Original Article

Effects of Masculinized and Feminized Male Voices on Men and Women's Distractibility and Implicit Memory

Graham Albert,[1] Marlena Pearson,[2] Steven Arnocky,[1] Mark Wachowiak,[3] Jeffrey Nicol,[4] and Dana R. Murphy[1]

[1]Department of Psychology, Nipissing University, North Bay, ON, Canada
[2]Department of Psychology, Ryerson University, Toronto, ON, Canada
[3]Departments of Computer Science and Math, Nipissing University, North Bay, ON, Canada
[4]Department of Psychology, Vancouver Island University, Nanaimo, BC, Canada

Abstract: Men's lower-pitched voices may serve to attract mates and/or deter same-sex rivals. If this is the case, then both men and women should be more attentive to men's lower-pitched voices because, attending to this information may contribute to survival or confer a reproductive advantage. The current study measured men and women's distractibility and implicit memory for sentences spoken by a masculinized (lower-pitched) and feminized (higher-pitched) male voice. Participants completed an irrelevant speech task followed by an implicit memory task to assess their memory for previously presented irrelevant speech. In the irrelevant speech task, distractibility did not differ between men and women. However, men demonstrated greater implicit memory for sentences previously spoken by the masculinized male voice, and women demonstrated greater implicit memory for sentences previously spoken by the feminized male voice. These results suggest men may have an increased sensitivity to dominance cues in other men's voices. Reasons why men demonstrated greater implicit memory for sentences spoken by a masculinized man's voice and why women demonstrated a trend toward greater implicit memory for sentences spoken by a feminized man's voice are discussed.

Keywords: distractibility, implicit memory, attractiveness, dominance, fundamental frequency, voice pitch

Men's sexually dimorphic characteristics may serve to attract mates and/or deter same-sex rivals (Arnocky, Bird, & Perilloux, 2014; Hodges-Simeon, Gaulin, & Puts, 2011). Lower vocal pitch, one such characteristic, has been conceptualized as a costly signal because, although it may communicate higher mate quality (Hodges-Simeon, Gurven, & Gaulin, 2015; Zahavi, 1975), the high testosterone levels required for its development could weaken the immune system (Folstad & Karter, 1992). Men who possess voices with a lower fundamental frequency (F0), the lowest frequency in a complex sound, may be more attractive to heterosexual members of the opposite sex. Women have been shown to rate men's voices with lower F0s as more attractive than voices with higher F0s (Feinberg, Jones, Little, Burt, & Perrett, 2005; Jones, Feinberg, DeBruine, Little, & Vukovic, 2010). In support of the idea that lower F0s may provide dominance cues to potential same-sex rivals, men tend to rate other men's voices with lower F0s as more dominant than voices with higher F0s (Jones, Feinberg et al., 2010; Puts, Hodges, Cárdenas, & Gaulin, 2007). However, because human beings often do not consciously contemplate the attractiveness and dominance of voices heard in naturalistic social interactions, it is important to examine whether differences in men's F0s are processed differently at an implicit level. The current study used an irrelevant speech task with a follow-up implicit memory task to determine if vocal characteristics influence distractibility and implicit memory. If men's F0s provide salient information about mate quality and dominance, then we anticipate both men and women should be more distracted by, and exhibit greater implicit memory for, irrelevant speech spoken by a man's voice manipulated to have a lower F0 relative to the same man's voice manipulated to have a higher F0.

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Relationship Between Men's F0s and Health

According to the immunocompetence-handicap hypothesis (Folstad & Karter, 1992), the development of some sexually dimorphic characteristics (e.g., those relying upon higher testosterone in men) can carry an immunological cost. At puberty, men experience an increase in testosterone production causing the vocal folds to thicken and the larynx to descend, producing a lower-pitched voice (Butler et al., 1989; Harries, Hawkins, Hacking, & Hughes, 1998; Harries, Walker, Williams, Hawkins, & Hughes, 1997). These structural changes of the vocal folds and the larynx only occur in men who produce sufficient levels of testosterone (Jenkins, 2000). Men with higher salivary testosterone levels usually have a lower F0 than men with lower salivary testosterone levels (Dabbs & Mallinger, 1999; Evans, Neave, Wakelin, & Hamilton, 2008; Puts, Apicella, & Cárdenas, 2012; but see Skrinda et al., 2014). Hodges-Simeon et al. (2015) found evidence that lower F0s could be a signal of higher testosterone levels and energetic reserves. Within an indigenous Bolivian sample, peri-pubertal males with higher body mass indices (BMIs) had higher levels of salivary testosterone and voices with lower F0s. The authors used BMI as a health measure because the sample was from an environment that requires considerable energy expenditure for survival; therefore, individuals who were able to retain energy, in the form of fat stores, may be at a survival advantage. The fact that higher BMIs were associated with lower F0s suggests these males were able to incur the potential costs associated with high testosterone levels necessary to produce a lower-pitched voice without compromising their energy stores. However, higher testosterone levels and a lower voice did not predict lower immune function as measured by secretory immunoglobulin-A (IgA). More recently, Puts and colleagues (2016) found that testosterone and cortisol interacted to predict F0 in men but not women, such that high testosterone and low cortisol predicted lower F0. Interestingly, high testosterone and low cortisol have previously been found to predict immune function (response to hepatitis B vaccination; Rantala et al., 2012), suggesting that F0 may serve as a particularly important marker of men's immunocompetence.

Women's Preference for Men's Low-Pitched Voices

As reviewed in Tybur and Gangestad (2011), women should benefit from mating with immunocompetent men for at least three reasons: (1) it reduces their likelihood of contracting a disease from their mate, (2) it increases their probability of securing men who are potentially more capable of caring for their offspring, and (3) it improves their offspring's fitness by enhancing the offspring's probability of possessing disease-resistant genes (see also Arnocky, Pearson, & Vaillancourt, 2015). Further, the Good Genes Sexual Selection (GGSS) Hypothesis states that women have evolved preferences for physical traits in men that indicate superior health and viability because mating with these men increases their probability of producing offspring that possess the same disease-resistant genes as their fathers' (Gangestad & Simpson, 2000). If ancestral women gained a reproductive advantage (i.e., produced healthier offspring who were more likely to survive to reproductive age) by reproducing with healthier men (i.e., men with intrinsically good genes) who have lower F0s, then it is possible that women's preference for lower-pitched men's voices has become more prevalent in the population (Arnocky, Hodges-Simeon, Ouellette, & Albert, 2017; Hodges-Simeon et al., 2015; Hughes, Dispenza, & Gallup, 2004). There is substantial evidence that contemporary women prefer men's voices with lower F0s. Women assign higher attractiveness ratings to men's voices with lower F0s (Collins, 2000). Similarly, they also rate recordings of masculinized men's voices (manipulated to have lower F0s) as more attractive than recordings of feminized men's voices (manipulated to have higher F0s; Feinberg et al., 2005; Jones, Feinberg et al., 2010; Puts et al., 2007).

Women's preference for masculinized men's voices is influenced by personality variables related to mating strategy. O'Connor et al. (2014) demonstrated that women with less restricted sociosexual orientations (i.e., women who have a more positive attitude toward uncommitted sexual relationships) also demonstrated a greater preference for masculinized male voices than did women with more restricted sociosexual orientations (i.e., women who are less comfortable engaging in uncommitted sexual relationships), suggesting that women who are more oriented toward short-term mating may use men's voices as a cue to their health and genetic quality. Women's fertility levels affect their preference for low-pitched men's voices; women show the strongest preference for low-pitched men's voices when they are most fertile (i.e., in the late follicular phase of their menstrual cycle; Feinberg et al., 2006; Puts, 2005). Additionally, researchers have demonstrated that women have marked preferences for other masculine traits, such as masculine faces and body types when they are at peak fertility (Little, Jones, & Burriss, 2007; Little, Jones, & DeBruine, 2008). Women may prefer masculine traits when they are fertile because engaging in an act of copulation with a masculine man at this point in the menstrual cycle may increase their probability of producing offspring that possess genes that may confer disease resistance (Penton-Voak & Perrett, 2000).

The Function of F0 in Mating

F0 may also be a cue that women use to guide them during mate selection. For example, Hughes et al. (2004) demonstrated that men whose voices are rated as more attractive by women tend to have sex at an earlier age, have more sex partners, and more extra-pair copulations than do men whose voices are rated by women as less attractive. Furthermore, within populations that do not have access to modern forms of contraception, men with lower F0s might have greater reproductive success. Apicella, Feinberg, and Marlowe (2007) found that, in the Hadza, a group of hunter-gatherers, men with lower F0s fathered more children, providing some evidence for the notion that women may use men's F0s to guide their mating decisions. Even though women rate men's voices with lower F0s as more attractive, the function of F0 during mate selection is unclear. Although men who have voices with lower F0s may have greater reproductive success, the extent to which men's voices were shaped by mate selection compared to intrasexual competition also remains to be elucidated. The greater reproductive success that men with lower F0s experience could be due to their ability to attract mates, or alternatively due to their ability to exclude same-sex competitors from mate competition (Puts, Gaulin, & Verdolini, 2006). Women rate masculinized men's voices as more attractive than feminized men's voices; however, both women and men rate masculinized men's voices as more dominant than feminized men's voices (Jones, Feinberg et al., 2010). Puts et al. (2006) and Puts et al. (2007) found that manipulating F0 and formant dispersion of men's voice recordings to produce more masculine sounding voices had greater effects on listener's dominance attributions than on their attractiveness attributions.

The abovementioned findings suggest that men's lower-pitched voices may signal the speaker's dominance and function to deter rival men from competing for access to the same women. Other research has emphasized that men's dominance attributions of other men's voices are influenced by objective and self-reported measures of dominance (Watkins, Fraccaro et al., 2010; Watkins, Jones et al., 2010; Wolff & Puts, 2010). For instance, Watkins, Fraccaro et al. (2010) found a relationship between a correlate of men's dominance (i.e., height) and their sensitivity to dominance cues (i.e., masculinized faces and masculinized voices) in other men. Specifically, shorter men assigned higher dominance ratings to recordings of masculinized men's voices than did taller men. Moreover, Wolff and Puts (2010) found that men who reported higher physical dominance assigned lower dominance ratings to recordings of other men's voices, including those voice recordings that had been masculinized, than did men who reported lower physical dominance. Therefore, physically dominant men may be less sensitive to dominance cues in other men, perhaps because they have the ability to successfully compete with most men in their environment. It could also be that less dominant men may have a tendency to be hypersensitive to dominance cues in other men, which in ancestral times may have provided them with a survival advantage because it helped them to avoid risky physical confrontation with physically dominant men (Keeley, 1997; Manson et al., 1991).

In support of the idea that people use vocal information to judge physical dominance of the speaker, Sell et al. (2010) provided evidence that both men and women can accurately determine the upper-body strength of men from standard voice recordings. These assessments were independent of the height and weight of the speaker. The authors suggested that men and women's ability to accurately assess men's upper-body strength from their voices may reflect an adaptation, shaped by natural selection, to judge the fighting ability of the speaker. Although men and women seem to be accurate at using certain vocal information to determine the speaker's upper-body strength, the research on their ability to judge speaker height and weight (other factors related to the speaker's physical dominance) is less clear. Taller men tend to be perceived as stronger (Vaz, Hunsberger, & Diffey, 2002), more aggressive (Archer & Thanzami, 2007), better fighters (Von Rueden, Gurven, & Kaplan, 2008), and more desired by women as mates (Pawlowski, Dunbar, & Lipowicz, 2000). Collins (2000) found that women judge lower-pitched men's voices to belong to taller men. Yet, she did not find any relationship between women's height attributions and men's actual height. Conversely, Skrinda et al. (2014) found a nonlinear relationship between men's height and women's ratings of these men's vocal attractiveness and vocal masculinity, suggesting that at least in some cases women accurately use vocal information to estimate men's height. Although the relationship between men's vocal cues and body height is not clear, there is evidence that men's voice pitch is related to other testosterone-dependent morphological characteristics. For example, Evans, Neave, and Wakelin (2006) found a negative relationship between men's F0s and their shoulder-to-hip ratios (SHR; a cue to upper body strength), demonstrating that men with lower F0s tend to have stronger upper bodies. Thus, both F0 and SHR are testosterone-dependent characteristics that could serve as honest signals of mate quality and or rival formidability. When examining links between both attractiveness and dominance ratings of male voices, Puts et al. (2016) have recently shown that F0 predicted men's but not women's vocal attractiveness to opposite-sex raters and men's vocal dominance to same-sex raters. Male and female observers may use these signals during intrasexual competition and mate selection to judge the mate quality or the fighting ability of the signaler (Hughes et al., 2004; Sell et al., 2010).

The Gap in the Current Research

Even though women tend to rate lower-pitched men's voices as more attractive, and both men and women tend to rate lower-pitched men's voices as more dominant, most studies on vocal pitch direct men and women to attend to and rate voice recordings where one characteristic of the voice (e.g., F0) has been altered (e.g., Doll et al., 2014; Jones, Feinberg et al., 2010; O'Connor & Feinberg, 2012; Puts et al., 2006, 2007; Smith, Jones, Feinberg, & Allan, 2012, but see Puts, 2005; Puts et al., 2006). In many of these experiments the tasks were not only made explicit to the participants, but also the objectives of the experiments were made relatively obvious. Therefore, it is possible that the results of the above experiments have been confounded by experimenter expectancy effects, because participants may be able to draw the conclusion that men's voices that have been masculinized sound more dominant/attractive than the feminized versions and should therefore be rated as such, regardless of whether or not they actually perceived masculinized men's voices as more attractive and/or dominant than feminized ones. In order to expand on the current body of research on responses to altered vocal characteristics, it is necessary to use alternative measures to determine if participants' perceptions of men's voices vary in a way that is more automatic relative to explicit ratings.

Some researchers have already begun to use alternative ways to measure women's attraction to lower-pitched men's voices. Smith et al. (2012) demonstrated that manipulating the F0s of male speakers' voices to create feminized and masculinized versions affected women's object memory. Specifically, women were better at recognizing images of objects when they were previously paired with masculinized men's voices saying the name of the object than with feminized men's voices saying the name of the object. Although this finding extended beyond women's explicit preferences for masculinized men's voices by demonstrating that men's F0s influenced women's memory for spoken information, it is unclear whether similar findings would occur using an implicit attentional measure and an implicit study design. Evidence suggesting that information spoken by masculinized men's voices is more distracting and more memorable would provide evidence that people have developed an adaptation to automatically attend to certain vocal characteristics, perhaps because ancestrally doing so provided listeners with survival and reproductive advantages (Bateson & Healy, 2005; Sherry & Schacter, 1987).

In their review of how natural selection has shaped memory systems, Sherry and Schacter (1987) described the idea of functional incompatibility, which argues that systems of memory and learning have developed to solve specific environmental demands such as finding food and avoiding predation. Additionally, Bateson and Healy (2005) suggested it is possible that memory systems have developed to address the problems that surround mate selection, and that environmental demands may have fostered the development of heuristics that allow animals to make mating-relevant decisions quickly. These authors argued that when females are selecting mates, they are presented with many different cues to males' health and reproductive fitness. The ability of females to make decisions quickly and efficiently regarding males' health and reproductive fitness would be beneficial to females, as it would allow them to conserve time and energy during mate selection. In support of these ideas, there is evidence that systems involved in human memory and attention have developed to aid in survival and reproduction (Kang, McDermott, & Cohen, 2008; Maner et al., 2003; Nairne, Thompson, & Pandeirada, 2007; Smith, Jones, & Allan, 2013; Smith et al., 2012; van Wingen, Mattern, Verkes, Buitelaar, & Fernández, 2008).

Men and women may have developed cognitive systems that direct attention to information related to survival and mate selection (Jones, Feinberg et al., 2010; Liu & Chen, 2012; Maner et al., 2003; Sui & Liu, 2009). Evidence from the facial attention literature suggests people more readily allocate automatic visual attention to attractive and dominant faces (Jones, DeBruine et al., 2010; Liu & Chen, 2012; Sui & Liu, 2009). For example, people are better at tracking the location of attractive faces (Liu & Chen 2012), and find attractive opposite-sex faces more distracting when presented as to-be-ignored information in an orientation judgment task (Sui & Liu, 2009). Both men and women selectively attend to physically attractive female faces when presented within a face array (Maner et al., 2003). Regarding attention to dominant faces, individuals are also faster to identify the location of a target letter (i.e., show a stronger gaze cueing effect) when primed with a masculinized (dominant) than a feminized (subordinate) face gazing toward the target location (Jones, DeBruine et al., 2010). This effect was strongest when participants were presented with masculinized faces for shorter durations, suggesting attentional allocation to dominant faces occurs at a reflexive level.

Perhaps people's predisposition to attend to attractive and dominant information extends beyond the visual domain and into the auditory domain. If this is the case, then women should inadvertently allocate more attention to information spoken by a masculinized man's voice (i.e., be more distracted by information spoken by a masculinized man's voice), since these voices have been consistently rated as attractive in other studies (e.g., Feinberg et al., 2005; Jones, Feinberg et al., 2010; Puts et al., 2006, 2007). Furthermore, both men and women should allocate more attention to masculinized men's voices since these have consistently been rated as more dominant in other studies (e.g., Jones, Feinberg et al., 2010; Puts et al., 2006, 2007).

The Current Study

If women are more distracted by information spoken by a masculinized man's voice over a feminized man's voice, this could suggest lower F0 is a vocal cue that women use when assessing men's mate quality. Furthermore, if both men and women are more distracted by information spoken by a masculinized man's voice, this could suggest that both sexes use F0 as a vocal cue when determining men's physical dominance. In the current study, we used an irrelevant speech task (Salame & Baddeley, 1982) and an implicit memory task to assess how masculinized and feminized male voices (presented as irrelevant background speech) influence participants distractibility and implicit memory. In Experiment 1, participants completed a Star Counting Task (SCT; i.e., an irrelevant speech task de Jong & Das-Smaal, 1995) while ignoring numbers and other sentences spoken in a masculinized and feminized voice. Then, they completed a Speech Perception in Noise (SPIN) task (i.e., the implicit memory task; Bilger, Nuetzel, Rabinowitz, & Rzeczkowski, 1984) in which they identified the final word of sentences (either the masculinized or feminized sentences heard but ignored during the SCT, or new, unmodified sentences) presented in a high level of background noise. Finally, because the new sentences used in Experiment 1 were unmodified, we conducted a second experiment to ensure that the results from the implicit memory task were not due to one voice condition being more perceptible within the background noise than another. In Experiment 2, a new sample of men and women completed the SPIN task without the previous presentation of the sentences as distracting background speech.

Hypotheses

Given that women rate masculinized men's voices as more attractive and both sexes rate masculinized men's voices as more dominant, we predicted both sexes would be more distracted, and therefore slower to complete SCT trials where the masculinized man's voice was presented as irrelevant background speech relative to when either the feminized man's voice was presented as irrelevant background speech, or when they completed the SCT in silence. In other words, the average length of time that it takes participants to complete SCT trials (i.e., participants' count time) should be longest during trials where recordings of sentences are spoken by the masculinized man's voice as irrelevant background speech (Hypothesis 1 [H1]). Furthermore, both sexes should demonstrate greater implicit memory for previously presented, but ignored, sentences spoken by the masculinized man's voice. Participants' greater implicit memory for information previously spoken by the masculinized man's voice would be demonstrated by greater accuracy at identifying the final words of these sentences when they were presented in a high level of background noise, suggesting participants inadvertently allocated more of their attention to this voice during SCT trials (Hypothesis 2 [H2]). Among women, those with less restricted sociosexual orientations (determined by their scores on the revised Sociosexual Orientation Inventory, SOI-R; Penke & Asendorpf, 2008) should have longer count times for SCT trials when sentences are spoken by the masculinized male voice than should women with more restricted sociosexual orientations (Hypothesis 3 [H3]). Finally, women with less restricted sociosexual orientations should also demonstrate greater implicit memory for final words of sentences previously spoken by the masculinized male voice during the SCT than women with more restricted sociosexual orientations (Hypothesis 4 [H4]).

Experiment 1

Methods

Sample Size Estimation

In order to ensure an appropriate sample size, we analyzed preliminary data from 18 men (M_{age} = 22.06 years, *SD* = 1.70 years, Range = 19–25 years) and 22 women (M_{age} = 20.77 years, *SD* = 3.04 years, Range = 18–29 years). These participants were analyzed later as part of the larger sample. A repeated-measures analysis of variance (ANOVA) was conducted to analyze accuracy in the SPIN task based on condition. There were three conditions in the SPIN task: (1) previously presented, but ignored sentences spoken by the masculinized male voice; (2) previously presented, but ignored sentences spoken by the feminized male voice; and (3) new sentences spoken by the unmodified male voice. Although the main effect of condition within men was significant, $F(2, 34) = 4.11$, $p < .03$, $\eta_p^2 = .20$, this main effect within women approached significance with a medium effect size ($p < .07$, $\eta_p^2 = .12$). A power analysis using G*Power 3.1.7 [Faul, Erdfelder, Buchner, & Lang, 2009; Effect size $f(U) = .37$, $\alpha = .05$, and Power $1 - \beta = .80$] revealed that a minimum sample size of 38 women was required to achieve significance with this effect size and power. In order to test a sex by condition interaction for the SPIN task, we ran an approximately equal number of men and women.

Participants

Participants were 40 women and 41 men. One woman was excluded from the final data analysis due to her poor performance in the SPIN task (i.e., greater than three *SD*s below the mean); two men were excluded from the final data analyses because they did not complete the second phase of the experiment. Therefore, the final sample included 39 women (M_{age} = 20.10 years, *SD* = 2.48 years, Range = 18–29 years) and 39 men (M_{age} = 20.90 years, *SD* = 2.02 years, Range = 18–25 years).

All participants were heterosexual, native English speakers recruited from the North Bay area or from Nipissing University's student participant pool and received either $10/hr or partial course credit, respectively, for their participation. All participants had visual acuity that was appropriate for completing the SCT ($\leq$ 20/25) verified by a Snellen acuity test, normal hearing as measured by an audiometer (i.e., pure tone thresholds $\leq$ 20 dB HL for 250, 500, 1,000, 1,500, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz), and a threshold for speech sound $\leq$ 35 dB SPL on a babble threshold test (Schneider, Daneman, Murphy, & Kwong See, 2000).

Materials

Visual stimuli consisted of an SCT display (Figure 1), which was different for each trial of the experiment (de Jong & Das-Smaal, 1995). Each display contained a start number, the number that participants started counting from, in the top left corner of the screen followed by 9 rows of symbols (i.e., asterisks, subtraction, and addition signs). Each of the 9 rows of the stimulus display could contain up to 6 asterisks. In the bottom right corner of the display was a probe number, which was either the correct final count for that trial or differed from the correct count by one. The visual stimuli were presented on a 17″ LG FLATRON W2053TQ-PF computer monitor (LG Electronics Canada, North York, ON, Canada). Participants sat approximately 40 cm from the screen. The 19.40 cm visual stimulus was displayed centrally on the computer monitor and subtended 13.83° of visual angle to the left and right of center.

The auditory stimuli were 170 recordings from the 200 High Predictability (HP) sentences from the revised SPIN task (Bilger et al., 1984), said by a single male speaker. In HP sentences the final word of each sentence may be predicted based on the words that precede it within that sentence. We selected HP sentences where the F0 of the male speaker's voice was closest to the average F0 of an adult male voice (i.e., approximately 120 Hz; Childers & Wu, 1991).

Using Praat's Pitch Synchronous Overlap and Add algorithm (Boersma & Weenink, 2014), we created masculinized

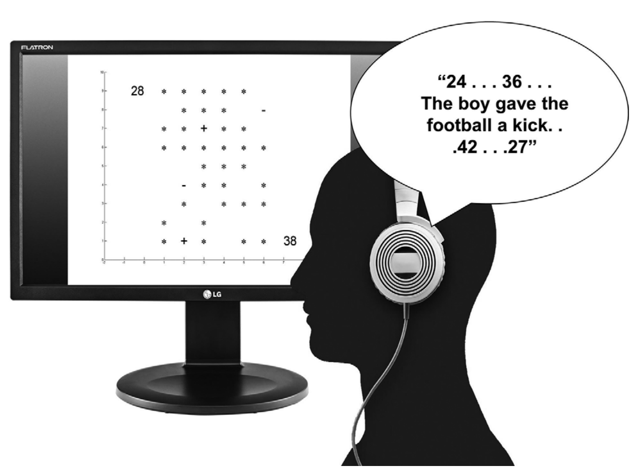

Figure 1. Sample star counting task trial and a high predictability sentence.

and feminized versions of each of the 170 HP sentences based on previous work by Jones, Feinberg et al. (2010). Masculinized versions of each sentence were created by lowering the F0 of the original speaker's voice (M_{F0} = 124.00 Hz) by 0.5 equivalent rectangular bandwidths (ERBs) or approximately 20 Hz (M_{F0} = 106.24 Hz). Feminized versions of each sentence were created by raising the F0 of the original speaker's voice by 0.5 ERBs or approximately 20 Hz (M_{F0} = 144.50 Hz). In addition to the 170 HP sentences to be presented in a masculinized or feminized man's voice, we also presented numbers (Range = 1–99) spoken by an unmodified woman's voice. The recordings of the numbers were provided by a female undergraduate who spoke English as a first language, saying the numbers in a clear, neutral voice. Including numbers in the recordings was intended to increase the difficulty level of the SCT. We used Praat to resample the auditory stimuli at a rate of 24.41 kHz, which is the operating rate of the Tucker Davis Technology (TDT) System III (Tucker Davis Technology, Alachua, FL, USA) sound presentation system. The signals were generated and converted from digital to analog using a RP 2.1 unit of TDT System III hardware. To ensure equal loudness for stimulus presentation, we digitally manipulated the stimuli to equalize the Root Mean Square (RMS) of all sentences and numbers. Participants were tested individually in a single-walled, sound-attenuating chamber (IAC Acoustics, Model No. 403-A, North Aurora, IL, USA). All auditory stimuli were presented through Sennheiser HD 280 Pro headphones (Sennheiser, Wedemark, Germany).

Women completed the SOI-R (Penke & Asendorpf, 2008). This questionnaire is designed to assess individual's attitudes toward engaging in uncommitted sexual relationships. We included this measure to determine if women's attitudes toward uncommitted sex influenced their distractibility and implicit memory when ignoring masculinized and feminized sentences. To obtain women's average SOI-R total scores, we reverse coded item 6 then computed the women's mean score from the 9-item scale. The measure yielded good internal consistency (α = .84).

Procedure

This study received ethical approval from the Nipissing University Research Ethics Board (reference number: 13-09-06). All participants provided written consent. Participants completed the experiment in two phases: (1) the Priming Phase (the SCT), and (2) the Implicit Memory Phase (the SPIN task).

For the Priming Phase, participants completed 60 trials of the SCT. On each trial, participants were presented with a star counting display (Figure 1), and were required to count the asterisks presented in the display; they could count either silently or aloud. Participants started counting forward from the number in the top left corner of the screen (i.e., the start number), increasing their count by one for each asterisk encountered. When participants reached a subtraction sign, they would count backwards, decreasing their count by one for each asterisk encountered beyond that point. When participants reached an addition sign, they would resume counting forward. Participants continued this counting procedure, reading the screen from left to right and top to bottom, until they reached the probe number in the bottom right corner of the screen. Upon completing the count, they pressed a button, which stopped the timer (count time was recorded for each SCT trial), and reported whether their count matched the probe number (i.e., the number in the bottom right corner of the screen which participants were instructed to compare their count to). Participants' count time was sent from the button box to the RP 2.1 unit of the TDT which uses 1-ms resolution when recording participants' count times. Participants said "same" when their count matched the probe number and "different" when their count did not. The experimenter recorded participant accuracy for each trial and accuracy feedback was not provided until the end of the experiment. In trials where the expected count and the probe number did not match, the probe number differed from the expected count by a value of ±1.

Participants completed 20 SCT trials in each of three conditions: (1) while ignoring numbers spoken by the woman's voice and sentences spoken by the masculinized man's voice, (2) while ignoring numbers spoken by the woman's voice and sentences spoken by the feminized man's voice, and (3) in silence. In trials where speech was presented to the participants, the irrelevant sentences were randomly interspersed with irrelevant numbers with no more than four numbers between each sentence. Condition order was counterbalanced between participants. Trial types were not randomized within each block (e.g., a participant might complete 20 trials in the masculinized voice condition, followed by 20 trials in the feminized voice condition, followed by 20 trials in silence). In each of the speech conditions, the numbers were within a range of 10 below the smaller of the start and end probe numbers and 10 above the larger of these two numbers. This was done to increase task difficulty. Participants were instructed to ignore the speech and complete the SCT trials as quickly and accurately as possible. All to-be-ignored speech was presented at a level 50 dB SPL above each participant's babble threshold (Schneider et al., 2000).

For the Implicit Memory Phase, participants were presented with sentences (50 dB SPL above the participant's babble threshold) in a high level of background noise (12-talker babble; Bilger et al., 1984). This phase occurred immediately after participants completed all three SCT conditions. Presented sentences consisted of the first two previously heard, but ignored sentences from each SCT trial, as well as new sentences that served as control stimuli. The background noise was presented 18 dB above the level of the presented sentences, creating a −18 dB signal-to-noise ratio (SNR). Participants completed 120 implicit memory trials: 40 of the sentences were previously presented, but ignored masculinized sentences; 40 were previously presented, but ignored feminized sentences; and 40 were new, not previously presented sentences. The 40 new sentences were presented in the unmodified male voice. On each trial, the participant identified, by saying aloud, the final word of the presented sentence. The experimenter recorded the participant's accuracy, and accuracy feedback was not provided until the end of the experiment. After the Implicit Memory Phase, participants completed a demographics survey and women also completed the SOI-R (Penke & Asendorpf, 2008).

Results

Distractibility in the Priming Phase

To analyze how the presentation of irrelevant background speech (spoken by either the masculinized or feminized man's voice) affected participants' count times, we conducted a 2 (Sex: male, female) × 3 (Voice Condition: masculinized, feminized, silence) mixed-factorial ANOVA with sex as the between-subjects factor, voice condition as the within-subjects factor, and count times as the dependent measure. These data violated Mauchly's test of sphericity; therefore, the results are reported using the Greenhouse-Geisser correction. Count times did not significantly differ as a function of sex, $F(1, 76) = 0.98$, $p = .325$, $\eta_p^2 = .01$. Furthermore, the Sex × Voice Condition interaction was not significant, $F(1.704, 129.49) = 0.05$, $p = .933$, $\eta_p^2 = .001$.

However, voice condition significantly influenced count times, $F(1.704, 129.49) = 4.09$, $p = .024$, $\eta_p^2 = .05$.

To further analyze the extent to which irrelevant background speech (i.e., voice condition) slowed participants' count times, we calculated distraction costs by subtracting each participants' mean count time in the silence condition from his or her mean count time in the masculinized and feminized voice conditions, respectively (Table 1). Analyzing these distraction costs allowed us to use the silence condition as a baseline measure of participants' SCT time and compare distractibility based on voice condition. To determine if participants showed a significant irrelevant speech effect (i.e., if the presentation of the masculinized and/or feminized man's voices were associated with a significant distraction cost relative to silence), we conducted two one-tailed, one-sample *t*-tests. Participants demonstrated a significant irrelevant speech effect in both the masculinized, $t(77) = 2.75$, $p = .004$, and feminized, $t(77) = 2.85$, $p = .003$, voice conditions (Figure 2).

Next, a 2 (Sex: male, female) × 2 (Voice Condition: masculinized, feminized) mixed-factorial ANOVA with distraction cost as the dependent measure revealed that the distraction costs associated with the two voice conditions did not significantly differ based on sex, $F(1, 76) = 0.04$, $p = .841$, $\eta_p^2 = .001$. Moreover, sex did not affect the degree of distraction associated with either the masculinized or feminized man's voice, $F(1, 76) = 0.06$, $p = .803$, $\eta_p^2 = .001$. Finally, the main effect of voice condition was not significant, $F(1, 76) < 0.001$, $p = .998$, $\eta_p^2 < .001$, indicating that the magnitude of the distraction effect was the same for the two voice conditions (Figure 2).

Table 1. Men and women's mean distraction costs (mean count time to complete the SCT in silence subtracted from mean count time to complete the SCT in the presence of irrelevant speech)

	Voice condition					
	Feminized			Masculinized		
Sex	*M* (s)	*SD* (s)	95% CI (s)	*M* (s)	*SD* (s)	95% CI (s)
Men	0.99	3.02	[−3.86, 7.47]	1.08	2.71	[−4.61, 6.12]
Women	0.95	3.03	[−4.48, 5.50]	0.86	3.50	[−3.80, 7.46]

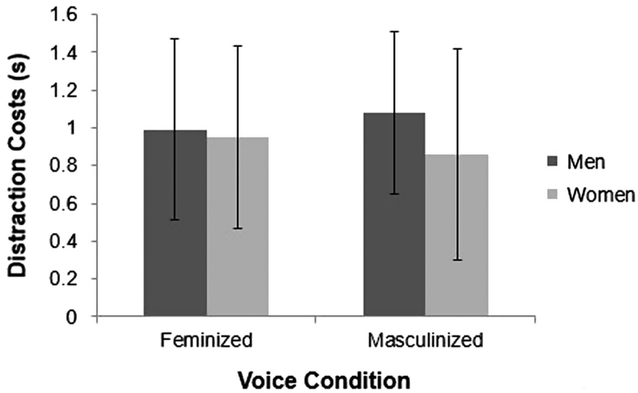

Figure 2. Mean distraction costs (mean count time to complete the SCT in silence subtracted from mean count time to complete the SCT in the presence of irrelevant speech) as a function of sex in the feminized and masculinized SCT conditions. Error bars reflect standard error of the mean.

Accuracy During the Implicit Memory Phase

Given that the two voice conditions had the same level of distractibility, we next sought to understand how the different voice conditions influenced implicit memory. Participants' implicit memory for the previously presented, but ignored sentences was assessed by determining the percent correct for the sentences presented, during the SCT, as masculinized and feminized irrelevant background speech and comparing that accuracy with their accuracy for the new sentences, which had not been previously presented. In order to determine whether previous presentation of these sentences, resulted in implicit memory for the information, we conducted a 2 (Sex: male, female) × 3 (Voice Condition: previously presented masculinized, previously presented feminized, and new unmodified) mixed-factorial ANOVA. For this ANOVA, sex served as the between-subjects factor, voice condition served as the within-subjects factor, and SPIN task accuracy (i.e., percentage of correctly identified final words in each voice condition) was the dependent variable. Overall, accuracy was similar between men and women, $F(1, 76) = 0.65$, $p = .421$, $\eta_p^2 = .009$, and did not vary according to voice condition, $F(2, 152) = 2.07$, $p = .13$, $\eta_p^2 = .027$; however, these effects were qualified by a significant Sex × Voice Condition interaction, $F(2, 152) = 3.56$, $p = .031$, $\eta_p^2 = .045$. This interaction revealed that men and women were influenced by the vocal characteristics in the irrelevant background speech differently during the SCT.

Previous Presentation Benefit

To compare the extent that previous presentation of masculinized and feminized sentences presented during the SCT enhanced participants' performance on the SPIN task, we calculated benefit scores for each voice condition. To calculate these scores, we assumed that participant performance in the new condition reflected their baseline accuracy on SPIN task trials, and that greater accuracy in the previously presented masculinized and/or previously presented feminized conditions reflected a benefit due to the previous presentation of those sentences during the SCT trials. Thus, in order to create scores that reflected only a benefit for previous presentation, we subtracted participant accuracy in the new sentence condition from their accuracy in the masculinized voice condition and feminized voice condition, respectively (Table 2).

Table 2. Men and women's mean benefit scores (percentage of new final words identified in noise subtracted from the percentage of previously presented final words identified in noise)

	Voice condition					
	Feminized			Masculinized		
Sex	*M* (% Cor)	*SD* (% Cor)	95% CI (% Cor)	*M* (% Cor)	*SD* (% Cor)	95% CI (% Cor)
Men	−0.30	10.31	[−17.50, 22.50]	3.12	8.73	[−10.00, 15.00]
Women	2.75	8.87	[−16.41, 15.00]	0.89	8.29	[−17.39, 12.50]

To determine if participants showed a significant previous presentation benefit (i.e., if the accuracy with which participants identified the final word of previously presented sentences spoken by the masculinized man's and/or feminized man's voice was significantly greater than that of new sentences), we conducted 2 one-tailed, one-sample *t*-tests (Figure 3). Men derived a significant benefit from sentences previously spoken by the masculinized man's voice, $t(38) = 2.24$, $p = .016$, but not from sentences previously spoken by the feminized man's voice, $t(38) = -0.18$, $p = .428$. In contrast, women derived a significant benefit from sentences previously spoken by the feminized man's voice, $t(38) = 1.93$, $p = .031$, but not from sentences previously spoken by the masculinized man's voice $t(38) = 0.67$, $p = .253$.

To analyze the effect of sex and voice condition on benefit scores, we conducted a 2 (Sex: male, female) × 2 (Voice Condition: masculinized, feminized) mixed-factorial ANOVA. Although neither the sex main effect, $F(1, 76) = 0.05$, $p = .825$, $\eta_p^2 = .001$, nor the voice condition main effect, $F(1, 76) = 0.73$, $p = .396$, $\eta_p^2 = .009$, were significant, these main effects were qualified by a significant Sex × Voice Condition interaction, $F(1, 76) = 8.22$, $p = .005$, $\eta_p^2 = .098$ (Figure 3). To understand this interaction, we conducted paired *t*-tests comparing benefit scores within the two groups and controlled for experimentwise Type I error using the Holm's sequential Bonferroni correction. As hypothesized, men received a significantly larger benefit from the previous presentation of sentences spoken by the masculinized man's voice compared to sentences spoken by the feminized man's voice, $t(38) = 2.53$, $p = .016$ (Figure 3). Women, on the other hand, demonstrated a larger previous presentation benefit for sentences spoken by the feminized man's voice compared to sentences spoken by the masculinized man's voice, but this difference was not significant, $t(38) = 1.49$, $p = .146$ (Figure 3).

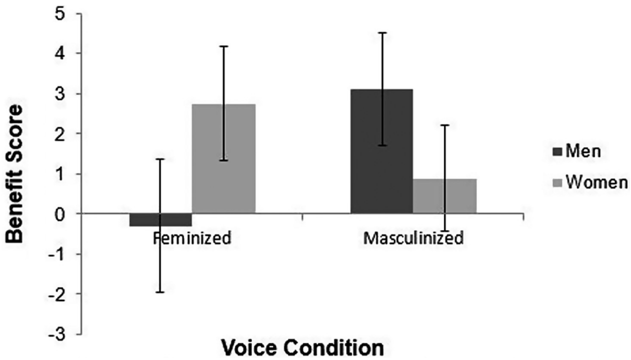

Figure 3. Mean benefit scores (percentage of new final words identified in noise subtracted from percentage of previously presented final words identified in noise) as a function of sex in the feminized and masculinized SPIN task conditions. Error bars reflect standard error of the mean.

Revised Sociosexual Orientation Inventory (SOI-R)

To determine if women's sociosexual orientations influenced their inadvertent attention toward sentences spoken by the masculinized or feminized man's voice during the SCT, we conducted Pearson's correlations between women's SOI-R scores and their distraction cost scores for the different voice conditions (Figure 4). There was no significant relationship between women's SOI-R scores and their distraction cost scores in the masculinized man's voice condition, $r = .04$, $n = 39$, $p = .825$, or the feminized man's voice condition, $r = .14$, $n = 39$, $p = .382$. Next, to see if women's sociosexual orientation influenced their levels of implicit memory for information spoken by either the masculinized or feminized man's voice, we conducted Pearson's correlations between women's SOI-R scores and their previous presentation benefit scores for the different voice conditions. The benefit women received from the previous presentation of masculinized sentences was significantly correlated with their SOI-R scores, $r = .42$, $n = 39$, $p = .008$. Thus, greater SOI-R scores predicted better memory for sentences previously said by the masculinized man's voice, but not the feminized man's voice, $r = .29$, $n = 39$, $p = .077$.

Experiment 1 Conclusions

Findings from Experiment 1 indicated that men and women automatically processed sentences presented as irrelevant background speech. Both sexes more accurately identified the final words of sentences presented as target speech within a high level of background noise when these

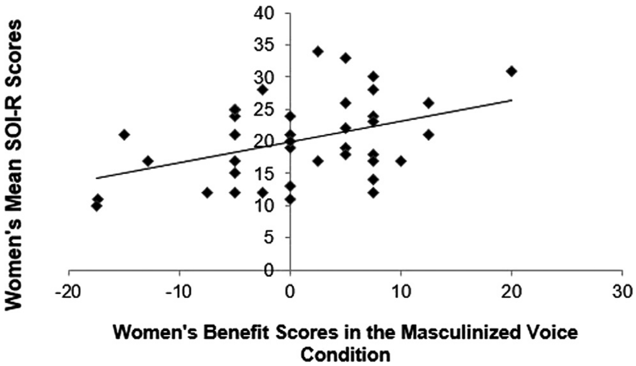

Figure 4. Scatterplot demonstrating the relationship between women's mean SOI-R scores and their mean benefit scores in the masculinized voice condition.

sentences had previously been presented as to-be-ignored, irrelevant background speech, compared to the accuracy for new sentences. The likelihood of this automatic processing was influenced by the way in which this speech was manipulated (i.e., the masculinization or feminization of the male voice). However, we presented both manipulated sentences and unmanipulated sentences in the Implicit Memory Phase of this experiment. Thus, these implicit memory results could possibly be due to the ease with which these sentences are heard in noise rather than a benefit received from their previous presentation. In order to determine whether there were differences in the ways in which men and women heard these masculinized, feminized, and unmodified sentences in noise, a small sample of men and women completed the SPIN task without previously hearing the sentences as distracting background speech (Experiment 2). We expected to find no differences between the accuracy with which individuals would identify the final word of the sentences in this experiment as they would not have heard the sentences previously.

Experiment 2

Method

Participants

Ten women (M_{age} = 20.00, SD = 1.15 years, Range = 19–22 years) and 10 men (M_{age} = 21.80 years, SD = 2.90 years, Range = 18–27 years) participated in this experiment. Participants were recruited and compensated in the same manner as in Experiment 1; participants had normal hearing according to the same measures as in Experiment 1.

Materials

Auditory stimuli were the same as in the Implicit Memory Phase of Experiment 1.

Procedure

This study was approved by the Nipissing University Research Ethics Board (reference number: 13-09-06 RV2 R1). Procedures for the SPIN task in Experiment 2 were identical to the procedures used in the Implicit Memory Phase of Experiment 1; however, participants completed the SPIN task without prior exposure to the sentences. Participant accuracy is reported in Table 3.

Results

To assess men and women's ability to accurately identify the last word of each sentence within the different voice conditions, a 2 (Sex: male, female) × 3 (Voice Condition: masculinized man's voice, feminized man's voice, and unmodified man's voice) mixed-factorial ANOVA was conducted. There was no significant Sex × Voice Condition interaction, $F(2, 36) = 0.74$, $p = .48$, $\eta_p^2 = .04$. Similarly, there was no significant main effect for sex, $F(1, 18) = 0.65$, $p = .43$, $\eta_p^2 = .04$, or voice condition, $F(2, 36) = 2.25$, $p = .12$, $\eta_p^2 = .11$. These results suggest that all voice conditions were equally perceptible for both men and women.

Discussion

Our first hypothesis (H1) was that both men and women would be more distracted by the presentation of irrelevant information in the masculinized man's voice than the feminized man's voice during the SCT, as reflected by longer count times for the masculinized man's voice than for the feminized man's voice and silence conditions. The results of the SCT from Experiment 1 showed longer count times for both the masculinized and feminized man's voice relative to the silence condition, partially supporting H1. However, the masculinized man's voice was not associated with significantly longer count times than the feminized man's voice. This finding indicates men and women show the same irrelevant speech effect for both the masculinized and feminized man's voice. However, it also suggests that, at least for this task, information spoken by the masculinized man's voice was not more effective at capturing listeners attention than was information spoken by the feminized man's voice, perhaps because both men and women were equally effective at ignoring spoken information regardless of speaker's vocal pitch.

Our second hypothesis (H2) was that both men and women should demonstrate greater implicit memory for information previously spoken by the masculinized man's voice compared to the feminized man's voice. Participants' SPIN task accuracy would be greatest for information previously presented in the masculinized man's voice,

Table 3. Mean accuracy for men and women in the new, masculinized and feminized SPIN task conditions

	Voice condition								
	Feminized			Masculinized			Unmodified		
Sex	*M* (% Cor)	*SD* (% Cor)	95% CI (% Cor)	*M* (% Cor)	*SD* (% Cor)	95% CI (% Cor)	*M* (% Cor)	*SD* (% Cor)	95% CI (% Cor)
Men	77.70	10.91	[60.00, 92.50]	79.75	10.57	[55.00, 90.00]	79.20	14.17	[60.00, 97.50]
Women	71.25	10.82	[57.50, 90.00]	78.97	12.51	[60.00, 95.00]	76.00	8.43	[57.50, 85.00]

followed by information presented in the feminized man's voice, followed by information that was not previously presented. Results of the SPIN task from Experiment 1 showed that men derived a significant previous presentation benefit for the masculinized man's voice and the feminized man's voice compared to new sentences (i.e., they more easily identified target words previously spoken by the masculinized man's voice and feminized man's voice compared to new words). Men also demonstrated a greater previous presentation benefit for the masculinized man's voice compared to the feminized man's voice. Both of these findings partially support H2. Women however, only had a previous presentation benefit for the feminized man's voice, which is contrary to H2. This finding may be consistent with that of Puts et al. (2016) who demonstrated that when entered together into regression analyses, male dominance ratings negatively predicted men's F0, but short-term attractiveness ratings made by women did not, suggesting a stronger role for male contests than female choice in shaping men's F0. In Experiment 2, we found that all three voice conditions were equally difficult to hear in noise when participants were unfamiliar with the sentences. Thus, the results of Experiment 1 were not due to a greater ease of hearing one voice in noise over any other.

Previous studies have shown that women rate lower-pitched men's voices as more attractive than higher-pitched men's voices (e.g., Collins, 2000; Feinberg et al., 2005; Jones, Feinberg et al., 2010; Puts, 2005; Puts et al., 2006); however, in this experiment, women did not show greater implicit memory for the information spoken by the masculinized man's voice. Rather they showed a significant previous presentation benefit for the feminized man's voice and a nonsignificant trend toward greater implicit memory for information spoken by the feminized man's voice relative to the masculinized man's voice. It is possible that vocal characteristics are processed differently at implicit compared to explicit levels.

Our third hypothesis (H3) was that women with less restricted sociosexual orientations, as measured by the SOI-R, would have longer count times than women with more restricted sociosexual orientations when sentences were spoken by the masculinized man's voice. We found no significant correlation between women's SOI-R scores and their distraction cost scores in either the masculinized man's voice condition or the feminized man's voice condition. Although most women in this study appeared to unconsciously process information spoken by the feminized man's voice, women with less restricted sociosexual orientations appeared to automatically process information spoken by the masculinized man's voice, which offers support for Hypothesis 4. Specifically, there was a positive relationship between women's SOI-R scores and the extent that they benefitted from the previous presentation of sentences spoken by the masculinized man's voice. This finding also corresponds with O'Connor et al.'s (2014) finding that women with less restricted sociosexual orientations assign higher attractiveness ratings to masculinized men's voices. The fact that only women, in our sample, with less restricted sociosexual orientation inadvertently attended to the masculinized man's voice may indicate that these women are using a mating strategy in which they are seeking to mate with men of high genetic quality (Fisher, 1958; Gangestad & Simpson, 2000; Westneat & Birkhead, 1998).

Men also exhibited greater implicit memory for information spoken by the masculinized voice compared to the feminized man's voice. Referring back to functional incompatibility (Sherry & Schacter, 1987), which states that memory systems have developed to solve adaptive problems that other systems cannot address, it is possible that men's greater implicit memory for information spoken by the masculinized man's voice may represent a broader cognitive system that deals with attending to information in the environment that could aid in their survival or reproductive success. Men's use of other men's F0s to identify dominant men in their environment may serve multiple purposes. For example, men's ability to attend to other men's vocal characteristics that are associated with dominance may function to identify dominant men for the purpose of avoiding confrontation with those who could harm them (Keeley, 1997; Manson et al., 1991). There is substantial evidence for a long history of violence between men (Keeley, 1997). In modern times, male-male violence is still the dominant form of dyadic aggression. The mortality rate for males is greater than the mortality rate for females. This can be partially attributed to male-male homicide, which accounts for a substantial portion of all homicides yet is only one of four options for homicides between the sexes (Wilson & Daly, 1985). Therefore, it is not surprising that men may have evolved cognitive structures that help them identify potentially dangerous men in their environment, because violence between men has been and still is a common threat to men's survival (Wilson & Daly, 1985). In support of this idea, Sell et al. (2010) demonstrated that both men and women can accurately assess the physical strength of men from their voice recordings. The authors suggest that this ability to assess men's physical strength from their recordings may have been adaptive, as it would allow men and women to assess the fighting ability of the speaker. The fact that men demonstrate greater implicit memory for information spoken by a masculinized man's voice provides further support that men attend to dominance cues in other men's voices, perhaps because doing so helps them to identify and avoid physical confrontation with physically dominant men.

Men's ability to attend to dominance cues in other men's voices may also help them to identify genetically fit competitors during mate competition. Evidence for this idea comes from O'Connor and Feinberg (2012), who found that men report greater levels of jealousy when asked to imagine their romantic partner flirting with a man with a masculinized voice. They also found that men would be less likely to allow their partner to go on a weekend trip with a man that had a low-pitched voice, suggesting that men are more likely to engage in mate guarding in the presence of masculine men. Overall, the results of O'Connor and Feinberg's (2012) study support the idea that men may attend to vocal cues during mate competition because their results demonstrate men's level of jealousy changes based on their competitors' F0. Men with masculine voices often have more masculine faces (Skrinda et al., 2014) and bodies (Hughes et al., 2004). Masculine voices, faces, and bodies are sexually dimorphic traits and may serve as honest signals of the individual's quality (Dabbs & Mallinger, 1999; Folstad & Karter, 1992; Hughes et al., 2004; Skrinda et al., 2014; Zahavi, 1975). Skrinda et al. (2014) have provided evidence that men who possess masculine traits have better immune functioning. Furthermore, these men tend to have greater reproductive success (Apicella et al., 2007). Therefore, it may be advantageous for men to identify high mate-value men during mate competition because it helps them determine their probability of attracting a prospective partner when other men are also competing for her.

Overall, these results suggest that men may automatically process irrelevant background speech when the speech has been masculinized, and may use vocal characteristics within speech to derive a potential survival or reproductive advantage. Women with less restricted sociosexual orientations demonstrated a previous presentation benefit for information spoken by the masculinized male voice, suggesting that some women may have a predisposition to inadvertently attend to low-pitched men's voices which could aid them during mate selection.

Limitations

Although the current findings address issues relevant to the automatic processing of vocal characteristics, there were some limitations to this research. First, stimuli were created using only one man's voice and one woman's voice; to allow for greater generalizability, future experiments should use vocal recordings from several men to ensure differences in participants' performance were due to vocal pitch and not a specific characteristic of one voice. Second, in the current experiment we did not include a rating phase. Although we used the pitch manipulation that is typically implemented in vocal attractiveness and dominance research (e.g., Jones, Feinberg et al., 2010), we have no way of knowing if our manipulation affected women's attractiveness perceptions and women and men's dominance perceptions. Moreover, we did not account for women's menstrual cycle phase. Previous research has shown that women's menstrual cycle phase and their circulating levels of estradiol affect their preference for masculine men's voices (Feinberg et al., 2006; Puts, 2005). Similarly, this study could have been improved by controlling the number of women who were taking hormonal contraception because women taking hormonal contraceptives tend to show a weaker preference for lower-pitched men's voices (Feinberg, DeBruine, Jones, & Little, 2008).

Future studies on how sexually dimorphic vocal characteristics capture attention should use both explicit and implicit measures and recordings of young adult men's voices to determine if dominance and attractiveness attributions occur at an automatic level. Specifically, by including a rating phase in future investigations where men and women listen to and rate the attractiveness and dominance of manipulated (i.e., masculinized and feminized) men's voices prior to testing the distractibility of information spoken by these voices, researchers would be in a better position to determine if vocal characteristics such as F0 are salient cues that listeners automatically use to judge the relative fitness of the speaker.

Conclusions

In conclusion, we found evidence that men automatically process and remember background speech presented in a masculinized man's voice more readily than background speech presented in a feminized man's voice. Only women with less restricted sociosexual orientations demonstrated greater implicit memory for the speech presented in the masculinized voice. Although only a few women appear to be affected by the presentation of information spoken by the masculinized man's voice, most men appear to be using this characteristic of the voice perhaps as a means of automatically identifying dominant individuals in their environment. Vocal attractiveness and vocal dominance research are relatively new fields that offer many testable predictions that have yet to be investigated. We hope that researchers in these fields will begin to use methodologies that test for the presence of cognitive systems that have developed for the purpose of attending to and remembering information relevant to survival (Kang et al., 2008; Nairne et al., 2007; Sherry & Schacter, 1987) and reproduction (Bateson & Healy, 2005).

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Author Contributions: G. Albert developed the study concept. D. R. Murphy developed the study design in collaboration with S. Arnocky, J. Nicol, and G. Albert. M. Wachowiak developed and implemented the software for the experiment. Testing, data collection, analyses, and interpretation were performed by G. Albert and M. Pearson under the supervision of D. R. Murphy and S. Arnocky. M. Pearson and G. Albert drafted the manuscript; D. R. Murphy, S. Arnocky, M. Wachowiak, and J. Nicol reviewed the manuscript. All authors approved the final version of the manuscript for submission.

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Steven Arnocky
Department of Psychology
Nipissing University
100 College Dr.
North Bay, ON P1B 8L7
Canada
stevena@nipissingu.ca

