001$). In other words, when parents were supposed to produce information-seeking questions in the initial stage of the experiment (that is, when the child was the teacher first), they produced questions that sounded more like pedagogical questions.

Table 1: Average accuracy scores by question type and order (Standard Error in parentheses; One sample t-test associated p values in bottom row).

Pedagogical Parent as Teacher First	Pedagogical Child as Teacher First	Information-Seeking Parent as Teacher First	Information-Seeking Child as Teacher First
0.54	0.54	.56	0.47
(0.016)	(0.016)	(0.016)	(0.017)
$p = .01$	$p = .02$	$p < .001$	$p = .10$

In conclusion, despite the order effects, on average, parents spontaneously vary the prosody of pedagogical and information-seeking questions when talking to their child. Importantly, parents were not told anything about pedagogical or information-seeking questions, and they did not know that the goal of the study was to investigate the prosody of questions. Furthermore, on average, naïve listeners were able to accurately classify the different

questions by relying on audio recordings that have been stripped from all contextual cues, thus leaving the prosody of the questions as the only cue as a basis of their judgments.

Prosodic analysis

To perform the acoustic analyses, we first manually segmented and annotated at a word level all 292 utterances in Praat. The annotated segmented files could then be used to compute the duration of speech in seconds per word. Similarly, the annotated files could be used to extract the average fundamental frequency per word, which was used to compare the average fundamental frequency of the last word to the average fundamental frequency of the second to last word in the utterance.

Duration of speech. To investigate whether there is a difference in the duration between pedagogical and information-seeking questions, we first computed the duration of speech by dividing the total duration in seconds of the utterance with the number of words in the utterance. Next, we standardized the rate of speech within speaker across pedagogical and information-seeking questions. Thus, a positive standardized score represents a longer duration, while a negative score represents a shorter duration. Figure 2 shows the standardized scores for the duration of the two types of questions broken down by order.
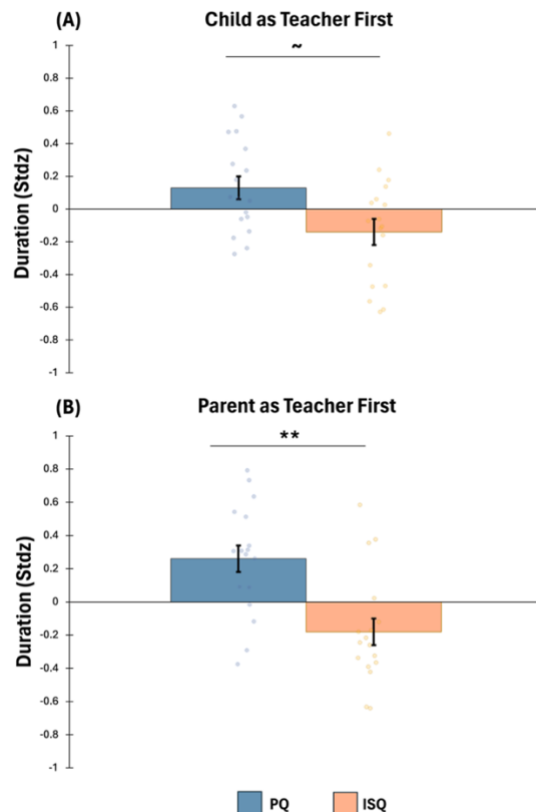

Figure 2. Average duration of pedagogical (PQ) and information-seeking (ISQ) questions across the two orders (Error bars represent Standard Error)

We found that pedagogical questions were on average with a longer duration than information-seeking questions. A repeated measures ANOVA with duration as a dependent variable, examined the effects of order (Child as a Teacher First vs Parent as a Teacher First) and type of questions (Pedagogical vs Information-Seeking). The analysis revealed a main effect of the type of question ($F(1, 33) = 11.23$, $p = .002$, a main effect of order $F(1, 33) = 4.33$, $p < .05$, and a non-significant interaction ($p = .45$). Thus, the speech produced by parents when asking pedagogical questions was with a slower rate than the speech when asking information-seeking questions. Furthermore, there was an order effect, mostly driven by the slower rate of speech of pedagogical questions in the parent as teacher first order. Note that this is consistent with the finding that the difference between pedagogical and information-seeking questions was more pronounced in the parent as teacher first order according to the ratings of the Mechanical Turk participants.

Pitch contour. To investigate the pitch contour at the end of the question, we computed a difference score of the average fundamental frequency of the last word in the question and of the average fundamental frequency of the second to last word in the question. If the pitch is dropping, then the difference score would be a negative number. Conversely, if the pitch is rising at the end of the question, then the difference score would be a positive number. In addition, we also standardized the difference scores within speaker. A negative standardized score would mean that the difference score was lower than the average difference score for that individual. Figure 3 shows the standardized difference scores broken down by order.

Inspection of Figure 3 suggest a cross-over interaction between type of question and order. To check this, we conducted a repeated measures ANOVA with a fundamental frequency difference score as a dependent variable and order (parent as a teacher first vs. child as a teacher first) and type of question as a repeated measure (pedagogical vs information-seeking) as independent variables. We found non-significant main effects and a significant Order x Type of Question interaction ($p = .04$), which is consistent with a cross-over interaction. A follow up simple effects analysis revealed that pedagogical questions had on average a higher difference score (consistent with a rising pitch), while information-seeking questions had on average a smaller (i.e., negative) standardized difference score (consistent with falling pitch at the end of the sentence) in the parent as teacher first order only ($p = .03$). This difference was not significant in the child as teacher first order ($p = .5$). Note that this is consistent with the ratings of the questions by the Mechanical Turk participants who could accurately identify both pedagogical and information-seeking questions in the parent as a teacher first order, but they had difficulty differentiating between pedagogical and information-seeking questions produced in the child as a teacher first order.
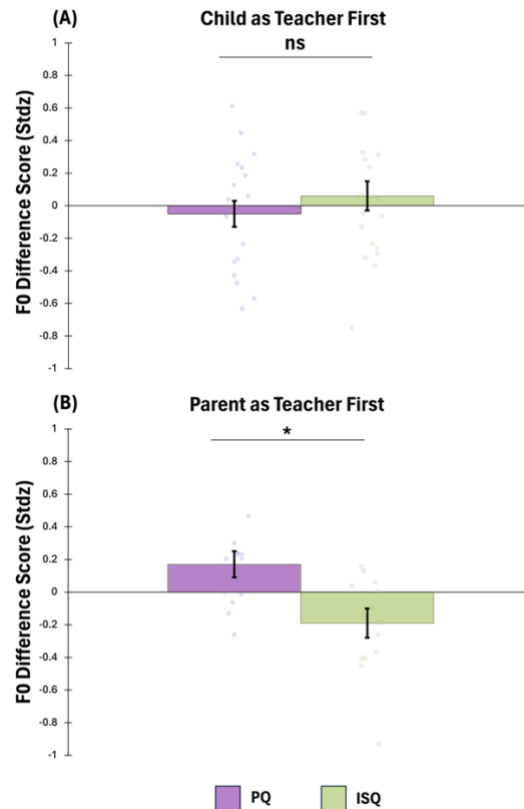

Figure 3. Average pitch difference score of pedagogical (PQ) and information-seeking (ISQ) questions across the two orders (Error bars represent Standard Error)

Discussion

Questions are an important information-seeking tool, and they play a critical role in development and learning (Aguirre, Brun, Reboul, & Mascaro, 2022; Buttler, Ronfard, & Corriveau, 2020). However, as argued above, not all questions are information-seeking (Yu et al., 2018). Pedagogical questions are often deployed by teachers and parents as tools for teaching rather than acquiring any new information. Furthermore, children behave differently and learn more when they are clearly told that the question that they received is pedagogical (Yu et al., 2018). Given that the accurate interpretation of the question's intent has consequences for learning, raises the issue of whether and how parents communicate the question's intent. The present study began addressing that issue and found that parents spontaneously modulate their prosody when asking questions with pedagogical and information-seeking intent in a way that naïve listeners can accurately recognize.

The finding of the present study further supports the conclusion that the prosody of pedagogical questions is different, at least in some respects, from the prosody of child-directed speech (Bascandziev et al., 2021). Three aspects of the present study support this conclusion. First, because of the within-subjects design of the parent child interactions study, the parents' questions were directed to the same speaker, namely their child, which means that it is unlikely

that they were switching between adult-directed and child-directed speech during the single session. The second point is that the age range of the children in the parent-child pairs was between ages of 74 to 119 months, which is an age range during which parents no longer use child-directed speech (Liu et al., 2009). Finally, the non-canonical pitch contour of pedagogical questions is a prosodic cue that is not associated with child-directed speech but is associated with questions where the speaker partially knows the answer to the question (Hedberg & Sosa, 2011).

One aspect of the results in the present study is that the effect sizes were small. The average accuracy of the Mechanical Turk participants – with the exception of the information-seeking questions in the child as teacher first order – hovered around 55%. There are two important points in relation to this result. First, the effect size is similar to effect sizes reported in similar studies. For example, Trott et al., (2023) reported 55% accuracy of human listeners who were identifying indirect requests on the basis of prosody alone. The second point is that all context, including semantic and syntactic cues, were completely stripped from the stimuli in the present study. That is, the same questions were sometimes asked as pedagogical and sometimes as information-seeking questions.

The order in which the games were played appears to have influenced the prosody of the information-seeking questions when those questions were asked at the beginning of the experimental procedure (i.e., child as teacher first order). A plausible post-hoc interpretation of this result is that parents are biased to produce pedagogical questions when they are in a learning and teaching context, as they were in the present study. It seems that parents were able to override this bias, if they were first given a chance to ask pedagogical questions (in the parent as teacher first order), and then switch to the role of a learner, when they were asking information-seeking questions in the second part of the experiment.

The departure from predicted results in the child as teacher first order, however, served as a good testbed for exploring the acoustic features of pedagogical and information-seeking questions. We found that the two acoustic features that we investigated, namely the duration and the pitch contour at the end of the questions, were different between pedagogical and information-seeking questions, but importantly, the difference was particularly pronounced or present only in the questions that were produced in the parent as teacher first order. Future research should explore in more detail how the different acoustic features influence the perception of the intent of a question.

In conclusion, to our knowledge, this is the first demonstration that parents *spontaneously* modulate their prosody when asking pedagogical questions. That they do so, raises questions about the effects of modulated prosody on the content and quality of parent-child interactions, on the type of answers children provide to questions with pedagogical vs. information-seeking prosody, as well as on the nature of the child's own question-asking in general.

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