

Children’s Learned Associations with Voice: Investigating Children’s Speech Perception and Socialization

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I. ABSTRACT

Examining the processing of spoken words enables us to investigate children’s burgeoning ability to extract social information in the speech stream. The speech signal contains not only phonemic information necessary for word recognition but abundant indexical information about the talker, including talker gender (Perry, Ohde, & Ashmead, 2001; Goldinger, 1998; Johnson et al., 1999; Johnson, 2006). A growing body of work has begun to investigate the effects of listeners’ associations between talkers’ social identity and phonetic cues in talkers’ voices, demonstrating that by adulthood listeners use talker information to make social inferences about a talker’s likely behavior (Van Berkum et al., 2008), especially when listeners expect talker identity to be useful or find it to be a reliable cue (Creel, Aslin, & Tanenhaus, 2008). Recent work suggests that children use acoustic cues to talker identity to constrain comprehension of spoken language (Creel, 2012), though the way in which children learn to integrate social knowledge with information from voice remains poorly understood. In this paper, we test the hypothesis that children are able to disambiguate between objects with gendered associations (a men’s pair of gloves and a women’s pair of gloves, say) based on talker voice. We explore children’s use of talker-specific information to infer speaker meaning through an experiment in which children interact with a web page on an iPad. Over 24 trials, children ages 3-5 were shown series of four images and asked by talkers to find one of the objects by clicking on it. During half of the trials, children heard a male talker’s voice, and during the other half they heard a female talker’s voice. In addition, half of the trials were non-competitor trials where there was only one image of the referent (hearing a man’s voice and seeing a man’s glove, say). The other half were competitor trials in which the target image competed with a variant which would stereotypically belong to a speaker of the other gender (hearing a man’s voice but choosing between both a man’s glove and a

woman’s glove). Children’s reaction time was measured from the onset of the utterance of the target word to their click on an image, and their choice of image was recorded. Our data suggest that by age 5, children regularly integrate phonetically-cued social information with their knowledge of speaker characteristics to guide their interpretations of speaker meaning in a real world paradigm. From age 3 to 5, their ability to associate voice types with speaker gender and speaker intention increases significantly. Our results suggest that children make use of socially-nuanced speaker-specific acoustic information by a young age, and reveal their robust understanding of gender stereotypes that guide their daily interactions with interlocutors and may bear on their linguistic and social development.

II. INTRODUCTION

A. Social Encoding and the Speech Stream

The speech stream is rich with phonetic variation that cues information about sounds and words, and information necessary for conveying and perceiving speaker identity (Perry, et al., 2001; Goldinger, 1998; Johnson et al., 1999). Contrary to early work in speech perception that posited that talker-specific acoustic information is normalized to give way to the abstract exemplars of phonemes necessary for listeners to correctly perceive words in their language, a substantial flurry of more recent work suggests instead that listeners use cues to talker identity in very early stages of speech signal processing (Remez et al., 1997; Johnson, 2005; Creel, Aslin, & Tanenhaus, 2008; Creel, 2012), if not immediately (Kaganovich et al., 2006; Van Berkum et al., 2008). Work from the past twenty years has established speech perception as a rather talker-contingent process (Nygaard, Sommers, & Pisoni, 1994) where listeners rapidly integrate acoustic cues relaying phonemic information about a speaker’s message and social information from their voice together at the same time. It has been argued that these two sources of information are not simply parallel but interactive, since social information in the voice can heavily influence listeners’ perception of speakers’ words, phones, and discourse (Sumner et al., 2014).

We can consider how this interweaving of social information at multiple layers of auditory encoding allows talker information in voice to act as a richly contextualizing element that listeners can use to guide their decision-making (Sumner 2015) as well as their expectations

(Van Berkum et al., 2008). This information is thus a highly informative cue that listeners can use to augment their comprehension. While this process is quite useful to listeners, it is nevertheless very complicated, as it requires rapid mapping of linguistic forms to dynamic social representations. Although it is evident that adults can navigate this process incredibly quickly (Kaganovich et al., 2006), we can imagine how this might be difficult for young children to perform. In order for this talker information to be truly actionable and for it to guide a listeners behavior, the listener must have accumulated sufficient social knowledge, be able to perceive the socially-nuanced acoustic cues performed by the speaker, assume that those cues will be informative, map those cues to existing social representations, activate that information, and then map it to co-present cues in their immediate context. Although prior work has begun to demonstrate that talker information in voice is available to and utilized by children under certain circumstances (Creel & Tumlin, 2011), and that children’s development of social representations is underway by the preschool years (Andersen, 1990), little is known of how children begin to use accumulated social knowledge to guide their speech perception and fully navigate this process. Understanding how children’s ability to integrate social knowledge with talker information in voice develops both cognitively and socially would be very important as it would illuminate the ways in which children begin to accumulate, access, and make inferences based upon social representations during speech perception, and would underline the ways in which the representations which help guide children’s social functioning are actually accessed and acted upon by children.

B. Children’s Developing Use of Talker Information

During the preschool years, childrens use of talker information in voice is an emerging process, as is their development of the social categories they will use to structure their representation of the world around them. Work by Creel has demonstrated that children augment their comprehension by using voice characteristics to develop and later access knowledge about individuals (Creel & Tumlin, 2011), and that children can use talker-specific acoustic information to learn an individual’s preferences for specific objects (Creel, 2012). In addition, she has demonstrated that adult listeners can use the joint presence of phonemic and identity information in voice to constrain the domain of what a speaker is likely to say or prefer (Creel, 2012), especially when listeners expect or find talker identity to

be a useful cue (Creel, Aslin, & Tanenhaus, 2008). Although adult listeners have been shown to use talker information to make inferences about a talker’s likely behavior (Van Berkum et al., 2008), little work has yet been done to investigate the extent to which children make similar inferences, or to investigate how children use any social knowledge accumulated from speech perception to guide their interactions with interlocutors.

C. Children’s Developing Social Representations

Another critical component which allows children listeners to map phonetic cues to social identities is the mass of social knowledge they must accumulate and then access during on-line comprehension. How do children obtain this representational social knowledge? Much of the prior work on childrens development of social representations has dealt with their representations of sex and gender. Prior work has established that gender is a salient perceptive cue even for young children. Children are able to discriminate individuals by gender from a very early age, as children as young as 6 months are able to distinguish male and female voices (Miller, 1983), and by 8 months, children are able to match faces and voices by gender (Patterson & Werker, 2002). By the age of 7, children are able to perform as well as adults in facial recognition tasks classifying individuals by internal facial structure (Wild, et al., 2000). By the preschool years, as children encounter more tokens of male and female speech in their linguistic communities they develop richer expectations about what speakers of different genders are likely to sound like, and about what they are likely to say given their social role (Andersen, 1990). Children’s representations about gender as a whole seem to be largely shaped by socialization they receive by being exposed to widespread cultural stereotypes, with these stereotypes in turn shaping their expectations of what gendered behavior looks like (Greenwald & Banaji, 1995; Philips, et al., 1987). Another important source of these representations is the linguistic interactions that children have with their parents (Bellinger & Gleason, 1982; Gleason, 1975; Greif, 1980).

Together, the influence of the stereotyped social representations children have built appears to be strong by the preschool years (Andersen, 1990). Elaine Andersen’s work examining children’s use of social registers in role play demonstrated that when children between the ages of 4 and 7 were asked to enact parents’ speech, their pitch was significantly deeper when they were playing as fathers than as mothers. In addition, when they spoke as a

father they modified their language by lowering their pitch, speaking more loudly (sometimes yelling), and using back and lower vowels. When they pretended to be mothers they spoke in higher pitch, used exaggerated intonation contours, and chose stereotypically female vocabulary. In their discourse, pretend fathers spoke about work, business meetings, how tired they were from working at the computer, and how they had to fire their secretary. In the role of mother, they complained about being exhausted from their errands. These patterns seemed to hold whether or not the children’s own parents spoke about these topics or whether or not their parents’ occupations were in line with gender stereotypes. These data suggest an influence of social stereotypes on children’s expectations with regards to gender by the preschool years.

Besides gender alone, children’s ability to use talker information in voice by this age appears to be quite strong (cf. Creel, 2012; Borovsky & Creel, 2014); however, these studies that have thus far investigated children’s use of talker information during speech processing have either tested children’s use of arbitrary speaker-preference mappings that were presented to the children during the experiment (Creel, 2012) or tested children’s use of speaker-preference mappings for (typically fictional) character types such as princesses or pirates (Borovsky & Creel, 2014). In each case, although the children in these studies demonstrate that they can and do combine inferences about talker identity with representational social knowledge they have built up about speakers, the extent to which children make use of meaningful social information remains understudied. That is, investigating how, during speech perception, children at the preschool age actively use social information, ideologies and construals that are used to propagate stereotypes and societal norms such as gender roles has yet to be done, even though these are constructs they are likely to encounter in the real world and learn to use to guide their interactions with others.

III. THE PRESENT STUDY

To investigate how children might develop the ability to map phonetic cues in voice to their growing social representations, I endeavor to test in what ways talker-specific acoustic information in voice guides children’s behavior as listeners. Previous research has demonstrated that children remain sensitive to much phonetic detail and acoustic information previously thought to be generalized, and that they use this fine-grained information to

access lexical candidates that would seem appropriate given the speaker’s social identity. In this study I examine whether preschool children, who are themselves beginning to construct the social categories they will carry with them as they develop, are yet able to use talker-specific identity information in voice to activate their accumulated social knowledge and guide their interpretation of speaker meaning.

IV. EXPERIMENT 1

A. Method

Participants. Participants were children age 3-5 ($N = 72$) from either Bing Nursery School or the Children’s Discovery Museum in San Jose, CA.

Stimuli. Our visual stimuli are 36 object pairs, rated by adult judges on Amazon Mechanical Turk as differing significantly in whether they are likely to be owned by a man or a woman. In each pair, one item was rated as being very likely to be owned by an adult male, not very likely to be owned by an adult female, and not very likely to be owned by a child. The other item was rated as being very likely to be owned by an adult female, not very likely to be owned by an adult male, and not very likely to be owned by a child. Difference scores were calculated for each pair, and the 36 pairs with the highest difference scores were chosen as the visual stimuli for this study.

Equipment. The experiment is run on an internet-connected iPad in Guided Access mode as a webpage. The experiment webpage on the iPad receives the conditions for that subject from the lab server and submits the results to the lab server as a spreadsheet.

Procedure. Children participated in a four-alternative forced choice (4AFC) task run in two blocks of 12 trials each. At the beginning of the experiment, five colored dots appeared on the iPad screen; the dots turned to x’s when the subject clicks on them. The child subject must have successfully clicked on all of them in order to proceed to the actual experiment, ensuring that the child understood how to properly click an iPad screen and reducing the chance of erroneous clicks to the screen.

Once the subject clicked on all five dots, twelve trials ensued in random order, with four images in a 2x2 grid appearing in each trial. At the beginning of each trial, a speaker’s voice played, asking the subject to *find my X*, where *X* is the name of the target object on the screen. The experiment was run in two blocks, with block order manipulated between subjects, such that half the subjects experienced a block with a male speaker first, and the other subjects experienced a block with a female speaker first. Noncritical trials consisted of there being one item on screen matching the speaker’s description (one correct-label item), accompanied by three distractor images. Critical trials consisted of two competing images appearing that match the speaker’s description, accompanied by two distractor images (two correct-label items). Crucially, the competing correct-label images in the critical trials differed along a gendered dimension, such that one item was rated as being very likely to be owned by an adult male (and not by an adult female), and its competitor was rated as being very likely to be owned by an adult female (and not by an adult male) by participants in an online survey on Amazon Mechanical Turk. I measured the proportion of critical trials in which children selected the correct-label, gender-consistent item, the item which semantically is identifiable by the word the speaker used to pick it out, and which contains visual features that would be consistent with it belonging to the speaker (gender-consistent). Each subject’s trials were randomly selected from one of 12 lists of trials. The distribution of lists was balanced between subjects such that every item from the 36 object pairs appeared as often as every other item, and every item appeared as the target item as often as it appears as a competitor.

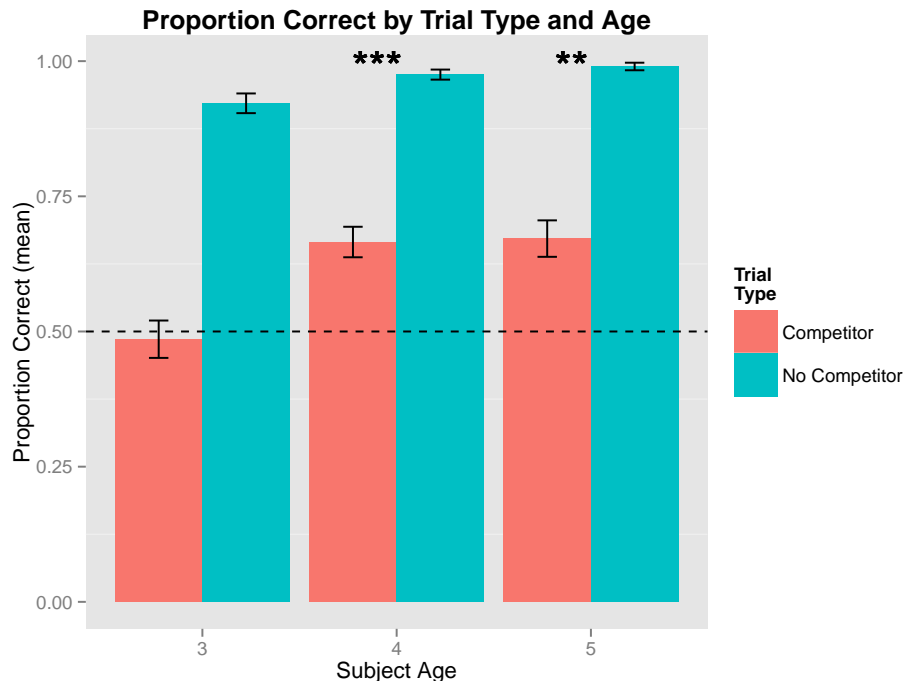
Motivation and Significance The task at hand requires children, in the critical trials, to completely navigate the potentially difficult process of identifying a speaker’s gender based on voice alone, observing that the pair of competing correct-label items differ along a gendered dimension, mapping the spoken item label to the image of that item, having the theory of mind necessary to take on the perspective of the speaker, and, having amassed sufficient representational social information and having assumed that the speaker’s gender and the visual information is informative, activating that information and mapping it to the talker information they receive from the speaker to guide their interpretation of which item the speaker intends.

If children were to consistently select the correct-label gender-consistent item, it would imply that children have amassed and utilized an impressive social skill set, not the least of

which is realizing which aspects of the multimodal information presented to them are informative (including talker information), amassing and accessing a body of social knowledge relevant to the social dimension in play, and making inferences based on that knowledge to guide their actual decision-making.

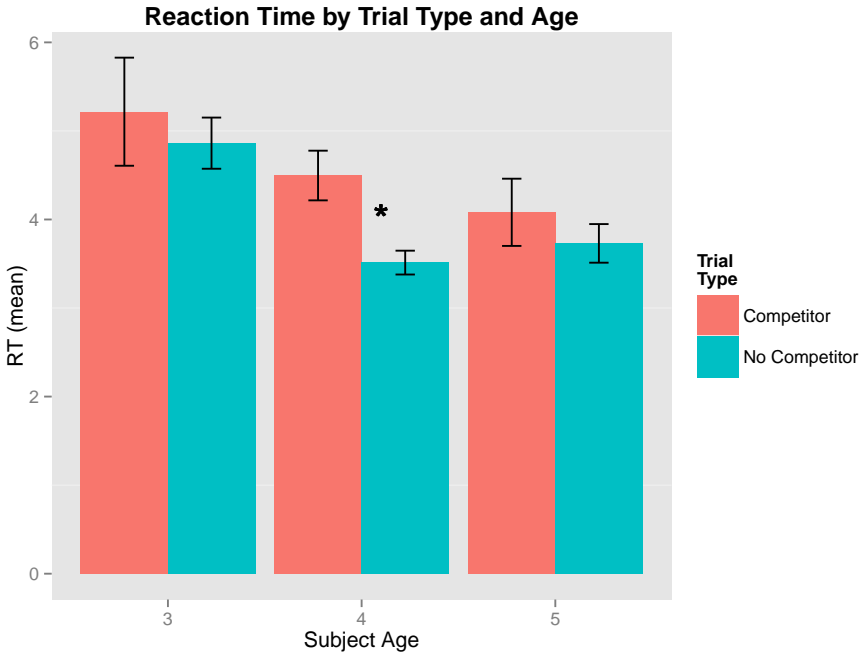
B. Results

If children are truly mapping social stereotype information from their developing social categories to inferred speaker preferences based on talker information in voice, then I would expect them to, of the two correct-label objects, choose the target object on competitor trials significantly more often than chance. In line with this hypothesis, I saw that in competitor trials, four- and five-year old children chose the target object (the one that would belong to the speaker if speaker preferences were congruent with social stereotypes) the majority of the time (4 year olds: $M = 66.5\%$, $SD = 47.2\%$ and 5 year olds: $M = 67.2\%$, $SD = 47\%$), whereas three-year old children did not choose the target object more often than chance ($M = 48.6\%$, $SD = 50\%$). To quantify the reliability of these results, I fit a logistic mixed effects model (Gelman & Hill, 2006; Jaeger, 2008; Quen & Van den Bergh, 2008) to children’s responses, with age group and condition as fixed effects, and with random effects of condition fit for each participant and each target item (Barr, Levy, Scheepers, & Tily, 2013; Baayen, Davidson, & Bates, 2008). The resulting coefficient estimates suggested that three-year-olds (the reference level) were not above chance in their responding on critical trials ($\beta = -0.24$, $SE = 0.29$, $z = -0.819$, $p = 0.413$).



There was a significant coefficient indicating higher performance on filler trials ($\beta = 3.22$, $SE = 0.31$, $z = 10.336$, $p < 0.001$). There were significant coefficients for the effect of age, suggesting that both four-year-olds ($\beta = 0.79$, $SE = 0.18$, $z = 2.794$, $p < 0.01$) and five-year-olds ($\beta = 1.10$, $SE = 0.32$, $z = 3.406$, $p < 0.001$) were above chance in their responses on critical trials, though five-year-olds were not significantly more accurate than four-year-olds ($\beta = 0.31$, $SE = 0.30$, $z = 1.031$, $p = 0.3$).

There was also a significant coefficient for the effect of gender ($\beta = 0.76$, $SE = 0.24$, $z = 3.101$, $p = 0.002$), suggesting that female children performed significantly more accurately than male children.



We see that during competitor trials, girls choose the correct-label, gender-consistent item during 66.4% of trials, while males only select the correct-label, gender-consistent item 56.2% of the time (for girls, $SD = 47.2\%$, and for boys, $SD = 49.7\%$). A model with a coefficient for gender provided sig-

nificantly better fit to the data, ($\chi^2_1 = 9.37$, $p = 0.0002$), whereas a model with an age by gender interaction did not ($\chi^2_2 = 0.55$, $p = 0.759$).

V. DISCUSSION

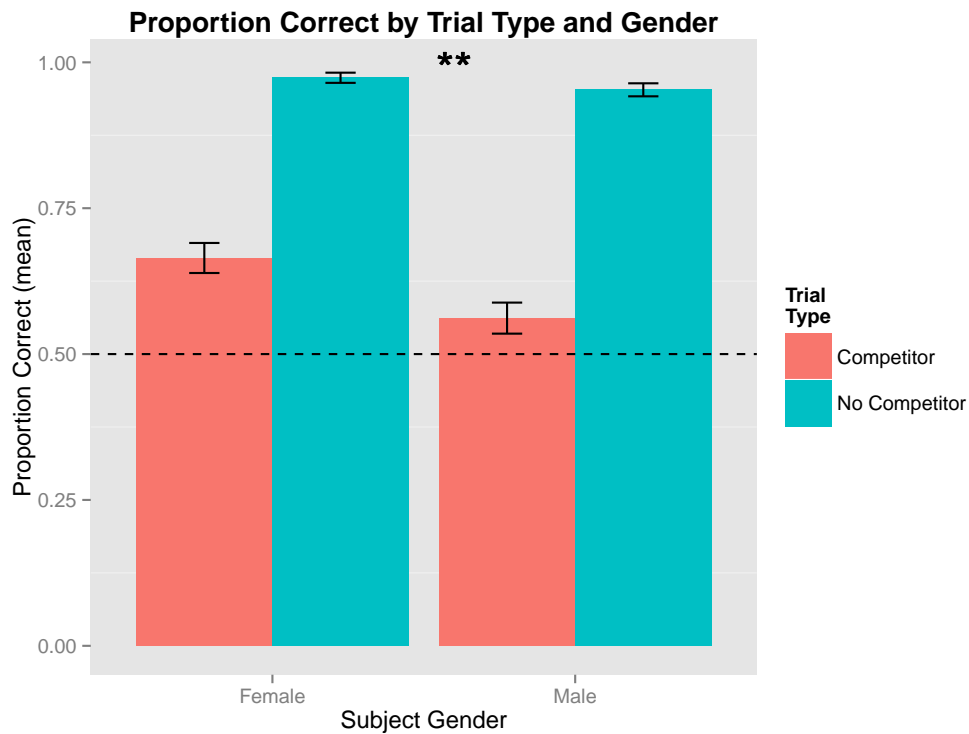
A. Discussion of Results

The results of Experiment 1 are consistent with the view that preschool-aged children do indeed use talker information in voice, map that information to developing forms of social categories, namely ideas and stereotypes about speaker gender, and can access and use this information to guide their interpretations and comprehension in situations where speaker meaning is ambiguous. These data also suggest a developmental trajectory for children’s navigation of this process, as children are significantly above chance in their inference of a speaker preferring the object consistent with social gender stereotypes at age four, but at the age of three remain at or below chance. These results raise two important questions: First, why do three-year-olds struggle with the task when four-year-olds do not? Second, how might we interpret the significant effect of gender as a predictor of children’s performance in the task?

As for the first question, by the nature of the task, there are several steps along the way to completing it at which children’s performance might break down. For instance, given that 3-year-olds choose one of the correct-label objects but are agnostic as to whether or not it is gender-consistent, it is first possible that 3-year-olds do not discriminate the gender of the speaker. Recall, however, that children as young as 6 months can discriminate the gender of a speaker based on speaker voice alone (Miller, 1983), so it is unlikely that the 3-year-olds are not correctly determining the gender of the speaker by their voice.

Or perhaps children have yet to be able to map the gender of the speaker to their representational social knowledge and stereotypes about gender, which would imply that their use of talker information during speech perception is poor at this age. As mentioned before, it is unlikely that the 3-year-olds are not correctly determining the gender of the speaker by their voice. Furthermore, children as young as 3 have been shown to be able to use acoustic cues to talker identity to activate their knowledge about the speaker and to constrain that speaker’s domain of reference when the speaker is referring to him- or herself (Creel, 2012). It is unlikely then that children at age 3 are unable to make a mapping between speaker identity as determined by their voice and their knowledge about the person speaking.

It could also be that children do not have access to representational social knowledge and stereotypes about gender, or that they do have access to it but do not think it is informative in this task. There is a consistent body of extensive survey data on American media consumption to suggest that children are at least exposed to these stereotypes by age three (Rideout et al., 2003, 2006), and four-year-olds successful completion of the task coupled with past research on childrens understanding of register implies that even if the influence of this information is not yet strong enough to influence childrens behavior, it soon will be (Andersen, 1990).



Finally, perhaps children do not discriminate the gendered valence of the correct-label items. While this is possible, the fact that four-year-olds can succeed in the task, coupled with the strength of the difference scores for the pairs of correct-label items in the image-norming task on Mechanical Turk at least cast some doubt on this interpretation. However, it is not unreasonable to think that while 3-year-old children may have access to stereotype and representational information about gender, the differentiation of the correct-label items, while strong enough for adult judges, is not sufficiently strong enough for children of this age to see their difference as meaningful given their limited experience.

This remaining possibility would imply that these children are mapping speaker identity

to their knowledge about social categories such as gender, but that their knowledge about these categories is not developed enough to allow them to infer the speakers intention based on their gender, at least not with respect to the items presented to them.

In order to fully appreciate the discrimination that the 4-year-old children can currently make in this task, I turn briefly to a consideration of how gender information manifests itself in voice.

B. Speaker Gender As Conveyed Through Voice

A speaker’s gender is a highly complex social construction that correlates with many linguistic variables, and it should be noted that multifaceted socially-influenced stylistic variation can still exist within gender groups, despite these correlations (Eckert, 1990).

While gender is a construct that influences many aspects of human behavior, what aspects of people’s voices convey social information such as gender? That males and females differ in their acoustic productions is well-known, with early experiments demonstrating significant differences in fundamental frequency and in formant structure between male and female speakers (Peterson & Barney, 1952). Much of this difference though is likely due to the fact that gender is performed. Differentiation of voice characteristics along a gendered dimension appears quite early in development, with children’s voices first differing by gender with respect to vowel formant frequencies (but not f_0) at the age of four, and then differing with respect to both vowel formant frequencies and fundamental frequency by the age of twelve. Even so, adults are able to reliably distinguish whether four-year-old children are male or female based only on their voice (Perry, et al., 2001).

Although the ways in which speakers perform gender is largely idiosyncratic to specific speech communities (Johnson, 2006), the sociophonetic individual listeners across speech communities and dialects maintain expectations and guidelines about how men and women are likely to talk in accordance with their gender (Podesva et al., 2015; Eckert, 1990, 2008;). Accordingly, there is a social component to the realization of gender in voice, leading to voice differences between different genders of speakers that are larger than might be expected if this difference were due to biological factors alone (Johnson, 2005). That is, speakers perform gender in line with their community’s expectations for how males and females should talk (Johnson, 2005, 2006). Evidence from previous studies suggests that these expectations are

quite robust, with adults being able to correctly categorize voices as male or female even when acoustic correlates of gender such as fundamental frequency have been reduced or removed altogether (Fellowes, et al., 1997). Listeners can still be convinced of a speaker’s gender, even when their speech signal is ambiguous or not strongly stereotyped (Johnson, 2006). Expectations about speaker gender and speaker voice will cause listeners to adjust their online interpretation of a speaker’s utterances (Johnson, 1989), even leading adults to perceive the same word differently if they are told it is spoken by a man as opposed to a woman. For example, in some communities the acoustic boundary between the vowels in *hood* and in *hud* are different for male and female speakers (Johnson, 2005). Listeners also adjust their expectations about fricative duration and frequency for speakers of different genders in accordance with gender stereotypes that exist in their communities (Strand & Johnson, 1996). Accordingly, listeners see a processing benefit when speaker voice is in line with their community’s guidelines and expectations for performance of gender, and see a corresponding detriment when speaker voices are ambiguous with respect to gender or are in violation of the stereotypes prescribing proper male and female acoustic phonetic behavior (Strand 1999). These data suggest a powerful role for gender in conveying identity. This can be seen in other modalities as well, as adults struggle to ignore identity information while attempting a visual sex categorization task (Bulthoff, 2009), and adults have been shown to categorize faces more accurately and more quickly by sex than by race (Contreras et al., 2013).

All of this evidence points to the strength of speaker gender as an acoustic variable, and a substantial source of social meaning that even children can recognize from an early age.

C. Implications for Children’s Socialization

Although this experimental paradigm was developed to examine young children’s ability to utilize phonetically-cued social information in voice, a paradigm such as this one also acts as a measurement of how children are actually constructing gender stereotypes and social categories more broadly, and could conceivably be expanded to test children’s intuitions about which variants of an object are more likely to belong to an adult speaker as opposed to a child.

I have argued that children’s performance on this task reveals a robust understanding of

gender stereotypes and thorough socialization by age 4. Prior work has for some time argued that socialization practices may be responsible for differences in male and female preschool competence (Baumrind & Black, 1967); might this be at work in the gender difference I find in this experiment?

Past work on young children’s socialization has found that gender and sex-role socialization is particularly focused on female preschoolers (Fagot & Patterson, 1969; Weitzman, Eifler, Hokada, & Ross, 1972). This work has found that it is often the case that teachers consistently reinforce feminine behaviors more than masculine behaviors, that girls are not affirmed by teachers when they perform opposite-sex behaviors but that boys are, and that by 3 years of age, there are sex differences in children’s play behavior, and that same-sex peers reinforce this gendered behavior (Fagot & Patterson, 1969). Yet other work has demonstrated that children’s books and other forms of children’s entertainment heavily reinforce to girls what feminine behavior ought to look like (Weitzman, et al., 1972). Therefore it should not come as a surprise that girls outperform boys on the critical trials, where children have to recognize the phonetically-cued social information in voice related to gender, recognize the gendered differences in the appearance of the two correct-label items, and use their knowledge of social stereotypes to align the speaker’s gender to their supposed preference for the stereotype-consistent item.

D. Future Directions

Ongoing or future work could attempt to manipulate the visual features of the image stimuli used in an experimental paradigm such as this one to examine which precise features (color, shape, apparent texture, etc.) best cue gender to children observers. Doing so would provide valuable insight into the sheer extent of the socialization that children have received within their first five years of life as it would point to the visual features that preschool-aged children have already been taught to treat as masculine or feminine.

Ongoing or future work could also incorporate other social dimensions into this paradigm in order to examine the socialization children have received by the preschool years. Although I propose above examining children’s performance on a version of this task with a child speaker and an adult speaker, the social dimensions that this paradigm could examine are not limited to age and gender.

The use of eyetracking in future studies would allow researchers to better investigate precisely why children who do not select the stereotype-consistent item in the correct-label pair do so, as their eyes' saccades and fixations would help to indicate whether they oscillate between the two correct-label choices or whether they select the first correct-label item they attend to (Nordmeyer & Frank, 2014).

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