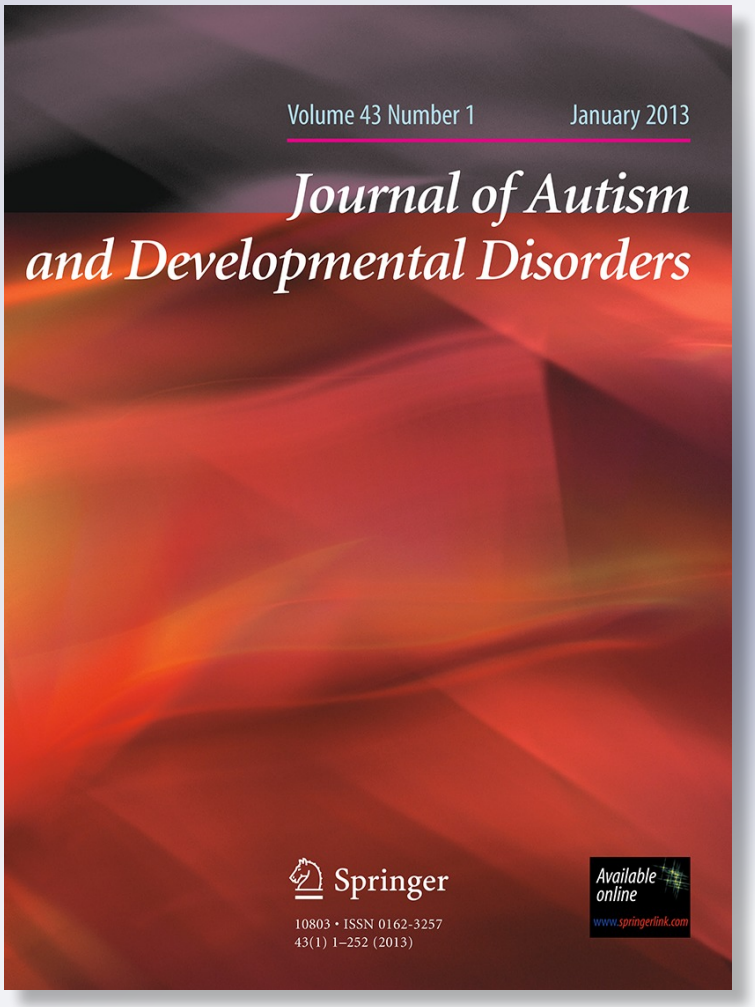
Perception of Talker Age by Young Adults with High-Functioning Autism

Cynthia G. Clopper, Kristin L. Rohrbeck & Laura Wagner

Journal of Autism and Developmental Disorders

ISSN 0162-3257
Volume 43
Number 1

J Autism Dev Disord (2013) 43:134-146
DOI 10.1007/s10803-012-1553-5



Springer

J Autism Dev Disord (2013) 43:134–146
DOI 10.1007/s10803-012-1553-5

Perception of Talker Age by Young Adults with High-Functioning Autism

Cynthia G. Clopper · Kristin L. Rohrbeck · Laura Wagner

Published online: 26 May 2012

Abstract People with high-functioning Autism (HFA) can accurately identify social categories from speech, but they have more difficulty connecting linguistic variation in the speech signal to social stereotypes associated with those categories. In the current study, the perception and evaluation of talker age by young adults with HFA was examined. The participants with HFA performed similarly to a typically-developing comparison group in age classification and estimation tasks. Moreover, the participants with HFA were able to differentiate among talkers of different ages in a language attitudes task and rated older talkers as more intelligent than younger talkers. These results suggest that people with HFA are able to make reasonable social judgments about talkers based on their speech, at least for familiar social categories and personally relevant social attitudes.

Keywords Age · Speech perception · Language attitudes · Social language · High-functioning Autism

Introduction

Speech conveys not only the information in the words and sentences, but also social properties of the talker, including gender, age, and region of origin. This kind of social indexical information is consistently produced and readily perceived in the course of normal conversational discourse. The current study considers the perception of one particular kind of indexical information: the age of the talker. Moreover, this study examines the perception of talker age among young adults with high-functioning Autism (HFA). This population has good language abilities in general, but has ongoing difficulties with various socio-communicative aspects of language (Baron-Cohen et al. 2000; Rice et al. 2005). Previous research examining another indexical category—regional dialect—has shown that young adults with HFA are capable of perceiving and categorizing speech based on relevant indexical cues, but that they fail to link the speech to common social stereotypes (Clopper et al. 2012). These results suggest a strong division between the acoustic and social processing aspects of speech perception in this population. However, regional dialect may be a social dimension with which the participants had relatively little experience. The current study focuses on an indexical category—talker age—with which participants are likely to have had a much richer set of personal experiences. These studies provide a better opportunity for the young adults with HFA to demonstrate their ability to perceive the social dimension of indexical information, if they are indeed able to do so.

Age Perception in the Typically-Developing Population

Typically-developing (TD) listeners can correctly classify talkers into age groups based only on the information contained in the speech signal (Ptacek and Sander 1966; Shipp and Hollien 1969; Ramig 1986; Huntley et al. 1987; Caruso et al. 1994; Hummert et al. 1999). They are similarly able to estimate a talker's exact age within a reasonable margin of error (Ryan and Burk 1974; Horii and

C. G. Clopper (✉)
Department of Linguistics, Ohio State University, 1712 Neil Avenue, Columbus, OH 43210, USA
e-mail: clopper.1@osu.edu

K. L. Rohrbeck · L. Wagner
Department of Psychology, Ohio State University, Columbus, OH, USA

Ryan 1981; Braun 1996; cf. Neiman and Applegate 1990). In a typical age perception study, participants hear a series of talkers and make either a forced-choice judgment (Does this talker sound like they are in their 30s, 40s, 50s, or 60s?) or a more open-ended judgment (How old is this talker?) for each talker in the stimulus set. The ability to make correct age judgments is observed throughout the typically developing population, including among amateurs and expert phoneticians (Braun 1996), male and female listeners (Hartman 1979), and native listeners of different languages (Benjamin 1992). In addition, listeners are able to make correct age judgments about talkers that speak a different language from themselves (Nagao 2006), when presented with relatively noisy speech, such as speech over a telephone (Cerrato et al. 2000), and on the basis of as little as one syllable of speech, although they perform substantially better when given at least a full clause (Nagao 2006).

To make these accurate age judgments, listeners can rely on a number of acoustic properties of the human voice that have been found to vary with age (Kreiman and Sidtis 2011). Some of these properties correspond to age-related anatomical changes in the vocal tract. For example, pitch tends to lower with age from young adulthood to middle-age and then increase for older adults (e.g., Hollien and Shipp 1972; Harnsberger et al. 2008) and older adults tend to have a more hoarse or rough voice quality than younger adults (Ptacek and Sander 1966; Hartman and Danhauer 1976; Hartman 1979). Other differences between older and younger talkers may be linked to changes in cognitive functioning. For example, older adults tend to speak more slowly (Ptacek and Sander 1966; Harnsberger et al. 2008) and have less precision in their articulation (Hartman and Danhauer 1976; Ryan and Capadano 1978) than younger adults. Other properties that vary with age among adults include harmonic-to-noise ratio, laryngeal tension, voice tremor, and pitch variation (Ryan and Burk 1974; Linville and Fisher 1985; Linville and Korabic 1986; Debruyne and Decoster 1999). While some of these acoustic characteristics, such as voice tremor and some measures of imprecise articulation, are largely restricted to talkers above 60 years old (Ryan and Burk 1974), other properties, such as mean f0, vary even among talkers in their 20s, 30s, and 40s (Hollien and Shipp 1972). Thus, properties of speech and voice change throughout adulthood and can be used by listeners to estimate an individual talker's age.

In addition to being able to correctly categorize talkers by age, listeners also have consistent social stereotypes about talkers of different perceived ages that are revealed in language attitudes tasks. In these tasks, listeners are asked to rate unfamiliar talkers on a range of social characteristics based on short speech samples (Giles 1970; Luhman 1990). When TD listeners are asked to evaluate talkers that vary with respect to age, older talkers are typically rated as being weaker and less flexible than younger talkers (Ryan and Capadano 1978; Sebastian and Ryan 1985; Giles et al. 1990). However, older talkers are also often rated as wiser and more benevolent than younger talkers (Giles et al. 1992) and middle-age adults are rated as more competent than young adults (Giles et al. 1992). These language attitudes largely correspond to familiar stereotypes about young people and the elderly (Giles et al. 2008) and reflect the importance of age as a social category in general (Montepare and Zebrowitz 1998).

Perception of Indexical Categories by People with Autism Spectrum Disorders

A growing body of research considers the ability of people with Autism spectrum disorders (ASD) to use and perceive indexical and social-communicative information from speech. With some kinds of indexical information, people with ASD perform as well as TD people: they can recognize individual voices and link them to individual talkers (Boucher et al. 2000), they can adjust their own speech as a function of the social identity of their interlocutor (Volden et al. 2007; Volden and Sorenson 2009), they can accurately identify talker gender (Groen et al. 2008), and they can accurately group talkers according to their regional dialect and categorize them as being from the local area or not (Clopper et al. 2012). Previous research has also shown that adults with HFA can accurately categorize talkers as being older or younger than 42 years old (Rutherford et al. 2002).

However, in tasks where the social component of speech is particularly important, people with ASD tend to do worse than their TD peers. For example, people with ASD have difficulties in perceiving the emotional intent of speech (Golan et al. 2007; Rutherford et al. 2002) and in producing target sentences in different emotional colors (Hubbard and Trauner 2007). They also have difficulty in determining if speech is conveying sarcasm or praise (Imaizumi et al. 2009). In addition, Clopper et al. (2012) found that young adults with HFA did not show systematic language attitude judgments about talkers of different regional dialects. The TD adults' ratings showed evidence of general social stereotypes, such as the stereotype that talkers of less prestigious dialects are less successful, and that talkers with a Southern accent are more friendly (see also Lambert et al. 1960; Luhman 1990). Although the adults with HFA could use the differences between talkers of different regional dialects to make fact-based judgments about their region of origin, they did not use the acoustic differences to make social judgments about friendliness and successfulness. They did, however, make distinctions between the dialects in their intelligence ratings. Talkers

from the local dialect were rated as more intelligent than talkers from the other dialect regions. The TD listeners also rated the local dialect talkers as most intelligent, but they also differentiated among all of the non-local dialects in their intelligence ratings. Thus, the adults with HFA were able to make one meaningful distinction between local and non-local dialects in the intelligence rating task, but, unlike the TD adults, they failed to distinguish among the non-local dialects.

The results from Clopper et al.'s (2012) study are consistent with the hypothesis described by Mottron et al. (2006) that people with ASD have enhanced perceptual functioning (see also Happé and Frith 2006). From this perspective, success in the free classification task depends primarily on acoustic perception—something that is not only preserved, but enhanced in the ASD population. The difficulties with attitude judgments are the result of two factors: first, the task is more complex because it requires the integration of the acoustic information with social information, and second, the enhanced perceptual abilities make it harder for the ASD participants to attend to the relevant (and only the relevant) information in the speech signal. To the extent that enhanced perceptual functioning makes it more difficult for people with ASD to focus on relevant information and, perhaps more importantly, integrate it with complex social information, we expect that factors which improve performance on complex tasks in general will also improve the performance of people with ASD in interpreting indexical information in the speech signal.

For example, in Clopper et al.'s (2012) study, the HFA and TD participant groups differed substantially in how much prior experience or exposure they had with the social category being examined—dialect variation. Most (67 %) of the participants with HFA were native speakers of the local dialect and had lived in the same dialect region all of their lives, whereas fewer than half (46 %) of the TD participants were lifetime residents of the local dialect area. The HFA participants' exposure to other regional dialects, therefore, may have been relatively limited and involved only personal experience with a small number of native speakers from other dialect regions and general media exposure to the other dialects. Limited experience with other dialects would not likely interfere with the ability of HFA adults to categorize talkers by regional dialect, as the objective acoustic differences among the dialects in combination with their enhanced perceptual functioning would be adequate for success. However, for the more complex task of integrating the dialects with social attitudes, their limited experience with dialect variation may not have been sufficient to support the required representations and inferences.

The indexical category of age is quite different from regional dialect in terms of participants' own experiences. Age is a property that varies within a local community and all children are likely to have many personal encounters with people of different ages, including their peers, their teachers and parents, and their grandparents. Moreover, age is correlated with differences in physical appearance. Whereas a speaker of Southern American English is unlikely to wear a sign indicating their home state, physical appearance alone can indicate whether a person is more likely to be in their 20s or their 40s. Thus, it is more common both to get exposure to people in a variety of age groups and to get independent verification about someone's age than it is to gain exposure to and verification about regional dialects. Both of these factors may make age an easier indexical category for young adults with HFA to perceive and connect to social qualities such as friendliness and successfulness.

Experimental Overview

The current study examined the perception of talker age by young adults with HFA in a series of three experiments. The first experiment was a free classification task in which the participants were asked to group a set of unfamiliar talkers by age (Clopper 2008). The actual ages of the talkers ranged from 22 to 44 years old—that is, young and middle-age adults. The second experiment asked participants to explicitly categorize each talker into one of five age groups ranging from "early 20s" to "early 40s". The third experiment was a language attitudes task in which participants were asked to rate each talker on two scales related to social status (intelligence, successfulness) and two scales related to talker-listener solidarity (friendliness, reliability) (Giles 1970; Luhman 1990). All three tasks were also completed by comparison groups of TD young adults.

Based on the previous literature on age perception, the TD adults were expected to correctly group talkers into age-based groups in the free classification task, correctly categorize talkers into age groups in the forced-choice categorization task, and show consistent attitude judgments based on age in the language attitudes task. The four attitude scales were chosen to be parallel to previous work on regional dialect (Clopper et al. 2012; Giles 1970; Luhman 1990), but have also been shown to reveal language attitudes towards young and middle-age adults (Giles et al. 1992). Based on previous research on language attitudes associated with age (Ryan and Capadano 1978; Giles et al. 1990, 1992), we predicted that the middle-age talkers would be rated higher than the younger talkers on both the solidarity scales (friendliness and reliability) and on the status scales (intelligence and successfulness).

For the participants with HFA, we predicted that performance on the free classification and explicit

categorization tasks would parallel performance on these kinds of tasks with regional dialect and gender (Groen et al. 2008; Clopper et al. 2012), and be consistent with the previous research on age perception that involved only two alternatives (Rutherford et al. 2002). In particular, participants with HFA were expected to perform as well as their TD peers on these tasks. In the language attitudes task, if adults with HFA are generally incapable of linking social information to acoustic differences in the speech signal, they should fail to exhibit consistent attitudes based on talker age, just as they largely failed to exhibit consistent attitudes based on regional dialect. However, if adults with HFA simply require more extensive experience with variation than TD adults to develop their social attitudes, they may be able to make consistent judgments based on talker age in the language attitudes task.

Experiment 1: Free Classification

Methods

Participants

Twenty-seven TD adults ($M = 21$ years; range 18–28 years; 8 males, 19 females) participated in this experiment and an unrelated experiment to receive course credit in an introductory linguistics course. Data from an additional three TD adults were excluded because they were not native English speakers ($N = 2$) or because they were more than four standard deviations older than the rest of the participants (age 36, $N = 1$). All of the remaining TD participants were monolingual native speakers of American English with no reported history of hearing or speech disorders.

In addition, fourteen adults with HFA ($M = 25$ years; range 21–30 years; 11 males, 3 females) were paid to participate in this experiment and an unrelated experiment. Data from one additional adult with HFA were excluded due to experimenter error. All of the participants with HFA were monolingual native speakers of American English and self-identified as having HFA. They were recruited from an outreach program run by a local center for developmental disabilities. The outreach program was specifically designed for young adults who have been diagnosed with HFA and most of the participants in this program ($\sim$90 %) have obtained a formal diagnosis on the Autism spectrum, either as a child (33 %) or as an adolescent (57 %). Health records of five of the participants were accessed through the outreach program to confirm the self-reported diagnoses.

Approximately 62 % of the program participants have completed some college, 28 % have graduated from high school but not attended college, and the remaining 10 % are currently enrolled in high school. Four of the participants with HFA reported having a history of a speech, language, or hearing disorder (1 with speech apraxia, 3 in speech therapy). When these 4 subjects were removed from the dataset, the results were not significantly different than when they were included, so their data have been retained in the final analysis.

The Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001) was administered to all participants prior to the experiment to support the division between the two populations. The AQ is a self-report survey designed to assess the degree to which adults—both on and off the Autism spectrum—exhibit characteristics associated with ASD. AQ scores range from 0 to 50, with higher scores indicating traits that are more representative of ASD. The participants with HFA in this study scored significantly higher on the AQ than the TD participants (TD $M = 17.48$; HFA $M = 29.14$; $t(39) = 4.74$, $p < .001$). However, only 7 of the participants with HFA scored above the threshold score of 32 that Baron-Cohen et al. (2001) have suggested is the minimum score for identifying people who are on the spectrum. Other researchers have similarly found that people with positive ASD diagnoses do not always score above 32, and the scores of our participants with HFA are similar to those found in other HFA participant populations (Ketelaars et al. 2008; Woodbury-Smith et al. 2005). Moreover, we found that the average AQ score for HFA participants with diagnoses confirmed via health records was not significantly different than the average AQ score for HFA participants without such confirmation (HFA with confirmation $M = 29.8$, HFA without confirmation $M = 28.94$; $t(12) = 0.16$, n.s.), and that both HFA groups independently had higher mean AQ scores than the TD participants (TD vs. HFA with confirmation: $t(30) = 3.42$, $p < .002$; TD vs. HFA without confirmation: $t(34) = 4.29$, $p < .001$). These comparisons support the interpretation of our two participant groups as representing different populations.

Stimulus Materials

The stimulus materials consisted of a single sentence "She had your dark suit in greasy wash water all year" produced by each of 18 talkers. All of the talkers were white males who were native speakers of the local dialect. The talkers varied with respect to their age: four talkers were in their early 20s, two were in their late 20s, four were in their early 30s, five were in their late 30s, and three were in their early 40s at the time of recording ($M = 32$ years, SD = 7.2 years). Seventeen of the talkers were taken from the TIMIT corpus (Fisher et al. 1986), and the remaining talker was recorded specifically for this study. The

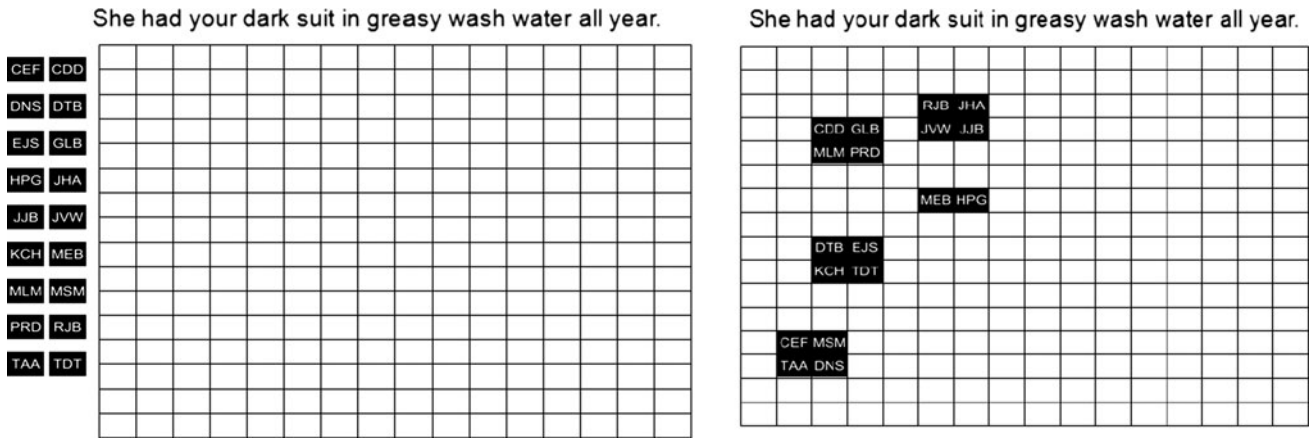


Fig. 1 The free classification experiment before (*left*) and after (*right*) a participant completed the task

relatively narrow age range of the talkers reflects the distribution of talker ages in the TIMIT corpus, which is skewed young for the local dialect region. Each sentence was stored in an individual digital audio file with a 22,050 Hz sampling rate and 16-bit resolution, and each audio file was linked to an image of the talker's initials (see Fig. 1).

Procedure

Participants were seated at a computer and were presented with a 16 × 16 grid. The stimulus sentence ("She had your dark suit in greasy wash water all year") was printed above the grid for reference. To the left of the grid were the 18 images of the talkers' initials representing the different talkers. The display at the beginning of the experiment is shown in the left panel of Fig. 1. Participants could hear the sound file for an individual talker by clicking on that talker's initials, and were allowed to listen to each talker as many times as they liked. Participants were told to listen to the talkers and to group them on the grid (by dragging the images with the mouse) according to age. They were told that they could make as many groups, containing as many talkers, as they thought was appropriate, and that the talker groups could be of different sizes. The participants were encouraged to rearrange the talkers as many times as they wanted until they were satisfied with their classification. A sample completed grid is shown in the right panel of Fig. 1.

Results

The HFA and TD groups performed very similarly in terms of their overall classification strategies. They created similar numbers of groups of talkers ($t(39) = 1.85$, n.s.) and placed similar numbers of talkers into each group ($t(39) = 0.03$, n.s.). The means and standard deviations of the number of groups and number of talkers per group produced by the adults with HFA and the TD adults are shown in Table 1.

Table 1 Means and standard deviations of the number of groups and number of talkers per group for each population

	Number of groups	Talkers per group
Adults with HFA	5.43 (2.82)	4.53 (2.75)
TD adults	4.30 (1.10)	4.51 (1.36)

To assess the perceived similarity of the talkers with respect to age, separate talker similarity matrices were constructed for the TD adults and the adults with HFA. The cells in these matrices correspond to the number of listeners who grouped each pair of talkers together. Perceptually similar talkers were grouped together by many listeners, whereas perceptually dissimilar talkers were grouped together by few listeners. The matrices were submitted to the additive clustering algorithm, ADDTREE (Corter 1982), to obtain a visual representation of the perceptual similarity of the talkers. The clustering solutions for the TD adults and the adults with HFA are shown in the left and right panels of Fig. 2, respectively. In these figures, the talkers are indicated by their age (in years) at the time of the recording and the perceptual distance between a pair of talkers is represented by the sum of the lengths of the horizontal branches connecting them.

The clustering solutions in Fig. 2 reveal two primary clusters of talkers for both the TD adults and the adults with HFA. The clusters are separated in the figures by hand-drawn horizontal lines to facilitate interpretation. For both populations, the top cluster of talkers represents a relatively younger group, whereas the bottom cluster represents a relatively older group. For the TD population, the "young" cluster includes four of the talkers in their 20s and five of the talkers in their 30s. The "middle-age" cluster

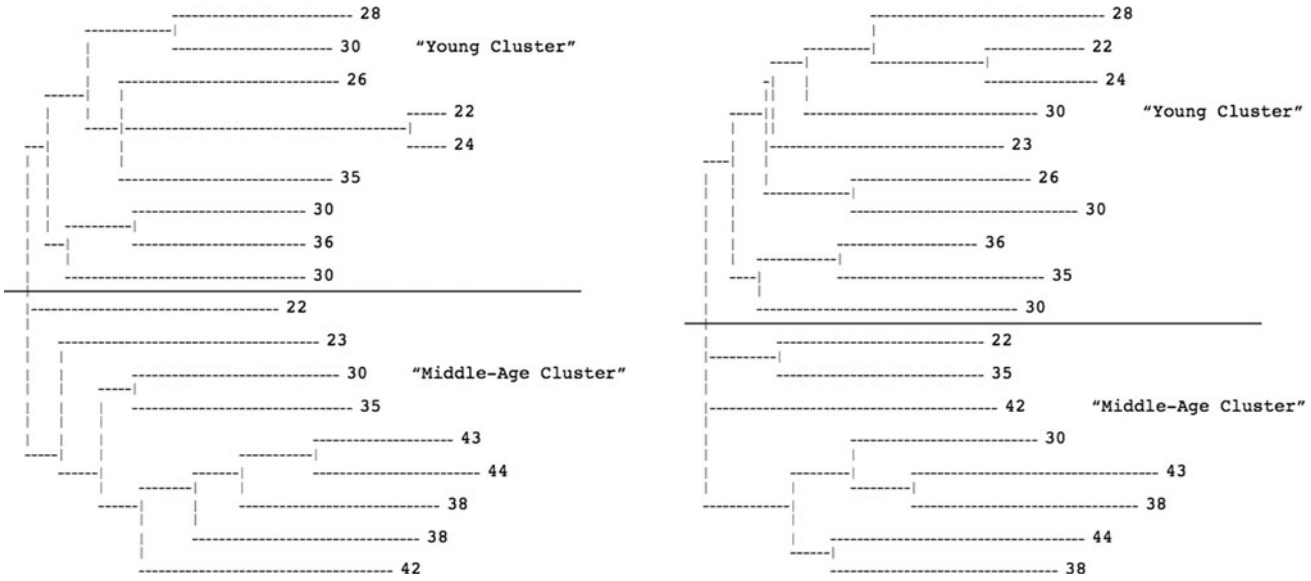


Fig. 2 Clustering solutions for the TD adults (*left*) and the adults with HFA (*right*)

includes two of the talkers in their 20s, four of the talkers in their 30s, and all of the talkers in their 40s. For the HFA population, the "young" cluster includes five of the talkers in their 20s and five of the talkers in their 30s. The "middle-age" cluster includes one talker in his 20s, four talkers in their 30s, and all of the talkers in their 40s.

The means and standard deviations of the actual ages of the talkers in each cluster are shown in Table 2 for each population. For the TD listeners, the young and middle-age clusters were only marginally differentiated with respect to age ($t(16) = 1.89$, $p = .07$). However, for the listeners with HFA, the actual ages of the talkers in the young and middle-age clusters were significantly different ($t(16) = 2.81$, $p = .01$), suggesting that the listeners with HFA were better able to perceive age-related differences between the talkers than the TD listeners. To assess individual differences in age classification performance, for each participant, the standard deviation of the actual ages of the talkers in each group was calculated. The mean of these standard deviations was taken as a measure of individual ability to distinguish among talkers of different ages. AQ score was not significantly correlated with mean standard deviation for either listener group, suggesting a population difference in age classification rather than individual differences related to AQ score.

Four acoustic measures that have been shown in previous research to vary with age (e.g., Debruyne and Decoster 1999; Harnsberger et al. 2008) were obtained from each of the stimulus sentences: duration (as a measure of speaking rate), mean f0, standard deviation of f0, and spectral slope (as a measure of voice quality). The spectral slope measure was the difference in amplitude between the 0–1,000 Hz range and the 1,000–5,000 Hz range, calculated from the long-term average spectrum of the entire target sentence. None of these acoustic measures were significantly correlated with the clustering solution for either the TD or the HFA population.

Table 2 Means and standard deviations of the actual ages of the talkers in the two clusters for each population

	"Young" cluster	"Middle-age" cluster
Adults with HFA	28.4 (4.77)	36.5 (7.45)
TD adults	29.0 (4.64)	35.0 (8.29)

Discussion

Overall, the young adults with HFA performed very similarly to the TD young adults on the free classification task. Both populations produced an average of 4–5 talker groups with 4–5 talkers per group and the clustering solutions revealed a cluster of young talkers and a cluster of middle-age talkers for both listener groups. Thus, as in the previous dialect classification experiment (Clopper et al. 2012), listeners with HFA were able to use properties of the speech signal to accurately classify talkers by the target indexical category, and to ignore differences between the talkers that were irrelevant for the task.

In addition, the more detailed examination of the actual ages of the talkers in the two perceptual clusters for each population revealed that the listeners with HFA were better able to differentiate the young and middle-age talkers than the TD listeners. This finding is consistent with the predictions of Mottron et al.'s (2006) enhanced perceptual functioning hypothesis. However, it contrasts with the

results of the dialect classification task, in which the participants with HFA exhibited fewer perceptual distinctions than the TD listeners with respect to the Northern dialect and the other dialects of American English (Clopper et al. 2012), and suggests that adults with HFA may have more robust perceptual categories for age than for dialect.

None of the acoustic measures that we examined were correlated with the classification performance of either listener group, suggesting that the listeners relied on other properties (or other combinations of properties) to make their classification judgments. Given that the age range of the stimulus talkers was only 22 years and that the oldest talker was only 44 years old, however, the lack of significant correlations between the acoustic measures and the clustering results may simply reflect a lack of sufficient variability in the stimulus materials for these measures. Stimulus materials produced by talkers with a wider range of ages, including older adults, would be more likely to reveal the acoustic properties that are most relevant for the perception of talker age by listeners with HFA.

The free classification task provides insights into how talkers are perceived relative to one another with respect to age, but it does not require the participants to explicitly link the groups that they produce to actual ages or age ranges. Thus, although we can characterize the two clusters produced by each population as "young" and "middle-age", we do not know if the listeners themselves would apply those same labels to their groups. In Experiment 2, we used an explicit age categorization task to explore how listeners' perception of age corresponds to the talkers' actual ages.

Experiment 2: Explicit Age Categorization

Methods

Participants

Thirty-two TD adults ($M = 20$ years; range 18–24 years; 7 males, 25 females) participated in this experiment and an unrelated experiment to receive course credit in an introductory linguistics course. Data from an additional five TD adults were excluded because they were not native English speakers ($N = 4$) or due to experimenter error ($N = 1$). All of the remaining TD participants were monolingual native speakers of American English with no reported history of hearing or speech disorders. None of the TD adults had participated in Experiment 1.

Thirteen adults with HFA ($M = 25$ years; range 19–28 years; 9 males, 4 females) were paid to participate in this experiment and an unrelated experiment. Data from one additional adult with HFA were excluded due to experimenter error. The diagnosis status was confirmed via health records for six of these participants. All of the participants with HFA were monolingual native speakers of American English, and three reported a history of a speech or language disorder (1 with speech apraxia, 2 in speech therapy). The participants with HFA were recruited from the same outreach program as the participants with HFA in Experiment 1. They all self-identified as having HFA and, as a group, scored significantly higher on the Autism-Spectrum Quotient than the TD participants (TD $M = 14.84$; HFA $M = 28.96$; $t(43) = 6.35$, $p < .001$). Moreover, there was no difference in AQ scores between the HFA participants who had confirmed diagnoses and those who did not (HFA with confirmation $M = 29.33$, HFA without confirmation $M = 28.64$; $t(11) = 0.13$, n.s.); and both HFA groups independently had higher AQ scores than the TD participants (TD vs. HFA with confirmation: $t(36) = 5.22$, $p < .001$; TD vs. HFA without confirmation: $t(37) = 5.39$, $p < .001$). Eleven of the participants with HFA also participated in Experiment 1 an average of 1.5 months prior to their participation in Experiment 2. It is therefore unlikely that their responses were influenced by their previous experience with the stimulus materials.

Stimulus Materials

The recordings from Experiment 1 of the 18 talkers reading the sentence "She had your dark suit in greasy wash water all year" were used in Experiment 2.

Procedure

Participants heard each talker say the stimulus sentence once and were asked to judge "How old do you think this person is?" on a 5-point scale consisting of "early 20s", "late 20s", "early 30s", "late 30s", and "early 40s". Each talker was rated twice across two blocks, such that each listener rated every talker once before rating all of the talkers a second time. For analysis, the responses were coded from 1 to 5, where 1 corresponded to the "early 20s" response and 5 corresponded to the "early 40s" response.

Results

A linear regression model was constructed to explore the effects of population (HFA or TD), actual talker age, and their interaction on the mean age ratings for each talker. The model accounted for 49 % of the variance in the data and revealed a significant effect of actual age ($p = .003$). The population factor and the interaction were not significant ($p = .46$ and $p = .39$, respectively). Given the larger sample of TD adults ($N = 32$) than adults with HFA ($N = 13$), planned comparisons were conducted on each population separately to ensure that the main effects did not

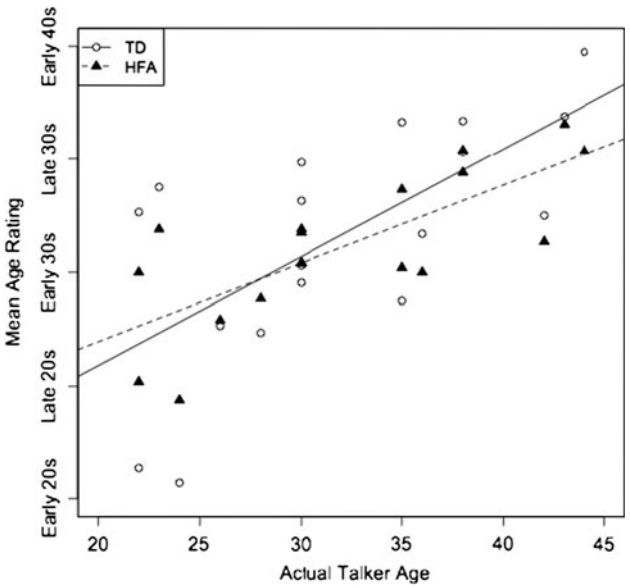


Fig. 3 Relationship between actual talker age and mean age ratings for the TD adults (*open circles*) and the adults with HFA (*filled triangles*). Regression lines show the best-fit line for each population

reflect the performance of only the larger TD population. The planned comparisons revealed that actual talker age was a significant predictor of the age ratings for both the TD listeners ($r^2 = .45$, $p = .002$) and the listeners with HFA ($r^2 = .57$, $p < .001$). For both populations, the older talkers were rated as older than the younger talkers. Figure 3 shows the relationship between the actual age of the talkers and the age ratings for each population. To explore individual differences in age rating, the slope of the relationship between perceived age and actual age was calculated separately for each participant. As in Experiment 1, AQ score was not significantly correlated with this measure of individual performance. In addition, as in Experiment 1, none of the acoustic measures were significantly correlated with the explicit age ratings.

Discussion

The young adults with HFA performed as well as the TD young adults in the explicit age categorization task. Both groups of listeners perceived younger talkers as younger than older talkers. This result extends Rutherford et al.'s (2002) finding that participants with HFA can distinguish between talkers who are older and younger than 42 years old, and demonstrates that adults with HFA can also make more fine-grained age distinctions between young and middle-age adults. Although the main effect of population was not significant in the regression analysis, the variance accounted for by the model with the data from just the HFA population is higher than the variance accounted for by the model with the data from just the TD population (57 vs. 45 %). This difference is consistent with the finding in Experiment 1 that the listeners with HFA performed slightly better than the TD listeners on the age classification task. Taken together, the results of Experiments 1 and 2 suggest that listeners with HFA can perceive talker age from the speech signal and can make explicit judgments about talker age that are as accurate, and in some cases more accurate, than age judgments by TD listeners. These results are not surprising, given that previous research on the perception of talker dialect and gender has also shown that listeners with HFA can map variation in the acoustic signal to these kinds of indexical categories (Clopper et al. 2012; Groen et al. 2008). However, perceptual differences have been shown to emerge between HFA and TD populations when the task requires the participants to connect phonetic variation to social stereotypes. In Experiment 3, we used a language attitudes task to explore the stereotypes that accompany age variation for listeners with HFA.

Experiment 3: Language Attitudes

Methods

Participants

Twenty-eight TD adults ($M = 20$ years; range 18–23 years; 6 males, 22 females) participated in this experiment and an unrelated experiment to receive course credit in an introductory linguistics course. Data from an additional three TD adults were excluded because they were not native English speakers. All of the remaining TD participants were monolingual native speakers of American English with no reported history of hearing or speech disorders. None of the TD adults had previously participated in either Experiment 1 or Experiment 2.

Fourteen adults with HFA ($M = 24$ years; range 19–28 years; 11 males, 3 females) were paid to participate in this experiment and an unrelated experiment. The diagnosis status was confirmed via health records for six of these participants. All of the participants with HFA were monolingual native speakers of American English, and two reported seeing a speech therapist. As in the previous two experiments, the participants with HFA were self-identified, and were recruited from an outreach program specifically designed for people diagnosed with HFA. In addition, the participants with HFA scored significantly higher than the TD participants on the Autism-Spectrum Quotient (TD $M = 15.25$; HFA $M = 27.86$; $t(40) = 6.10$, $p < .001$). Moreover, there was no difference in AQ scores

between the HFA participants who had confirmed diagnoses and those who did not (HFA with confirmation $M = 30.6$, HFA without confirmation $M = 22.3$; $t(12) = 0.53$, n.s.); and both HFA groups independently had higher AQ scores than the TD participants (TD vs. HFA with confirmation: $t(32) = 5.33$, $p < .001$; TD vs. HFA without confirmation, $t(34) = 5.24$, $p < .001$). Finally, one of the participants with HFA also participated in Experiment 1, two also participated in Experiment 2, and 10 participated in both Experiment 1 and Experiment 2. Participants completed Experiment 3 an average of 2.8 months after Experiment 1 and an average of 1.3 months after Experiment 2. It is therefore unlikely that their responses in this task were influenced by their previous experience with the stimulus materials.

Stimulus Materials

The recordings from Experiments 1 and 2 of the 18 talkers reading the sentence "She had your dark suit in greasy wash water all year" were also used in Experiment 3. Recordings from 17 additional white male talkers reading the same stimulus sentence were also included in this experiment. The current analysis is limited to the 18 talkers also used in Experiments 1 and 2 (but see Clopper et al. 2012 for a discussion of the responses to the additional 17 talkers).

Procedure

The experiment consisted of four blocks in which participants were asked to rate the talkers along different dimensions. Two status-oriented dimensions were tested (intelligence and successfulness) and two solidarity dimensions were tested (friendliness and reliability). In each block, participants heard each talker say the stimulus sentence once and were asked to judge "How friendly/reliable/intelligent/successful do you think this person is?" on a 5-point scale, where 1 was "not very" and 5 was "very." Each talker was rated once for each block. The order of the blocks and the order of the talkers within each block were randomized across participants.

Results

Linear regression models were constructed to explore the effects of population (HFA or TD), perceived age, and their interaction on the mean language attitude ratings for each talker. Given that stereotypes related to age should be mediated by perceived age, the mean age ratings from Experiment 2, rather than actual talker age, were used as the independent variable in this analysis.[1] For friendliness, reliability, and successfulness, no significant predictors emerged in the analyses. For intelligence, the model accounted for 35 % of the variance and revealed a significant effect of perceived age on intelligence ratings ($p = .03$). The main effect of population and the interaction were not significant ($p = .62$ and $p = .19$, respectively). Given the larger sample of TD adults ($N = 28$) than adults with HFA ($N = 14$), planned comparisons were conducted on each population separately to ensure that the main effects did not reflect the performance of only the larger TD population. The planned comparisons revealed that the effect of perceived age on intelligence ratings was significant for the listeners with HFA ($r^2 = .32$, $p = .014$), but not for the TD listeners ($r^2 = .05$, n.s.). For the listeners with HFA, talkers who were rated as older were also rated as more intelligent. In addition, the acoustic analysis revealed a significant effect of duration on intelligence ratings for the listeners with HFA ($r^2 = .37$, $p = .007$). Faster talkers were rated as more intelligent than slower talkers. Figure 4 shows the relationship between the age ratings and the friendliness (top left), reliability (top right), successfulness (bottom left), and intelligence (bottom right) ratings for each population. As in Experiment 2, the slope of the relationship between perceived age and each of the attitude ratings was calculated separately for each participant to explore individual differences, and these slopes did not correlate with AQ score.

Discussion

In this task, the TD listeners did not exhibit any consistent stereotypes related to age for friendliness, reliability, successfulness, or intelligence. These results differ from previous research on language attitudes associated with age, in which middle-age adults were rated higher than young adults on both solidarity and status dimensions (Giles et al. 1992). As noted in the Discussion of Experiment 1, however, the age range of the talkers in the current study was fairly small and the oldest talker was only 44 years old. Although the perceived age range in Giles et al.'s (1992) study was also only 20 years, the older voices were perceived as 57 years old. Older talkers may therefore be necessary to elicit evidence for the relationship between perceived age and these status and solidarity traits for TD listeners.

The listeners with HFA similarly did not exhibit any consistent stereotypes related to age for friendliness,

[1] This analysis used responses from the listeners in Experiment 2 to predict responses from (different) listeners in Experiment 3. Qualitatively similar results are obtained if actual age is used as a predictor variable, which is not surprising given the correlation between perceived age and actual age.

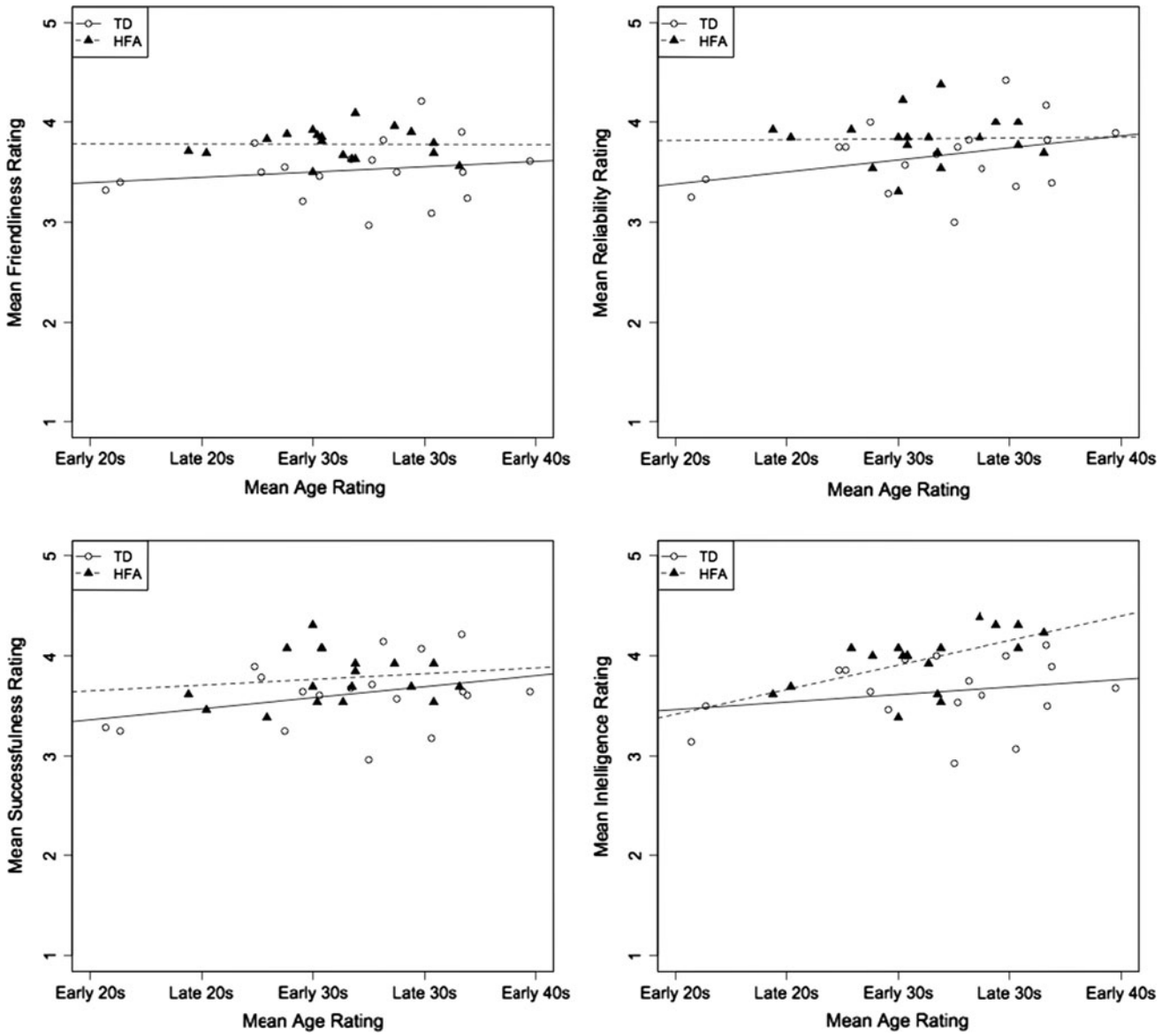


Fig. 4 Relationship between mean age ratings and mean friendliness (*top left*), reliability (*top right*), successfulness (*bottom left*), and intelligence (*bottom right*) ratings for the TD adults (*open circles*) and the adults with HFA (*filled triangles*). Regression lines show the best-fit line for each population

reliability, or successfulness. However, the ratings for intelligence suggested a positive relationship between age (in the range that we examined) and intelligence for listeners with HFA. Older talkers were rated as more intelligent than younger talkers. In addition, sentence duration was correlated with intelligence ratings for the listeners with HFA, suggesting that faster talkers are also perceived as more intelligent than slower talkers for this population (see Brown et al. 1973, 1974; Stewart and Ryan 1982 for evidence of a similar correlation among TD adults). This result is particularly interesting given that duration was not correlated with the age ratings in Experiment 2 and suggests that both perceived age and speaking rate contribute to perceived intelligence for listeners with HFA. A regression model including both perceived age and duration as predictor variables confirms that both factors contribute independently to the intelligence ratings for the listeners with HFA (model $r^2 = .61$, $p = .008$ for perceived age, $p = .004$ for duration).

General Discussion

Taken together, the results of Experiments 1 and 2 demonstrate that both TD adults and adults with HFA can accurately categorize unfamiliar talkers into age groups on

the basis of their speech. These findings are consistent with previous research demonstrating that listeners with HFA can accurately classify unfamiliar talkers by social categories, such as gender, age, and region of origin (Rutherford et al. 2002; Groen et al. 2008; Clopper et al. 2012). In the current age classification experiments, however, the listeners with HFA outperformed the TD listeners. Their perceptual young and middle-age clusters in Experiment 1 were significantly different with respect to actual talker age and they exhibited a higher correlation than the TD listeners between actual talker age and mean age ratings in Experiment 2. The results of Experiment 3 suggest that for TD listeners, perceived age is not significantly related to judgments of friendliness, reliability, successfulness, or intelligence for the age range that we examined (22–44 years old). However, for listeners with HFA, perceived age and speaking rate are important indicators of intelligence, even within this relatively small age range.

In a parallel set of dialect classification tasks, Clopper et al. (2012) found that the listeners with HFA made fewer distinctions between the dialects than the TD listeners in a free classification task, but more distinctions between the dialects than the TD listeners in a localness judgment task. The combined results from these two sets of experiments suggest that young adults with HFA have social categories for indexical properties such as age and region of origin and that they can use the relevant information in the speech signal to classify talkers along these dimensions. The relatively strong performance by the HFA population in the tasks that required grouping talkers based on acoustic–phonetic variation in the speech signal is consistent with the finding that people with ASD exhibit strengths in acoustic processing tasks and may have enhanced perceptual functioning (see Mottron et al. 2006; Happé and Frith 2006 for reviews). Moreover, the information that is most relevant for classifying talkers by dialect is different than the information that is relevant for classifying talkers by age. Whereas segmental information related to consonants and vowels is central for dialect classification (Clopper and Pisoni 2004; Clopper et al. 2012), the relevant cues for age classification include prosodic and voice quality information (Debruyne and Decoster 1999; Ryan and Burk 1974). Thus, adults with HFA are not only able to attend to the variation in the speech signal in these indexical classification tasks, they are also able to ignore the irrelevant variation and focus on only the information that is relevant for a particular type of classification (see also Järvinen-Pasley et al. 2008).

An alternative interpretation of the success of the HFA participants in the first two experiments in this study is that they are not representative of the HFA population. They were recruited from an outreach program for people with HFA, and the diagnoses were independently confirmed for only about half of the participants. In addition, only about half of the participants with HFA exceeded the AQ threshold score of 32 described by Baron-Cohen et al. (2001) as indicative of ASD. However, more recent research has suggested that a lower threshold of 26 might be more appropriate for distinguishing between people with and without HFA (Woodbury-Smith et al. 2005), and the AQ means for the participants with HFA in all three experiments exceeded this lower threshold. In addition, the participants with HFA scored significantly higher than the TD population on the AQ in each of the three experiments and AQ score was not significantly correlated with individual differences in performance on any of the three tasks, suggesting a meaningful distinction between the two participant populations. Thus, although the two populations exhibited significant differences in performance on the age perception tasks, the AQ scores suggest relatively mild impairment for the HFA population examined in the current study, and the results may not generalize to more severely impaired populations on the Autism spectrum.

The language attitudes task in Experiment 3 was intended to provide an opportunity to determine if having substantial personal experience with a social variable would allow participants with HFA to succeed in linking acoustic information in the speech signal to social judgments. Unfortunately, the fact that the TD participants did not provide consistent social attitudes for talkers of different ages makes it quite difficult to interpret the HFA participants' behavior. Thus, whether stereotypes about age are easier for people with HFA to learn than stereotypes about regional dialect remains an open question.

Interestingly, however, the HFA participants differed from the TD participants in the language attitudes task for the intelligence ratings. In this case, the HFA participants (but not the TD participants) consistently rated older talkers as more intelligent than younger talkers. This singular result suggests that the attitude ratings task may not be more difficult in general than the perceptual classification tasks, but instead that the difficulty of the task depends on the specific trait being considered. Further support for this idea that not all traits are equivalent comes from a related result found in the parallel task with regional dialect (Clopper et al. 2012). In that case, TD listeners showed significant attitudes associated with dialect for all four traits (friendliness, reliability, successfulness, and intelligence), whereas HFA listeners showed a significant relationship only for intelligence. Taken together, these language attitudes tasks suggest that intelligence has a special resonance for this population. Indeed, previous work on self-perception among children and adolescents with HFA has shown that this population provides lower self-ratings for social competence relative to TD peers, but equivalently high ratings for cognitive and academic

abilities (Bauminger et al. 2004; Capps et al. 1995). Moreover, qualitative work reports that adolescents with Aspergers mention high intelligence as a characteristic and distinctive feature of their condition (Mullen 2009).

Thus, the strongest interpretation of the current findings (in combination with the related findings reported by Clopper et al. 2012) is that intelligence is the only social dimension among those examined that people with HFA care enough about to track and that the other three characteristics are not relevant enough to their social view of the world to be mapped to properties of the speech signal. This interpretation would suggest that people with HFA are as capable as TD people in tracking social-indexical information in the speech signal, but that they simply do not index most of the social attitudes that we tested. However, additional language attitudes research exploring the social traits that adults with HFA do and do not link to speech is needed to confirm this interpretation.

The goal of the current study was to explore the perception of indexical variation in the speech signal by young adults with HFA. Previous research on the perception of regional dialect suggests that people with HFA can make explicit, factual judgments about social categories, but that they have more difficulty connecting variation in the speech signal to social stereotypes (Clopper et al. 2012). We expected that talker age might provide a better test case than regional dialect of the abilities of people with HFA to map stereotypes onto speech, because they are likely to have more personal experience with age variation than dialect variation. The results of the first two experiments provide some evidence to support this hypothesis. In particular, although the age and dialect results cannot be compared directly, the listeners with HFA performed better in the age tasks than the dialect tasks relative to the TD listeners, suggesting that they have more robust categories for age than for dialect and that experience is critical for developing social categories. However, the third experiment demonstrated that even with the more familiar age category, differences between the TD and HFA populations can be observed. Specifically, intelligence is related to age for the HFA population, but not the TD population, suggesting that there is a fundamental difference in how social information is linked to speech for the two populations. We have suggested that intelligence may be more relevant as a social characteristic for people with HFA than the other traits that we examined, but it remains an open question what other stereotypes people with HFA can and do link to variation in speech.

Acknowledgments This research was partially funded by a seed grant from the Ohio State University Center for Cognitive Science. We thank Jeff Siegel, Bridget Smith, and Renee Devlin for their help with this research.

References

Baron-Cohen, S., Tager-Flusberg, H., & Cohen, D. J. (2000). *Understanding other minds: Perspectives from developmental cognitive neuroscience*. Oxford: Oxford University Press.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5–17.

Bauminger, N., Shulman, C., & Agam, G. (2004). The link between perceptions of self and of social relationships in high-functioning children with autism. *Journal of Developmental and Physical Disabilities, 16*, 193–214.

Benjamin, G. R. (1992). Perceptions of speaker's age in natural conversation in Japanese and English. *Language Sciences, 14*, 77–87.

Boucher, J., Lewis, V., & Collis, G. M. (2000). Voice processing abilities in children with autism, children with specific language impairments, and young typically developing children. *Journal of Child Psychology and Psychiatry, 41*, 847–857.

Braun, A. (1996). Age estimation by different listener groups. *Forensic Linguistics, 3*, 65–73.

Brown, B. L., Strong, W. J., & Rencher, A. C. (1973). Perceptions of personality from speech: Effects of manipulations of acoustical parameters. *Journal of the Acoustical Society of America, 54*, 29–35.

Brown, B. L., Strong, W. J., & Rencher, A. C. (1974). Fifty-four voices from two: The effects of simultaneous manipulations of rate, mean fundamental frequency, and variance of fundamental frequency on ratings of personality from speech. *Journal of the Acoustical Society of America, 55*, 313–318.

Capps, L., Sigman, M., & Yirmiya, N. (1995). Self-competence and emotional understanding in high-functioning children with autism. *Developmental Psychopathology, 7*, 137–149.

Caruso, A. J., Mueller, P. B., & Xue, A. (1994). Relative contributions of voice and articulation to listener judgments of age and gender: Preliminary data and implications. *Voice, 3*, 1–9.

Cerrato, L., Falcone, M., & Paoloni, A. (2000). Subjective age estimation of telephonic voices. *Speech Communication, 31*, 107–112.

Clopper, C. G. (2008). Auditory free classification: Methods and analysis. *Behavior Research Methods, 40*, 575–581.

Clopper, C. G., & Pisoni, D. B. (2004). Some acoustic cues for the perceptual categorization of American English regional dialects. *Journal of Phonetics, 32*, 111–140.

Clopper, C. G., Rohrbeck, K. L., & Wagner, L. (2012). Perception of dialect variation by young adults with high-functioning autism. *Journal of Autism and Developmental Disorders, 42*, 740–754.

Corter, J. E. (1982). ADDTREE/P: A PASCAL program for fitting additive trees based on Sattath and Tversky's ADDTREE algorithm. *Behavior Research Methods and Instrumentation, 14*, 353–354.

Debruyne, F., & Decoster, W. (1999). Acoustic differences between sustained vowels perceived as young or old. *Logopedics, Phoniatrics, Vocology, 24*, 1–5.

Fisher, W. M., Doddington, G. R., & Goudie-Marshall, K. M. (1986). The DARPA speech recognition research database: Specifications and status. *Proceedings of the DARPA speech recognition workshop* (pp. 93–99).

Giles, H. (1970). Evaluative reactions to accents. *Educational Review, 22*, 211–227.

Giles, H., Coupland, N., Henwood, K., Harriman, J., & Coupland, J. (1990). The social meaning of R.P.: An intergenerational perspective. In S. M. Ramsaran (Ed.), *Studies in the*

pronunciation of English: A commemorative volume in honor of A. C. Gimson (pp. 191–211). London: Croom Helm.

Giles, H., Henwood, K., Coupland, N., Harriman, J., & Coupland, J. (1992). Language attitudes and cognitive mediation. *Human Communication Research, 18*, 500–527.

Giles, H., Ryan, E. B., & Anas, A. P. (2008). Perceptions of intergenerational communication by young, middle-aged, and older Canadians. *Canadian Journal of Behavioural Science, 40*, 21–30.

Golan, O., Baron-Cohen, S., Hill, J. J., & Rutherford, M. D. (2007). The 'reading the mind in the voice' test-revised: A study of complex emotion recognition in adults with and without autism spectrum conditions. *Journal of Autism and Developmental Disorders, 37*, 1096–1106.

Groen, W. B., van Orsouw, L., Zwiers, M., Swinkels, S., van der Gaag, R. J., & Buitelaar, J. K. (2008). Gender in voice perception in autism. *Journal of Autism and Developmental Disorders, 38*, 1819–1826.

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36*, 5–25.

Harnsberger, J. D., Shrivastav, R., Brown, W. S., Jr., Rothman, H., & Hollien, H. (2008). Speaking rate and fundamental frequency as speech cues to perceived age. *Journal of Voice, 22*, 58–69.

Hartman, D. E. (1979). The perceptual identity and characteristics of aging in normal male adult speakers. *Journal of Communication Disorders, 12*, 53–61.

Hartman, D. E., & Danhauer, J. L. (1976). Perceptual features of speech for males in four perceived age decades. *Journal of the Acoustical Society of America, 59*, 713–715.

Hollien, H., & Shipp, T. (1972). Speaking fundamental frequency and chronologic age in males. *Journal of Speech and Hearing Research, 15*, 155–159.

Horii, Y., & Ryan, W. J. (1981). Fundamental frequency characteristics and perceived age of adult male speakers. *Folia Phoniatrica, 33*, 227–233.

Hubbard, K., & Trauner, D. A. (2007). Intonation and emotion in autistic spectrum disorders. *Journal of Psycholinguistic Research, 36*, 159–173.

Hummert, M. L., Mazloff, D., & Henry, C. (1999). Vocal characteristics of older adults and stereotyping. *Journal of Nonverbal Behavior, 23*, 111–132.

Huntley, R., Hollien, H., & Shipp, T. (1987). Influences of listener characteristics on perceived age estimations. *Journal of Voice, 1*, 49–52.

Imaizumi, S., Furuya, I., & Yamasaki, K. (2009). Voice as a tool communicating intentions. *Logopedics, Phoniatrics, Vocology, 34*, 196–199.

Järvinen-Pasley, A., Wallace, G. L., Ramus, F., Happé, F., & Heaton, P. (2008). Enhanced perceptual processing of speech in autism. *Developmental Science, 11*, 109–121.

Ketelaars, C., Horowitz, E., Sytema, S., Bos, J., Wiersma, D., Minderaa, R., et al. (2008). Brief report: Adults with mild autism spectrum disorders (ASD): Scores on the autism spectrum quotient (AQ) and comorbid psychopathology. *Journal of Autism and Developmental Disorders, 38*, 176–180.

Kreiman, J., & Sidtis, D. (2011). *Foundations of voice studies: An interdisciplinary approach to voice production and perception*. Malden, MA: Wiley-Blackwell.

Lambert, W. E., Hodgson, R. C., Gardner, R. C., & Fillenbaum, S. (1960). Evaluational reactions to spoken language. *Journal of Abnormal and Social Psychology, 60*, 44–51.

Linville, S. E., & Fisher, H. B. (1985). Acoustic characteristics of perceived versus actual vocal age in controlled phonation by adult females. *Journal of the Acoustical Society of America, 78*, 40–48.

Linville, S. E., & Korabic, E. W. (1986). Elderly listeners' estimates of vocal age in adult females. *Journal of the Acoustical Society of America, 80*, 692–694.

Luhman, R. (1990). Appalachian English stereotypes: Language attitudes in Kentucky. *Language in Society, 19*, 331–348.

Montepare, J. M., & Zebrowitz, L. A. (1998). Person perception comes of age: The salience and significance of age in social judgments. *Advances in Experimental Social Psychology, 30*, 93–161.

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*, 27–43.

Mullen, S. M. (2009). *Adolescents with Aspergers syndrome and self-perceived social competence*. Doctoral dissertation, Philadelphia College of Osteopathic Medicine.

Nagao, K. (2006). *Cross-language study of age perception*. Doctoral dissertation, Indiana University.

Neiman, G. S., & Applegate, J. A. (1990). Accuracy of listener judgments of perceived age relative to chronological age in adults. *Folia Phoniatrica, 42*, 327–330.

Ptacek, P. H., & Sander, E. K. (1966). Age recognition from voice. *Journal of Speech and Hearing Research, 9*, 273–277.

Ramig, L. A. (1986). Aging speech: Physiological and sociological aspects. *Language & Communication, 6*, 25–34.

Rice, M. L., Warren, S. F., & Betz, S. K. (2005). Language symptoms of developmental language disorders: An overview of autism, Down syndrome, fragile X, specific language impairment, and Williams syndrome. *Applied Psycholinguistics, 26*, 7–27.

Rutherford, M. D., Baron-Cohen, S., & Wheelwright, S. (2002). Reading the mind in the voice: A study with normal adults and adults with Asperger syndrome and high functioning autism. *Journal of Autism and Developmental Disorders, 32*, 189–194.

Ryan, W. J., & Burk, W. (1974). Perceptual and acoustic correlates of aging in the speech of males. *Journal of Communication Disorders, 7*, 181–192.

Ryan, E. B., & Capadano, H. L. (1978). Age perceptions and evaluative reactions toward adult speakers. *Journal of Gerontology, 33*, 98–102.

Sebastian, R. J., & Ryan, E. B. (1985). Speech cues and social evaluation: Markers of ethnicity, social class, and age. In H. Giles & R. N. St. Clair (Eds.), *Recent advances in language, communication, and social psychology* (pp. 112–143). London: Erlbaum.

Shipp, T., & Hollien, H. (1969). Perception of the aging male voice. *Journal of Speech and Hearing Research, 12*, 703–710.

Stewart, M. A., & Ryan, E. B. (1982). Attitudes toward younger and older adult speakers: Effects of varying speaking rates. *Journal of Language and Social Psychology, 1*, 91–109.

Volden, J., Magili-Evans, J., Goulden, K., & Clarke, M. (2007). Varying language register according to listener needs in speakers with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 37*, 1139–1154.

Volden, J., & Sorenson, A. (2009). Bossy and nice requests: Varying language register in speakers with autism spectrum disorder (ASD). *Journal of Communication Disorders, 42*, 58–73.

Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening adults for Asperger syndrome using the AQ: A preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders, 35*, 331–335.