



# Hypotheses in adult-child interactions stimulate children's reasoning and verbalizations ☆☆☆

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## ABSTRACT

Adult-child interactions can support children's development and are established as predictors of program quality in early childhood settings. However, the linguistic components that constitute positive interactions have not yet been studied in detail. This study investigates the effects of hypotheses proposed by adults on children's responses in a dyadic picture-book viewing situation. In 2 experiments, adults' use of hypotheses (e.g., "Maybe this is a dwarf's door") was tested against the use of instructive statements ("This is a dwarf's door") and in combination with open questions ("What do you think, why is the door so small?"). In Experiment 1, hypotheses differed from instructions only by the modal marker "maybe". Children's responses to hypotheses were longer and contained more self-generated explanations as compared to responses to instructions. The use of hypotheses also seemed to encourage children to attach more importance to their own explanations. In Experiment 2, combining hypotheses with open-ended why questions elicited longer responses but no more self-generated explanations in children than open-ended questions alone. Results indicate that subtle differences in adults' utterances can directly influence children's reasoning and children's contributions to dialogues.

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## 1. Introduction

Developmental research has long emphasized that adult-child interactions offer important opportunities for children's learning and development. For instance, it is well established that mothers' conversational style affects their children's memory and narrative skills (Fivush, Habermas, Waters & Zaman, 2011; Reese, Haden & Fivush, 1993). This influence is not limited to parent-child interactions but has been shown to generalize to children's verbal interactions with nonparent adults (Cain, 2004; Hedrick, Haden & Ornstein, 2009). Moreover, intervention studies have shown that adults' conversational style can be positively changed by training, which in turn affects children's narrative skills (Boland, Haden

& Ornstein, 2011; Reese & Newcombe, 2007). All this research is of great significance for extra-familial early educational settings, where interactions between teachers and children are assessed as a measure of program quality (Melhuish et al., 2015; Pianta et al., 2005). This is because in settings of early childhood education, positive teacher-child interactions have been found to stimulate the development of children's social, emotional, and cognitive skills (Burchinal et al., 2009; Hamre & Pianta, 2001; Melhuish et al., 2015; Siraj-Blatchford, Sylva, Muttock, Gilden & Bell, 2002). However, it has been claimed that more sensitive measures of positive adult-child interactions are needed in order to address 2 main challenges in early childhood education: first, to better understand the broad concept of positive interactions, the specific educational benefits of certain elements that might constitute a stimulating adult-child interaction need to be investigated and delineated in more detail. Second, from the perspective of formal education, a characterization of the respective elements is required in order to develop appropriate training programs for teachers working in early education (Neale & Pino-Pasternak, 2017; Purdon, 2016).

The present research aims to contribute to a more detailed description of the specific aspects of adult speech that might positively impact children's cognitive development. To this end, we based our investigation on existing characterizations of positive

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adult-child interactions, and, following a micro-analytic approach, we aimed to test if the use of individual linguistic components might specifically influence children's reasoning and verbalizations. More specifically, we focused on a prominent concept in conversational style that has been emphasized to characterize positive interactions in early education: *Sustained Shared Thinking* (SST). Additionally, findings from developmental psychology and linguistics complement the theoretical account of SST.

### 1.1. Sustained shared thinking

The quality of teacher-child interactions in early educational settings is typically measured by standardized rating scales, for example the *Early Childhood Environment Rating Scale* (ECERS) (Harms, Clifford, & Cryer, 2014; Sylva, Siraj-Blatchford, & Taggart, 2003) and the *Classroom Assessment Scoring System* (CLASS) (Pianta, La Paro, & Hamre, 2008). These scales provide global measures of interaction quality and, on a more detailed level, subscales, for example of emotional and instructional support, and classroom organization (CLASS). However, these global rating scales are not suitable for the detection of specific linguistic or behavioral components that are associated with positive interactions. A somewhat different approach was employed by Siraj-Blatchford et al.: first, they identified effective childcare institutions as indicated by high scores on global quality measures and child-related outcomes in the longitudinal study *Effective Provision for Pre-school Education* (EPPE). Second, in extensions of this project, they performed post-hoc qualitative analyses to describe the characteristics of teacher-child interactions in those institutions (Siraj-Blatchford & Sylva, 2004; Siraj-Blatchford et al., 2002; Sylva, Melhuish, Sammons, Siraj-Blatchford & Taggart, 2004). With this approach, the authors thus identified SST as a specifically beneficial interaction format. They defined SST as follows:

An episode in which two or more individuals 'work together' in an intellectual way to solve a problem, clarify a concept, evaluate activities, extend a narrative etc. Both parties must contribute to the thinking and it must develop and extend. (Siraj-Blatchford et al., 2002, p. 8)

Obviously, SST is a broad concept by definition: it is neither specific to teaching situations, nor to topics or contents of interactions between teachers and children. Instead, the authors provide case examples for SST in which adult actions are described and interpreted in terms of their pedagogical function, for example, tuning in, scaffolding the child's thoughts, provoking speculation, asking open-ended questions, or "inviting children to say what they thought" (Siraj-Blatchford et al., 2002, p. 47). It becomes obvious that the described components are not clearly distinguishable from one another. In fact, the authors might not have intended to make exact distinctions between these components. For example, inviting a child to say what she thinks might be accomplished by asking an open question ("Why does the turtle eat salad?"), or by explicitly questioning the child's epistemic state using a closed question ("Do you think he likes vegetables?"). Therefore, the concept of SST does not allow for a concrete distinction of the linguistic features of positive adult-child interactions and their effects. It rather merely describes the kinds of actions and pedagogical intentions that can be involved in positive interactions. Furthermore, while the same pedagogical function might be met by employing different linguistic means (see the example above), different functions may involve the same linguistic components. For example, a modal marker, such as the adjunct "maybe", can be used to mark a speaker's uncertainty regarding a given matter ("Maybe he likes vegetables"). Moreover, expressing a hypothesis instead of claiming facts may be used to invite further speculation by the addressee ("Yes, maybe all turtles are vegetarians!").

Also, a modal marker might be employed to re-formulate and to extend another speaker's utterance (child: "He loves salad", adult: "You mean, maybe salad is his favourite food?"). The question remains open as to which of these components that were observed in episodes of SST are per se effective and which are simply co-occurring, but potentially ineffective features of adults' conversational style. In order to tease apart the features and their possible effects, in the following section we will summarize studies from developmental psychology that have reported differential effects of adult speech acts on children's reasoning and behavior.

### 1.2. Uncertainty markers

When interacting with adults, children evaluate adults' utterances and adapt their own behavior accordingly. This has been demonstrated for children's verbal responses to adequate explanations versus non-explanations (Frazier, Gelman & Wellman, 2009), as well as for inferences that children draw from information given by knowledgeable versus ignorant speakers (Cole, Harris & Koenig, 2012; Mills, 2013). Particularly in teaching situations, studies have shown that children tend to interpret adults' utterances as credible information and even as normatively binding. Irrelevant actions that are put forward pedagogically, for example, that are preceded by the adult saying "I'm going to show you how this toy works," are more likely to be imitated by children than irrelevant actions that are not explicitly demonstrated pedagogically, for example, when the adult indicates ignorance of the toys function (Buchsbaum, Gopnik, Griffiths & Shafto, 2011). In an object exploration task as given in Bonawitz et al. (2011), children explored longer and discovered more functions of a novel toy when the adult who initially demonstrated the toy indicated ignorance. In contrast, children explored less when the same demonstration was communicated pedagogically, that is, when the adult indicated expertise. These findings suggest that children may interpret pedagogically communicated information as trustworthy and exhaustive. Instructions in particular, might signal to children that there is no need for further questioning or exploration. In short, pedagogically communicated information seems to be over-generalized by children (Csibra & Gergely, 2009; Shafto, Goodman & Frank, 2012), while children seem to be less confident in trusting information that is marked as uncertain. In the consequence, children might be more likely to come up with own solutions when they are presented with uncertain information.

The above studies varied the reliability of information provided by adults by introducing informants who claimed to be either knowledgeable or naïve. A different approach was taken by studies that investigated children's understanding of linguistic markers of uncertainty. There is evidence from corpus analyses that even 3-year-old employ modal markers to express uncertainty (O'Neill & Atance, 2000). However, it seems that not until the age of 4 can children correctly infer a speaker's certainty on the basis of modal markers (Moore, Bryant, & Furrow, 1989, 1994). It has been suggested that an understanding of other's mental states might be a prerequisite for the evaluation of speakers' relative certainty. Empirical evidence on the relation between children's uncertainty evaluations and their Theory of Mind (ToM) competencies support this claim (Harris, Rosnay & Pons, 2005; Moore, Pure & Furrow, 1990; Mulder & Gautero-Watzema, 2018). This means, that in order to evaluate a speaker's hypothesis correctly, and to reason about it in terms of it being one possibility among others, it is not sufficient to know the linguistic markers that usually accompany hypothetical utterances. It might also be necessary to acknowledge the fact that speakers have subjective perspectives on the world and thus might express ideas that do not correspond to others' ideas, or to objective realities.

To sum up, findings from developmental psychology and linguistics suggest that incomplete or unreliable information provided by adults encourages children's further thinking and their verbal contribution to a dialogue. Children as young as 4 years of age can determine the reliability of information as indicated by speakers' claims about their own expertise or by the use of modal markers in their speech, but competency might be developmentally linked with their understanding of other's mental states. Furthermore, research suggests that children uprate the validity of information that is pedagogically communicated compared to information that is communicated under conditions of uncertainty.

### 1.3. Open-ended questioning

Another component of adult-child interactions that has been suggested to support children's development is adults' open-ended questioning. Siraj-Blatchford et al. (2002) provide case examples of teachers stimulating children's imagination by asking open questions, such as the following:

TEACHER 1 (Goes to home corner) - What's this?

CHILD - teatime

TEACHER 1 - can I join in?

CHILD - yes

TEACHER 1 - what's for dinner?

CHILD - Spaghetti

TEACHER 1 - what kind, long or short? [Encouraging descriptive language]

CHILD - Short

TEACHER 1 - Well I'll have a little bit.

CHILD - Would you like a yellow plate? What else would you like?

TEACHER 1- an egg please. (Siraj-Blatchford et al., 2002, p. 44)

The authors describe open-ended questioning in terms of a conversational technique employed by a teacher in order to become involved in children's play, to extend an interaction, or to encourage shared thinking. However, at the same time the authors emphasize the low frequency of teachers' open-ended questioning even in the most effective early educational institutions: the relative frequency of open questions out of all questions coded was 5.1% for all institutions studied and 5.5% for the most effective institutions (Siraj-Blatchford & Manni, 2008; Siraj-Blatchford et al., 2002). Although open-ended questioning was not found to reliably lead to episodes of SST in this research (Siraj-Blatchford & Manni, 2008), there is more evidence that identified open-ended questioning as a powerful tool for stimulating children's reasoning. For example, in adult-child talk about past events, adult's open-ended questioning has been found to positively relate to children's memory and narration skills (Fivush et al., 2011; Fivush, Haden & Reese, 2006; Taumoepeau & Reese, 2013). More generally, teachers' open-ended questioning in child care centers has been associated with children's maths and literacy skills (Wylie & Thompson, 2003). In an experimental paradigm, Yu, Landrum, Bonawitz and Shafto (2018) showed that open questions ("What happens if you push this button?") as compared to direct instructions ("Push this button to see what happens") promote children's explorative behavior. Building upon the studies of Bonawitz et al. (2011), in which incomplete demonstrations and demonstrations of naïve informants were found to foster exploration, the authors hypothesized that "direct instruction could indicate a closure" for the addressee, whereas an open question "opens avenues for exploration" (Yu et al., 2018, p. 7). Thus, less reliable information in the form of adults' hypotheses and assumptions, as well as open-ended questioning, might be more suitable than pedagogical instructions in order to invite children to think further and to generate their own ideas.

Out of all the kinds of open questions, *why* questions have shown to be of particular importance for the promotion of children's reasoning. Children as young as 3 years old readily ask and answer *why* questions in order to find explanations for observable facts and to expand their knowledge about the world (Hickling & Wellman, 2001; Hood, Bloom & Brainerd, 1979). In particular, *why* questions provide the person asked with an effect and require reasoning about plausible causes (e.g., "Why is the garden chair wet?"). Limiting the range of possible answers to causally relevant explanations (e.g., it was raining last night, or, the water bottle has leaked on it), *why* questions are supposed to be easier to answer for young children than, for example, hypothetical questions. However, both types of questions are supposed to stimulate the generation of hypotheses and contribute to children's conceptual learning (Wellman & Liu, 2007).

### 1.4. Objectives of the present study

At first glance, it may seem counterintuitive that explicit pedagogy building upon instructive statements turns out not to be a promising candidate for the investigation of constitutive elements of positive teacher-child interactions in early education. This is because effective pedagogy, as described in the SST framework, is characterized by the verbal scaffolding of self-directed learning rather than knowledge transmission. According to the concept behind SST, the principal goal of positive teacher-child interactions is to encourage children's reasoning and promote their active participation in dialogues. The literature reviewed above suggests that the provision of uncertain information may be appropriate for achieving this goal. Uncertainty markers should lead children to question the informative value of an utterance and to engage in further thinking. However, it is unclear whether the provision of hypotheses is individually effective in adult-child interactions. Instead, it might be the case that positive interactions are manifest only in longer interactions, where adult's repeatedly employ the same, or combine different elements of SST.

To our knowledge, Hildebrandt, Scheidt, Hildebrandt, Hédervári-Heller and Dreier (2016) undertook the only study that experimentally tested the effects of different elements of SST in adult-child interactions: in a within-subject design, they contrasted teachers' instructive explanations of unusual events with explanations that contained modal and epistemic markers as well as open questions. They found that, in the latter condition, which was denoted SST condition, children's verbal responses were longer and included more self-generated explanations for the unusual events. Also, children more often contradicted the adult's hypothesis in the SST condition as compared to the instruction condition. These findings suggest that linguistic markers in adult's speech can directly affect children's verbal contributions in a dialogue. However, in this study a combination of 3 SST elements was tested against explicit instruction. The question thus remains open as to whether a single element alone would have evoked comparable results. Also, the finding that children contradicted adults more often in the SST condition suggests that children in this condition trust adults' explanations less compared to instructive explanations in the other condition. It remains unknown whether relative uncertainty implied by a single modal marker would likewise lead children to evaluate the validity of an explanation differently.

In order to extend these findings, we conducted 2 experiments in which children and adults interacted in dyadic picture-book viewing situations. In Experiment 1, our aim was to investigate the effectiveness of a modally marked hypothesis in an adult-child interaction. To this end, we adopted the paradigm employed by Hildebrandt et al. (2016). We contrasted hypotheses with instructive statements and measured the length of children's verbal responses as well as the number of children's self-generated hy-

potheses. Our prediction was that introducing pictures of unusual events by modally marked hypotheses or by instructive statements would differentially affect children's reasoning and their immediate verbal responses. Furthermore, we explored whether children would learn and subsequently reproduce information that was generated in contexts of speculation and instruction differently. As a proxy for the possible influence of children's developing understanding of others' mental states we included a simple ToM task in this experiment.

The focus of Experiment 2 was to investigate if there is an additional effect of combining more than one elements of SST. We used open questions, which have already been shown to effectively stimulate children's reasoning, and contrasted their use alone with a combination of open question and hypothesis.

### Experiment 1

The first aim of Experiment 1 was to investigate specific effects of modally marked hypotheses on children's verbal contributions to adult-child interactions. For this, children were shown pictures of unusual scenarios by an adult experimenter. For each picture the experimenter provided a possible explanation for the unusual aspect, either without a modal marker (*instruction condition*, e.g., "This is a dwarf's door"), or with the modal adjunct *maybe* (*modal marker condition*, e.g., "Maybe this is a dwarf's door"). In line with previous research, we expected different effects of the 2 conditions with respect to children's reasoning measured by their verbal contributions in the dialogue. Our hypotheses were as follows:

(H1) Children's responses to adult introductions are longer in the modal marker condition compared to the instruction condition.

(H2) Children generate more hypotheses by themselves in the modal marker condition compared to the instruction condition.

In line with research on the understanding of uncertainty terms, we further predicted that the above postulated effects would be moderated by children's ToM abilities.

(H3) Only children who pass the ToM task are sensitive to modally marked utterances.

The second aim of Experiment 1 was to explore whether the use of a modal marker affected children's evaluation of the adult's explanation. Specifically, we expected that children would trust the explanation less in the modal marker condition than in the instruction condition if they interpreted the manipulation in our experiment in terms of varying speaker certainty. We assumed that reduced trust in the adult's explanation would lead children to evaluate their self-generated explanations higher. Therefore, we predicted that children would be more likely to reproduce the experimenter's explanations later on when these had been previously presented as instructions, and their own explanations if these had been generated in the modal marker condition.

(H4a) The likelihood that children will reproduce the experimenter's explanations is higher for pictures that were presented in the instruction condition, compared to the experimenter's explanations that were presented in the modal marker condition.

(H4b) The likelihood that children will reproduce their own explanations is higher for explanations that children initially generated in the modal marker condition, compared to explanations that children generated in the instruction condition.

## 2. Method

### 2.1. Participants

Children were recruited either at their day-care center or on an excursion to a science-day that was organized by their day-care center. Parental written consent was acquired prior to testing. 59 children aged 4–6 years volunteered to participate in the experiment. We dropped the data from two 4-year-old girls and one 5-year-old boy, who chose to discontinue their participation dur-

ing the session. The final sample included 56 children (31 female,  $M_{\text{age}} = 5.7$  years,  $SD = 0.48$ , age range = 4.5–6.6 years).

This research was conducted in accordance with the ethical guidelines of the German Psychological Association (DGPs). It was carried out as part of a project that was funded by the German Federal Ministry for Family Affairs, Senior Citizens, Women and Youth, in 2016.

### 2.2. Materials

The picture-book comprised 12 colored drawings, 8 of which were stimuli adopted from Frazier et al., 2009 and Hildebrandt et al., 2016. Four similar drawings were added in order to increase the number of trials. The pictures showed unusual scenarios (e.g., a house with a very small door, a boy running with buckets on his feet). The pictures were intended to elicit irritation in the viewer and promote speculation and the production of possible explanations. Pictures were laminated cards printed on A4 format (33.11 × 46.81 inch), and were presented one after another by turning them like pages of a book.

### 2.3. Procedure

Children were tested individually in single sessions that were videotaped. Individual sessions lasted approximately 25 minutes and consisted of 3 tasks which were always presented in the same order: *learning task*, *reproduction task*, and *ToM task*.

#### 2.3.1. Learning task

Child and experimenter sat next to each other on pillows. The experimenter placed the picture-book on the ground in front of the child and suggested they look at the pictures together. Pictures were presented one after another. After turning a page, the experimenter silently examined the drawing for approximately 3 seconds. Then, she pointed with her finger to the unusual aspect (e.g., to the house's tiny door) and provided an explanation either in the form of an instruction ("This is a dwarf's door"), or in the form of a modally marked hypothesis ("Maybe this is a dwarf's door"). In order to keep the conditions as parallel as possible, the experimenter was trained to use the same falling intonation both for instructions and modally marked hypotheses. She waited up to 5 seconds for the child to respond, occasionally trying to establish eye contact with the child. Children received neutral feedback to their responses (e.g., "Hm", "Ah", or a friendly shrug of the shoulders if a child asked a question). In case a child did not respond to the experimenter's initial statement within 5 seconds, the experimenter proceeded with the next picture without further prompting.

The instruction condition and the modal marker condition were alternated over the 12 trials, resulting in 6 trials per condition. Conditions differed only in the experimenter's initial explanation. Unlike the instructions, modally marked statements included the prefix *maybe* and the postponement of the subject, which is necessary in German adverbial clauses ("Vielleicht ist das eine Zwergentür", literally: *Maybe is this a dwarf's door*, see Appendix for examples of experimenter introductions in Experiments 1 and 2). The picture sequence was fixed, with half of the children receiving an instructive explanation and half receiving a modally marked explanation in Trial 1. Thus, the experimental condition (instruction, modal marker) was instantiated as a within-subject factor, whereas the order of presentation (instruction first, modal marker first) varied between subjects. We measured the *number of words* uttered by the child and the *number of self-generated explanations* as dependent variables.

### 2.3.2. Reproduction task

A second experimenter replaced the first and repeated the book-viewing situation as described above using the same picture book again. There were 2 differences compared with the learning task. First, at the beginning of the reproduction task, the second experimenter emphasized that the book was new to her. The aim was to encourage children to explain the pictures to her. Second, the experimenter's prompts were the same for all 12 pictures. If children did not spontaneously explain a picture after the page was turned, the experimenter pointed out the unusual aspect of the picture, asking "What's going on here?" Similar to the learning task, children received neutral feedback on all their verbal contributions. We measured the *number of experimenter explanations reproduced* by the child and the *number of self-generated explanations reproduced*.

### 2.3.3. Theory of Mind task

At the end of each individual session, children's ToM competency was assessed via an adaptation of the unexpected content false belief task employed by [Perner, Leekam and Wimmer \(1987\)](#). After children were introduced to an egg box that contained a wooden flower, they were asked the control question "Now what is in here?" and the 2 test questions "Initially, before you looked into the box, what did you think was inside?" and "(Name of experimenter 2) doesn't know the box yet. What will (name of experimenter 2) think is in the box?" Children's correct answers to the test questions were counted, resulting in a ToM score ranging from 0 to 2.

**2.3.3.1. Coding.** Children's verbalizations during the learning and reproduction tasks were transcribed from the videos. A word count for all verbalizations was performed for each trial of the learning and reproduction tasks. We coded every single word, included interjections, but excluded repetitions from the word count: e.g., a word count of 8 would be assigned to the utterance "Ehm, yes! And he has, he has, he has pots as shoes." A research assistant who was blind to the experimental conditions and hypotheses of the study, coded children's verbalizations in the learning task for *self-generated explanations*. A child's utterance was coded into this category if the propositional content was rated either as an extension of, or as an alternative to the adult's hypothesis. For example in case of the picture of a house with a tiny door, which the experimenter suggested to be a dwarf's door, both the response "I think, this is where the Seven Dwarfs live" (boy, 5.75 years), and "But it's a cat flap! I have a cat flap at home" (boy, 5.5 years), were rated as *self-generated explanations*.

Children's verbalizations in the reproduction task were compared with those of the corresponding trials in the previous learning task. There were 4 mutually exclusive coding categories:

- *Experimenter explanation reproduced* - the child explains the unusual aspect by reformulating the hypothesis that was originally uttered by the first experimenter, for example, "This is a door for dwarfs".
- *Self-generated explanation reproduced* - the child explains the unusual aspect by restating her previously self-generated hypothesis, for example, "This is the house of the Seven Dwarfs", or "This is a cat flap"
- *Self-generated and experimenter explanations reproduced* - for example, "This is the house of the Seven Dwarfs and here is the dwarfs' door"
- *Other utterances* - for example, "This is a funny house, look!"

A second blind coder additionally coded a subset of the reproduction task data (11 out of 56 subjects). Inter-rater agreement was acceptable (Cohen's  $\kappa = 0.807$ ).

All statistical analyses were conducted in the R Software for Statistical Computing, especially with the lme4 package for generalized mixed effects modeling ([Bates, Maechler & Bolker, 2012](#)).

## 3. Results

Preliminary analyses revealed no differences between the instruction-first and modal marker-first groups. Therefore, the 2 groups were collapsed for all subsequent analyses. Utterance length summed across all items and both experimental conditions was broadly distributed, ranging between 0 and 492 word counts. There were 11 children with less than 20 words spoken, as well as 11 who spoke over 100 words. The number of generated hypotheses ranged between zero and 7, 19 out of 56 children generating no hypotheses.

### 3.1. Number of words

**(H1) Children's responses to adult introductions are longer in the modal marker condition compared to the instruction condition.** Descriptively, the average sum of words uttered by the children in the 2 experimental conditions indicated a mean difference between modal marker and instruction conditions of 7.82 words. Thus, on average across items and participants, children used about 8 words more in the modal marker condition than in the instruction condition ([Fig. 1](#)). To statistically test whether the observed difference was substantial, we estimated a mixed effects Poisson regression, which is appropriate for count data. The model predicted word counts by the experimental condition and included a random effect for individuals. Here, the fixed effect of condition is relevant for hypothesis testing:  $\beta = 0.22$  ( $z = 7.10$ ,  $P < 0.01$ ), indicating a significantly higher count of words in the modal marker condition.

### 3.2. Number of self-generated explanations

**(H2) Children generate more hypotheses by themselves in the modal marker condition compared to the instruction condition.** Similar to H1, we addressed H2 by conducting a Poisson mixed effects regression. In this second model, the dependent variable was given by the number of self-generated explanations formulated by the children across different items of the 2 experimental conditions. On average, children produced 1.3 own explanations per picture in the modal marker condition and 0.7 in the instruction condition. The mean difference between conditions was 0.59. Thus, on average across items and participants, children drafted half a hypothesis more in the modal marker condition. Similar to the average sum of words, this difference was statistically significant. The estimated Poisson mixed effects regression model predicted hypotheses counts by the experimental condition. Here, the fixed effect of condition is relevant for hypothesis testing:  $\beta = 0.63$  ( $z = 3.15$ ,  $P < 0.01$ ), indicating a significantly higher count of hypotheses in the modal marker condition.

### 3.3. Moderation effect of Theory of Mind

**(H3) Only children who pass the ToM task are sensitive to modally marked utterances.** We were further interested in testing whether the observed effects of the interaction format (modal marker vs. instruction condition) are dependent on children's age as well as ToM abilities. We specifically expected that only children who had already developed a ToM would profit from the modal marker condition, and that this was true for both dependent variables, the *number of words* and the *number of self-generated explanations*. To test the moderation effects of age and ToM ability

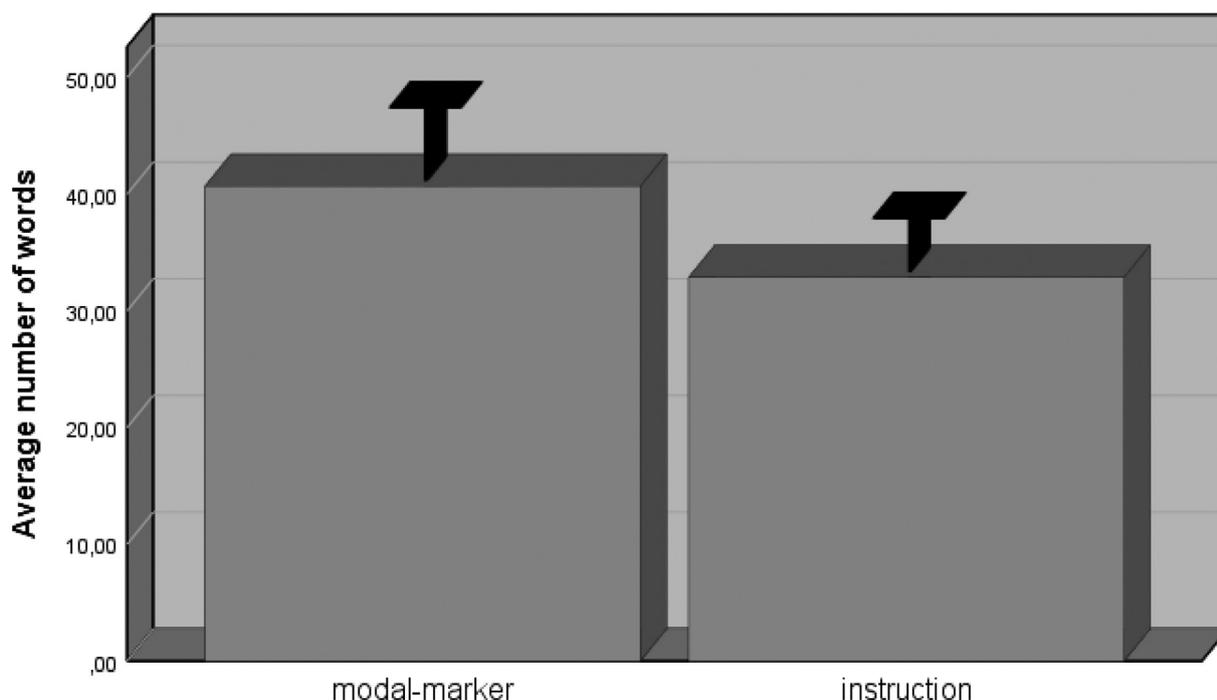


Fig. 1. Average number of words children uttered in the modal marker and instruction conditions in Experiment 1.

on the experimental effects, the Poisson mixed effects regression models were extended with 2 additional person level predictors, age and ToM, and interactions between condition and age, as well as condition and ToM. For utterance length analyses revealed no main effect of age and ToM, but an interaction between the experimental condition and age, however not with ToM. The interaction with age was positive ( $\beta = 0.03$  [ $z = 5.25$ ,  $P < 0.01$ ]), suggesting that older children profit more from modal markers. In case of hypotheses counts the analyses revealed no main effect of age and ToM, as well as no interaction (Age\*Condition:  $\beta = 0.05$  [ $z = 1.45$ ,  $P = 0.14$ ; Age\*ToM:  $\beta = 0.01$  ( $z = 1.15$ ,  $P = 0.25$ )). For both dependent variables (word count and hypotheses count), the interaction between children's performance on the ToM task and the experimental condition was not statistically significant. The number of children scoring zero on the ToM task was however strongly limited, at  $n = 6$ . Further,  $n = 18$  children answered one test question correctly, and most children ( $n = 32$ ) answered both test questions correctly. Thus, the capacity for testing moderation effects by children's ToM was limited in our sample.

### 3.4. Reproduction of explanations

**(H4a) The likelihood that children will reproduce the experimenter's explanations is higher for pictures that were presented in the instruction condition, compared to the experimenter's explanations that were presented in the modal marker condition.** This hypothesis could not be tested due to a condition-independent ceiling effect at recalling the experimenter's explanations in the reproduction task. Thus, irrespective of the experimental condition, children recalled these hypotheses in most of the cases.

**(H4b) The likelihood that children will reproduce their own explanations is higher for explanations that children initially generated in the modal marker condition, compared to explanations that children generated in the instruction condition.** We estimated a generalized mixed-effect model with random subject effects predicting reproduction success of a child's own explanations by the interaction condition (modal marker vs. instruction) using

a logit link function. This model predicted a higher logit score for the modal marker condition:  $\beta = 0.97$  ( $z = 3.42$ ,  $P < 0.01$ ).  $e^{\beta 1}$  was 2.64, showing a probability more than twice as high that children would reproduce their own explanations if these had been formulated in the modal marker condition as compared to the instruction condition. In summary, the likelihood that children would reproduce their own explanations if these were initially formulated in the modal marker condition was 14%. This probability is more than twice that of expressing their own explanations if these were initially formulated in the instruction condition. The chances that children would reproduce their own explanations increased by a factor of 2.64 in the modal marker condition compared to the instruction condition.

### Experiment 2

Findings from Experiment 1 and the literature reviewed in the first section support the idea that uncertainty markers serve the same functions in adult-child interactions that open-ended questioning is supposed to: promoting children's active contribution to verbal interactions as well as the generation of their own ideas. As discussed in the introductory section, it is possible that an additive effect in the sense of "more is better" applies for the use of SST elements, generally. To this end, in Experiment 2, we investigated the possibility of an additive effect by contrasting *why* questions (*question-only condition*) with a combination of modally marked hypothesis and *why* question (*combined condition*). Similar to Experiment 1, we expected different effects on children's verbal responses, and postulated the following:

(H1) In the combined condition, children speak more than in the question-only condition.

(H2) In the combined condition, children generate more of their own explanations than in the question-only condition.

## 4. Method

### 4.1. Participants

We collected a second sample of children between 4 and 10 years of age who were invited to participate in the study during

their day-care center's science-day excursion. Parental written consent was acquired for all children before testing. Data of all children were included in the analyses ( $N = 102$ , 49 female,  $M_{\text{age}} = 6.8$  years,  $SD = 1.8$ , range = 4.0–10.4 years).

#### 4.2. Materials

The same picture-book from Experiment 1 was used in Experiment 2.

#### 4.3. Procedure

The procedure of Experiment 2 closely matched the learning task of Experiment 1: the child and experimenter looked at the picture book together. The experimenter introduced the pictures to the child. Two conditions, which differed only in the verbal introduction provided, were alternated over the 12 pictures. In the question-only condition, the experimenter used open-ended questioning, for example for the picture of a house with a very tiny door "What do you think, why is the door so small?" In the combined condition, the experimenter provided a modally marked explanation, just as in the learning task of Experiment 1, but this time in combination with open questioning, for example "Maybe this is a dwarf's door. What do you think, why is the door so small?" (see Appendix for examples of experimenter introductions in Experiments 1 and 2). In fact, the open-ended questioning always included 2 questions: "What do you think?" and "Why is ...?" To test for the specific effect of an open question, one might argue that the "why" question alone would have been sufficient. In our experimental setting, however, the question was posed without a preceding conversation or engagement of the child with the experimenter's question. Thus, the children could have interpreted the *why* questions as the experimenter addressing either herself or the child. Furthermore, it was our aim to elicit reasoning about possible alternative explanations, that is children's self-generated explanations. Instead of allowing for the possibility that the experimenter might request a single true explanation, the "What do you think?" question explicitly asked children to express their own ideas and thoughts. Therefore, in order to avoid any confusion about the addressee or the expected type of answer, we included the question "What do you think?" in both the question-only and combined conditions.

Each participant received a total of 12 trials, that is, one trial per picture, resulting in 6 trials per condition. A session lasted about 7 minutes. As in the learning task of Experiment 1, children's verbal responses in Experiment 2 were coded into the categories *number of words* and *number of self-generated explanations*. Conditions (question-only, combined) varied within subjects, whereas the order of presentation (question-only first, combined first) varied between subjects.

### 5. Results

Preliminary analyses revealed no differences between the question-only-first and combined-first groups. Therefore, the 2 groups were collapsed for all subsequent analyses.

#### 5.1. Number of words

**(H1) In the combined condition, children speak more than in the question-only condition.** A paired sample *t*-test with the dependent variable given by the average sum of words uttered by the children in the 2 experimental conditions indicated an average mean difference between question-only and combined conditions of 9.38 words. Thus, on average across items and participants,

children used about 9 words more in the combined condition compared to the question-only condition. This difference was statistically significant:  $t = 2.819$ ,  $P < 0.01$ .

#### 5.2. Number of self-generated hypotheses

**(H2) In the combined condition, children generate more of their own explanations than in the question-only condition.** A paired sample *t*-Test with the dependent variable given by the average number of self-generated explanations produced in the 2 experimental conditions indicated an average mean difference between the question-only and combined conditions of  $-0.11$ . Thus, on average across items and participants, children produced slightly more of their own hypotheses in the question-only condition compared with the combined condition. This difference was very small, against the postulated effect, and not statistically significant:  $t = 1.922$ ,  $P = 0.06$ .

### 6. Discussion

Educational research has defined episodes of SST by the different pedagogical functions and occurring linguistic elements that can be involved (e.g., Siraj-Blatchford et al., 2002). These longitudinal studies show that SST positively relates to a variety of child-related outcomes. Findings from a micro-analytic approach suggest that the impact of SST can also be measured immediately in children's responses to adults' utterances (Hildebrandt et al., 2016). Consistent with these lines of research, the present study has shown that specific linguistic markers in adults' speech directly affect children's reasoning and verbalizations.

Experiment 1 tested for the effect of using the modal marker *maybe* on children's verbal contribution to a dialogue and on children's evaluation of the adult's explanation. In the learning task, children spoke more and formulated more of their own hypotheses in response to explanations that were marked as uncertain by the adult. Adults' instructive statements, in contrast, were less effective in eliciting verbal contributions from the children. This effect was moderated by children's age, suggesting that older children were more likely to recognize the subtle difference between the conditions. We conclude from this finding that the use of uncertainty markers in pedagogical situations needs to be considered an important element of adult-child verbal interactions because it stimulates in particular older children's verbalizations and their generation of hypotheses. In the subsequent reproduction task, we found an overall tendency for children to reproduce the explanations that were initially provided by the first experimenter, irrespective of whether or not these were modally marked in the learning task. Therefore, the use of uncertainty markers such as the word *maybe* does not necessarily result in a rejection or a devaluation of the idea by children. This adds to the findings from Hildebrandt et al. (2016), where children contradicted the experimenter more often in the SST condition than in the instruction condition; in our data, there is no evidence that children inferred reduced validity of the adult's explanation in the modal marker condition. Instead, the likelihood that children would reproduce their own explanations was higher if these were generated in this condition. This finding suggests that children do not only interpret linguistically marked uncertainty as an invitation to speculate about alternative explanations. Adults who express uncertainty might also encourage children to attach more importance to their own alternative ideas. Children who ascribe similar importance to their own ideas and the ideas of adults are, in turn, more likely to participate in discussions and the exchange of arguments.

In Experiment 2, we investigated the possibility that elements of SST might be more effective if they are used in combination. Similar to what we found for the modal marker *maybe* in Experiment 1, earlier research has shown that open-ended questioning encourages children's contributions in verbal interactions (Siraj-Blatchford & Manni, 2008). Therefore, we tested the "more is better" hypothesis by asking children open questions alone, or open questions in combination with modally marked hypotheses that already provided a plausible explanation. Interestingly, in the combined condition, children spoke more but they did not produce more own explanations than when asked an open question alone. Thus, in Experiment 2, the combination of hypotheses and open-ended questioning did not result in an additional benefit compared to open-ended questioning alone. In Experiment 1, though, where adult hypotheses were contrasted with instructive statements, children did produce more of their own explanations in response to hypotheses. It might therefore be the case that both hypotheses and open questions are effective communicational tools to invite children to express their own ideas. However, their combination seems not to be necessary to achieve this goal. For the stimulation of children's speech production, however, our data suggest this combination to be beneficial. It is important to note, though, that in the combined condition, not only children's responses but also the experimenter's verbal introductions of the pictures were longer as compared to the question-only condition. It is therefore possible that children in Experiment 2 simply adapted their response to the length of the previous speech act, irrespective of the content of the adult's utterance. Although we believe it to be unlikely that children adapted only the length of their responses, but not the type of response to the experimenter's introduction, we cannot rule out the possibility that longer adult statements, irrespective of the linguistic elements enclosed, elicit longer responses by children. Another question that remains unanswered concerns the potential developmental link between children's understanding of modally marked hypotheses and their understanding of others' mental states. Unfortunately, the number of children who did not succeed on the ToM task in our sample was too small to identify a possible moderation effect. Further research in which a more heterogeneous sample is selected may clarify this issue.

Despite these limitations, the reported experiments methodologically complement and extend the findings of educational research, where adult-child interactions are typically investigated in natural settings, precluding a differentiated analysis of specific components of SST. Our results suggest that subtle differences in adult speech encourage children to actively participate in adult-child conversations, while instructive statements seem to be less encouraging. This finding is relevant for early pedagogical practice: instructions are short, time-saving, and may be convenient in a variety of situations in pedagogical practice, for example efficient classroom management (e.g., "All children tidy up now") or the communication of factual information (e.g., "Sally is sick today"). However, they are not always appropriate. In the latter example, the epistemic state of the speaker is rather unclear. It might reflect the speaker's belief, a hypothesis or a fact. The use of a modal (or epistemic) marker precludes this ambiguity (e.g., "I know that", "I think", or "Maybe Sally is sick today"). These markers might help children to better evaluate information that is provided by adults, to draw reasonable conclusions, and to react appropriately in adult-child conversations. Experiment 1 showed that even a single word can make a difference here. And although a combination of different elements of SST might have a positive impact on children's speech production, employing a single element seems to be already sufficient to stimulate children's generation of own ideas.

These findings are impressive, given that adult-child interactions in this study were operationalized as only one-turn conversations between experimenter and child. On the one hand, in natural adult-child interactions the effects reported here might accumulate with an increasing number of turns. Also, longer responses by a child provide more opportunities for the adult to extend the interaction and to initiate subsequent turns. In sum, the findings of this micro-analytic experimental approach suggest that also in natural settings small interventions in adults speech might bring about short-term effects on children's participation, reasoning and learning. It remains open to future research to identify the dynamics that may be at play in multiple-turn interactions and to revisit the question of whether individual differences moderate children's sensitivity to specific components of SST.

### Author contributions

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- Conceptualization
- Methodology
- Investigation
- Writing - Original Draft

Andrea Hildebrandt

- Formal analysis
- Writing - Review & Editing

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- Conceptualization
- Methodology
- Resources
- Supervision
- Funding acquisition

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### Appendix

Examples of experimenter introductions in the two conditions of Experiments 1 and 2

Stimulus picture	Experiment 1		Experiment 2	
	Instruction	Modal marker	Open question	Combined
House with a tiny door	This is a dwarf's door. <i>Das ist eine Zwergentür.</i>	Maybe this is a dwarf's door. <i>Vielleicht ist das eine Zwergentür.</i>	What do you think, why is the door so small? <i>Was denkst Du, warum ist die Tür so klein?</i>	Maybe this is a dwarf's door. What do you think, why is the door so small? <i>Vielleicht ist das eine Zwergentür. Was denkst Du, warum ist die Tür so klein?</i>
Man with umbrella in a boat	He uses the umbrella as a sail. <i>Er benutzt den Schirm als Segel.</i>	Maybe he uses the umbrella as a sail. <i>Vielleicht benutzt er den Schirm als Segel.</i>	What do you think, why does he have that umbrella? <i>Was denkst du, warum hat er den Schirm da?</i>	Maybe he uses the umbrella as a sail. What do you think, why does he have that umbrella? <i>Vielleicht benutzt er den Schirm als Segel. Was denkst du, warum hat er den Schirm da?</i>
Boy running with buckets on his feet	He forgot his shoes. <i>Er hat seine Schuhe vergessen.</i>	Maybe he forgot his shoes. <i>Vielleicht hat er seine Schuhe vergessen.</i>	What do you think, why does he have buckets on his feet? <i>Was denkst Du, warum hat er Eimer an den Füßen?</i>	Maybe he forgot his shoes. What do you think, why does he have buckets on his feet? <i>Vielleicht hat er seine Schuhe vergessen. Was denkst Du, warum hat er Eimer an den Füßen?</i>

Note. Introductions were presented in German.

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