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Masking release effects of a standard and a regional linguistic variety

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Abstract: Previous research has shown that the more similar the target and the masker signal, the harder it is to segregate the two streams effectively [i.e., *target-masker linguistic similarity hypothesis*, e.g., Brouwer, Van Engen, Calandruccio, and Bradlow (2012). J. Acoust. Soc. Am. **131**(2), 1449–1464]. The present study examined whether this hypothesis holds when a standard variety of a language (Dutch) is paired with one of its regional varieties (Limburgian). Dutch and Limburgian listeners were tested on a speech-in-speech recognition task to investigate whether familiarity with the target and/or maskers influenced their performance. The findings provide support for the hypothesis and suggest an influence of Limburgians' bidialectal status.

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1. Introduction

In everyday life, interlocutors are often faced with the challenge to ignore a variety of background noises. These background noises may or may not contain linguistic information. Pollack (1975) proposed a distinction between energetic and informational masking (see also Kidd *et al.*, 2007, for a review). Energetic masking refers to difficulties in understanding the target signal because of spectral and temporal overlap with the noise. In the case of informational masking, however, the target and noise may both be audible but may be difficult to separate due to linguistic, attentional, and/or other cognitive factors. Previous research has shown that manipulations in the linguistic content of the background signal can have substantial effects on the recognition of the target signal (e.g., Calandruccio *et al.*, 2010b; Garcia-Lecumberri and Cooke, 2006; Van Engen and Bradlow, 2007). This work has led to the formulation of the *target-masker linguistic similarity hypothesis* which assumes that the more similar the target and the masker signal the harder it is to segregate the two streams effectively. Conversely, the more dissimilar the target and the masker speech, the easier it is to segregate the two streams effectively (Brouwer *et al.*, 2012, p. 1449). The present study aims to test whether this hypothesis holds when a standard variety of a language (i.e., Dutch) is paired with one of its regional varieties (i.e., Limburgian).

Evidence for the *target-masker linguistic similarity hypothesis* has come from experiments manipulating two different factors. First, a number of studies have found language-related factors that support this hypothesis (e.g., Calandruccio *et al.*, 2010a; Garcia-Lecumberri and Cooke, 2006; Van Engen and Bradlow, 2007), demonstrating a recognition advantage when the language of the masker was different from the language spoken in the target. For example, in Van Engen and Bradlow's (2007) study, native English listeners performed better when English target sentences were presented in the presence of two-talker (unfamiliar) Mandarin versus English babble. This pattern was also found for target-masker language pairs that were typologically more similar and thus linguistically closer to each other (English-in-English vs English-in-Dutch; Brouwer *et al.*, 2012; Calandruccio *et al.*, 2013). Note that the Van Engen and Bradlow (2007) study also discussed their findings in light of differences between spectro-temporal properties of Mandarin-Chinese versus English. That is, an English masker also is likely to cause more energetic masking than a Mandarin-Chinese masker when the target is English. The authors argue that a complex interaction of informational masking and energetic masking contributes to the masking release. Calandruccio *et al.* (2010a) varied the linguistic (dis)similarity between the target and masker even further by looking at the effect of a foreign-accented masker (i.e., Mandarin-accented English) compared to native-English and unfamiliar Mandarin speech. Their results showed that performance differences between the maskers could be explained by spectral differences. However, at a more difficult signal-to-noise ratio (SNR), the amount of linguistic content in the masker played a role. That is, the effectiveness of the masker increased when it was more similar to the target signal.

A second factor that influences the relative target-masker similarity is listeners' knowledge/familiarity with the target and masker language(s). For example, Van Engen and Bradlow (2007) demonstrated that Mandarin-English sequential bilinguals obtained a masking release in their second language (*L*2) when the masker was changed from their *L*2 (i.e., English-in-English) to their first language (*L*1, i.e., English-in-Mandarin). However, the masking release was reduced compared to English native listeners who are familiar with English but for whom Mandarin was unintelligible. Similarly, Brouwer *et al.* (2012) found a smaller release from masking for bilingual Dutch-English listeners than for native English listeners when listening to English targets in English versus Dutch background speech. Hence, these studies reveal that familiarity with the target and/or the masker is a significant predictor of speech-in-speech recognition.

The first aim of the current study is to test the limits of the *target-masker linguistic similarity hypothesis*. More specifically, the question addressed here is whether this hypothesis also holds when the linguistic distance between the target and masker language is even smaller than between two typologically-related languages such as Dutch and English (cf. Brouwer *et al.*, 2012). To do this, we use Standard Dutch, the official language used in formal and institutional settings in the Netherlands, as our target language and Standard Dutch and Limburgian as our maskers. Several Limburgian dialects of Dutch are spoken in the province Limburg in the Netherlands and the Rhineland regions along the Dutch-Belgian-German border (Gussenhoven, 2000). Around 75% of the inhabitants of Limburg speak a Limburgian dialect (Driessen, 2006). Most of them also speak Standard Dutch and are therefore considered bidialectal (Cornips, 2014). Bidialectalism can be understood as bilingualism involving closely related linguistic varieties, where an indigenous variety operates alongside more widespread norms in a community of speakers. Both Dutch and Limburgian are West-Germanic languages and belong to the Low Franconian languages. Note that English is also a West-Germanic language but belongs to the Anglo-Frisian group, thereby creating more linguistic distance between Dutch and English.

A second, related aim of this study is to test whether familiarity with the target and/or maskers influences speech-in-speech recognition. We therefore compare native Dutch listeners with limited to no experience with the Limburgian dialect with Limburgian listeners who have extensive, long-term experience with the Limburgian dialect. The Limburgians in this study were born and raised in the province Limburg. Both listener groups are familiar with Standard Dutch, as this is the dominant variety of Dutch and is also available through Dutch national broadcasting media (see Sec. 2 for more information). Although Dutch listeners are less familiar with the Limburgian dialect than Limburgians, previous research has shown that Limburgian is intelligible to Dutch listeners (Bezooijen and Van den Berg, 1999).

In summary, our experiment has been designed to compare Dutch and Limburgian listeners' performance on a speech-in-speech recognition task with Standard Dutch target sentences in two-talker Standard Dutch (henceforth Dutch) and Limburgian babble under two relatively difficult SNR levels. We chose two-talker babble and relatively unfavorable SNR levels, as previous research has shown that linguistic interference is most prominent in such conditions (e.g., Calandruccio *et al.*, 2010a).

Given previous findings (e.g., Brouwer *et al.*, 2012), it was predicted that target sentence recognition in Dutch-in-Dutch would be harder than in Dutch-in-Limburgian for the Dutch listeners. This would be due to the linguistic similarity (i.e., match) between the Dutch target and Dutch masker language and due to Dutch listeners' familiarity with Dutch. Alternatively, it is possible that the release from masking for the Dutch-Limburgian language pair is reduced or even absent compared to what we have observed for more linguistically distant language pairs (e.g., English and Dutch; English and Mandarin). This would imply that, although the Limburgian dialect is dissimilar from Dutch, it is too linguistically similar to elicit a release from masking.

For the Limburgian listeners it is possible to find the same pattern as for the Dutch listeners. That is, Dutch-in-Dutch would be more difficult than Dutch-in-Limburgian due to the linguistic similarity (i.e., match) between the Dutch targets and the Dutch masker. Given previous findings (e.g., Brouwer *et al.*, 2012; Van Engen and Bradlow, 2007), it is however conceivable that this masking release is smaller or even absent for Limburgian compared to Dutch listeners. Three explanations are possible for this pattern. First, it could be due to the fact that the Dutch-Limburgian language pair is linguistically so similar that no or a reduced masking release will be elicited. Second, it is possible that the Limburgians' extensive experience with Limburgian prevents a (significant) masking release. Finally, a possible reduced or lack of masking release may be due to Limburgians' bidialectal status as they are highly proficient in the standard and the regional variety and learned both varieties before the age of 4.

2. Method

Twenty-four Dutch (16 females; $M_{AGE} = 20;4$, $SD_{AGE} = 0;2$, SD is standard deviation) and 25 Limburgian listeners (11 females; $M_{AGE} = 22;6$, $SD_{AGE} = 0;3$) without hearing or speech impairments were tested at the Radboud University in Nijmegen. Both listener groups filled out a questionnaire. They had to self-rate their proficiency in Dutch and Limburgian on a 7-point Likert scale (1 = very bad; 7 = very good). Independent *t*-tests showed significant differences between the two groups on Limburgian but not on Dutch proficiency (see Table 1). The Limburgian listeners were all born in Limburg and indicated that they learnt Limburgian and Dutch between the age of 0 and 4 yrs (Limburgian: $M_{AGE} = 0;11$; $SD_{AGE} = 1;6$; Dutch: $M_{AGE} = 1;1$; $SD_{AGE} = 1;6$), confirming their (simultaneous) bidialectal status.

The Dutch target sentences were produced by a native female Dutch speaker (same as in Brouwer *et al.*, 2012). These sentences were selected from four lists (1, 7, 8, and 9) of the revised Bamford-Kowal-Bench test (Bamford and Wilson, 1979), which were translated from English to Dutch by a Dutch native speaker (S.B.). Each list contains 16 simple, meaningful sentences with 3 or 4 keywords for a total of 50 keywords per list. In total, 64 target sentences were presented.

The background sentences were produced by two native female Dutch (same as in Brouwer *et al.*, 2012) and two native female Limburgian talkers. One hundred sentences were taken from the Harvard/IEEE sentence lists (IEEE, 1969), which were translated from English to Dutch by a Dutch native speaker (S.B.). Two Limburgian native speakers, who both came from the Sittard region in Limburg (East-Limburgian), each translated half of the sentences into Limburgian and checked each other's translations. After that, we recorded them for the Limburgian background sentences. Recordings were made in a sound-attenuated booth (22 050 Hz; 24 bit).

The 2-talker Dutch masker from Brouwer *et al.* (2012) was re-used in this study. To create the 2-talker Limburgian masker the same steps were followed as for the Dutch masker. We concatenated the Limburgian sentences for each speaker in Praat (Boersma, 2001). The Dutch and Limburgian tracks were normalized and the long-term average speech spectra (LTASs) of the two tracks were normalized to each other as a means of reducing unequal amounts of energetic masking between the two backgrounds. Next, the babble tracks were manipulated to achieve the two desired SNR levels. Each target sentence was combined with 500 ms of silence at the start and 500 ms of silence at the end. Subsequently, they were mixed with a pseudorandom part from the Dutch or the Limburgian babble track in Audacity. The babble portions used for each target sentence were different.

During the test session, participants first completed a questionnaire asking about their knowledge and use of Dutch and Limburgian. After that, they were instructed that they would hear Dutch sentences spoken by a Dutch female speaker in the presence of two-talker background speech. In line with previous work (Brouwer *et al.*, 2012; Van Engen and Bradlow, 2007), listeners were not provided with clues about which talker to attend to. The relatively easy trials in the practice session (played at an SNR of +10, +5, and 0 dB) made sure that listeners knew whom to pay attention to. Their task was to report what they heard by typing the sentence using the keyboard. In case they could not hear the entire sentence, they were asked to type in the individual words they were able to hear. They could only listen to each sentence once and proceeded to the next trial by pressing the ENTER button.

The experiment started with eight practice trials in order to familiarize participants to the task and the target speaker. After the practice, participants were presented with 64 experimental items in 4 blocks of 16 sentences each. The babble came on

Table 1. Language background details of Dutch and Limburgian listeners. SDs are reported between parentheses.

	Listeners		Independent
	Dutch	Limburgian	*t*-test
Proficiency in Dutch			
Listening	6.6 (0.5)	6.6 (0.6)	$p > 0.1$
Speaking	6.5 (0.5)	6.8 (0.5)	$p > 0.1$
Proficiency in Limburgian			
Listening	2.8 (1.7)	6.3 (1.0)	$t(39) = -8.73$, $p < 0.001$
Speaking	1.5 (1.0)	5.1 (2.3)	$t(34) = -7.28$, $p < 0.001$

500 ms before and continued for 500 ms after the target sentence. The level of the target sentences was fixed at 65 dB sound pressure level (SPL). In line with previous work (Brouwer *et al.*, 2012; Calandruccio *et al.*, 2013), babble tracks were played at 68 dB SPL to produce a SNR of −3 dB (first and second block) and at 70 dB SPL to produce a SNR of −5 dB (third and fourth block). Each background language was presented at both SNR levels. The order of the background languages was randomized within each SNR block, but in such a way that a Dutch block never directly followed another Dutch block and a Limburgian block also never directly followed another Limburgian block to prevent learning. The stimuli were presented in Presentation® software (Version 18.0, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com) and played out diotically over headphones. Each session lasted about 5–10 min. A maximum of two participants were tested in the same room at the same time.

Data were analyzed using linear mixed-effects regression model (Baayen *et al.*, 2008) with keyword identification accuracy as the dichotomous dependent variable. A logistic linking function was used to deal with the categorical nature of the dependent variable. A $2 \times 2 \times 2$ model of recognition accuracy with SNR (easy vs hard), Background Language (Dutch vs Limburgian), and Listener Group (Dutch vs Limburgian) as contrast-coded fixed effects and their three-way interaction was included. The maximal random effects structure included random intercepts for participants and items along with a random slope for Background Language by participants and by items. Significance was assessed via likelihood ratio tests comparing the full model to a model lacking only the fixed effect.

3. Results

The results for the effects of interest are summarized in Fig. 1. The analysis showed a main effect of SNR [$\beta = -1.38$, $SE = 0.37$, $\chi^2(1) = 12.92$, $p < 0.001$, SE is standard error], indicating that the easier SNR level ($M = 71.8\%$ correct) resulted in better target sentence recognition than the harder SNR level ($M = 55.2\%$ correct). The analysis also revealed a main effect of Background Language [$\beta = 1.16$, $SE = 0.26$, $\chi^2(1) = 21.47$, $p < 0.0001$]. Listeners performed significantly better when the background was Limburgian ($M = 71.2\%$ correct) than Dutch ($M = 55.8\%$ correct). There was no main effect of Listener Group [$\beta = -0.21$, $SE = 0.23$, $\chi^2(1) < 1$, $p > 0.1$] and none of the interactions reached significance (all $ps > 0.2$).

4. General discussion

The aim of the present study was twofold. First, we examined whether listeners received a release from masking when the target and masker languages are very similar, thereby testing the limits of the *target-masker linguistic similarity hypothesis* (Brouwer *et al.*, 2012). Second, we investigated whether familiarity with the target and/or masker language(s) influences speech-in-speech recognition.

The results of this study replicated previous work (e.g., Brungart, 2001) by showing that listeners perform better in easier than in harder SNR conditions, independent of background language or listener group. Importantly, both listener groups showed a similar performance on the speech-in-speech recognition task. That is, they experienced a release from masking from the Limburgian masker compared to the Dutch masker. This finding provides additional support for the *target-masker linguistic similarity hypothesis* because it shows that a target-masker language match is more detrimental to target sentence recognition than a target-masker language mismatch. The novel aspect of this finding is that it shows that the *target-masker linguistic similarity hypothesis* not only applies to unrelated languages (e.g., English-in-Croatian in Calandruccio *et al.*, 2013; English-in-Mandarin in Van Engen and Bradlow, 2007), related languages (English-in-Dutch in Brouwer *et al.*, 2012), and to language pairs produced with and without a foreign accent (Calandruccio *et al.*, 2010a), but also for a pairing of a standard variety of a language and one of its regional varieties between which the linguistic distance is even smaller than for the language pairings that have been investigated so far. It seems that the release from masking provided by Limburgian patterns rather similar to previously investigated language pairs (between 10 and 20 percentage points, depending on the SNR level). However, this interpretation has to be regarded with caution given that the results are reported differently in different studies (i.e., in percentage correct versus rationalized arcsine units; in boxplots with or without means). A within-subjects experiment in which different language(-dialect) pairs are presented to participants would do full justice to examine whether the masking release effects are gradient or not (cf. Calandruccio *et al.*, 2013).

Although mutual intelligibility is relatively high between Limburgian and Dutch (Bezooijen and van den Berg, 1999), the acoustic properties of Limburgian

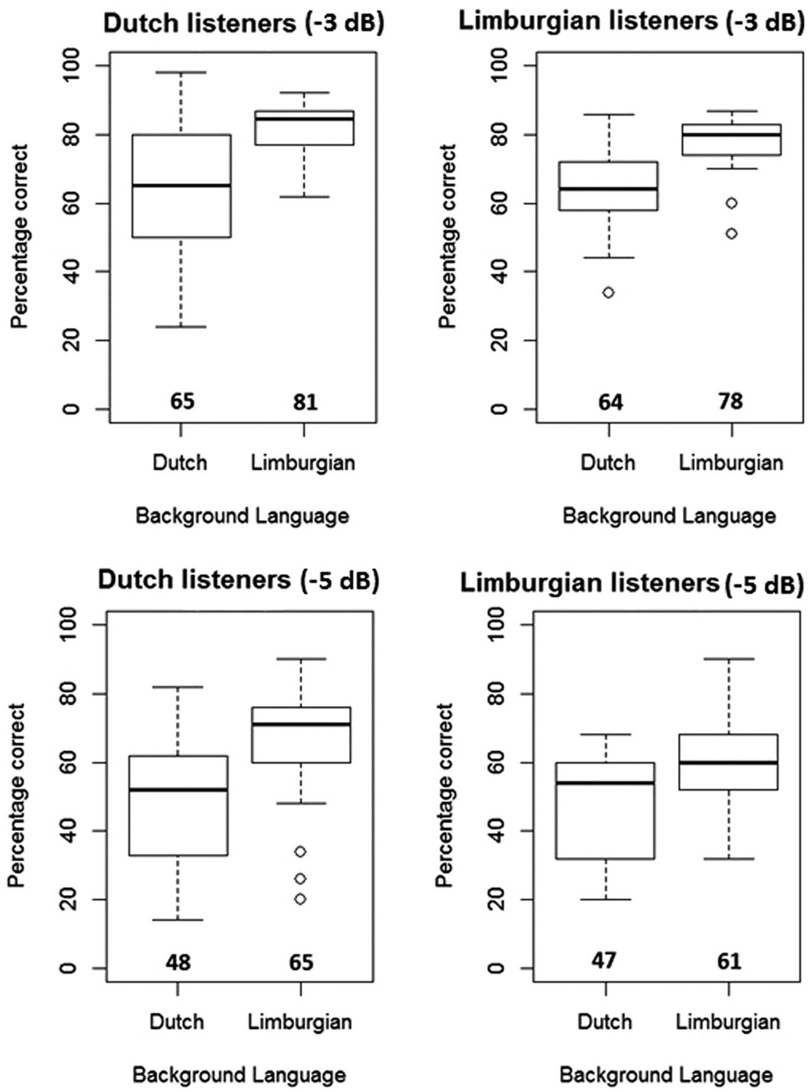

Fig. 1. Boxplots showing the interquartile ranges of intelligibility scores (in % correct) for Dutch and Limburgian listeners on Dutch target sentence recognition in the −3 dB SNR condition (top panel) and the −5 dB SNR condition (bottom panel) for Dutch and Limburgian background noise. Whiskers extend to the most extreme data point that is no more than 1.5 times the interquartile range of the box. The mean is given at the bottom of each plot.

(e.g., Keulen *et al.*, 2007) and the acoustic differences between Limburgian and Dutch (e.g., van Hout *et al.*, 2000) reveal that the phoneme inventory of Limburgian deviates reasonably from Dutch. For example, Limburgian tends to have more vowels and more consonants than Dutch. Moreover, the prosody of Limburgian is quite different from Dutch because Limburgian is a restricted tone language and yields an intriguing interaction between lexical and intonational tones. Thus, these differences between the two varieties have probably contributed to the release from masking from Limburgian compared to Dutch.

The similarity in performance between our two listener groups was not entirely foreseen. In Sec. 1, we hypothesized that it is conceivable that the masking release would be smaller or even absent for Limburgians compared to Dutch listeners, reflecting an effect of familiarity with the (Limburgian) background language. This idea is consistent with the previous literature (e.g., Brouwer *et al.*, 2012; Van Engen, 2010). However, no interaction between listener group and background language was found. A possible explanation for the lack of such an interaction in the current study could not be that the varieties are too similar to each other. As mentioned above, there are linguistic/phonetic differences between the two variants. Moreover, the Dutch listeners indicated in our questionnaire to have hardly any experience with Limburgian (input frequency: $M = 1.0$; $SD = 0.4$ on a 7-point scale) and they rated themselves as being very poor to quite poor on producing and listening to Limburgian (see Table 1). This does not mean though that the Dutch participants had no passive exposure to Limburgian at all because many students, who are originally from Limburg, decide to study in Nijmegen, where the research was conducted. Furthermore, the release from masking for the Dutch listeners is no less than 16 percentage points which may also indicate that this is a maximum possible release (i.e., a ceiling effect).

Another way to explain the absence of an interaction effect is to look more closely at Limburgian listeners' performance. First, it is possible that the Limburgian listeners we tested were not sufficiently proficient in Limburgian to give rise to a familiarity effect. In a *post hoc* analysis, we therefore tested this idea further by comparing highly proficient Limburgians with the Dutch listeners. In this analysis, we only included those Limburgian listeners ($N = 15$) who reported to speak Limburgian well to very well (i.e., scores 6 and 7 on the 7-point scale of our language background questionnaire). Note that we could not use their self-rated proficiency scores in listening as these scores did not differentiate the Limburgian listeners in two groups (i.e., most of them rated themselves as well to very well). The scores for the excluded participants confirmed that these listeners were also the ones who used Limburgian rather infrequently ($M = 2$; $SD = 1.3$). This analysis demonstrated similar results as the analysis on the whole group. We found a main effect of SNR [$\beta = -1.32$, $SE = 0.37$, $\chi^2(1) = 11.92$, $p < 0.001$] and a main effect of Background Language [$\beta = 1.24$, $SE = 0.24$, $\chi^2(1) = 22.93$, $p < 0.0001$]. No main effect of Listener Group and none of the interactions reached significance (all $ps > 0.1$). On the basis of these data, we therefore conclude that proficiency does not explain the lack of an interaction effect.

It is also possible that our Limburgian listeners were too heterogeneous as a group, which prevented us from finding an interaction effect. As mentioned in Sec. 1, there are several Limburgian dialects of Dutch spoken in the province Limburg in the Netherlands, which makes Limburgian a heterogeneous language variety (Gussenhoven, 2000). For example, dialects that belong to the same region show a greater degree of phonological overlap than dialects from different regions. Follow-up research should therefore take into account the exact region in which the Limburgian listeners were born and raised.

An alternative explanation for the lack of an interaction effect that is related to Limburgians' performance is their bidialectal status. On the one hand, it is possible that bidialectals experience a lack of processing resources in more difficult listening situations. In the Brouwer *et al.* (2012, p. 1461) study it was found that "…when Dutch-English bilinguals focus on L2 (i.e., English targets) speech recognition, their processing resources are primarily committed to relevant information (i.e., English background speech) resulting in a reduction of processing recourses available for competing irrelevant information (i.e., Dutch background speech)." The pattern of these bilinguals is comparable to the performance of the Limburgian-Dutch bidialectals. They were also effectively inhibiting $L1$ background speech (i.e., Limburgian) when attending to $L2$ speech targets (i.e., Dutch), whereas it was more difficult for them to inhibit $L2$ background speech (i.e., Dutch). Limburgians' familiarity with their $L1$ did thus not preclude them from successfully tuning out their $L1$ during $L2$ sentence recognition.

On the other hand, it is possible that bidialectals are more efficient in processing than monolinguals. This notion is consistent with the bilingual advantage in executive control functioning, in particular the case of language switching, relative to monolinguals (e.g., Bialystok *et al.*, 2008). The systematic switching between any two forms of language, even quite similar ones, seems to aid higher cognitive performance. Recent research suggests that this advantage also holds for bidialectals (Antoniou *et al.*, 2016; but see Blom *et al.*, 2017). In the current task it is thus possible that the bidialectals have benefited from their switching experience between their $L1$ and $L2$. More research needs to be done to fully understand how Limburgian listeners allocate their resources depending on whether they listen to their dialect or the standard variety of their language. An interesting next step would be to examine how Limburgians perform on Limburgian targets instead of Dutch targets in Dutch and Limburgian babble.

Finally, differences in masking effectiveness of individual talkers, as has been suggested by an anonymous reviewer, could have played a role in the current results (e.g., Freyman *et al.*, 2007). In other words, differences obtained between the Dutch and Limburgian maskers cannot be attributed entirely to dialect, since different talkers were used to produce these maskers. This issue would need to be addressed in the future when bidialectal talkers are used for babble.

To conclude, our results provide additional support for the *target-masker linguistic similarity* hypothesis. Our data showed that this hypothesis not only applies to unrelated languages, related languages, and to language pairs produced with and without a foreign accent, but also to a target-masker pair as closely related as a standard variety and a regional variety. However, familiarity with the target and/or maskers did not result in a smaller masking release for the Limburgian than the Dutch listeners as has been found in previous studies with less similar target-masker pairs. A possible explanation for this is the bidialectal status of the Limburgians. Future research should address whether our findings hold for different standard-regional variety pairings.

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