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Power mediates the processing of gender during sibilant categorization

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Prior studies suggest that listeners are more likely to categorize a sibilant ranging acoustically from [ʃ] to [s] as /s/ if provided auditory or visual information about the speaker that suggests male gender. Social cognition can also be affected by experimentally induced differences in power. A powerful individual's impression of another tends to show greater consistency with the other person's broad social category, while a powerless individual's impression is more consistent with the specific pieces of information provided about the other person. This study investigated whether sibilant categorization would be influenced by power when the listener is presented with inconsistent sources of information about speaker gender. Participants were experimentally primed for behavior consistent with powerful or powerless individuals. They then completed a forced choice identification task: They saw a visual stimulus (a male or female face) and categorized an auditory stimulus (ranging from 'shy' to 'sigh') as /ʃ/ or /s/. As expected, participants primed for high power were sensitive to a single cue to gender, while those who received the low power prime were sensitive to both, even if the cues did not match. This result suggests that variability in listener power may cause systematic differences in phonetic perception.

1. Introduction

Listener-specific sources of variability can shape linguistic perception. Significant work has been undertaken to outline the effect of differences in cognitive processing—including working memory (e.g., Swets, Desmet, Hambrick, & Ferreira, 2007; Yu, Grove, Martinovic, & Sonderegger, 2011), executive function (Kim & Hazan, 2010; Kong & Lee, 2018), and autistic-like traits (e.g., Yu, 2010; Yu et al., 2011; Yu, Abrego-Collier, & Sonderegger, 2013; Jun & Bishop, 2015)—and neurophysiological differences (e.g., Díaz, Baus, Escera, Costa, & Sebastián-Gallés, 2008; Tettamanti et al., 2005) on linguistic processing. These domains of variability can specifically affect how listeners make use of contextual information during speech perception.

Differences in social cognition may also serve as a source of variability in linguistic processing. Phonetic perception is sensitive to the listener's expectations about the speaker, which depend on a variety of factors including the listener's experiential history with the speaker, the speaker's perceived social identities, and expectations rooted not specifically in the speaker but in people who share their identities. With new information, the listener can strengthen or revise earlier expectations about the speaker's behavior; they may also become correspondingly more or less likely to perceive certain linguistic variables with socioindexical value (e.g., Bouavichith et al., 2019). If individuals vary in how they attend to and integrate social information about a speaker, the outcome of phonetic perception may in turn differ for different listeners.

Power is a factor associated with precisely this kind of variability—powerful and powerless individuals have been shown to differ in social cognition. It also behaves somewhat differently than some of the listener-specific sources of variability described earlier. Differences in power, understood in this study as "an individual's relative capacity to modify others' states by providing or withholding resources or administering punishments" (Keltner, Gruenfeld, & Anderson, 2003) are not fixed for any individual independent of context. This experiment details one mechanism by which power may be able to influence phonetic categorization.

The experimental treatment of power in this study is not isomorphic with the modes by which power manifests in naturalistic settings. In dyadic interactions, people transition seamlessly between powerful or powerless positions according to the situation and the individuals involved. Similarly, certain roles or social groups within a community may be afforded differential degrees of power. This study uses a priming task to induce behavior consistent with a powerful or powerless individual, and the linguistic task does not provide a grounding naturalistic context that relates to the priming task. While this study fails to recreate the necessary context to precisely understand the relationship between power and affect linguistic perception, it offers a concrete step toward addressing this question, which may ultimately provide insight into how differences in power among groups may contribute to differences in linguistic performance.

1.1. The role of speaker gender in sibilant perception

The speech of men and women tend to differ from one another along several acoustic dimensions. With respect to female adult speakers of General American English, adult male speakers tend to: have a lower fundamental frequency (Hillenbrand, Getty, Clark, & Wheeler, 1995), produce vowels with lower formant frequencies (Huber, Stathopoulos, Curione, Ash, & Johnson, 1999), produce [d] and [t] with shorter voice-onset time (Swartz, 1992), produce [s] and [ʃ] with a lower peak frequency (Schwartz, 1968), produce [l] with lowered second formant (Stevens & Blumstein, 1994), and use less non-modal phonation (Podesva, 2011). There may not be a single originating cause for these phonetic differences. Physiology may help to explain some differences in the productions of cisgender men and women, but differences across men and women more generally may reflect behaviors associated with speaker identity. Fuchs and Toda (2010), outlining the effect of anatomical factors on the production of English speakers in the UK, found that palate and front cavity length were all significantly correlated with the center of gravity of [s]. However, this finding did not fully explain gender differences in production. Even with the physiological variables under study factored out, women still tended to produce [s] with a more front articulation and shorter front cavity. Spectral differences in sibilant production according to gender are also not universally observed across speaker communities; Calder and King (2020), for example, found no difference in the center of gravity of [s] according to gender among African American residents of Bakersfield, California. Such a result also suggests that physiology alone may not provide sufficient explanation for differences in sibilant production among men and women. Finally, a family of studies underscore the presence of a social component in [s] production more generally—[s] has been found to vary among populations of English speakers according to age, gender expression, regional affiliation, sexuality, and socioeconomic class (Munson, Jefferson, & McDonald, 2006; Stuart-Smith, 2007; Hazenberg, 2012; Podesva & Van Hofwegen, 2014; Zimman, 2017).

Listeners are sensitive to these patterns of phonetic variability. For example, Schwartz (1968) and Ingemann (1968) both found a perceptual result analogous to the tendency for men who speak General American English to produce [ʃ] and [s] with a lower peak frequency than women. Both authors found that participants were able to identify the gender of the speaker at a rate well above chance by listening to isolated productions of [ʃ] and [s]. Strand and Johnson (1996) also showed that speech perception could be sensitive to information about speaker gender. A continuum of consonants ranging from [ʃ] to [s] were more likely to be categorized as /s/ if the following vowel sounded male and if a voice non-prototypical of their gender was played in synchrony with video of a male face. The effect of gender on sibilant categorization has since been replicated in several studies (Munson et al., 2006; Munson, 2011; Winn, Rhone, Chatterjee, & Idsardi, 2013; Munson, Ryherd, & Kemper, 2017; Bouavichith et al., 2019).

In contrast to the approach taken by Strand and Johnson (1996), this effect can be observed even if the participants listen to sibilant-initial syllables where the vowel has been acoustically manipulated. In Munson (2011) and Munson et al. (2017), fundamental frequency and formant spacing were modified to produce speech that sounded more male or more female. The exact methodology differed across these studies: In Munson (2011), the peak frequencies of the male and female voices were both adjusted to 135 Hz, a value intermediate between the two. The formant spacing for the voices took on one of two values—one associated with shorter apparent vocal tract length and one with a longer vocal tract length. Munson et al. (2017) used listener judgments to identify a gender-neutral sounding voice, and this voice was ultimately achieved by a moderate change in fundamental frequency and formant spacing. In Bouavichith et al. (2019), fundamental frequency and formant spacing were manipulated together, forming a continuum ranging from an unmodified male or female voice to a maximally modified version of each voice.

Listeners appear to respond differently to different sources of information about speaker gender during the task of categorization. In Munson (2011), listeners were more likely to categorize a sibilant ambiguous between [ʃ] and [s] as /s/ when a male or female voice was paired with a male face, but only for one formant spacing parameter. Informational source also played a role in the results of Winn et al. (2013). When participants with normal hearing heard unprocessed speech, they were more likely to categorize a sibilant as /s/ according to auditory information about gender, but not according to visual information about gender. However, the effect of visual information on participant response was larger than that of auditory information when participants with cochlear implants listened to unprocessed speech and when participants with normal hearing listened to vocoded speech. Finally, Munson et al. (2017) observed qualitatively different effects according to whether participants received visual information about the speaker (i.e., a picture of a male or female) or whether the utterance included gendered names or content stereotypically associated with a single gender. Taken together, these results suggest that sources of gender information do not function interchangeably. Listener responses may give preference to one informational channel over another depending on the reliability of that cue within the context of the task.

1.2. Power and social cognition

This study investigates how variability in perceived power can influence the processing of social information during phonetic perception. This paper adopts the definition of power formalized in Keltner et al. (2003)—"an individual's relative capacity to modify others' states by providing or withholding resources or administering punishments." This description backgrounds several aspects of power, including its distribution among individuals, the circumstances that allow it to be acquired, the precise means by which it is gained, and whether an individual takes concrete action to wield power over another. Instead, this description highlights the effect that the perception of control (or a lack of control) can have on an individual's cognition and behavior.

In this way, the definition proposed by Keltner et al. (2003) provides a useful framing for power as a source of listener variability as studied in linguistics.

Power distinguishes itself from several other previously studied sources of inter-listener variability. One's degree of power is conditioned on factors intrinsic to the speaker—an individual's physiology and personality—as well as extrinsic factors—material possessions, the people with whom an individual interacts, the social role(s) an individual occupies, their social standing, and their social identities. This inherent dynamism places power in contrast with sources of interpersonal variability described as 'individual differences.' Neurophysiological differences and cognitive processing style, for example, can be characterized as enduring traits for a single individual, and contextually independent. In contrast, power is highly dependent on circumstance, though constrained in part by the individual.

Power affects how individuals process social information. Individuals experimentally assigned to a powerful role within the context of a study attend to information about others for less time, both generally (S. A. Goodwin, 1993) and when this information is inconsistent with the other person's social category (S. Goodwin & Fiske, 1995; Dépret & Fiske, 1999; S. A. Goodwin, Gubin, Fiske, & Yzerbyt, 2000; Rodríguez-Bailón, Moya, & Yzerbyt, 2000). In contrast, powerless individuals appear to attend more to information inconsistent about the other's social category (Erber & Fiske, 1984; S. A. Goodwin et al., 2000). Impression formation also varies according to power. The assessments of others by powerful individuals may be less accurate (Ebenbach & Keltner, 1998) and are also more likely to reflect category-level information about the other while those of powerless individuals reflect attention to individuating features about the person (S. A. Goodwin et al., 2000; Guinote & Phillips, 2010; but see Ric, 1997). Analogously, the impressions of powerless individuals also tend to weight contextual information more heavily (Pittman & D'Agostino, 1989). In S. A. Goodwin et al. (2000), participants completed a task in which they played a powerful or powerless role. The participants' subsequent impressions of other target individuals tended to correlate most closely with the target's college major for participants who were assigned the powerful role. Impressions correlated most strongly to the student's individual traits when the participant assumed a powerless role. However, powerful individuals do not necessarily perform less accurately on tasks that specifically rely on attention to individuating information. Overbeck and Park (2001) found that powerful participants were better able to identify individuals than powerless participants.

Researchers have outlined several possible routes by which power may mediate social cognition. The processing style associated with powerful individuals may reflect increased cognitive load associated with their position (Fiske, 1993); such an account would be consistent with the tendency for individuals to engage in category-level processing when performing a complex social evaluation (Bodenhausen & Lichtenstein, 1987) or a task that is mentally taxing (Gilbert & Hixon, 1991). Conversely, the processing style of powerless individuals may be due in part to external motivation. This account is described intuitively by Fiske (1993, p. 24): "People pay attention to those who control their outcomes. In an effort to predict and possibly influence what is going to happen to them, people gather information about those in power." Effective analysis of one's environment may be especially beneficial in situations where the individual lacks control of their environment. Mood may also play a role in the cognitive processing associated with powerful individuals. Powerful individuals are more likely to show behavioral measures consistent with positive mood (Hecht & LaFrance, 1998; Anderson & Thompson, 2004), and participants primed for positive mood were more likely than controls to form an impression consistent with the other's person category (Bodenhausen, Kramer, & Süsser, 1994). Asymmetries in perceived social distance may cause powerful individuals to process social information in a more abstract manner than powerless individuals (Smith & Trope, 2006; Magee & Smith, 2013). Finally, differences in processing may have a neurochemical component. Individuals who produced powerful (i.e., expansive, open-limbed) poses tend to experience a significant increase in testosterone and decrease in cortisol levels, while individuals who produced powerless poses experienced the opposite (Carney, Cuddy, & Yap, 2010).

1.3. Power and linguistic processing

The role of power in linguistic processing has received little experimental study thus far. Dimov, Katseff, Johnson, Sabater, and Recasens (2012) found that participants who scored higher (indicating a higher degree of self-reported power) on the "Power-Powerlessness" sub-score of an empowerment questionnaire (Rogers, Chamberlin, & Ellison, 1997) showed less acoustic change in response to altered auditory feedback. The author offered several potential explanations for this result, including a tendency for powerful individuals to demonstrate reduced behavioral self-awareness, which has been observed in non-linguistic behavioral tasks (e.g., Ward & Keltner, 1998). In Uskul, Paulmann, and Weick (2016), participants with a higher score on the "Sense of Power Scale" (Anderson & John, 2012) were worse at identifying emotion from intonational information than participants with a lower score. Furthermore, participants who completed a priming task (from Galinsky, Gruenfeld, & Magee, 2003) to induce behavior consistent with powerful individuals tended to perform worse in the same task than individuals primed for behavior consistent with powerless individuals. This result is consistent with Galinsky, Magee, Inesi, and Gruenfeld (2006), which found that individuals primed for powerful behavior tended to identify the emotions of others less accurately. Ongoing research also suggests that individuals primed for low power may be more likely to diverge from their interlocutor in a conversational setting (Lutzross, Cheng, Shen, Wilbanks, & Mirzaagha, 2018).

This study synthesizes the literatures on the influence of speaker gender on sibilant categorization and on the effects of power on social cognition by addressing whether power can act as a source of systematic variability in phonetic categorization when socioindexical context is relevant. It also offers additional insight into which linguistic domains can be affected by differences in power. In this study, listeners, provided with auditory and visual sources of information about speaker gender, categorized an ambiguous sibilant as /ʃ/ or /s/. In similar studies where participants performed sibilant categorization while being provided with multiple cues to speaker gender (e.g., Munson, 2011; Winn et al., 2013), the effect size and significance level of each informational source tended to depend on the participant population and task. I predict that the weighting of each cue will also depend on the listener's degree of power. Consistent with S. A. Goodwin et al. (2000) and Guinote and Phillips (2010), powerful listeners are predicted to adopt a categorization strategy that tracks with a single cue to a speaker's social category and poorly accommodates multiple inconsistent sources of information about this category. In contrast, powerless listeners are expected to adopt a strategy sensitive to multiple cues to speaker gender even if they are mutually inconsistent with one another.

2. Methodology

2.1. Participants

Forty-four University of Michigan undergraduates were recruited for this study. All participants described themselves as native speakers of American English with no known hearing deficits. One additional participant was recruited for the study, but their results were excluded from analysis because they had not grown up in environment where an American English variety was predominantly spoken. Participants were compensated according to the length of time they were involved in the study ($10 USD for 0–60 min, and $15 for 60–90 min).

2.2. Stimuli

During this study's identification task, participants were co-presented with auditory and visual stimuli. Auditory stimuli were two nine-step continua of words ranging from 'shy' to 'sigh.' Each stimulus was constructed by splicing together a fully synthesized sibilant and an acoustically manipulated naturally produced vowel.

The continuum of sibilants (ranging from [ʃ] to [s]) was synthesized in PRAAT (Boersma & Weenik, 2021) using the KlattGrid speech synthesizer. The synthesis parameters (listed below in **Table 1**) match those used in Strand and Johnson (1996) and Munson (2011). The fricative formant frequencies for each step were spaced evenly along Bark scale. Initially the fricative steps were generated with equal intensity. However, during piloting listeners reported that the high peak frequency sibilants were too loud, and that spliced syllables formed with these sibilants sounded less word-like than the sibilants created from a lower peak frequency sibilant. Consequently, fricative intensities were altered so that the most [s]-like step had a lower intensity than the most [ʃ]-like step. Munson (2011) also performed a similar manipulation on their synthesized sibilant, though for independent reasons. Power spectrum densities for the most [s]-like and most [ʃ]-like steps are visualized below in **Figure 1**.

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9
F_3(*Hz*)	2466	2838	3265	3754	4314	4954	5689	6530	7500
F_4(*Hz*)	3108	3573	4107	4717	5417	6219	7137	8191	9405
Intensity (dB)	72	72	70	70	68	68	67	67	67

Table 1: Klatt Synthesizer parameters and token mean intensities for sibilant continuum.

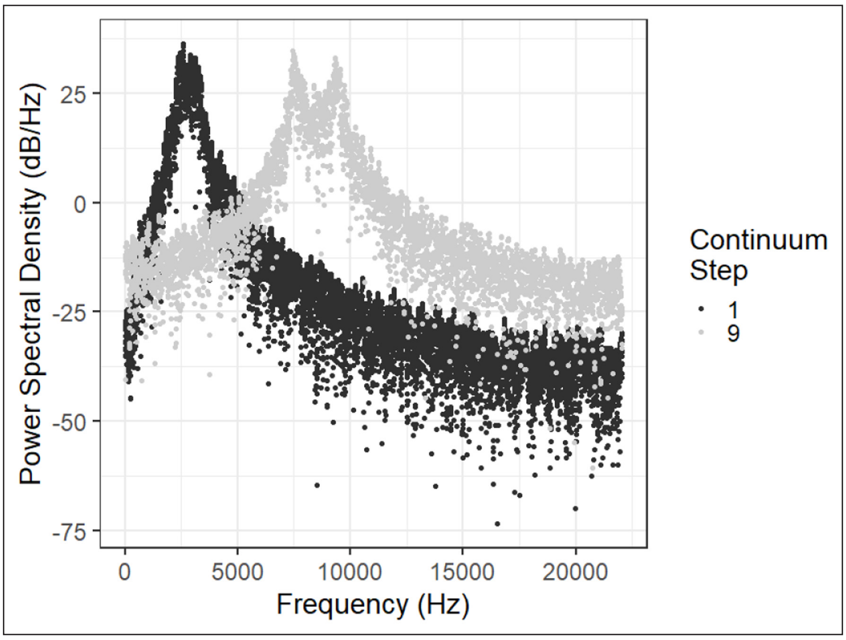

Figure 1: Spectral slices for sibilant step 1 (most /ʃ/-like) and sibilant step 9 (most /s/-like).

Two vowels ([aI]) were extracted from recordings of 'sigh' produced by native speakers of American English. One speaker, a 28-year-old, white, middle-class, straight, cis woman, grew up in Southern California, while the other, a 31-year-old white, middle-class, gay, cis man, grew up in Utah. Recordings were made with an AKG P420 microphone in a sound-attenuated booth, and the target word was embedded in the carrier phrase "Say 'sigh,' sir." As discussed in Section 1.1, listeners show sensitivity to visual information about speaker gender during sibilant perception when auditory cues suggest non-prototypical gender. Accordingly, the vowels were modified to reduce gender prototypicality, an alteration which finds precedent in prior studies investigating the effect of auditory and visual information about speaker gender on identification. Strand and Johnson (1996) paired a face image with a speaker whose voice was rated non-prototypical of their gender, while Munson (2011), Munson et al. (2017), and Bouavichith et al. (2019) paired faces with voices acoustically altered to reduce the acoustic cues associated with gender. This manipulation has been shown to be sufficient to allow visual gender information to modulate the outcome of identification, but further research is needed to determine whether this manipulation is in fact necessary. Perhaps a highly incongruous cue pairing (e.g., a prototypically male voice paired with a female face) is less able to modulate linguistic processing than a less incongruous cue pairing (a non-prototypically male voice paired with a female face), but this result has not yet been shown.

The mean fundamental frequency of the resynthesized vowels was 135 Hz, the geometric mean of the fundamental frequency of the male and female speakers' vowels (95 Hz and 195 Hz, respectively). Similarly, formant dispersion was manipulated in each voice to achieve an apparent vocal tract length of 16.2 cm. This value was the approximate geometric mean of the apparent vocal tract lengths of the two speakers as estimated using the third formant of the vowel center of [aI]. The final formant values for each vowel are listed below in **Table 2**. Both modifications were performed in PRAAT.

	Male Voice		**Female Voice**	
	/a/ (20% of V duration)	**/I/ (80%)**	**/a/ (20%)**	**/I/ (80%)**
F_1(*Hz*)	980	480	900	410
F_2(*Hz*)	1470	2180	1550	2270
F_3(*Hz*)	2580	2420	2510	2880

Table 2: Formant values for acoustically modified /aI/ at 20% and 80% of vowel duration.

The visual stimuli (shown in **Figure 2**) for the identification task were a male and female face from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015). At the time of designing this study, this corpus consisted of photographs of 158 individuals varying in age, gender, and race. A subset of these images was rated by participants with respect to masculinity, femininity, and racial prototypicality (among other variables). Several of the subjective measures reported for

Figure 2: Visual stimuli for Section 2.2—the male (left) and female (right) face, Chicago Face Database (Ma, Correll, & Wittenbrink, 2015).

the faces in **Figure 2** can be found in **Table 3**. The two faces selected for this study were rated similar in age and were both highly likely to be evaluated as being of the same race. Although the male and female faces were equally consistently categorized as male or female, respectively, the male face received more intermediate masculinity and femininity ratings than the female face.

	Male Face	**Female Face**
Perceived Age	26.1	27.8
Likelihood of being categorized as white	0.97	0.97
Likelihood of being categorized as male	1.00	0.03
Likelihood of being categorized as female	0.00	0.97
Masculinity (7 – Extremely Masculine)	3.31	1.45
Femininity (7 – Extremely Feminine)	2.03	5.31

Table 3: Subjective measures for the visual stimuli (as reported by the Chicago Face Database).

2.3. Procedure

This study, conducted in the Phonetics Laboratory at the University of Michigan, was composed of several tasks. Participants were first experimentally primed for a high or low degree of self-perceived power. They then completed a task verifying the effectiveness of the prime, an identification task, and finally a questionnaire about their language history. All tasks in this study were self-paced; after the participant completed an informed consent form, they were given a folder containing the instructions for each task, and they completed them in the order given.

2.3.1. Priming task I – writing prompt

Participants were randomly assigned to a 'high power' or 'low power' priming condition. All participants hand-wrote a one-page response to one of two writing prompts, listed below.

> *Writing prompt (high power condition)*
> Please recall a particular incident in which you had power over another individual or individuals. By power, we mean a situation in which you controlled the ability of another person or persons to get something they wanted or were in a position to evaluate those individuals. Please describe this situation in which you had power—what happened, how you felt, etc.
>
> *Writing prompt (low power condition)*
> Please recall a particular incident in which someone else had power over you. By power, we mean a situation in which someone had control over your ability to get something you wanted or was in a position to evaluate you. Please describe this situation in which you did not have power—what happened, how you felt, etc.

In previous studies where this priming task was used (e.g., Galinsky et al., 2003; Galinsky et al., 2006; Magee, Galinsky, & Gruenfeld, 2007; Uskul et al., 2016), participant performance in certain downstream tasks could be predicted by the priming task they completed. The behavior of those completing the high power prime tends to align more closely with the predicted or observed behavior of a powerful individual while the behavior of those completing the low power prime tended to align with that of a powerless individual. Accordingly, participants' behavior in the Prime Effectiveness Task (Section 2.3.3) and Identification Task (Section 2.3.4) are predicted to be sensitive to the priming task they completed.

2.3.2. Priming task II – money allocation

Participants then completed a second task designed to reinforce the effect of writing assignment. In this task, adapted from Galinsky et al. (2006), participants must either decide how much money to give to a future study participant (in the high power condition) or how much a previous participant allocated to them (in the low power condition). The two behavioral prompts for this task are listed below.

> *Money allocation (high power condition)*
> You and the next participant have the chance to earn up to ten additional dollars during this study. You have the option to keep some or all of this additional money for yourself, and whatever amount you don't keep will go to the next participant. The next participant will not know who gave this money to him or her, just the amount they received. Please take some time to decide how much money you wish to give to the next participant and provide an answer in the space below.

> *Money allocation (low power condition)*
> You and the previous participant have the opportunity to earn up to ten additional dollars during this study. The other participant received ten dollars. They had the option to keep some or all of this money for himself or herself and the remaining amount will go to you. Please estimate how much money you think this other participant allotted for you.

Each participant hand-wrote their response on the same sheet of paper as the prompt. As noted in Section 2.1, however, participants were in fact compensated solely according to the time spent in the study. They were informed of this act of deception after the study's completion.

2.3.3. Prime effectiveness task

A task (from Magee et al., 2007) was assigned to independently verify the efficacy of the power prime. Because powerful individuals tend to "initiate and move first in competitive interactions" (Magee et al., 2007, p. 207), participants in the higher power condition are expected to be more likely to negotiate than participants in the low power condition. In this task, participants responded to the prompt below by choosing a value on a Likert scale, ranging from one (not at all likely) to five (very likely).

Prime effectiveness prompt
You are buying a new car. How likely would you be to negotiate the price?

2.3.4. Identification task

Participants completed a two-alternative forced-choice identification task. It was designed using the SuperLab 4.5 experimental software and was run on a MacBook Pro in a sound-attenuated booth.

At the start of each trial, a visual stimulus (an image of a male or female face) appeared in the center of the screen; it remained onscreen for the duration of the trial. Five hundred milliseconds after the start of the trial, the two response choices—'sigh' or 'shy'—appeared on the screen, vertically centered and spaced equidistant from the vertical axis; these words then remained on the screen for the duration of the trial. The relative positioning of each response choice was randomized across participants but was fixed for each participant throughout the task. Responses were recorded on a Cedrus-730 button box. The left and right buttons on this button box are colored red and green, respectively, so the left and right response choices on the screen were colored correspondingly. One thousand ms after the start of the trial, an audio stimulus (a word ranging from 'shy' to 'sigh') was played over AKG K271 MK II headphones. Participants then pressed the button on the button box corresponding to the word they heard. After the participant's response, there was a 500 ms delay before the start of the next trial. If their reaction time (recorded but not reported in this study) exceeded 3000 ms after the start of the audio, the participant was prompted to respond more quickly after their button press. Less than 1% of the trials had a reaction time that exceeded three seconds. At the start of this task, the participant read through a short, self-paced explanation, described below.

Identification task instructions
Take some time to look at each speaker [Visual stimuli shown on this slide]
Press the red/green button if the speaker said "sigh"
Press the green/red button if the speaker said "shy"
(You will be reminded of this throughout the task—responses will be color-coded for you.)

Participants were randomly assigned to a 'matched cue' or 'mismatched cue' condition, independent of their high or low power priming condition. If a participant was assigned to the 'matched cue' condition, the gender of the face will always match the gender of the speaker that produced the auditory stimulus. If assigned to the 'mismatched cue' condition, the respective genders of the face and the speaker will always mismatch.

This task was composed of a practice block (18 trials) and two main blocks (108 trials each) with a break in between each, for 234 trials in total. Across the main blocks, each unique auditory stimulus was presented 12 times. Token presentation was randomized for each participant.

2.3.5. Questionnaire

Finally, participants completed a questionnaire to verify that they fulfilled the study's inclusion criteria and to aid the interpretation of their performance. The first portion of the questionnaire asked participants about their language history: where they were born, the language(s) they spoke at home, where they have lived, the language(s) they currently know, and the language(s) they speak at home. The second part elicited impressionistic evaluations about the voices in the study, including their perceived gender and any noticeable peculiarities.

2.3.6. Condition assignment

Each participant was assigned to one of four conditions, shown in **Table 4**, according to 1) whether they were primed for high or low power and 2) whether the auditory and visual cues to speaker gender in the identification task were matched.

	High Power	Low Power
Matched Cues	11	11
Mismatched Cues	11	11

Table 4: Distribution of participants by experimental condition.

2.4. Results

2.4.1. Participant description

Of the 45 participants who completed the study all ranged in age from 18–23. Nearly half were born in Michigan and several others in other nearby states (e.g., Ohio, Indiana, and Illinois). The remaining participants were born elsewhere in the United States, except for one participant, who was born in South Korea (and moved to the US at age 1) and one participant who was born and lived in India (and therefore excluded from further analysis). All eligible participants reported speaking English at home when growing up, and eight participants reported speaking another language in addition to English. Likewise, all participants reported speaking English at home currently, with fewer indicating additional language usage. Most participants also indicated some level of experience with another language, and most reported having moved at least once in their life prior to living in Ann Arbor, Michigan; eight reported living outside of the United States (but for periods no longer than two years). These results suggest a regionally and linguistically diverse population of English-dominant participants, though with exposure primarily to at least one variety of American English.

2.4.2. Prime effectiveness task

The results of the Prime effectiveness task (2.3.3) are shown below in **Figure 3**. Participants in this study were asked to indicate on a Likert Scale how likely they would be to negotiate a car deal. While participants assigned to the high power condition indicated being 'very likely' most often, participants assigned to the low power condition indicated a lower degree of willingness to negotiate (=2) most often. A multinomial logistic regression was computed using the *nnet* package in R (Venables & Ripley, 2002), with the Likert scale response indicating the participant's willingness to negotiate a car deal (an unordered categorical variable ranging from one ['not at all likely'] to five ['very likely']) as the dependent variable and the type of priming task completed by the participant (high power prime or lower power prime) as the independent variable. Consistent with the observed results, participants who completed the low power prime were more likely than those who completed the high power prime to choose a Likert scale response of two ($\beta = 1.40$, $z = 1.71$, $p = 0.04$). As expected, participants primed for powerless behavior show a decreased willingness to negotiate.

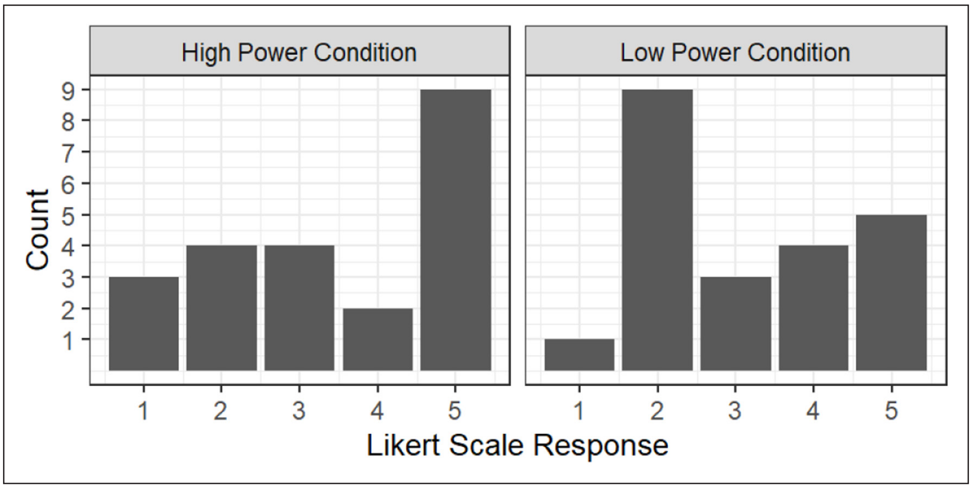

Figure 3: Results for the Prime effectiveness task.

2.4.3. Identification task

Auditory stimuli containing synthesized sibilants from continuum steps one and two were uniformly categorized as 'shy' across all possible conditions, and sibilants from continuum steps eight and nine were uniformly categorized as 'sigh' across experimental conditions. Consequently, these steps were excluded from further analysis.

Figures 4 and **5** are visualizations of the results of the identification task for participants primed for low power and high power, respectively. The average likelihood for each participant to categorize the auditory stimulus as 'sigh' is plotted against the continuum step of the synthesized sibilant spliced to form the auditory stimulus—step three sounds more like [ʃ] and step seven sounds more like [s]. Visual inspection of both figures suggests that participants are more likely to categorize the word as 'sigh' when 1) the sibilant step is closer to seven (i.e., the sibilant sounds more [s]-like) and 2) the imputed gender of the auditory stimulus is male. The latter observation aligns with the many other previously mentioned studies (e.g., Strand & Johnson, 1996; Munson, 2011; Winn et al., 2013; and Bouavichith et al., 2019), also finding that listeners tend to categorize an ambiguous sibilant as 'sigh' when the speaker sounds male.

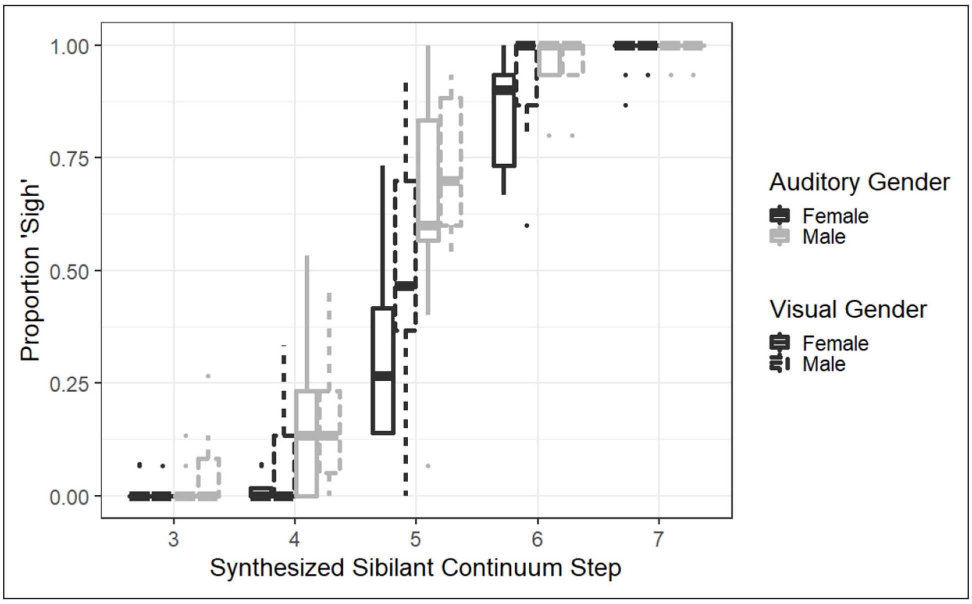

Figure 4: Participant-averaged responses for listeners primed for low power; gray lines indicate that the listener heard a male voice, and dashed lines indicate that the participant saw a male face.

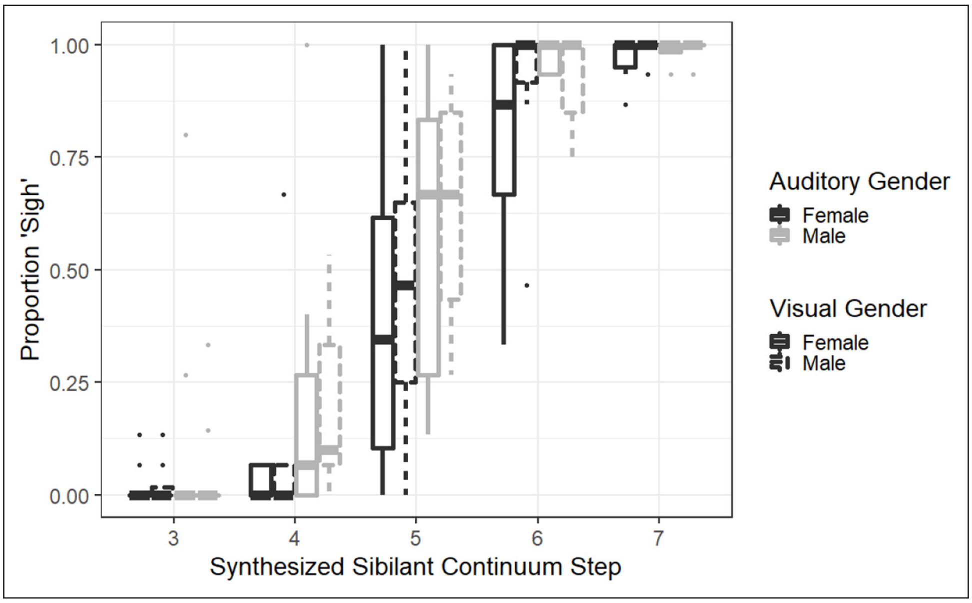

Figure 5: Participant-averaged responses for listeners primed for high power; gray lines indicate that the listener heard a male voice, and dashed lines indicate that the participant saw a male face.

In **Figure 4**, which plots the results for participants primed for low power, listeners also appear to be more likely to categorize the auditory stimulus as 'sigh' when the stimulus is paired with a male face. In **Figure 5**, which visualizes the results of the task for participants primed for high power, responses appear more variable among this group of participants, and the relationship between visual stimulus and categorization pattern is less readily apparent. A mixed-effects logistic regression was computed on these data using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015). Recalling Section 1.1, sibilant categorization is sensitive to information about auditory and visual sources of information about speaker gender. In addition, recalling Section 1.2, powerful individuals appear to process incongruous social information differently than powerless individuals. Accordingly, if the priming task induced behavior consistent with powerful or powerless individuals, an appropriate model to test the effect of power on sibilant categorization would be one that considered the effect of the information about speaker gender as well as the mediating effect of the priming task on each of these sources of information. The statistical model was constructed with participant response ('sigh' or 'shy') as the categorical dependent variable, sibilant step (/ʃ/-sounding to /s/-sounding), imputed auditory gender (male or female sounding voice) visual gender (male or female face), and priming condition (high or low power) as main effects, the interactions of priming group with auditory gender and with visual gender as additional fixed predictors, participant as a random intercept, and random slopes for auditory gender and visual gender by participant. Modeled parameters are shown in **Table 5**. Several simpler model structures were compared; sibilant step, auditory gender, and visual gender each independently improve model fit as main effects. However, the effect of priming condition does not improve model fit on its own as a main effect, nor is there a significant difference in the response according to this variable alone; the effect of this variable on listener response only emerges, when its interaction with both sources of information about speaker gender are considered.

Predictor	***β***	**Lower 95%**	**Upper 95%**	***z***	***p***
Intercept	–13.61	–14.45	–12.76	–31.06	< 0.0001
Sibilant Step (3–7)	2.56	2.43	2.69	39.3	< 0.0001
Auditory Gender (Male-Sounding Voice)	1.21	1.10	1.61	9.33	< 0.0001
Visual Gender (Male Face)	0.69	0.44	0.97	5.48	< 0.0001
Priming Condition (High Power)	0.24	–0.48	0.94	0.66	0.51
Auditory Gender × Priming Condition	–0.14	–0.49	0.20	–0.81	0.42
Visual Gender × Priming Condition	–0.38	–0.73	–0.03	–2.13	0.03

Table 5: Identification task model estimates.

The logistic regression reveals a significant main effect of auditory gender and visual gender on the participant's likelihood to categorize the auditory stimulus as 'sigh.' As expected, the presence of a male-sounding voice or male face both increase the likelihood of categorizing the token as 'sigh.' The effect of power in participant behavior is more nuanced. Recalling Section 1.3, listeners were not predicted to vary globally according to power in their likelihood to categorize a sibilant as /s/, and indeed there was no main effect of power on participant behavior observed. High power listeners' categorization was predicted to track with a single cue to a speaker's social category and to poorly accommodate multiple potentially inconsistent sources of information about the same category. In contrast, the categorization strategy of powerless listeners was predicted to be sensitive to multiple cues to speaker gender. The results above appear consistent with such a prediction. While neither power group differed according to auditory gender information, participants in the high power condition were in fact less likely than participants in the low power condition to categorize a sibilant as 'sigh' if an auditory stimulus was paired with a male face. The effect of additional gender cues on participant response was diminished in participants primed for high power behavior.

3. Discussion

The results of the identification task suggest that listeners choose /s/ more often in an [ʃ-s] continuum when provided auditory or visual information suggesting that the speaker is male. Furthermore, listeners in the high or low power prime condition were found to process social information differently during lexical categorization. While both groups were similarly likely to categorize the sibilants according to auditory information about speaker gender, listeners in the high-power condition were less likely than those in the low power condition to categorize a sibilant as /s/ when a voice was paired with a male face.

The latter result is consistent with the hypothesized effect of power on sibilant categorization. As discussed in Section 1.2, the perceptual strategy of powerful individuals tends to poorly accommodate incongruous cues about a social category, in comparison to powerless individuals. Powerful individuals attend less to incongruous social information about an individual, and judgments by powerful individuals appear to show less sensitivity to this information. In this study, participants were provided information about speaker gender in the auditory and visual modalities; both groups showed sensitivity to auditory cues to speaker gender. However, participants who completed the high power prime showed less sensitivity to the visual cues to speaker gender than those who completed the low power prime. The response of low power participants showed greater variation according to both sources of information about speaker gender.

In studies that look at the effect of power on impression formation (as discussed in Section 1.2), the participant receives a reliable cue or set of cues to the other individual's identity (e.g., a name), after which the participant is given additional information about the individual. In those studies, the participant seems able to reliably identify the social identity of the speaker from this information; the processing of subsequent information appears to be conditioned on the category established by the initial information, as well as their priming condition. In this study, there is only a 500 ms difference in the presentation of the two informational sources of gender, with the visual information in fact leading the auditory. Despite the ordering of the two cues, auditory information appears to be treated as the more influential indicator of speaker gender (or speaker physiology) for this classification task. For both groups of participants, the odds of categorizing a sibilant as /s/ increase by 2.0–4.0 (95% CI) when the participant hears a male voice. While pairing a voice with a male face increases the odds of categorizing the sibilant as /s/ by 0.6–1.6 for listeners who completed the low power prime, this increase is diminished by 0.03–1.1 for listeners who completed the high power prime.

The asymmetry in the strength of effect of the visual and auditory information is not wholly unexpected. Although the participants were not instructed to pay closer attention to the voice than to the face, the auditory gender information was (necessarily) aligned with the token, in contrast to the visual information, which was just a stationary image. The auditory cues to gender may have provided a stronger influence than the visual cues due to the design of the task. The results of Winn et al. (2013) suggest that the effect size and significance of visual and auditory gender information to phonetic categorization can change according to the listener population and the quality of each signal. It may be possible to reformulate the study where the effect is reversed—the auditory signal is degraded, and the visual signal is treated as a more informative cue to speaker gender. For example, the listener could watch clear video of the speaker aligned with noisy audio. All participants would be predicted to show sensitivity to the visual information about speaker gender, and participants in the lower power condition would be predicted to be more sensitive to changes to information about speaker gender in the auditory signal.

Alongside Uskul et al. (2016) and Lutzross et al. (2018), this study outlines a point of contact between phonetic perception, social processing, and power. However, more study is needed to define the relationship between each of these factors in more precise terms. For example, it is unclear how power influences phonetic perception if the information about the speaker lacked socioindexical relevance. As mentioned in Section 1.2, there is not a singular unifying theory relating differences in power to their associated behavioral differences. Despite the multiplicity of accounts, they tend to align in suggesting that powerful individuals process information in a manner characterized by reduced cognitive effort, relative to powerless individuals. A more general shift in cognition could in turn affect how cues are integrated by listeners without this information itself having social relevance. Dimov et al. (2012) may serve as an example of such an effect. Participants who scored higher in the self-administered power assessment were also less sensitive to altered acoustic auditory feedback; it does not seem necessary to ground this result in social cognition, as opposed to, for example, differences in environmental awareness. It may also be worth considering whether socioindexical relevance is necessary for the effect observed in the study to be replicated. If the integration of redundant (potentially incongruous) cues varies between powerful and powerless people, then it might be possible to observe an analogous effect if listeners performed an identification task where two acoustic cues targeting the same phonetic contrast were covaried which were also devoid of socioindexical relevance. If the effect mirrored that of this study, the low power listener would show greater sensitivity to both acoustic cues.

It is also unclear how experimentally induced variability in phonetic perception aligns with differences according to when an individual embodies a contextually relevant high power or low power role or identity. The methodology employed in the study belies the fact that differences in power are not randomly assigned in the world. Power is unequally distributed among groups of individuals, and under circumstances it is even possible to observe differences in behavior due to power outside the direct context of the role motivating a difference in power. In Guinote and Phillips (2010), hotel managers and subordinates were asked to evaluate a target's suitability for a job; subordinates attended more to individuating information about the candidate than did the managers. More remarkably, these results persisted beyond the context of their work in their position. Keltner et al.'s (2003) formalization of power suggests that different sources of power affect the individual's behavior in fundamentally similar ways. However, for a single social group it may be difficult to disentangle the behaviors attributable to differences in power from those associated with other causes. Use of an experimental power manipulation in combination with an analysis of participant variables associated with power inequality (e.g., race, gender, occupation), could provide additional insight into the relationship between power and that aspect of participant identity. Investigating how experimentally induced behaviors align with those associated with a particular participant group may also provide more information about the generalizability of experimental power manipulations.

Finally, it remains unclear how variability in phonetic perception due to power manifests at the level of the language community. These results suggest that powerful listeners may be less sensitive to socioindexical cue congruity in perception, but there is a sizeable theoretical gap between any community-level behavior and the experimental work relating power to phonetic performance. However, continued work will likely be able to provide additional insight on linguistic phenomena seemingly connected to differences in power. The relationship between gender and sound change may be one such phenomenon. Sound change does not typically spread uniformly throughout a community; individuals tend to differ in the degree or frequency with which they use a novel form. This spread often takes on a gendered aspect, with female speakers leading many (though not all) sound changes (Labov 2001). It has been suggested that gendered differences in linguistic behavior are at least partially rooted in power—Eckert (1989, p. 256) wrote that "whereas men can justify and define their status on the basis of their accomplishments, possessions, or institutional status, women must define theirs on the basis of their overall character." Systematic constraints on how women can accrue social capital motivate increased attention on the subset of remaining ways to increase status. This account of gendered behavior also bears some resemblance to accounts of power (discussed in Section 1.2) that suggest the behavior of powerless individuals is motivated by external factors.

In the social psychology literature, researchers have probed at power from a variety of perspectives. Some experiments center the analysis on the comparison of individuals who occupy high or low power roles outside the laboratory (e.g., Guinote & Phillips, 2010). Others establish an experimental frame where the participant's (ostensible) power over another individual is made contextually relevant to their activity in the study (e.g., Dépret & Fiske, 1999; S. A. Goodwin et al., 2000). Still other studies have the participants complete a priming task not contextually relevant to downstream tasks in the study, but which nonetheless induces a temporary and consistent change in behavior of the individual (e.g., Galinsky et al., 2003; Galinsky et al., 2006). None of these experimental paradigms fully recreate a naturalistic context where power might influence an individual's behavior or decision-making. This paper and the few other studies looking at the effect of power on phonetic processing cannot escape questions of ecological validity when attempting to generalize the findings beyond the experimental context. The types of manipulations performed in this study do not clearly resemble the contexts where differences in power might be expected to affect listener behavior, nor do they reflect the distribution of power observable in real-world settings. Constructing a study where participants interact with one another and embody their high or lower power roles, for example, would be a significant step toward aligning laboratory manipulations with natural social environments where phonetic perception might happen for a powerful or powerless individual.

Nonetheless, this paper makes several contributions. Like other studies that adopt this methodology, it suggests that participant behavior downstream of the priming manipulation is consistent with behavior predicted by at least one theoretical formulation of power—one where it is understood as a perceived ability to control others. Like Dimov et al. (2012), Uskul et al. (2016), and Lutzross et al. (2018), this result offers further support to the possibility that power can influence phonetic perception. This study suggests that power may affect how listeners integrate redundant sources of socioindexical information about a speaker.

Finally, this paper suggests that cue integration strategies may show intralistener variability. As detailed in Section 1, several sources of perceptual variability may be listener-specific. Neurophysiological variability and differences in processing style, for example, are modes of variability that are associated with predictable differences in perceptual behavior and also not expected to vary much across communicative context. In contrast, the differences in behavior observed in this study were experimentally induced. Listeners do not necessarily tend to act like a powerful listener independent of context, but listeners who adopt that behavioral pattern tend to manifest a well-defined pattern of perceptual behaviors. Sources of intralistener variability in linguistic perception may warrant additional consideration, particularly in cases where (like power) differences in the conditioning factor are not distributed randomly across the speaker community.

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Competing Interests

The authors have no competing interests to declare.

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