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Role of speaker gender in toddler lexical processing

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Abstract

Adults and children utilize social category information during incremental language processing. Gender is a particularly salient social category that is often marked both in speakers' voices and the visual world. However, it is unknown whether toddlers exploit gender cues to draw connections between language and other aspects of their environment. The current study investigates whether toddlers use gender cues available in voices and objects during real-time language processing. 22- to 24-month-old toddlers ($N = 38$) were tested in a looking-while-listening paradigm. On each trial, toddlers viewed two highly familiar objects designed to be prototypically masculine and feminine (via color and patterns) and heard either a male or female speaker label the target object. Lexical processing was facilitated when the vocal gender matched the gender of the target object. This work demonstrates that toddlers consider both object-feature information and inferred speaker gender (based on speaker' voice) during online language processing.

1 | INTRODUCTION

Comprehenders exploit myriad linguistic and contextual cues to reduce ambiguity and make predictions during real-time language processing. Despite children's limited experience, they use many of the same linguistic and real-world cues as adults, including verb semantics (Borovsky & Creel, 2014; Fernald et al., 2008; Nation et al., 2003), adjectives (Fernald et al., 2010), and

grammatical gender (Lew-Williams & Fernald, 2007). Children are also sensitive to indexical information (cues to speaker identity) during language processing, linking voices to objects based on speakers' preferences (Creel, 2014; Thacker et al., 2018a, 2018b) and emotions (Berman et al., 2010). Preschoolers also use speaker's voice (e.g., pirate vs. princess) to anticipate specific target nouns (e.g., "sword" vs. "wand"; Borovsky & Creel, 2014). These data suggest that preschool-aged children demonstrate person-referent mapping.

Skilled language users also capitalize on their knowledge about social categories (e.g., gender) to process linguistic and nonlinguistic environments. Adults use social categories to make inferences about others (Brock, 1965; Krueger and DiDonato, 2008), with particular attention to race and gender (Andreoletti et al., 2015; Fiske, 1998; Johnson et al., 2012). Gender may be a particularly informative link between speakers and the visual world because it can be marked by both vocal and object attributes, especially for objects designed to appear gendered. Adult listeners rapidly classify speakers based on voice and use gender stereotypes to assess congruity between speakers and the contents of their utterances (Van Berkum et al., 2008). Young children also activate stereotypes to make inferences about speakers. For example, 4- to 6-year-olds choose to learn from female speakers when the object is pink and male speakers when the object is blue or yellow (Ma & Woolley, 2013). These data suggest that young children can map speaker gender to objects based on their design characteristics.

The emergence of children's ability to exploit speaker gender cues during online language processing is poorly understood. To do so, perceivers must (a) detect gender cues in their linguistic and nonlinguistic environments, and (b) integrate those cues across domains/modalities. Most infants in Western cultures are surrounded by gendered environments (Pomerleau et al., 1990; Smith Leavell & Tamis-LeMonda, 2013). By the latter half of the first year, infants can match voices with faces based on gender (Bahrick et al., 1998; Martin et al., 2002). Children in the USA understand gender labels by their second birthday (Campbell et al., 2002). They also have gendered stereotypes about clothing and activities, and label their own and others' genders (Campbell et al., 2002; Serbin et al., 2001; Zosuls et al., 2009).

To what extent can toddlers make use of gender cues for incremental language processing? It is possible that, such as adults and children, toddlers exploit gender cues to facilitate real-time language processing. Unlike many of the other cues used for incremental language processing, speaker-gender cues are highly familiar to toddlers and do not require extensive linguistic knowledge. However, it is currently unknown whether toddlers' knowledge about male and female vocalizations influences their real-time word recognition for masculine- and feminine-designed objects.

This study was designed to test the hypothesis that toddlers exploit speaker gender cues during incremental language processing based on their knowledge of stereotypical male and female preferences. On each trial, toddlers saw a pair of objects from a highly familiar category and heard the speaker ask for a target item. The manipulation consisted of the match/mismatch between the gender of the speaker and the gendered design of the objects. Note that rather than using objects drawn from gendered categories (e.g., a female purse and a male tie), we used objects such as shoes and coats that are not inherently gendered but can be designed to appear gendered through features such as color and pattern (Van Tilburg et al., 2015). This methodological choice allowed us to focus on toddlers under age 2, who do not typically understand words such as *purse* and *tie* but do know *shoe* and *coat* (Frank et al., 2017). Half of the trials were Consistent: The speaker's gender matched the prototypical gender design of the target object. The other half of the trials were Inconsistent: The speaker's gender mismatched the prototypical gender design of the target object. Each object pair included one prototypically female object

and one prototypically male object. We predicted that the speaker's gender would lead toddlers to anticipate the gender-matched object prior to the onset of the target word. We also predicted that word recognition would be more accurate on Consistent (gender-matched) trials than on Inconsistent (gender-mismatched) trials. The hypotheses and analytic approaches were pre-registered (https://osf.io/rt5u2/?view_only=de293ab76079429ca9dd279f4ae2449d).

2 | METHOD

2.1 | Participants

Thirty-eight full-term, monolingual English-learning toddlers (24 female) with a mean age of 22;9 months (22;0–24;0) were included in the analyses (35 White; 3 Multiracial). We selected this age based on literature suggesting Western children are aware of gender categories by the end of their second postnatal year (Campbell et al., 2002; Zosuls et al., 2009). Children were reported to have no history of developmental concerns, hear fewer than 10 h/week of another language, were currently free of ear infections, and lived in a household with both a male and female caregiver. The present study was conducted according to Declaration of Helsinki guidelines, with written informed consent provided by caregiver/guardian prior to any data collection. All procedures involving human subjects in this study were approved by the Education and Social/Behavioral Science Institutional Review Board at the University of Wisconsin - Madison.

2.2 | Materials

Caregivers completed a child-environment questionnaire and the MB-CDI Level 2 Short Form (Fenson et al., 2000) vocabulary production checklist. Caregivers also reported whether their child understood all the target words in the study; all children understood at least 9 of the 10 words.

We selected nouns/objects that (a) could be designed to appear either prototypically female or male, and (b) that are highly familiar to toddlers of this age (Frank et al., 2017; Table 1). Each stimulus consisted of two sentences: a carrier phrase with the target noun in the final position (e.g., *Can you find the cup?*) followed by an attention-getter phrase (e.g., *I like that!*; Table 2). Auditory stimuli were recorded using infant-directed speech by one male and one female native English speaker. Carrier phrases were edited using Praat to match in duration (1100 ms) and intensity (65 dB). Target words were not matched for duration to avoid distortion due to varied lengths (i.e., *bib* v *toothbrush*). Each word served as the target in both conditions, so the average word lengths across conditions were identical. The average F0 was 239.58 Hz (SD = 70.39) for the female speaker and 170.92 Hz (SD = 87.03) for the male speaker.

Prototypically gendered familiar objects were edited to match in size. Pictures were selected for gender prototypicality using a forced-choice sorting task with 3- to 5-year-olds ($n = 38$). During norming, children saw 72 images of children's items from online retailers marketed as "for girls" or "for boys." Children were asked to judge whether the object belonged to a boy or a girl. We selected items that at least 75% of the children sorted as belonging to a boy or a girl (boundary pre-determined by the researchers). Objects were yoked into 5 pairs that included a prototypically male and a prototypically female object (Figure 1). We attempted to match

TABLE 1 MB-CDI comprehension norms for study target words

Noun	Percentage of children reported to understand at 18 months
Bib	76%
Hat	85%
Pajamas	83%
Shirt	74%
Shoe	99%
Sock	94%
Bowl	79%
Cup	93%
Toothbrush	92%
Coat	80%

Note: Norms retrieved from Wordbank (Frank et al., 2017).

TABLE 2 Study carrier phrases and attention getters

Carrier phrases	Attention getters
Where's the XXXX	I like that!
Can you find the XXXX	That's cool!
Do you see the XXXX	Check that out!
	Wow!

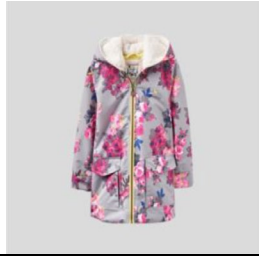
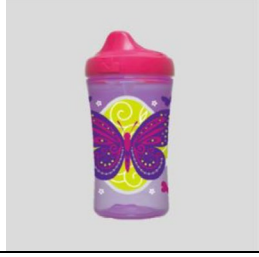
Note: XXXX denotes target word.

objects within pairs for visual salience based on looking-time data for the objects presented in silence, collected during a pilot study. Each object/word occurred equally as often as target and distractor.

2.3 | Procedure

Participants were tested using a Tobii X2-60 eye tracker using a 60 Hz sampling rate. This eye tracker allows a participant to be 40–90 cm from the eye tracker with a head-movement range of 50–36 cm. Participants sat on their caregiver's lap approximately 1m from the screen (140 cm Toshiba LCD monitor) and 60 cm from the eye tracker. Visual angle was approximately 36° from screen center. We used a 2-large-AOI design in which fixations are either left, right, or neither (Fernald et al., 2008). The eye tracker was calibrated using a 5-point calibration procedure (red pulsing dots with an attention-grabbing noise). Caregivers wore darkened glasses to minimize bias. Each session was video-recorded as a backup at 30 frames-per-second. For 8 toddlers

FIGURE 1 Yoked object pairs and forced-choice norming task ratings. Note: Each yoked pair contained a prototypically feminine and masculine object, as sorted via a norming task with 3- to 5-year-olds. Percent of children that rated the object as belonging to a girl (feminine) or belonging to a boy (masculine), respectively, is presented

Feminine Object	Forced-Choice Task Rating	Masculine Object	Forced-Choice Task Rating
Shirt 	78.9%	Hat 	76.3%
Coat 	84.2%	Bowl 	76.3%
Sock 	94.7%	Bib 	78.9%
Shoe 	94.7%	Pajamas 	76.3%
Cup 	78.9%	Toothbrush 	78.9%

whose eye-tracking data were incomplete due to excessive movement ($n = 2$) or poor calibration ($n = 6$), data were hand-coded by coders unaware of target side and condition using custom software (iCoder). The mean percentage of all frames on which coders agreed on fixation location was 94.9%, and the mean percentage of shifts in fixation location on which coders agreed within one frame was 98.4%.

Word comprehension was assessed using the Looking-while-Listening procedure. On each trial, two pictures of familiar objects were displayed simultaneously in silence for 1500 ms. Toddlers then heard speech from a male or female speaker labeling one of the objects in a carrier phrase (1100 ms) ending in the target noun. On Consistent trials, the gender of the speaker's voice matched the prototypical gender of the target object. On Inconsistent trials, the speaker's voice mismatched the prototypical gender of the target object. There were 20 test trials (10 Consistent and 10 Inconsistent); half were voiced by a female and half by a male. The same set of target words and objects occurred across trial type.

3 | RESULTS

There were two pre-registered analysis windows of interest. The *Anticipatory window* (800 ms) included the time frame from 300 ms after the onset of the speaker's voice to the onset of the target word. Looks during this time period reflect visual attention as a function of the objects and speaker's voice, but not the target word (which had not yet been heard). The *Post-Target-Onset window* began 300 ms after the onset of the target word and ended 1800 ms after target word onset (Fernald et al., 2008). Looks during this time period reflect lexical processing. If a child does not look at the screen for at least 50% of a trial, it suggests inattention; therefore, for a trial to be included in the analyses, at least 50% of its frames must have included looks to either the target or distractor object. This was inadvertently omitted from the preregistration but occurs across eye-tracking literature (Borovsky & Creel, 2014; Fernald et al., 2010). Out of 20 total trials, toddlers contributed an average of 17.8 useable trials (9.0 Consistent, SD = 1.3; 8.8 Inconsistent, SD = 1.35). All analyses were conducted in RStudio (version 1.2.1335; R Core Team, 2019) using the lme4 package (version 1.1-21; Bates et al., 2015).

Our first hypothesis was that toddlers would fixate the object that matched the speaker's gender during the Anticipatory window (−800 to 0 ms), prior to the onset of the target word. We estimated a linear-mixed effects model in which we regressed proportion of looking time to the target onto trial condition (contrast coded, −0.5 = Inconsistent and 0.5 = Consistent), including a by-subject random intercept and a by-subject random slope for trial type. Participant-looking behavior is plotted in Figure 2. There was not a significant difference in anticipatory looking to the target on Consistent trials (M = 48.6%, SD = 15.5%) compared with Inconsistent trials (M = 46.9%, SD = 15.1%). The within-subject effect of trial type was not statistically significant [beta = .02, $F(1,37) = 0.24$, $p = .62$] (Figure 3).

Our second hypothesis was that toddlers would fixate the object that matched the speaker's gender during the Post-Target-Onset window (300–1800 ms). We estimated a linear-mixed-effects model. As predicted, toddlers were significantly more accurate in fixations to the target on Consistent trials (M = 66.9%, SD = 16%) than Inconsistent trials (M = 61.2%, SD = 12.4%) post-target onset. The within-subject effect of trial type was statistically significant [beta = .06, $F(1,37) = 5.75$, $p = .02$]. These results indicate that gender-matched voices facilitated toddlers' lexical processing.

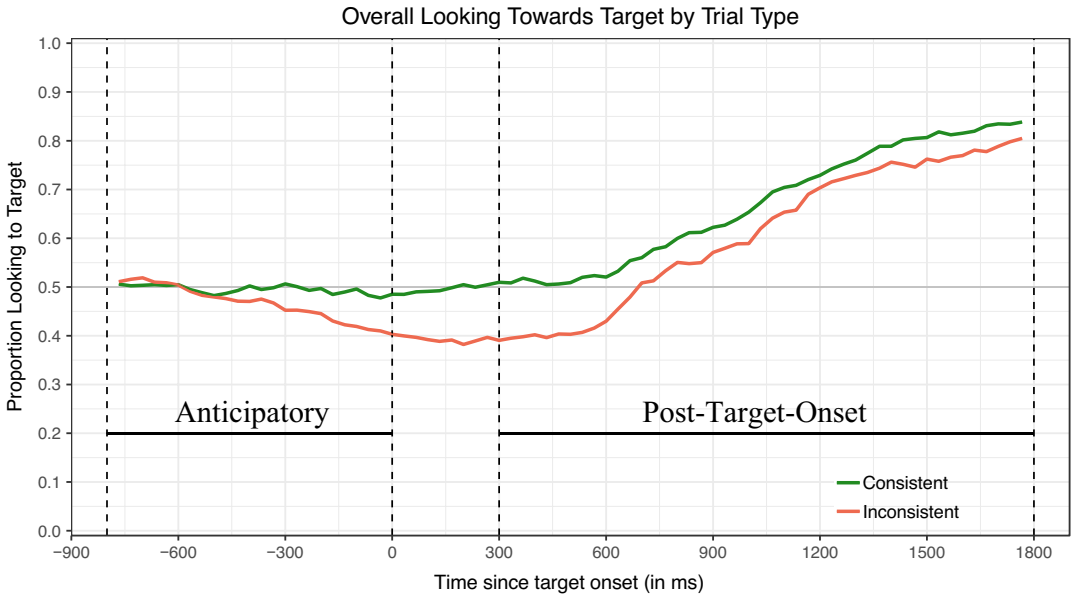


FIGURE 2 Overall Time course Fixations by Condition Across Analysis Window. Note: Time course from the onset of spoken language to the end of the target window for Consistent and Inconsistent trials. Anticipatory window from −800 ms to 0 ms. Target word onset is at 0 ms. Post-Target-Onset window from 300 ms to 1800 ms

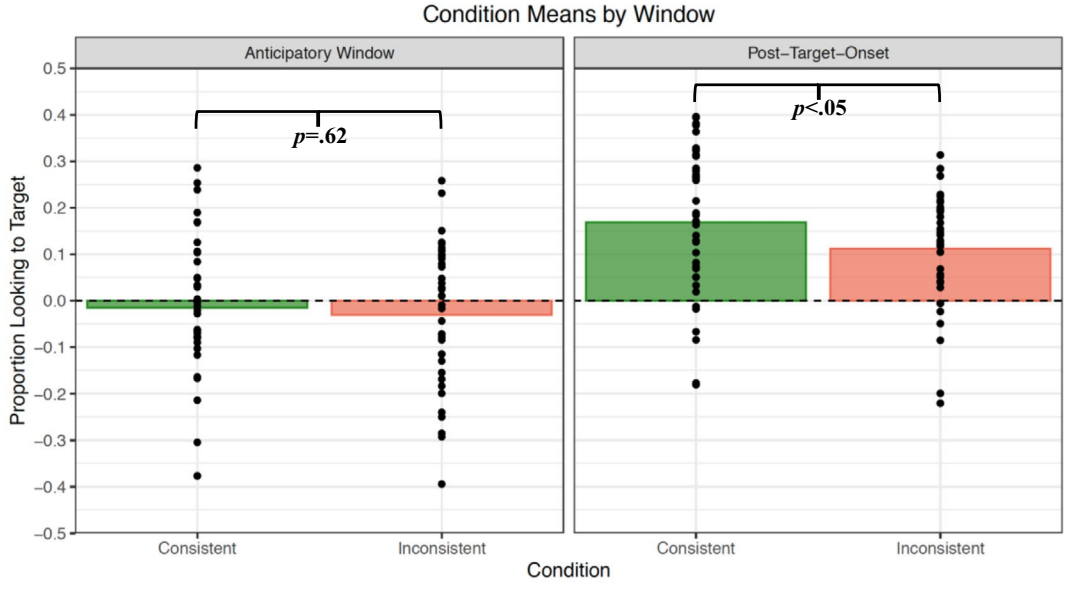


FIGURE 3 Condition Means for Anticipatory and Post-Target-Onset windows. Note: Proportion looks to the target is on the *Y*-axis. The dashed line indicates 50% accuracy (chance). Each point denotes an individual participant

4 | DISCUSSION

Comprehenders are faced with myriad speech cues, including those that provide social information such as dialects, accents, and speaker gender. This variability leads to both challenges and

opportunities. Language users have differing amounts of experience with speech cues and draw on that experience to capitalize on the rich information these cues can provide individually and combinatorially. Some cues co-occur more than others, and the environments an individual has experienced impact the statistics of cue co-occurrence and reliability. In this study, we asked whether toddlers combine cues from speaker gender and visual attributes of objects during lexical processing. We predicted that toddlers would utilize speaker gender as a cue in combination with the object attributes on each trial.

Contrary to our first hypothesis, toddlers did not use the speaker's gender to predict the upcoming target object during the Anticipatory window. One reason for the lack of significant difference across trial types may be that toddlers heard only 1000 ms of speech prior to target word onset ("*Do you see the...*"). More speech prior to target word onset might have given toddlers additional time to process the speaker and object cues in tandem. Speech that indicated speaker interest in or ownership of an object ("*Look, that one is mine! Do you see the...*") could be particularly informative (e.g., Creel, 2012). Future work will investigate whether additional contextual information leads to the greater use of speaker gender for anticipatory fixations.

Supporting our second hypothesis, lexical processing was facilitated when the speaker's gender matched the gender of the target object. Well before they can reliably label the gender of themselves or others, toddlers can integrate speaker and object gender cues during incremental language processing. The difference in performance between the two conditions was driven by the first half of the Post-Target-Onset window, potentially due to lagging use of the speaker voice cue from the Anticipatory window. We also found that toddlers did not reach the same level of accuracy between conditions at the end of the Post-Target-Onset window. This may be another indication that the speaker voice cue is disrupting toddlers' fixations to the target in the Inconsistent condition. In future studies, we will manipulate the reliability of the speaker voice to attempt to shift the direction of disruption in infant performance.

The current study provides the first evidence that toddlers utilize speaker gender in combination with object attributes during online language processing. These results are consistent with findings suggesting that toddlers are sensitive to other types of social cues available via perceptual information, such as speaker race (via facial cues), in generating expectations during language processing (e.g., Weatherhead & White, 2018). This emerging literature suggests that toddlers can be a key into perceptual cues about social categories during language comprehension well before they are able to use social category information for other purposes, such as language production (e.g., labeling the genders or races of themselves or others). Further investigation is warranted to understand when this ability becomes adult-like, as well as the consequences of this processing skill, including how it impacts the learning of novel word/object pairs. For example, do toddlers integrate gender information in their representations of novel word meanings? It is also plausible that environmental factors, such as childcare settings or siblings, impact the degree to which toddlers exploit gender during online language processing (e.g., Havron et al., 2019; Soderstrom et al., 2018). These influences may be linked to both gender and language development in ways not yet understood, interacting with one another to affect toddlers' ability to attend to and exploit gender information during online language processing.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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