# Show or Tell? Preschool-aged children adapt their communication to their partner's auditory access

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## Abstract

Adults routinely tailor their communication to others' auditory access, such as substituting gestures for speech in noisy environments. Yet, assessing the effectiveness of different communicative acts given others' perceptual access—especially when it differs from one's own—requires mental-state reasoning, which undergoes significant developmental change. Can young children tailor their communication to others' auditory access? In Study 1, parental report ($n$=98) indicated that most children, by age 4, adjust their communicative behaviors in noisy settings. Study 2 elicited these behaviors experimentally with 4- to 5-year-olds ($n$=68). Children taught how a novel toy works to a learner who wore headphones playing either loud music or nothing. Children were more likely to use physical demonstrations, and less likely to use verbal explanations, when the learner's auditory access was obstructed. These findings illustrate how mental-state reasoning might support children's ability to communicate successfully across perceptually-compromised contexts and individuals.

**Keywords:** Communication, Social cognition, Theory of Mind, Cognitive development, Auditory perception

## Introduction

Humans use a remarkably wide range of communicative tools—voices, hands, faces, symbols, and even objects—to share information with others (Clark, 1996; Lopez-Brau & Jara-Ettinger, 2023). The relative effectiveness of these tools, however, varies by context. Imagine, for example, that you want to ask a friend to hand you a cookie. Under normal circumstances, you would likely *tell* her you want a cookie, expressing your request verbally. If you are at a loud party, however, you might instead *show* her what you want by pointing to the cookie. While such a change in strategy may seem intuitive or even trivial, choosing to communicate via gesture instead of speech requires an understanding of what others can hear and see; you'd have a better shot at achieving your communicative goal if you leveraged your friend's visual perception, which remains intact, rather than relying on their auditory perception, which is temporarily impaired.

As this example illustrates, effective communication often requires an understanding of the factors that shape others' perceptual access. Many common exogenous factors, such as lighting and environmental noise, can simultaneously affect the perceptual access of multiple individuals within the same environment. Other factors have an asymmetric effect; headphones or sunglasses (exogenous) as well as impaired vision or hearing (endogenous) only affect a particular individual while sparing others. Even though we can communicate the same message using different modalities, figuring out how to do so effectively can be particularly challenging when it requires representing and responding to perceptual states that differ significantly from one's own.

Adults can use others' visual access to act as informative communicators (Hanna et al., 2003; Hawkins et al., 2021; Jara-Ettinger & Rubio-Fernandez, 2022). Such flexibility, however, likely involves mental-state reasoning that is computationally intensive and therefore may show a protracted developmental trajectory. Despite much research on the development of mental-state reasoning in early childhood (Beaudoin et al., 2020; Rakoczy, 2022), open questions remain regarding children's ability to consider others' perceptual access—particularly auditory access—in communication. To fill this gap, the current work examines whether young children can tailor their communicative behaviors to their partner's auditory access. In what follows, we motivate our work by reviewing related literature on children's understanding of others' visual and auditory perception and their role in children's communicative behaviors.

In the last few decades, many studies have examined children's understanding of the relationship between an agent's visual access, mental states (e.g., goals, beliefs), and behavior. Research suggests that even infants take others' gaze into account when inferring their goals or predicting where they will search for preferred objects (Kim & Song, 2015; Luo & Baillargeon, 2007; Luo & Johnson, 2009; Surian et al., 2007). By around 2-3 years, toddlers become adept at hiding objects from others' view, suggesting they can estimate others' visual access from different perspectives (Flavell et al., 1978; Lempers et al., 1977). As they age, children begin to explicitly attribute false beliefs to agents who lack critical visual access (Hogrefe et al., 1986; Király et al., 2018) and infer that agents who can predict (rather than merely describe) an object's location must have "seen" where it was hidden (Aboody et al., 2022). Thus, a basic sensitivity to others' visual access appears to emerge early in life, followed by a more comprehensive understanding of how an agent's visual access influences and reflects their mental states.

Prior research has also found that children modulate their communicative behaviors based on others' visual access. Even as early as 12 months of age, infants point more when others are looking at them (Liszkowski, Albrecht, et al., 2008)) and when others could not see where an object was hidden (Liszkowski, Carpenter, & Tomasello, 2008). Young children also adapt their language use based on others' visual access, naming objects (O'Neill, 1996) or describing objects (Greenberg et al., 1983; Nadig & Sedivy, 2002) and events (Menig-Peterson, 1975) in greater detail (i.e., by using more nouns and modifiers) to people who did not see them firsthand. Collectively, these findings demonstrate how young children can use their partner's visual access to decide whether and what to communicate.

While the literature on mental-state reasoning has primarily manipulated others' *visual* attention and perception, other lines of work suggest that similar reasoning abilities might extend to the auditory domain. For instance, infants appear to appreciate that certain auditory signals (e.g., speech or contingent beeps, but not nonverbal vocalizations) systematically influence agents' behaviors (Martin et al., 2012; Vouloumanos et al., 2010, 2012; Tauzin & Gergely, 2018). By 2 to 3 years of age, children also understand that agents can hear, as opposed to smell or touch, from a distance (Yaniv & Shatz, 1988), and track what others have heard in the past (Moll et al., 2014). An awareness of others' auditory perception also influences children's own behaviors. For instance, 2- to 3-year-olds refrain from creating noise that could bring unwanted attention to themselves (Melis et al., 2010), but intentionally create noise when trying to wake someone up (Williamson et al., 2015). Together, these findings support an early-emerging understanding of how others' auditory perception influences their behaviors. However, these studies still fall short of testing whether children understand how auditory access influences mental states more broadly.

Similar to how visual occlusion has informed prior research in mental-state reasoning, auditory occlusion, such as auditory noise that masks speech, offers a useful way to study children's abstract understanding of how others' auditory access relates to their underlying mental states. In a recent study (Chuey et al., 2022), children viewed an event where a speaker described two novel toys to a listener, but loud environmental noise masked one of the explanations. When the listener was initially ignorant about both toys (and thus needed the explanations to learn), 4- and 5-year-olds judged that the listener would want to hear about the noise-masked toy again, but not when the listener already possessed prior knowledge about the noise-masked toy. These findings suggest that by 4 years of age, children possess a mature, theory-like understanding of others' auditory access, including how auditory noise can corrupt others' auditory perception and prevent them from learning via verbal communication.

In sum, prior work suggests that by the early preschool years, children can reason about others' perceptual access, both visual and auditory. In particular, children seem to understand how physical barriers or environmental noise can corrupt that access and influence others' mental states. Taking these findings together, one might assume that children, like adults, would have no trouble flexibly choosing an appropriate means to communicate—show or tell—depending on others' perceptual access.

Importantly however, most studies reviewed above have focused on children's understanding of a single modality at a time. Choosing the appropriate means of communication based on others' perceptual access requires reasoning across multiple perceptual modalities in a given context. Furthermore, despite understanding that auditory noise can prevent listeners from hearing speech (Chuey et al., 2022), it remains unclear how well children can reason about factors that specifically alter others' auditory access while sparing their own, such as loud headphones or hearing loss. Finally, the ability to reason about others' auditory access as third-party observers might not always translate to children's own communicative behaviors, especially if they have a preference for a communicative modality that is familiar or salient to them. Thus, despite children's commanding understanding of others' perceptual access, whether they can apply it to their own communicative behaviors remains an open question. Here we report two studies that address whether young children can adapt their communication depending on others' auditory access, using a survey with parents of 2- to 10-year-olds (Study 1) and an experiment with 4- to 5-year-old children (Study 2).

## Study 1

Study 1 sought to gather preliminary evidence that children may communicate differently in everyday noisy environments. We surveyed parents of 2- to 10-year-old children, asking them if they had observed their children acknowledge noise or communicate differently in noisy settings. We also asked them to describe any specific instances of such modifications, what strategies their children used, and at what age they first noticed their children engage in them.

### Methods

**Participants** Ninety-eight parents of 153 children aged 2 to 10 years were recruited using Cloud Research (Litman et al., 2017) and participated via Qualtrics for $2 payment. An additional 3 parents participated but were excluded for not reporting any children in the requested age range.

**Procedure** Participants were instructed that we were developmental scientists interested in how children learn and communicate in noisy environments, and that they would be asked some questions about how their children behave and communicate in noisy environments. Next, they listed the number of children they had between ages 2 to 10 years and were asked a block of questions for each child listed. At the start of each block, participants provided their child's age, gender, race, and whether they suffered from any language or hearing disorders, delays, or disabilities. Afterwards, participants completed the main block of questions.

The main block began with two "select all that apply" questions about children's behaviors in noisy environments. The first was about children's behaviors as listeners: (Q1) "When it is noisy around [your child], have you ever observed them spontaneously do any of the following without being asked

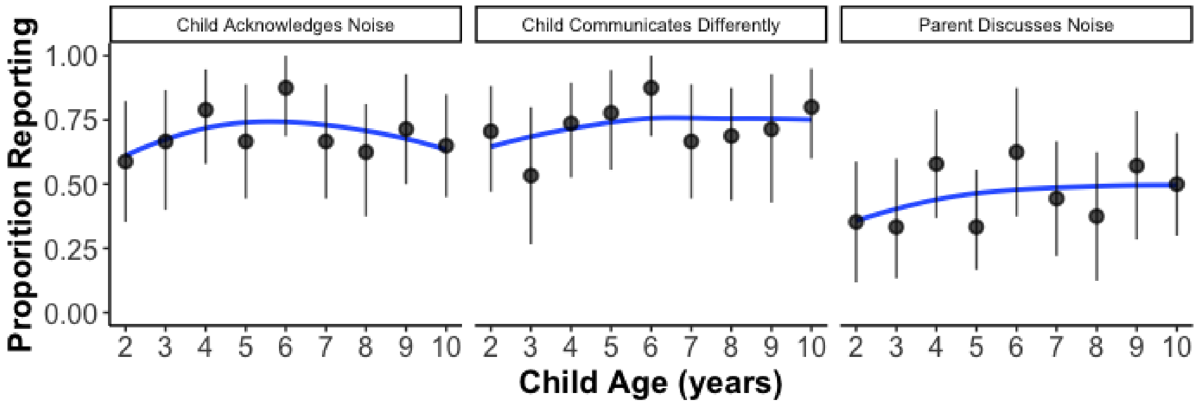


Figure 1: Proportion of parents reporting they 1) observed their child explicitly acknowledge noise, 2) observed their child communicate differently in noisy environments, and 3) explicitly discuss noise with their child, by age (years). Dots represent means for a given age group; error bars are 95% bootstrapped CIs. Blue trend lines are loess curves fitted to the data.

when someone is trying to communicate with them?" The second was about children's behaviors as communicators: (Q2) "When it is noisy around [your child], have you ever observed them spontaneously do any of the following without being asked when they are trying to communicate with someone?" For each question, participants were presented with six options that could each be checked, worded from either a listener's or speaker's perspective: (1) pay closer attention, (2) ask someone if they have any questions about what was communicated, (3) talk louder or yell, (4) repeat themselves, (5) stop talking or wait until noise has stopped or abated, (6) use more gestures (e.g., pointing) or physical demonstrations, or use gestures or physical demonstrations instead of speech.

The next three questions were about their children's acknowledgement of noise, children's communicative behaviors in noisy situations, and the extent to which they (parents) talked about noise with their children; if they answered "Yes" to one of these question, participants were asked to estimate how old their child was when such events first occurred, and to briefly describe a memorable instance of the behavior if possible. These questions were: (Q3) "Have you ever observed [your child] explicitly acknowledge or refer to auditory noise (e.g., "That's really loud!", "It's noisy right now!", or plugging their ears)?"; (Q4) "Have you ever observed [your child] communicate differently when it is noisy (e.g., talking louder, repeating themselves more often, using more gestures)?"; (Q5) "Have you ever explicitly talked to [your child] about noise, or how they should act or communicate when it is noisy (e.g., telling them to talk louder or to wait until a loud noise passes to speak)?".

After answering all questions, participants completed a demographic questionnaire, including their age, gender, education level, and native language.

## Results and Discussion

The main purpose of this study was to gather information about children's communicative behaviors in response to noise and approximately at what age these behaviors were first observed. Thus, we focus on summarizing these responses; no statistical tests were conducted.

Across all children parents listed, 69.3% were reported as having explicitly acknowledged or referred to auditory noise. The mean earliest age at which parents observed such behaviors was $M(SD)$=3.1(1.55) years. Additionally, 72.5% of children were reported to have communicated differently when it was noisy (mean earliest age $M(SD)$=3.24(1.45) years). Interestingly, only 45.8% of the children were reported to have been explicitly told about noise by their parents (mean earliest age, $M(SD)$=3.39(1.71) years). While the three items showed a generally similar pattern in their relative proportion of "Yes" responses across age, the data suggest that explicit discussion about noise does not necessarily precede children's spontaneous responses to noise (Figure 1).

Of particular note are the communicative strategies children reportedly exhibited in noisy environments. First, of the 111 children that parents reported communicating differently in noisy settings, 79.3% talked louder, 62.2% repeated themselves, 35.1% stopped talking or waited to communicate until noise stopped, 34.2% used more gestures or physical demonstrations, 27% requested others' attention, and 8.1% solicited questions from listeners (these responses were not mutually exclusive; parents could check any number of the above items if their child had engaged in them).

Additionally, parents generated open-ended responses describing specific instances of these behaviors for 97 of the 111 children reported to communicate differently in noisy environments; we coded these responses using the same six categories. These responses generally coincided with their earlier choices; 58.6% mentioned children talking louder, 11.7% repeating themselves, 7.2% waiting until noise has stopped, 16.2% using more gestures, 5.4% requesting others' attention, and 7.2% soliciting questions from listeners.

Overall, parents in our sample reported that most of their children acknowledge and communicate differently around

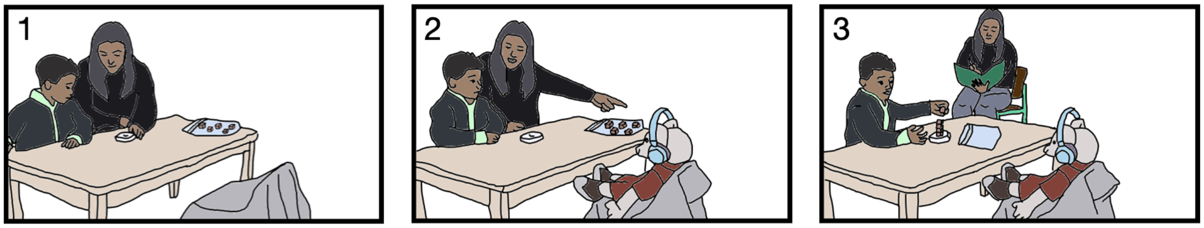


Figure 2: Study 2 procedure: 1) The experimenter verbally described a novel toy to the child, explaining that stacking five blocks in the center causes it to light up. 2) The experimenter introduced a puppet, Gus, who was wearing headphones that either played loud music or were silent. 3) The experimenter invited the child to teach Gus how the toy works. We measured whether children a) verbally instructed Gus and b) physically demonstrated the toy to Gus.

noise from a young age. The onset report data provide preliminary evidence that, at least by around 3 to 4 years, children begin to engage in adaptive communication in environments where others' auditory access is inhibited. Further, children appear to employ a variety of strategies in noisy settings; talking louder was particularly common, followed by other strategies like increased verbal repetition and gesture use.

Nonetheless, these findings do not provide conclusive evidence for children's adaptive communication. First, parental reports are retrospective and indirect, relying on limited recall from the parents' perspective rather than real-time observation of children's behavior in context. Second, most instances of noise affect the auditory perception of both children and their conversation partners; even if children adapt their communication in noisy environments, it is unclear to what extent they can do so when others' auditory access differs from their own. Thus, while parents' reports provide some evidence that children may be able to adapt how they communicate based on others' auditory access, an experimental approach is needed to investigate when and how they are able to do so.

## Study 2

Study 2 was designed to experimentally investigate children's ability to use others' auditory access to adapt their communication strategy. To this end, we manipulated their communicative partner's auditory access in a between-subjects design while keeping the child's auditory access intact. Importantly, we used a puppet (rather than a human) as the communicative partner to elicit communicative behaviors while minimizing children's expectations about the partner's real-time reactions (e.g., requesting their partner to remove the headphones, asking whether they can hear, or feeling confused about their lack of responsiveness, which could not be matched across conditions). While the puppet's visual access remained intact, choosing the appropriate means to communicate still required an understanding of both modalities. The key measure of interest was whether children verbally described or physically demonstrated the toy's mechanism depending on whether the puppet could hear. We predicted that children would rely more on "showing" and less on "telling" if their communicative partner could not hear them.

In this study, we recruited 4- and 5-year-olds for two reasons. First, while parents in Study 1 reported that children began displaying adaptive behaviors as early as age 3, these behaviors may not necessarily reflect their understanding of others' auditory access that differs from their own, which may be more challenging and later emerging. Second, pilot testing suggested that a majority of children under age 4 had difficulty understanding and verbally describing how the toy used in our procedure worked. Our predictions and analysis plan were preregistered at https://osf.io/s6m5z/.

### Methods

**Participants** Sixty-eight (out of 96 planned) 4-5 year-old children (mean age = 56 months, 43% White, 28% Asian American/Pacific Islander, 6% Black, 9% Hispanic/Latino, 15% Mixed-race, 46% female) from a local preschool participated in the study in a quiet room in the school. An additional 13 children participated but were excluded for deviating from the study protocol (*n*=6), experimenter error (*n*=2), technical issues (*n*=1), or failing an auditory check question (*n*=4).

**Materials** Experimental stimuli consisted of a flat platform with a light in the middle (10 x 6 cm), which was introduced as a "toy" that was out of batteries (in fact the light was inert), and a clear plastic bag containing five red blocks. An anthropomorphic mouse puppet (approximately 64 cm in height) was introduced as "Gus", who wore a pair of over-ear Bluetooth headphones. The headphones were either silent or playing loud guitar music ("Eruption" by Van Halen, 1978).

**Procedure** See Figure 2 for a schematic of the study procedure. Children were first seated at a table with a toy platform and a bag of five red blocks positioned at the corner. The experimenter sat beside the child and said: "I have a really cool toy to show you! It's out of batteries right now, but I'm going to tell you about it anyways". The experimenter explained that the toy normally lights up when five red blocks are stacked on top of each other in the center of the toy. Im-

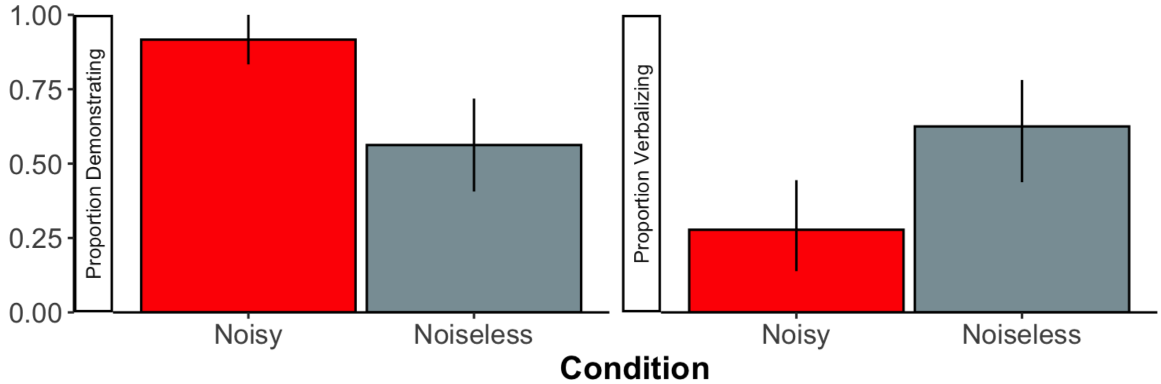


Figure 3: Study 2: Proportion of children physically demonstrating and verbally instructing Gus by condition. Error bars indicate 95% bootstrapped CIs.

portantly, the experimenter only provided a verbal description and pointed to the bag of red blocks, but did not use the blocks to demonstrate the toy. The experimenter then asked the child to explain how the toy worked, and provided the explanation again if the child did not answer correctly.

Next, the experimenter said they were going to introduce the child to their friend Gus, and retrieved the puppet from under the table. Children were assigned to one of two conditions (noisy or noiseless) between-subjects. In the noisy condition, Gus' headphones were playing loud music which was audible from several feet away but did not significantly disrupt the participant's own auditory access. In the noiseless condition, Gus' headphones were silent. The experimenter first asked the child what Gus was wearing on their head. If the child said "headphones" or something similar (e.g., earphones), the experimenter agreed; if the child was not sure or produced an incorrect answer, the experimenter explained that Gus was wearing headphones which can play music.

The experimenter then asked the child if they could hear anything coming from Gus' headphones. In the noisy condition, the experimenter remarked that Gus was listening to loud music. In the noiseless condition, the experimenter said that the headphones were not playing anything right now and that Gus just liked to wear them because they "look cool". The experimenter then asked children if they thought Gus could hear them talking. If they answered correctly (i.e., could not hear in the noisy condition and could hear in the noiseless condition), the experimenter agreed. If they answered incorrectly, the experimenter corrected them (i.e., "actually, I think Gus can/can't hear us right now") and repeated the question. If they answered incorrectly again, they were excluded from subsequent analyses (see *Participants*).

Then the experimenter said: "Gus really wants to learn how the toy works; can you teach Gus how the toy works? You can teach Gus however you like, just let me know when you are finished". The experimenter then sat in a chair off to the side and pretended to read something on a clipboard; this minimized the possibility that children were addressing the experimenter rather than Gus. After the child indicated they were finished teaching Gus, the experimenter complimented their teaching and concluded the study.

### Results and Discussion

We were primarily interested in how children's usage of demonstrations (coded as any physical interaction with, or intentional motions towards, the blocks) and verbal instruction (coded as producing an utterance related to the toy, directed toward the puppet) varied by condition (noisy or noiseless). Since children could produce both behaviors, we conducted a Bayesian multivariate logistic regression[1] from the `brms` package to predict whether children engaged in 1) demonstrations and 2) verbal instruction based on condition (noisy vs noiseless). We evaluated both the coefficient estimates and 95% credible intervals (CrI), with non-overlapping CrIs indicating a significant effect, to measure these behaviors.

As predicted, children were significantly more likely to demonstrate in the noisy condition (92%), $\beta = 2.46, \mathrm{CrI} = [1.34, 3.89]$, than in the noiseless condition (56%), $\beta = -2.19[-3.77, -0.84]$.Conversely, children were significantly more likely to verbally instruct in the noiseless condition (63%), $\beta = 1.49[.40, 2.63]$, relative to the noisy condition (28%), $\beta = -0.90[-1.75, -0.11]$. Thus, children used verbal explanation more often when Gus could hear than when he could not; in contrast, they used visual demonstrations more often when Gus could not hear than when he could (Figure 3). There were no effects of age on children's demonstration $\beta = 0.01[-0.11, 0.14]$ or production $\beta = 0.05[-0.05, 0.15]$.

## General Discussion

The current studies investigated whether young children can tailor their communication to others' auditory access. First, we surveyed parents about their children's communicative behaviors in noisy environments. Parental reports suggest that by around 3 or 4 years of age, children appear to engage in a number of adaptive strategies in noisy environments, such

[1] We originally preregistered two separate logistic regressions; however, we use a multivariate approach here because it better models the relationship between the two outcome variables.

as talking louder, repeating themselves, and using more gestures. Second, we conducted an experiment to directly assess 4- to 5-year-olds' ability to tailor their communication to a learner's auditory access. Although data collection is ongoing, we have collected a majority of our sample and the data are clear. When a learner's vision and audition were both intact, children relied more heavily on speech and less on physical gestures and demonstrations; however, when the learner's auditory perception was compromised asymmetrically (i.e., because they were listening to loud music), children used markedly more physical demonstrations and less verbal instruction. Thus, by around 4 years, children can not only reason about others' perceptual access, but also adapt their communicative strategies accordingly.

What inferences enabled children to tailor their teaching to the perceptual access of the learner? First, children needed to infer and track the learners' visual and auditory access. In the experiment, this meant assessing the puppet's line of sight and estimating the extent to which the puppet could hear them given the noise (or the absence of noise) from the headphones. Critically, although noise often affects the auditory access of both speakers and listeners, the noise used in Study 2 affected only the puppet's auditory access while leaving children's auditory perception intact. Thus, children needed to decouple the puppet's auditory perception from their own. Given their understanding of the puppet's visual and auditory perception, children also had to select and execute a series of communicative acts that would convey the desired information.

Verbal instruction appeared to be the favored strategy when the puppet could both see and hear. This finding is unsurprising given that children learned how the toy works from the experimenter's verbal description. Furthermore, we deliberately designed the toy's mechanism and setup such that it was easy to describe but rather cumbersome to demonstrate (i.e., the child had to retrieve the five blocks from the bag and carefully stack them on the platform). Nonetheless, when the puppet's auditory perception was compromised, children substituted verbal instruction for costly demonstration, suggesting they understood that demonstration would better achieve their communicative goal (i.e., to convey how the toy works) via the puppet's intact visual perception.

The current study leveraged children's ability to teach others as a methodological tool. Prior work has used this approach to demonstrate children's ability to flexibly communicate; children demonstrate more or fewer buttons (Gweon et al., 2018) and selectively perform costly demonstrations (Gweon & Schulz, 2019) depending on others' prior knowledge or expectations. The current work adds to the growing literature documenting children's developing abilities as effective and efficient communicators. Importantly, their selective use of demonstrations in this study goes beyond the ability to modulate the frequency or exhaustiveness of demonstrations per se; children aptly changed their communicative modality—showing vs. telling—by navigating their relative strengths with respect to the learner's perceptual constraints.

Note that our sample consisted of American preschoolers who routinely participate in pedagogical interactions at school and also have prior experience with headphones. This likely helped, or even necessitated, their ability to reason about and respond to the recipient's auditory access in this particular experiment. Children's communication was also deliberately elicited by encouraging them to teach the puppet, an activity that may not be as familiar for children in some cultures. Thus, demonstrating this ability in a different population might require other culturally appropriate ways to manipulate the listener's perceptual access and elicit communication. Also, while parents' reports in Study 1 suggest that children spontaneously adapt their communication in noisy environments (even without parents explicitly discussing noise with them), it remains to be seen whether children spontaneously adapt to auditory access that differs from their own—the ability tested in our experimental study—in more informal communicative contexts.

In general, children's everyday sensory environments are considerably more dynamic and complex than the carefully controlled scenario in our study. For example, others' visual and auditory access varies as they move (e.g., shutting a door or moving behind a wall) and as elements of the environment change (e.g., a loud ambulance passing by, the sun becoming obscured by clouds, etc.), raising the need to track others' perceptual access across time rather than at a single point. As adults, tracking others' perceptual access can be intuitive and even automatic, enabling us as communicators to adjust the intensity of our speech (Summers et al., 1988), use of gesture (Clark, 2016), and the position of our bodies (Clark & Brennan, 1991). The use of diverse methods will hopefully enable researchers to elicit and measure children's adaptive behaviors in more naturalistic contexts.

Notably, the current studies focused on children's reasoning about auditory noise, which exerts an exogenous and temporary influence on others' auditory perception. However, many endogenous factors also influence auditory perception in practice, including attention (Snyder et al., 2012), age (Babkoff & Fostick, 2017), and individual differences (Kidd et al., 2007). In particular, deaf and hard-of-hearing individuals have severely limited to no auditory access; learning how to respect these individual differences and successfully communicate with them may be an important yet challenging task for young children. While the current work provides evidence that children possess the requisite skills to reason about and communicate with such individuals from a young age, the extent to which they can do in practice, and the barriers that may prevent them from doing so effectively, remains untested.

Ultimately, the current work demonstrates how young children leverage mental-state reasoning to navigate the trade-offs of different communicative strategies. Even at a young age, children do more than play "show-and-tell"; they can also flexibly decide whether to *show-vs-tell*, a foundational ability for successfully communicating across diverse contexts and constraints.

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