Bidirectional clear speech perception benefit for native and high-proficiency non-native talkers and listeners: Intelligibility and accentedness^{a)}

Rajka Smiljanić^{b)}

Department of Linguistics, University of Texas at Austin, Austin, Texas 78712

Ann R. Bradlow

Department of Linguistics, Northwestern University, Evanston, Illinois 60208

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This study investigated how native language background interacts with speaking style adaptations in determining levels of speech intelligibility. The aim was to explore whether native and high proficiency non-native listeners benefit similarly from native and non-native clear speech adjustments. The sentence-in-noise perception results revealed that fluent non-native listeners gained a large clear speech benefit from native clear speech modifications. Furthermore, proficient non-native talkers in this study implemented conversational-to-clear speaking style modifications in their second language (L2) that resulted in significant intelligibility gain for both native and non-native listeners. The results of the accentedness ratings obtained for native and non-native conversational and clear speech sentences showed that while intelligibility was improved, the presence of foreign accent remained constant in both speaking styles. This suggests that objective intelligibility and subjective accentedness are two independent dimensions of non-native speech. Overall, these results provide strong evidence that greater experience in L2 processing leads to improved intelligibility in both production and perception domains. These results also demonstrated that speaking style adaptations along with less signal distortion can contribute significantly towards successful native and non-native interactions. © 2011 Acoustical Society of America.

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I. INTRODUCTION

In the US, according to the 2009 census, 19.6% of the population speaks a language other than English at home (www.census.gov). Daily interactions between two interlocutors, including those occurring at schools, clinics, nursing homes, and businesses, increasingly involve native and non-native speakers of English. Such communication may be challenging for both the native and non-native participants. In order to overcome some of these challenges, talkers will likely engage in some form of speech accommodation. In this paper, we focus on one specific speaking style adaptation called “clear speech,” a speech style that talkers resort to when they are aware that the listeners may have hearing problems or are not native speakers of the target language [see [Uchanski \(2005\)](#) and [Smiljanić and Bradlow \(2009\)](#) for reviews of central issues and main findings in clear speech research]. Specifically, we examine how speaking style adaptations vary between native and proficient non-native talkers in improving intelligibility for native and proficient non-native listeners. In addition, we look at the effect of dif-

ferent noise levels on non-native speech intelligibility. Finally, we examine how perceived accentedness interacts with intelligibility for non-native conversational and clear speech sentences. This study, thus, aims to shed light on both speech production and perception abilities in individuals operating in their second language.

Previous research on clear speech has focused largely on native English talkers and on native listeners with impaired hearing or healthy native adult listeners (see [Uchanski, 2005](#); [Smiljanić and Bradlow, 2009](#), and references therein). These studies found a reliable and robust clear speech intelligibility gain for many native listener groups in various communicative situations ([Picheny et al., 1985](#); [Uchanski et al., 1996](#); [Ferguson, 2004](#); [Ferguson and Kewley-Port, 2002](#); [Krause and Braida, 2002](#); [Smiljanić and Bradlow, 2005](#); [Liu et al., 2004](#); [Schum, 1996](#); [Gordon-Salant et al., 2010](#)). A similar clear speech benefit was found for native listeners of languages other than English, namely, Croatian and Canadian French ([Smiljanić and Bradlow, 2005](#); [Gagne et al., 1994, 2002](#)).

Detailed acoustic and articulatory analyses have identified typical conversational-to-clear speech modifications, including a decrease in speaking rate (longer segments as well as longer and more frequent pauses), wider dynamic pitch range, greater sound-pressure levels, more salient stop releases and increased energy in the 1000–3000 Hz range of long-term spectra, ([Picheny et al., 1986, 1989](#); [Matthies et al., 2001](#); [Perkell et al., 2002](#); [Krause and Braida, 2004](#); [Bradlow et al., 2003](#); [Liu et al., 2004](#); [Ferguson and](#)

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^{b)}Author to whom correspondence should be addressed. Electronic mail: rajka@austin.utexas.edu

Kewley-Port, 2002, 2007; Smiljanić and Bradlow, 2005). The results also showed that distinctiveness of phonological contrasts increases in clear speech. For instance, vowel categories are produced in more peripheral positions in the vowel space, tense vowels are lengthened more than lax vowels (increasing the duration contrast between tense and lax vowels) and English plosives are made more distinct in voicing and place of articulation in clear speech compared with conversational speech (Ferguson and Kewley-Port, 2002; Bradlow, 2002; Smiljanić and Bradlow, 2005, 2008; Maniwa *et al.*, 2008). The acoustic “distance” between the contrastive categories is thus enlarged in clear speech. Importantly, these enhancement strategies were shown to reflect language-specific phonological and prosodic properties and have been found to vary across languages (Smiljanić and Bradlow, 2008) and even across generations of speakers of the same language in which there is a sound change in progress (Kang and Guion, 2008).

Non-native talkers’ and listeners’ problems in processing their second language (L2) arise, in part, from the lack of extensive experience with the L2 sound structure, including the system of phonological contrasts, language-specific phonetic implementation of those contrasts, phonotactics, and prosody. Second language learning research has amply demonstrated the difficulties that second language learners experience during L2 acquisition and, furthermore, how the native L1 sound system and the native speech experience serve as organizing principles that systematically relate to the adult learners’ non-native perception and production processes (e.g., Iverson *et al.*, 2003; Flege, 1995; Best and Tyler, 2007; Aoyama *et al.*, 2007; Bohn and Flege, 1992, 1997; Tsukada *et al.*, 2005; Davidson, 2006; White and Mattys, 2007; Jilka, 2007 and many others). Intelligibility problems for non-native speakers and listeners are thus qualitatively different from those of native speakers and listeners who may have problems accessing the speech signal due to noise or hearing loss.

Lack of experience in processing a second language has been shown to affect clear speech production and perception as well. Bradlow and Bent (2002) investigated whether clear speech produced by native talkers of English is an effective intelligibility enhancement strategy for low proficiency non-native listeners. They found a substantially smaller clear speech gain for non-native listeners compared to native listeners. In a recent investigation of the ability of non-native talkers to enhance intelligibility of vowels in bVd syllables for native English listeners, Rogers *et al.* (2010) found that monolingual English speakers and early learners of English provided a similar and large clear speech benefit compared to the late learners of English who produced the smallest clear speech gain for native English listeners (background L1 of both non-native groups was Spanish). The late learners, those who had least experience with the target English sounds, even exhibited a decrease in clear speech intelligibility for the vowel /t/ in “bid.” This pattern demonstrates a difficulty in enhancing the L2 vowel category in a target-language appropriate way. The difference in the clear speech benefit for low proficiency non-native talkers and listeners compared to native speakers and listeners in these two stud-

ies reflects the nature of the second language speech processing deficits, i.e., the inexperience in attending to the relevant dimensions of clear speech enhancements that are specific to the target language.

The present study aims to explore further how talker and listener native language background interacts with speaking style and noise in determining levels of speech intelligibility. Here, we compare the clear speech intelligibility benefit for native and *high proficiency* non-native talkers and listeners. This comparison provides us with a testing ground for the hypothesis that clear speech perception and production crucially involve a relatively high level of mastery of the language-specific sound structure of the target language. This hypothesis predicts that high proficiency non-native talkers and listeners who have had more extensive experience in processing the target language will be more similar to native talkers and listeners in producing and perceiving clear speech. Due to their inexperience, low proficiency non-native talkers may fail to enhance some of the acoustic-phonetic features typically produced in L2 clear speech which may result in a smaller intelligibility advantage for native listeners (cf. early bilinguals in Rogers *et al.*, 2010). Similarly, non-native listeners may not perceive and utilize subtle acoustic-phonetic cue enhancements specific to L2 and may therefore benefit less from L2 clear speech compared to native listeners (cf. Bradlow and Bent, 2002). Clear speech production and perception should become more in line with native clear speech processing with increased exposure to the target language (cf. late vs early learners of English in Rogers *et al.*, 2010).

To test these predictions, we conducted three speech-in-noise listening experiments in which we looked at conversational and clear speaking style intelligibility produced by native American English (AE) and fluent non-native Croatian (CRO) talkers for native AE and fluent non-native CRO listeners. Throughout the paper, we will use “native” and “non-native” labels to refer to the native AE talkers and listeners and non-native talkers and listeners whose L1 is Croatian, respectively. In the first experiment, we examine whether *talker* language background (native vs non-native) interacts with speaking style in determining intelligibility levels for proficient non-native listeners. In the second experiment, we look at whether *listener* language background (native vs non-native) interacts with speaking style in determining intelligibility levels for proficient non-native talkers. In the third experiment, we examine whether speaking style adaptations interact with noise levels [+5 vs 0 dB signal-to-noise ratio (SNR)] in determining intelligibility of proficient non-native talkers for native listeners. That is, are non-native clear speech strategies beneficial under more adverse listening conditions? We compare the results in this experiment with the ones obtained for the matched AE talker-listener native groups at the same more difficult SNR as reported in Smiljanić and Bradlow (2005). This manipulation in SNR allowed us to assess more directly the effect of foreign accent on intelligibility.

Croatian and English are well suited for this comparison since they differ in their sound inventories and in the implementation of some phonological contrasts. Croatian has

5 monophthongs and English has 10+ monophthongs and diphthongs. In addition, Croatian has a lexical contrast between short and long vowels that primarily differ in duration, while English has tense and lax vowels that are mainly distinguished through qualitative/spectral differences, but that also have a secondary duration contrast. Croatian has pre-voiced and short lag stops while English has short and long lag stops. The same phonetic category of short lag is encoded in Croatian as a phonologically voiceless and in English as a phonologically voiced stop. Smiljanić and Bradlow (2005, 2008) showed that clear speech strategies reflected language-specific patterns of duration cue manipulation. For instance, duration difference between long and short vowels in Croatian was increased by a larger amount than between the English tense and lax vowels reflecting the primacy of the role that duration plays in encoding the contrast in Croatian. Similarly, in Croatian, voicing of prevoiced stops was lengthened while in English, aspiration of long lag stops was lengthened more in clear speech. These results have implications for the current study by suggesting that some of the L1 clear speech production strategies may affect how clear speech is produced and perceived in L2 which would then impact intelligibility levels even for the proficient second language learners.

Finally, we explored how perceived accentedness of non-native speech interacts with intelligibility. Previous work has established that accentedness and intelligibility, comprehensibility, and grammaticability of speech are related but partially independent dimensions of L2 speech production. It is possible for a non-native talker to be perceived as having a strong foreign accent and yet be highly intelligible (Derwing and Munro, 1997, 2009; Munro and Derwing, 1999). Our goal was to explore whether non-native conversational and clear speech productions differ in their perceived accentedness in addition to their intelligibility. Do non-native conversational-to-clear speech modifications result in increased intelligibility and a change in the perceived amount of foreign accent? Some clear speech productions by fluent non-native talkers could be used as “repair” strategies which allow them to produce more “canonical” L2 targets, resulting in the perception of less accented speech. In order to assess the relationship between objective intelligibility, measured as a correct keyword score in a sentence-in-noise tests, and subjective accentedness measures, we obtained accentedness ratings of native and non-native conversational and clear speech.

II. METHOD

A. Participants

1. Talkers

Native talkers of AE and non-native talkers whose L1 was Croatian were recruited for the experiments. All talkers were between the ages of 18 and 32. Four native talkers (3 female, 1 male) were recorded reading test sentences in conversational and clear speaking styles. They were graduate students in the Linguistics Department at Northwestern University and were all native talkers of General American Eng-

lish (they were the same talkers as in Smiljanić and Bradlow, 2005, 2008). Four non-native talkers (2 female, 2 male) were recorded reading the same materials in English, i.e., in their second language. They were all undergraduate students at Northwestern University and came to the US within five years prior to the recordings to pursue undergraduate degrees. These non-native talkers started studying English in elementary school as part of the standard foreign language curriculum in Croatia. They were fluent in English as confirmed by the Test of English as a Foreign Language (TOEFL) scores required for admission to a US university and by their daily use of English in the University setting. They all continue to use Croatian daily (in communicating with each other on campus and with their families in Croatia), yet are simultaneously engaged in their undergraduate studies at Northwestern in the English-language medium leading to a high level of functional fluency in their L2. The length of residence in the US was on average 5 years at the time of the recordings. None of the native or non-native talkers had any known speech or hearing impairment at the time of recording. They were not aware of the purpose of the recordings. All participants were paid at the end of the recording session.

2. Listeners

a. Sentence-in-noise test listeners. Two groups of native listeners, forty each, were recruited from the Northwestern University Linguistics Department subject pool. One group listened to the non-native sentences mixed with noise at +5 dB SNR. The other group listened to the non-native sentences mixed with noise at 0 dB SNR. They received class credit for their participation in the listening test. Their ages ranged between 18 and 22 years.

Two groups of non-native listeners, sixteen each, participated in the sentence-in-noise listening test. One group listened to the native talkers and the other listened to the non-native talkers. All listeners were undergraduate students at the University of Zagreb. They were either English majors or had a significant amount of instruction in English in school and in specialized language institutes. For both groups, English proficiency was estimated in a pre- and a post-test. In a pre-test, they listened to 16 syntactically simple and meaningful sentences chosen to include words highly familiar to non-native speakers (see materials). The pre-test sentences were mixed with noise at +5 dB SNR which was the same as in the test sentences. Subjects were instructed to write down what they heard. The correct keyword score was obtained for each listener. The average pre-test keyword intelligibility score for the first group of listeners was 43 out of possible 50 (range: 33–49). The average keyword correct score for the second group of participants for the pre-test sentences was 44 out of 50 (range: 38–49).

Non-native subjects’ familiarity with the words used in the test sentences was assessed in a post-test. They were given the list of the 20 test sentences and were asked to circle the words they were unfamiliar with or did not know the meaning of. The word-familiarity task showed that the vast

majority of words were familiar to most listeners. The average number of unfamiliar words as reported by the first group of subjects was 2 out of 80 key words (range: 0–6). The second group of subjects identified on average 3 out of 80 key words as unfamiliar (range: 0–13). We used the combined pre-test intelligibility and post-test familiarity scores as an indication that all of the non-native listeners were highly proficient in English and importantly that the two groups of non-native listeners formed a homogenous group with regard to their English proficiency. Given the high intelligibility and familiarity scores in the pre- and post-tests, none of the non-native subjects were excluded from the test. None of the native or non-native listeners had any known speech or hearing impairment at the time of the test

b. Accent rating listeners. Two groups of 24 native listeners were recruited from the subject pool at Northwestern University for participation in accent rating listening tests. These listeners were different individuals, but came from the same population as the ones who provided intelligibility scores above. They were all undergraduate students and received class credit for their participation. Their ages ranged between 18 and 22 years. The first 24 listeners rated accentedness of non-native speech in quiet. The second 24 listeners provided accent ratings of non-native speech in noise. None of the listeners had any known speech or hearing impairment at the time of the test. During the debriefing none of the subjects indicated that they had close contact or extended experience with native Croatian speakers.

3. Materials

Twenty semantically anomalous sentences were used for the recordings. The same sentences were used previously to examine clear speech production and perception by matched native talker and listener groups (i.e., talker and listener came from the same native language background, see Smiljanić and Bradlow, 2005, 2008). These sentences were constructed in order to minimize the beneficial effect of sentence context on intelligibility (e.g., “your tedious beacon lifted our cab”). A full list of sentences is provided in the Appendix.

The results of the sentence-in-noise perception tests and acoustic analyses for native AE talkers and listeners, as well as for the parallel materials for the matched native CRO talker and listener groups (performing the task in their L1), were reported in Smiljanić and Bradlow (2005, 2008). The use of the same English materials in the current experiments allowed us to make direct comparisons between non-native and native listeners’ responses to native and non-native conversational and clear speech. The same materials were used in all experiments reported below.

In addition, non-native listeners heard 16 meaningful AE sentences in the pre-test (e.g., “the book tells a story”). The sentences were taken from the revised Bamford-Kowal-Bench Standard Sentence Test (BKB-R), list 9, developed by the Cochlear Corporation for use with American children. They were selected based on their equivalent intelligibility scores for normal-hearing children and for non-native listen-

ers (as reported in Bamford and Wilson, 1979, and in Bent and Bradlow, 2003). The recordings of these sentences were from Bradlow and Bent (2002).

D. Procedure

1. Production

All talkers were recorded in a sound-attenuated booth reading the 20 sentences once in conversational speech and once in clear speech. They read into a microphone and the speech was recorded directly to disk at 24 bit accuracy using an Apogee PSX-100 A/D D/A converter at a sampling rate of 16 kHz. For the conversational style, the talkers were instructed to read as if they were talking to someone familiar with their voice and speech patterns. For the clear speaking style, the talkers were instructed to read as if they were talking to a listener with a hearing loss or a non-native speaker (for the discussion of the use of “clear” and “conversational speech” terminology see Smiljanić and Bradlow, 2009).¹ After the recordings were made, the digital speech files were segmented into sentence-length files.

2. Stimuli preparation

All speech files were equated for rms amplitude and then mixed with broadband noise at a +5 dB SNR and with 0 dB SNR in four different experiments. The target speech was always presented at 65 dB SPL. We used the same broadband noise with sloping energy at higher frequencies as in Smiljanić and Bradlow (2005). Note that the type of the materials, noise, listeners and talker characteristics are all going to affect the level of noise acceptable to achieve similar baseline performance (cf. Rogers *et al.*, 2010). The intelligibility results for the matched native listeners and native talkers reported in Smiljanić and Bradlow (2005) and pilot testing were used as a baseline in deciding the noise levels in the experiments reported here. We aimed to achieve the same average conversational intelligibility score range of 45–65% across native and non-native listeners, i.e., a similar baseline performance, so that we can better assess the amount of clear speech benefit from a relatively constant baseline level of recognition accuracy. In the first three experiments, we, therefore, increased SNR for the mis-matched groups of native talkers and non-native listeners and for matched groups of non-native talkers and listeners from 0 dB SNR (used for native-native matched groups in a previous study) to +5 dB SNR. Furthermore, even though native listeners were performing the task in their native language, we opted to use the +5 dB SNR to aid these listeners in processing foreign-accented speech and to make the comparison with the results obtained in other experiments more direct. Additionally, we included a 0 dB SNR condition as well in order to make a direct comparison of the effect of noise on non-native talkers’ intelligibility for native listeners.

3. Sentence-in-noise perception test

In the test condition, subjects were seated in front of a computer. Stimulus presentation was controlled by special-purpose experiment running software, SUPERLAB PRO 2.01.

Listeners heard one target sentence at a time over headphones. Native listeners first heard 4 practice sentences mixed with noise at +5 dB SNR. These short meaningful sentences produced by one male and one female Croatian talkers were obtained from the Speech Accent Archive and used with the permission from Steven H. Weinberger (available at <http://accent.gmu.edu/>). For non-native listeners, the pre-test, in which they heard 16 meaningful AE sentences, was taken as a practice run. These sentences were recorded by one female native speaker of General American English (Bradlow and Bent, 2002). The practice sentences were given to listeners so that they could get familiar with the nature of the stimuli mixed with noise and the procedure of advancing to the next trial. Since the goal of the study was to examine sentence-in-noise recognition for fluent second language learners, non-native listeners heard more sentences in the pre-test compared to native listeners. The pre-test scores were then used to assess their overall English proficiency levels.

After they completed the practice set, subjects heard the semantically anomalous test sentences in conversational and clear speech. After each trial, the subject pressed the space bar on the keyboard to initiate the next trial. They could hear each sentence only once but could take as much time as needed between the sentences to record their answer. In all conditions, each sentence in the listening test was preceded by a 400 ms leading silence and a 500 ms noise interval, and followed by a 500 ms noise interval. Each participant in the perception experiment heard a total of 20 sentences produced by only one of the talkers. Half of the sentences were in the conversational style and half in the clear style for each talker condition. The listeners never heard the same sentence twice. In each talker condition, clear speech sentences preceded conversational sentences so that any intelligibility increase in the clear speech condition could not be accounted for by the adjustment to the task during the experiment. Subjects were instructed to write down every word they heard. Each participant received a keyword correct score out of 40 for the 10 sentences they heard in each style (conversational vs. clear). All content words were counted as keywords. Percentage correct scores were calculated and then converted to rationalized arcsine transform units (RAU) for statistical analysis (Studebaker, 1985).

4. Accent ratings

All participants were tested in a sound attenuated booth. They were seated in front of a computer monitor and listened to sentences presented over the headphones (Sennheiser HD580) at a comfortable listening level. Each listener rated 200 sentences: 160 sentences produced by 4 non-native talkers (20 conversational + 20 clear $\times$ 4 talkers) and 40 sentences produced by 4 native talkers (5 conversational + 5 clear $\times$ 4 talkers). Native talkers were included in the test to provide the basis of accent comparison to the listeners. Half of all sentences were in clear and half in conversational speaking style. Each listener rated all 200 sentences. The order of sentences was randomized for each listener. All 200 test sentences were the same sentences used in the intelligibility tests reported above.

Participants were instructed to provide accent rating for each sentence on a scale from 1 to 9 with 1 being most native-like and 9 having the strongest accent (similar to Derwing and Munro, 1997). They recorded their response by pressing number keys 1–9 on the keyboard after they heard each sentence. They could hear each sentence only once. For one group of native listeners, test sentences were presented in quiet. For the other group, the sentences were mixed with speech-shaped noise at a +5 dB SNR, the same signal-to-noise ratio that was used in the intelligibility experiments.

III. RESULTS

The average intelligibility scores for each talker and each listener group (averaged across listeners) in the clear and conversational speaking styles as well as the clear speech gain are given in Table I. Overall, the results of the listening-in-noise tests at +5 dB SNR (1–3 in Table I) revealed that we were successful in eliciting the target baseline conversational intelligibility levels between 45 and 65% for most native and non-native talkers. The average conversational speech intelligibility for all talker-listener groups was similar: 54% for native talker and non-native listener groups, 52% for non-native talker and native listener groups, and 49% for non-native talker-listener groups.

A. The effect of *talker language* on conversational and clear speech intelligibility

In this analysis, we examined the effect that the *talker language* background (native vs non-native) has on English conversational and clear speech intelligibility while holding the listeners' language background constant (L1 = Croatian, L2 = English). The results for this comparison are shown in Fig. 1.

A factorial analysis of variance (ANOVA) with speaking style (conversational vs clear) as a within-subjects factor and talker language (native vs non-native) as a between-subjects factor for RAU-transformed percentage correct score as a dependent variable was performed. There was a significant main effect of style on intelligibility scores: [$F(1, 6) = 107.145$, $p < 0.001$]. The effect of talker language on intelligibility scores was not significant: [$F(1, 6) = 1.100$, $p = 0.335$]. The style by talker language interaction was not significant: [$F(1, 6) = 1.353$, $p = 0.289$]. These analyses revealed that both native and proficient non-native talkers provided a similar clear speech benefit for non-native listeners (16 and 13% gain). Even though there was a slight decrease in the overall intelligibility for non-native speech compared to native speech this was not significant. The results showed that language background was not a significant factor in determining intelligibility levels for these two groups of talkers.

The results also demonstrated that the highly proficient non-native listeners here, unlike relatively low proficiency non-native listeners in previous studies (Bradlow and Bent, 2002; Bradlow and Alexander, 2007), gained a large clear speech advantage from native talkers in their second language. Acoustic analyses of the conversational-to-clear speech modifications (Smiljanić and Bradlow, 2005, 2008) showed that in addition to enhancing the overall acoustic

TABLE I. Average intelligibility scores in the clear and conversational speaking styles, the clear speech gain and proportional gain for each talker and each listener group (averaged across listeners). Parts 3 and 4 in the table are for two different signal-to-noise ratios (+5 vs. 0 dB).

1. AE talkers/Cro. listeners (+ 5 dB SNR)	Talker	Plain	Clear	Clear-Plain	Proportional gain
	AF01	55.63	71.88	16.25	29.21
	AF02	57.50	77.50	20.00	34.78
	AF03	47.50	63.13	15.63	32.89
	AM01	55.63	68.13	12.50	22.47
	<u>AVERAGE</u>	<u>54.06</u>	<u>70.16</u>	<u>16.09</u>	<u>29.77</u>
2. Cro. talkers/Cro. listeners (+ 5 dB SNR)	Talker	Plain	Clear	Clear-Plain	Proportional gain
	CM01	53.13	67.50	14.38	27.06
	CF01	41.88	58.13	16.25	38.81
	CF02	61.25	76.88	15.63	25.51
	CM02	38.75	45.63	6.88	17.74
	<u>AVERAGE</u>	<u>48.75</u>	<u>62.03</u>	<u>13.28</u>	<u>27.28</u>
3. Cro. talkers/AE listeners (+ 5 dB SNR)	Talker	Plain	Clear	Clear-Plain	Proportional gain
	CM01	50.75	52.50	1.75	3.45
	CF01	35.50	55.00	19.50	54.93
	CF02	69.25	80.50	11.25	16.25
	CM02	52.75	54.00	1.25	2.37
	<u>AVERAGE</u>	<u>52.06</u>	<u>60.50</u>	<u>8.44</u>	<u>19.25</u>
4. Cro. talkers/AE listeners (0 dB SNR)	Talker	Plain	Clear	Clear-Plain	Proportional gain
	CM01	22.25	24.25	2.00	8.99
	CF01	23.00	33.75	10.75	46.74
	CF02	50.25	63.00	12.75	25.37
	CM02	29.00	41.50	12.50	43.10
	<u>AVERAGE</u>	<u>31.13</u>	<u>40.63</u>	<u>9.50</u>	<u>31.05</u>

salience of the speech signal through a decrease in speaking rate and expansion of pitch range, clear speech modifications increased the spectral distances between vowel categories and enhanced durational contrasts for tense and lax vowels and voiced and voiceless stops. In addition to increasing intelligibility for native listeners, these L1-specific clear speech modifications may have provided more salient acoustic cues for L2 processing for the relatively proficient non-native listeners as well. The amount of intelligibility gain by

the non-native listeners in the current experiment was the same (~ 16 percentage points) as for the native listeners in [Smiljanić and Bradlow \(2005\)](#). This suggests that fluent non-native listeners with longer exposure and more extensive experience with the L2 sound structure learned to attend to the L2-specific enhancement strategies in English and were able to take advantage of native clear speech enhancements as much as native listeners did. In order to achieve a similar level of performance by native and non-native listeners in

FIG. 1. Intelligibility scores (percent keyword correct) for two speaking styles for native talkers and non-native listeners (left), and non-native talkers and non-native listeners (right). In all figures, the talker labels (on the x-axis) indicate the background language (“A” for American English or “C” for Croatian), gender (“F” for female or “M” for male) and the recording order. For each talker, the two bars represent the conversational (left) and clear (right) speech scores. The boxes represent the interquartile range, which contains the middle 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers (given as circles). A line across the box indicates the median.

conversational speech and in the clear speech gain, the level of noise had to be decreased by 5 dB (compared to 0 dB SNR for native talkers and listeners). In other words, the added difficulty in speech processing for these fluent non-native listeners could be offset by a 5 dB increase in SNR.

B. The effect of *listener* language on conversational and clear speech intelligibility

In this analysis, we compared native and non-native listeners' responses to conversational and clear speech as produced by non-native talkers. Intelligibility results are given in 2 and 3 in Table I and in Fig. 2.

A factorial ANOVA with speaking style (conversational vs clear) as a within-subjects factor and listener language (native vs non-native) as a between-subjects factors for RAU-transformed percentage correct score as a dependent variable showed a significant main effect of style: [$F(1, 6) = 19.132, p = 0.005$]. The effect of listener language was not significant: [$F(1, 6) = 0.010, p = 0.925$]. The style by listener language interaction was not significant: [$F(1, 6) = 0.900, p = 0.379$]. The overall intelligibility results showed that both groups of listeners found non-native speech highly intelligible.² The results also demonstrated that the clear speech *productions* of these highly proficient non-native talkers were significantly more intelligible compared to their conversational speech productions. The fluent non-native talkers, thus, can modify their spoken output to significantly increase intelligibility for both native and non-native listeners.

Although the style by listener language interaction was not statistically significant, the clear speech benefit differed somewhat for the two groups of listeners due to some noteworthy degree of individual variability across the non-native talkers. Non-native talkers in this study varied both in their overall intelligibility and the clear speech intelligibility benefit (similar to Rogers *et al.*, 2010 with CVC monosyllables). For instance, the clear speech gain for the two non-native talkers that showed most increase in intelligibility for native listeners, namely, CF01 and CF02, was 20 and 11% respectively. This clear speech benefit was roughly the same as the clear speech increase by the native talkers in this study (in A) and in the previous study (Smiljanić and Bradlow, 2005). In contrast, CM01 and CM02 provided negligible clear speech benefits. However, their baseline conversational intelligibility levels were rather high (51 and 53%) suggesting that their overall low English proficiency could not account for the lack of improvement. The variability in these clear speech intelligibility gains suggests that some of the non-native clear speech strategies deviated from the native "norm" and, therefore, did not improve intelligibility for native listeners.

The same non-native talkers who did not provide clear speech intelligibility benefits for native listeners produced clear speech that increased intelligibility for non-native listeners. It seems likely that some of the non-native clear speech strategies employed by these talkers enhanced speech along the articulatory-acoustic dimensions that non-native listeners (but not native listeners) recognized and took advantage of while listening to their L2 (i.e., L1-specific enhancement strategies). Sharing the same background L1

sound structure appears to provide some additional benefit when listening to L2 productions for some talkers. Acoustic analysis of the differences in the productions between the "high" and "low" gain talkers that may account for the difference in the intelligibility scores (forthcoming) may shed some light on these issues.

C. The effect of *noise* on conversational and clear speech intelligibility

The results above showed that native listeners found non-native speech relatively highly intelligible. However, in order to make a direct comparison with the results for native AE talker-listener groups reported in Smiljanić and Bradlow (2005), the noise level had to be increased from +5 dB (in Sec. III B above) to 0 dB SNR. Decreasing the SNR will allow us to assess more directly the effect of style and noise on non-native talker intelligibility.

The intelligibility scores for the two noise conditions are shown in Fig. 3 and in 3 and 4 in Table I. ANOVA results for the effect of style (conversational vs. clear) as a within-subjects factor and noise (0 dB SNR vs +5 dB SNR) as a between-subjects factor for RAU-transformed percentage correct score as a dependent variable showed a significant main effect of style: [$F(1, 6) = 12.891, p = 0.011$]. The effect of noise was not significant: [$F(1, 6) = 4.400, p = 0.081$]. The two-way style-by-noise interaction was not significant [$F(1, 6) = 0.064, p = 0.808$]. The results showed that conversational-to-clear speech articulatory modifications resulted in increased intelligibility in both noise conditions. Increasing the noise level predictably lowered the overall intelligibility scores. This impact was similar for both speaking styles. Even though statistically not significant, it is likely that the effect of noise on intelligibility would have become significant with an increased sample size. The proportional clear speech gain was higher in the more difficult SNR condition (31 vs 19%).

Relative intelligibility across talkers remained similar in the two noise conditions. For instance, CF02 produced most intelligible conversational and clear speech for listeners at both SNR levels. For some talkers, though, the amount of clear speech gain varied between the two noise conditions. For instance, the clear speech gain for CM02 was only 1.25% when SNR was +5 dB but it increased to 13% with a more difficult SNR. Conversely, the clear speech gain for CF01 at +5 dB SNR was 20% and it decreased in the more unfavorable SNR condition to 11%. Increasing the noise level, thus, allowed some clear speech features to be weighed more heavily and improve intelligibility further for native listeners while some other clear speech features may have been masked and not used by native listeners when listening to L2 speech.

Compared with the results for the *matched* native AE talker and listener groups at the same 0 dB SNR (from Smiljanić and Bradlow, 2005), the effect of foreign accent on conversational and clear speech was reflected in the overall lower intelligibility. Conversational and clear speech intelligibility was 46 and 62%, respectively for native talker and listener groups compared with 31 and 41% for non-native talker and native listener groups. These results show

FIG. 2. Intelligibility scores (percent keyword correct) for two speaking styles for non-native talkers and non-native (left) and native (right) listeners.

that under the same listening conditions, i.e., 0 dB SNR, native talkers were more intelligible compared to these fluent non-native talkers. Parallel to the finding that non-native listeners need more favorable listening conditions in order to fully benefit from native clear speech enhancements, native listeners also need less signal distortion (better SNR) to take most advantage of the non-native clear speech adaptations. In fact, non-native conversational and clear speech intelligibility improves significantly with an increase of 5 dB SNR.

Despite the overall lower intelligibility for the non-native talkers, the clear speech improvement was remarkably similar for native and non-native talkers (roughly 34 and 32%, respectively). This suggests that these fluent non-native talkers were able to produce clear speech adjustments that were highly beneficial to native listeners. These results further demonstrate that fluent non-native talkers can adapt

their speech in a way similar to native talkers. Some of these modifications may reflect high levels of L2 knowledge which allows them to apply L2 appropriate enhancement strategies in addition to the overall signal enhancements. It remains to be determined through detailed acoustic analyses which L2 articulatory patterns contribute to the overall lower intelligibility of the non-native speech and, furthermore, how they interact with the enhancements that underlie the clear speech intelligibility benefit.

D. Accent ratings of non-native speech by native listeners

The average accent ratings for native and non-native talkers' conversational and clear sentences in quiet and in noise are given in Table II and shown in Fig. 4. Native listeners perceived the native talkers as not having any degree

FIG. 3. Intelligibility scores (percent keyword correct) for two speaking styles for non-native talkers and native listeners at +5 dB SNR (left) and 0 dB SNR (right).

FIG. 4. Accentedness ratings in noise (solid lines) and in quiet (dashed lines) for conversational (squares) and clear (triangles) speech sentences for non-native talkers.

of “foreign-accent” and showed a shift towards the “accented” end of the scale for all non-native talkers in both speaking styles and both noise conditions. Since native talkers were included in this task only to provide the listeners with a point of comparison and since none of the listeners found any level of accent for native sentences, we will proceed by analyzing only the non-native talkers’ results further. All listeners have utilized the entire scale in their judgments of non-native accentedness. Fourteen listeners used 1–9, 6 listeners used 1–8, 3 listeners used 2–9, and 1 listener used 2–8 points on the scale. ANOVA results for the effect of style as a within-subjects factor and of noise as a between-subjects factor on accent ratings showed no significant main effect of style [$F(1,6) = 3.516$, $p = 0.110$] or of noise [$F(1,6) = 0.133$, $p = 0.728$]. The two-way style-by-noise interaction was not significant either. The results revealed that perceived accentedness remained constant across speaking styles and across noise levels. In other words, the articulatory-acoustic modifications that non-native talkers implemented when producing clear speech did not affect the amount of perceived foreign accent in their speech.³ Talkers did vary in how accented their speech was perceived, such that CM02 received higher accentedness ratings compared to the other three talkers. However, for each talker, clear and conversational utterances received similar ratings. Similarly, no accent features were made more salient or were more masked by the introduction of noise.

The comparison between the accentedness and intelligibility results demonstrates that intelligibility was significantly increased for most non-native talkers even though non-native clear speech sentences were perceived to be as foreign-accented as conversational speech sentences. Clear speech intelligibility was improved independently of any change in accent ratings. Furthermore, it can be noted that within-talker accentedness and intelligibility levels are not

predictive of each other. For instance, CM02 has the highest accent ratings of all non-native talkers, yet his conversational and clear speech intelligibility levels are not the lowest as judged by native listeners in both noise conditions (Table I: 2 and 4). Similarly, even though the other three non-native talkers received similar accentedness ratings, their conversational and clear intelligibility levels varied. CF02 received highest intelligibility scores compared to CF01 and CM01. This suggests that the presence of different accent features that characterize conversational and clear speech sentences by different non-native talkers may affect intelligibility differently. Combined, these results provide further support for the previous findings that intelligibility and accentedness are in part separate dimension of non-native speech (Derwing and Munroe, 1997, 2009). This separation of the two speech dimensions may be especially true for the more fluent non-native talkers that were used in this study.

VI. GENERAL DISCUSSION

The overall goal of this study was to examine how language background affects spoken language adaptation aimed at increasing speech intelligibility in both perception and production. To that end, we asked whether non-native listeners can benefit from the clear speaking style modifications produced by native talkers and whether non-native talkers can themselves adapt their spoken output in L2 to enhance intelligibility for native and non-native listeners. Here we focused on fluent non-native talkers and listeners who have extensive familiarity with the sound structure of the target L2 language. It was hypothesized that these talkers and listeners would perform more in line with the native talkers and listeners in benefiting from and in providing the clear speech intelligibility benefit due to their increased experience in processing L2 compared to the more inexperienced L2 learners. We also explored whether perceived accentedness of the foreign-accented speech interacts with the intelligibility levels of the non-native conversational and clear sentences.

With regard to these questions, the present results revealed four important findings. First, fluent non-native listeners benefited significantly from native clear speech articulatory-phonetic adjustments. The clear speech benefit was similar for native and non-native listeners when listening to native clear speech. Less fluent non-native listeners benefited substantially less from native clear speech compared to native listeners (Bradlow and Bent, 2002) and fluent non-native listeners in this study. The present data thus indicate that as non-native listeners gain expertise in L2 processing, they increasingly manage to attend to and utilize the helpful L2 clear speech enhancements implemented by

TABLE II. Average accent ratings on a scale from 1 (native-like) to 9 (strongest accent) for native and non-native talkers’ conversational and clear sentences in quiet and in noise (+5 dB SNR).

In quiet	AF01	AF02	AF03	AM01	Average	CF01	CF02	CM01	CM02	Average
conv.	1.04	1.03	1.36	1.16	1.15	4.18	4.30	4.78	7.28	5.14
clear	1.05	1.03	1.31	1.29	1.17	4.60	4.62	4.80	7.19	5.30
In noise (+5 dB SNR)	AF01	AF02	AF03	AM01	Average	CF01	CF02	CM01	CM02	Average
conv.	1.13	1.23	1.46	1.44	1.32	4.79	3.75	4.65	6.18	4.84
clear	1.38	1.12	1.53	1.84	1.47	4.74	4.24	4.72	6.27	4.99

native talkers, including both global signal enhancements and language-specific modifications (Smiljanić and Bradlow, 2005, 2008).

The second finding regarding the effect of the language background and speaking style on intelligibility is that the fluent non-native talkers managed to produce clear speech that increased intelligibility significantly for native listeners. Previous research has shown that native listeners find native speech more intelligible compared to non-native speech (Bent and Bradlow, 2003; Munro, 1998; Munro and Derwing, 1999; van Wijngaarden, 2001, and many others). Results presented here show that native listeners may find clear speech of highly proficient non-native talkers as intelligible as conversational speech of native talkers. Moreover, the proportional clear speech gain provided to native listeners by these fluent non-native talkers was similar to that provided by native talkers. Furthermore, the amount of clear speech intelligibility gain for some of the non-native talkers in the present study was similar to the gain provided by the native talkers to the fluent non-native listeners here and by some of the native talkers to the native listeners reported in (Smiljanić and Bradlow, 2005). Clear speech strategies of more fluent non-native talkers, therefore, can be as beneficial for the native listeners as those of native talkers. Rogers *et al.* (2010) found a similar pattern of increased intelligibility of CVC syllables for the early learners compared to the late learners of English. Interestingly, the non-native talkers and listeners in the present study are not simultaneous or even early bilinguals. All of them were born and raised in Croatia and started learning English only in school, at the age of 6 or 7, as a part of the standard language curriculum. None of them have been immersed in an English speaking environment for extended periods of time prior to high school or for some listeners even prior to college. Yet they benefited greatly from clear speech enhancements produced by native speakers and produced a large clear speech benefit themselves, i.e., some of them performed similarly to the native talkers and listeners in both production and perception domains. This result suggests that second language learners can successfully perform certain communicative tasks, including the accommodation strategies reflected in clear speech production and perception, in L2 even without early exposure and long residence in an L2 speaking country. It remains to be shown what linguistic, learner and environment variables contribute to the high levels of functionality of these “late” learners in L2.

It is important to note that the comparable levels of intelligibility for non-native and native conversational and clear speech intelligibility were achieved when non-native speech was tested at a more favorable SNR. In more difficult listening conditions (at 0 dB SNR in this study) the overall non-native conversational and clear speech intelligibility for native listeners was lower. However, the proportional clear speech gain was larger when the level of noise was increased (19% at +5 dB SNR and 31% at 0 dB SNR). This suggests that while some features of foreign accented-speech may adversely affect intelligibility under less favorable listening conditions for native listeners, some non-native clear speech features appropriate for the L2 target language are quite ro-

bust against the masking effect of noise. And, similar to the finding that non-native listeners need more favorable listening conditions in order to fully benefit from native clear speech enhancements, native listeners also need less signal distortion (better SNR) to take most advantage of the clear speech features produced by non-native talkers. Importantly, though, the present results demonstrate that fluent non-native talkers *can* produce relatively highly intelligible speech and can increase their intelligibility for native listeners through clear speech modifications.

The third result related to the effect of the native language background and speaking style on intelligibility regards the L1 matched non-native listener-talker groups (CRO talkers and CRO listeners). The present study revealed that non-native clear speech was beneficial to the non-native listeners as well as to the native listeners. Similar intelligibility levels were achieved for these Croatian talker-listener groups when they performed the task in their L1 and in their L2 (50 and 65% for conversational and clear speech intelligibility in L1, as reported in Smiljanić and Bradlow, 2005, compared to 49 and 62% for conversational and clear speech intelligibility in L2 in the present study). The main difference in the two experiments was the level of noise used: +5 dB here vs 0 dB SNR in the earlier study. The combined results of these two studies suggest that, for non-native listeners, a similar level of performance when listening to Croatian-accented English and to native Croatian speech can be achieved if the level of noise is decreased for the Croatian-accented English. The same increase in SNR (5 dB) was shown to aid the non-native listeners when listening to English conversational and clear speech as produced by native English speakers compared to native listeners (as shown in section A above). It is important to note, however, that the matched non-native talker-listener pairs, CRO talkers and listeners doing the task in their L2, overall did not perform significantly differently from the mismatched native talker non-native listener groups (in A above). This result suggests that for highly proficient L2 learners sharing the same L1 background may not provide the interlanguage speech intelligibility benefit, the advantage that a shared interlanguage provides for non-native talkers and listeners presumably due to the similar L2 phonological representations (van Wijngaarden, 2001; van Wijngaarden *et al.*, 2002; Munro, Derwing, and Morton, 2006; Bent and Bradlow, 2003; also Stibbard and Lee, 2006, for different results). That is, once a certain level of fluency and experience in L2 processing has been achieved it may no longer be advantageous to hear L1-specific or some intermediate forms of L2 production. This, however, may not hold for all talkers, listeners and language pairings. At this point it is not clear what other factors, besides the overall fluency levels, may contribute to this phenomenon.

The final finding concerns judgments of the conversational and clear speech accentedness and their interaction with speech intelligibility. The results showed that non-native speech was consistently rated as having a higher degree of foreign accent compared to the native speech. The accentedness judgments did not differ for speech presented in noise and in quiet. Crucially, the accent ratings did not

differ for the two speaking styles. This was true of all non-native talkers regardless of the overall accent level and of the intelligibility levels. Non-native talkers, thus, did not change accentedness levels of their speech through conversational-to-clear speech adjustments. It is possible, though, that some accent features were changed, such that some L2 sounds were produced in a more native-like way in the intelligibility enhancing clear speech while some other accent features became more salient through target-language inappropriate modifications with the total net result of the constant accent ratings. This result offers further evidence for the partial independence of the perceived degree of foreign accent and speech intelligibility. Previous work has established that accentedness and intelligibility, comprehensibility and grammaticability of speech are related but partially independent dimensions of L2 speech production (Derwing and Munroe, 1997, 2009). Here, we offer additional support by demonstrating that despite the same degree of foreign accent, non-native clear speech productions significantly increased intelligibility for native listeners under various listening conditions.

One limitation of the present study is that it only examined Croatian non-native talkers and listeners. That is, the relatively high intelligibility of the fluent non-native talkers and listeners could be specific to the Croatian-English pairing examined here. It is possible that such successful non-native clear speech production and perception would not be found for talkers and listeners from a language that is typologically more different from English. However, Croatian and English differ in their sound inventory and phonetic implementation of sound categories which leads to substantially different clear speech strategies (Smiljanić and Bradlow, 2005, 2008). It is therefore, not likely that Croatian talkers are successful at producing and perceiving AE clear speech simply because they transfer their native language clear speech strategies to AE. Instead, we believe that Croatian talkers' success with AE clear speech is more likely due to their high English proficiency. We are currently examining acoustic features of non-native conversational and clear speech sentences in an attempt to identify clear speech features which differ across L1 and L2 and which, therefore, would have contributed to the L2 intelligibility benefit.

As shown in this paper, fluent non-native talkers and listeners, who under less favorable listening conditions and in different tasks, may perform with significantly more difficulty compared to native talkers and listeners (Mayo *et al.*, 1997; Rogers *et al.*, 2006), can improve both their perceptual performance and intelligibility of their speech through simple spoken style adaptations and with less signal distortion. Instructing non-native and native talkers to speak clearly and providing a quieter environment may be a simple and beneficial way of alleviating some of the problems during native and non-native interactions in clinics, hospitals, businesses or schools, for instance, and, in that way, contributing towards more successful communication. This observed "bidirectional" benefit of clear speech in native plus high proficiency non-native talker-listener groups underscores the adaptive nature of spoken language communication. The challenge now is to identify the factors that promote (or

limit) this channel of adaptation so that we can ultimately control it better.

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APPENDIX: SEMANTICALLY ANOMALOUS SENTENCES USED IN SENTENCE-IN-NOISE TESTS

- (1) Your tedious beacon lifted our cab.
- (2) A cabbage would sink his tired Tuesday.
- (3) Their stew was digging a curious bet.
- (4) My puppy may stress their fundamental gallon.
- (5) The fast bucket was pecking her twin.
- (6) The distant budget is baking the sleepy cap.
- (7) Betty will consist of a tepid token and a pig.
- (8) Her duplex would tutor a dubious truck.
- (9) Peter and his chief ticket were hooded by their bed.
- (10) His kind pudding was taping a decade over my pick.
- (11) Her dense writer would fork their toga and clerks.
- (12) The routine body was keeping our wood.
- (13) The ultimate captain will creak the bottle tomorrow.
- (14) His grilled cookie derived the baby through a clause.
- (15) The braided habit twisted her pigeon into the segments.
- (16) Her abundant pocket circles to his marble.
- (17) My grill would milk her plump topic with the facts.
- (18) The ground baggage missed the soda briefly.
- (19) The theory should drag her home into the ocean.
- (20) Our rare future submitted a jump to the judges.

¹Speaking style adaptations may vary somewhat depending on whether an interlocutor is actually present or who the imagined dialog partner is (Uther *et al.*, 2007). For our purposes, the main focus is on the consequences of such conversational-to-clear speech modifications on intelligibility regardless of the exact directions given to the talkers.

²Even though non-native intelligibility is only in the 50%–60% range, these levels of performance are expected in noise and are similar to the native-native talker and listener groups under a more difficult SNR (Smiljanić and Bradlow, 2005). Therefore, we consider these talkers to be relatively highly intelligible.

³Sentence repetition during the accent rating task may have affected listeners' performance. It is not clear, however, if hearing an accented sentence more than once would increase or decrease the saliency of the perceived foreign-accent features. The clear and conversational sentences in this experiment were presented in random order which would have made the repetition effect equally possible for sentences produced in both styles.

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