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Effects of bilingualism on cue weighting: How do bilingual children perceive the Dutch [ɑ]-[a:] contrast?

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Abstract

The effects of bilingualism on vowel perception and cue weighting behaviour have not been established definitively. What influence does heritage bilingualism have on cue weighting of spectral and durational cues? What role does the duration cue play in cue weighting behaviour of heritage bilinguals: is it universally accessible or related to the first language?

Purpose: This study examines the perception and cue weighting of child heritage bilinguals to assess whether exposure to multiple acoustic systems has an effect on cue weighting.

Design: Bilinguals with a language containing a durational vowel contrast (Moroccan-Arabic) or a non-durational contrast (Turkish) were tested in order to explore cue preference and cue weighting behaviour for the multiple cued Dutch [ɑ]-[a:] contrast: their alternate first language.

Data and analysis: An identification task was performed for the Dutch [ɑ] and [a:]. The F1 and F2 were logarithmically manipulated, in equal steps for the spectral and durational cue, creating a seven-step continuum. The analysis revealed cue preference by examining cue usage and relative cue weight.

Conclusions: Dutch monolinguals use both cues but assign more weight to the spectral cue. Moroccan-Arabic/Dutch heritage speaker (HS) bilinguals use both cues, but weigh the spectral cue more heavily. Turkish/Dutch HS bilinguals rely almost exclusively on the spectral cue. This suggests a transfer from the alternate first language onto the perception of Dutch, regardless of language dominance.

Originality: Not much research on the cue weighting behaviour of school-aged heritage bilinguals has been conducted, as this age group is yet to develop their perceptual behaviour completely. The results of this case study show an influence on perceptual behaviour as a result of bilingualism.

Significance: This study provides insight into the cue weighting behaviour and cue preference of school-aged heritage bilinguals.

Keywords

Simultaneous bilingualism, heritage bilingualism, cue weighing, durational cue, acoustic salience, transfer, multiple cued vowel

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Introduction

Each language has a distinct sound system, acquiring the relevant, or language-specific, sound system begins very early on in life (DeCasper & Spence, 1986). Because speech sounds are produced with great variability and have multiple acoustic dimensions, listeners need to learn to successfully map the sounds in their environments onto the correct speech sound categories (Brown, 1998). The acoustic signal contains multiple types of information, along different acoustic dimensions (Williams & Escudero, 2014). These *acoustic cues* are each assigned a relative weight, which differs per language. In perception, adult native listeners pay different amounts of attention depending on the acoustic cues, where some information is primary, and some secondary (Nittrouer, 2000; Scobbie, 1998). This is known as *cue weighting* or *cue reliance*. Heeren (2006) adds to the notion of language-specific cue weighting by explaining that in order to learn a language, one must learn the relevant *phoneme contrasts*, the different phonetic and acoustic features of phoneme pairs, which includes the task of learning the language-specific cue weighting. Many factors are known to influence the listener's perception and cue weighting behaviour, for example, the language set, exposure to language(s) and manipulation of cues in experimental settings (Elman, Diehl, & Buchwald, 1977; Reinisch & Sjerps, 2013). For early bilinguals, who have been exposed to two native languages from birth, this means having to acquire the relevant phoneme contrasts and cue weightings for multiple languages since not every language employs the acoustic space similarly. For instance, some languages have vowel contrasts based on vowel length, while other languages do not have contrastive length and rely exclusively on spectral cues. Still, a language with contrastive duration may also use spectral information. For example, Dutch may be called a 'quantity language' since it has contrastive vowel length; however, for a Dutch listener to perceive the difference between minimal word pairs such as *bon* [bɔn]–*boon* [bo:n] ('ticket'–'bean') and *man* [mɑn]–*maan* [ma:n] ('man'–'moon'), not only *vowel duration*, but also *vowel quality* plays a role (Chládková, Escudero, & Lipski, 2015; Pols, Tromp, & Plomp, 1973). This study will explore the vowel perception and the acoustic cue weighting of bilinguals, who have been exposed to two native languages from birth, among which one is Dutch, for the Dutch /ɑ/-/a:/ contrast, in order to establish whether exposure to multiple languages and hence multiple acoustic systems affects the preferred cue and the cue weighting process. If so, this would indicate what direct effect bilingualism has on perceptual behaviour, since previous research found multiple effects of bilingualism on perception, that is, related to cue sensitivity, cue weighting and the development of cue weighting strategies. These findings will be elaborated on in the rest of the Introduction.

Duration as a universal cue

It has been suggested that the durational cue is a salient feature that is universally accessible to listeners that do not have this acoustic cue in their native language. More specifically, it has been hypothesised that reliance on durational cues in non-native listeners' vowel perception "reflects a general speech perception strategy that takes over whenever information conveyed by spectral differences is insufficient" (Bohn 1995, p. 300). Several studies have found results supporting this hypothesis. For example, Bohn (1995) showed that native Spanish and native Mandarin listeners rely heavily on durational rather than spectral cues in the English vowel contrasts /i/-/ɪ/ and /ɛ/-/æ/, yet Spanish does not use duration contrastively and Mandarin uses duration only as a property supporting tone contrasts. Escudero (2001) and Escudero and Boersma (2004) similarly found that Spanish second language (L2) listeners of English use the durational cue to listen to English vowel contrasts, while Cebrian (2006) reported similar results for the identification of English vowels by Catalan L2 listeners. Van Heuven, van Houten, and de Vries (1986) found that adult Turkish-Dutch

L2 listeners rely almost exclusively on the durational cue to identify the Dutch vowels /ɑ/-/a:/, even though the Turkish language contains only very limited durational features. Brasileiro (2009) investigated Dutch-Brazilian Portuguese bilingual children's perception of the Dutch /ɑ/-/a:/ contrast and found that, as compared to monolingual Dutch children, bilinguals are delayed in their reliance on spectral information, yet accelerated in their reliance on duration. Bilingual children increase reliance on the durational cue with age, possibly in order to cope with the spectrally crowded input intrinsic in their bilingual environment. In summary, the salience and universality of the durational acoustic cue would influence the cue weighting behaviour of all listeners regardless of their language background, both in L2 and bilingual acquisition settings.

Bilingualism and cue weighting

The effects bilingualism can have on cue perception have been attested by a number of studies. For example, Hazan and Boulakia (1993) found that language dominance influences cue sensitivity in English–French bilinguals' consonant identification based on voice onset time (VOT). Escudero, Benders, and Lipski (2009) compared first language (L1) listeners of German and Dutch, both languages with durational and spectral cues, to L1 Spanish listeners that have Dutch as a L2, thus a non-durational language and a durational language. They found that the exposure to Dutch helped the Spanish listeners use both the durational and the spectral cue when listening to the Dutch /ɑ/-/a:/ contrast; these L2 listeners were better at categorising the contrast in comparison to the German listeners, who had no prior exposure to Dutch. Baker and Smith (2010) studied the production and perception of vowels by Anglophone learners of Québec French versus Anglophone learners of European French and found that familiarity with a dialect (Québec versus European) can influence the perception of Parisian French vowels. For bilinguals it has been hypothesised that the (dominant) L1, that is, the most developed language, will shape the acoustic space such that the acoustic dimensions occupied in the L2 will have to fit into the L1 setting space (Best, 1995; Morrison, 2009). It should be noted that this hypothesis has been developed for sequential bilinguals (those who first learn a L1 then a L2) and not for simultaneous bilinguals (those who have two L1s – 2L1) or heritage bilinguals (those who have been exposed to two languages from birth, but the majority language developed into the dominant language, restricting the development of the heritage language).

An important exposure factor that is known to influence the listener's perception and cue weighting behaviour is bilingualism. For example, Gerrits (2001) and Heeren (2006) discovered that the language experience gained with age allows monolinguals and bilinguals to use finer-grained acoustic cues and develop more advanced cue weighting behaviour in vowel perception, including the Dutch /ɑ/-/a:/ contrast. Several studies, including Nittrouer (1996), Kuhl (2000) and Brasileiro (2009), have found that children as compared to adults rely more strongly on universal cues and become more sensitive to finer-grained, language-specific cues with age. Brasileiro also found that bilingual and monolingual children do not differ in their perception, but that the developmental paths of bilingual listeners are different from those of monolinguals. Mayo, Scobbie, Hewlett, and Waters (2003) showed that with increased phonemic awareness listeners also develop the ability to change cue weighting strategies.

When investigating bilingual children's perception, it is important to distinguish 2L1 bilinguals from *heritage speakers* (HSs). Benmamoun, Montrul, and Polinsky (2013) define a HS as

> An early bilingual who grew up hearing and speaking the heritage language (L1) and the majority language (L2) either simultaneously or sequentially in early childhood (that is, roughly up to age 5; see Schwartz, 2004; Unsworth, 2005), but whose L2 became their primary language at some point during childhood

> (typically after the onset of schooling). […] The crucial criterion is that the heritage language was first in the order of acquisition but was not completely acquired because of the individual's switch to another dominant language or become attrited under pressure from the dominant host language (pp. 6–7).

Saadah (2011) argues that HSs

> Despite growing up in the same community and speaking the dominant language, […] can be considered a distinct group from L2 learners. HSs generally come from immigrant communities. The UCLA Steering Committee (2000: 339: 15) considers a HS as someone who has been exposed to the heritage language at home.

In Saadah's study, the HSs' home language was Arabic, while their dominant language was English. Saadah shows that the HSs' proficiency may vary in a number of aspects, such as their proficiency of the heritage language, their attitude towards the language and feeling of association with the heritage language and their opportunity to study the heritage language formally (Saadah, 2011, p. 15). Saadah argues that their different use of language across social domains causes their language experience to be distinct from native speakers. Relevant for the current study, Saadah found that Arabic HSs raised in English speaking environments developed a hybrid phonetic system for their vowels, which revealed acoustic characteristics from both languages, English and Arabic.

The different results regarding cue weighting in bilingual children found in previous studies may hint at possible effects on cue weighting due to either the characteristic of the durational cue and/or due to the nature of bilingualism itself. The durational cue can be seen as a universal, salient cue, which can be weighed in the target language even when it is not present in the native language. In addition, the effects of bilingualism can be either confining or enhancing, that is, there can be transfer from the native or dominant language thus the perception of the other language is limited by what is familiar or the language experience can result in a hybrid acoustic landscape allowing an enhanced acoustic landscape with features from both languages. Heritage bilinguals provide yet another case, since they do have two native languages, yet one is more developed, but both were present during the critical period of language acquisition. Benmamoun, Montrul, and Polinsky (2013) explain that for the HS it can be expected that characteristics from their first (heritage) language are projected onto their second (dominant) language; thus, their exposure to multiple acoustic cues can influence their cue weighting behaviour. This leads to the following questions. What influence does heritage bilingualism have on cue weighting of spectral and durational cues? What role does the durational cue play in cue weighting behaviour of heritage bilinguals: is it universally accessible or related to the alternate L1?

Based on these studies regarding perceptual preferences and strategies by bilinguals, three theoretical models were constructed to predict the possible perceptual behaviour of HSs of 2L1 Moroccan-Arabic/Dutch and Turkish/Dutch for the Dutch /ɑ/-/a:/ contrast investigated in this study, that is, (a) the transfer effect; (b) duration as a universally salient cue; and (c) integrated cue usage. Table 1 provides an overview of the models and their expected outcomes.

Model 1: The transfer effect. Transfer or 'access' theory refers to the fact that learners make use of their L1 to cope with the learning task for the other language(s). For HSs, it can be expected that characteristics from their first (heritage) language are projected onto their second (dominant) language (Benmamoun, Montrul, & Polinsky, 2013). For the current study, it is expected that the Moroccan-Arabic/Dutch heritage listeners predominantly use the F2 spectral cue from their L1 for the identification of Dutch short /ɑ/ and long /a:/, as they would do for the Moroccan-Arabic /ɑ/~/a:/ contrast. This expectation is supported by a cue weighting study with adult

Table 1. Overview of exploratory models and expected results per model.

Model 1: The transfer effect	Model 2: Duration as a universally salient cue	Model 3: Integrated cue usage
Hypothesis: The characteristics of the language dominant at birth/heritage language are projected onto the other language system. Transfer: The heritage first language, Moroccan-Arabic or Turkish, is expected to be the source of transfer onto the dominant first language, Dutch. Moroccan-Arabic transfer: Moroccan-Arabic/Dutch bilingual listeners predominantly use the F2 spectral cue, and to some extent use the durational cue. Turkish transfer: Turkish/Dutch bilingual listeners exclusively use the spectral cue.	Hypothesis: The durational cue is a salient, universal feature that is used in cue weighting irrespective of language background. Expected results: Moroccan-Arabic/Dutch and Turkish/Dutch bilingual listeners use and depend strongly on the durational cue for the identification of Dutch /ɑ/ and /a:/.	Hypothesis: HS bilinguals rely on a trading relation between durational and spectral information. They use and weigh cues that are present in both languages, but will differ in their perceptive behaviour compared to that of monolingual natives. Expected results: Moroccan-Arabic/Dutch and Turkish/Dutch bilingual listeners use and weigh both the spectral and durational cue for the identification of Dutch /ɑ/ and /a:/. The spectral cue is used and weighed stronger than the durational cue.

HS: heritage speaker.

Moroccan-Arabic listeners conducted by Shoul (2009), where it was found that the difference for the Moroccan-Arabic /ɑ/~/a:/ contrast primarily resides in the F2 dimension. Moroccan-Arabic/Dutch listeners are also familiar with the durational cue due to its contrastive nature in Moroccan-Arabic and, hence, they are expected to use the durational cue to some extent, yet this cue would not be decisive for the identification of the vowels. In contrast, Turkish/Dutch heritage listeners are expected to use the spectral cue exclusively for the identification of Dutch short /ɑ/ and long /a:/, due to lack of the durational cue in Turkish. In particular, the perceptive behaviour of the Turkish/Dutch listeners may provide insights into the influence of the heritage languages, which has been developed during the critical period, on the dominant language, Dutch. In summary, the perceptive behaviour of the Moroccan-Arabic/Dutch listeners may be similar to that of the Dutch listeners, yet the lack of the durational cue in the cue weighting behaviour of the Turkish/Dutch listeners would prove transfer from the Turkish language background onto the perception of the Dutch vowel contrast, even if both languages are native.

Model 2: Duration as a universally salient cue. It has been claimed that duration is a salient feature and, hence, a universally available cue for vowel perception (Bohn, 1995; Escudero, 2001; Escudero & Boersma, 2004). Specifically for listeners that do not have this acoustic cue in their native language, reliance on the durational cue cannot be attributed to their L1 and, hence, the universal salience of duration could be a plausible account of their perceptual behaviour. For the current study, it would be expected that both the Moroccan-Arabic/Dutch and Turkish/Dutch listeners use and weigh the durational cue significantly for the identification of the Dutch /ɑ/ and /a:/. Yet, only Turkish/Dutch listeners' use of the durational cue would offer exclusive evidence for duration as a universally salient cue, since this cue is lacking in Turkish.

Model 3: Integrated cue usage. Prior studies indicate that bilinguals that have been exposed to a language quite extensively integrate acoustic cues that are not present in their L1 into the perceptual behaviour of their L2 (Bohn & Flege, 1990; Elman et al., 1977; Escudero & Boersma, 2004; Gerrits, 2001; Gottfried & Beddor, 1988; Saadah, 2011; Liu, 2014; Strange, 1989; Kuhl, 1994). Elman et al. (1977) and Strange (1989) concluded that bilinguals rely more on (finer-grained) acoustic information than monolinguals. Strange (1989, p. 2085) claimed that "no single spectral cross section adequately captures all the perceptually relevant information; rather, the acoustic information for vowel identification resides in the changing spectral structure". Furthermore, Gottfried and Beddor (1988) claim that bilingual listeners experience a trading relation between durational and spectral information. Hence, a bilingual's perception of a phonemic contrast depends on the perceptual integration of these acoustic cues and the prominence of the co-variation in the phonological systems of their two languages. Elman et al. (1977) and Escudero and Boersma (2004) also found that bilingual listeners vary in their placement of category boundaries as a result of the language they were exposed to. Their findings suggest that bilinguals are able to adjust their cue weighting behaviour when they master an L2 and that they are more sensitive to higher-order linguistic information due to their familiarity with different acoustic properties. Saadah (2011) found that Moroccan-Arabic 2L1 (heritage) speakers had attained a hybrid phonetic system; they displayed more similarities with the L2 learners concerning F1 values, and more similarities with native speakers for F2 values. For the current study, it would be expected that the Moroccan-Arabic/Dutch and Turkish/Dutch listeners use and weigh both the spectral and durational cues for their identification of Dutch /ɑ/ and /a:/. If the Moroccan-Arabic/Dutch and Turkish/Dutch listeners have developed perceptual behaviour geared towards monolinguals' Dutch cue weighting behaviour it would be expected that they use the spectral cue more than the durational cue but do indeed use both cues. Since Moroccan-Arabic/Dutch listeners have both the spectral and durational cues in their first (heritage) language, it is to be expected that these listeners will have similar cue weighting behaviour compared to Dutch natives: namely, a recognition of both the spectral and durational cue for the Dutch /ɑ/-/a:/ vowel contrast, but with a preference for the spectral cue, as found in native Moroccan-Arabic listeners for the /ɑ/~/a:/ vowel contrast (Shoul, 2009). For the Turkish/Dutch listeners the perceptive behaviour could deviate more from the Dutch listeners regarding durational cue usage, where the Turkish and Dutch acoustic landscapes differ; hence, Turkish/Dutch listeners' perceptive behaviour could exhibit characteristics from both languages, as found by Saadah (2011). This would predict a trading relation between the spectral cue and the durational cue for Dutch /ɑ/-/a:/ vowel contrast, similar to what was found by Saadah.

Methodology

Participants

In total 52, school-aged children, between the ages of 8 and 12, participated in the experiment. Twenty-two were boys and 30 were girls. Of all the 52 participants, five were eight years old, five were nine years old, 16 were ten years old, 23 were 11 years old and three were 12 years old. Children of the same age were in the same grades; 8 year olds in fifth grade; 9 and 10 year olds in sixth grade, 11 year olds in seventh grade and 12 year olds in eighth grade; the children in the same grade are considered to have a similar level of schooling and literacy. The children attended two primary schools in the province of Utrecht, that is, de Wegwijzer in Zeist and Abu Da'oed in Utrecht. The children attended grades five, six, seven, and eight. The participant pool was divided in three groups: (a) monolingual Dutch listeners (n =15) with an average age of 10.13 (SD = 1.24 years, min = 8, max = 12); (b) bilingual Moroccan-Arabic/Dutch listeners (n =16) with an average

age of 10.06 years old (SD = 1.05, min = 9, max = 11); and (c) bilingual Turkish/Dutch listeners (n =21) with a mean age was 10.52 years old (SD = 0.87, min = 9, max = 12). Since these children are most likely third generation immigrants, we classified them as HSs. According to Guadalupe Valdés (1999), as cited by Saadah (2011), a heritage bilingual is classified as such when the bilingual is raised in a home where a non-English language is spoken (English can be substituted for any dominant, official language; in the current case, Dutch). The bilingual may speak or merely understand the heritage language, and to some degree [is] bilingual in English (Dutch) and the heritage language. The participants were asked to fill in a language-background questionnaire. This questionnaire served to gain further insight into their knowledge of, exposure to and usage of their languages in different domains and with different interlocutors, and whether they have active or (only) passive knowledge of the languages. All bilingual participants stated that they encountered both languages in their home domain. Dutch was present in their home domain as well as in the official domains, but usually their alternate L1 was confined to the home domain. The bilingual participants received input of Turkish and Moroccan-Arabic from their parents and/or grandparents and sometimes heard it on TV. The Dutch input was from friends, teachers and TV, as well as from their parent(s). The participants all attended a Dutch primary school and had no lag in Dutch proficiency, as reported by their teachers; however, not all bilingual participants were active speakers of the heritage L1 (Turkish or Moroccan-Arabic) some were merely receptive language users. This indicates that the participants are not early balanced bilinguals; although they have been exposed to both languages since birth, the Dutch language is best developed; therefore, these participants are considered Dutch-dominant heritage bilinguals.

The children were selected based on the grades they were in and corresponding age based on findings by Gerrits (2001), who found that Dutch children's vowel perception settles around the age of nine and that children before that age rely more on the durational cue. Little research has been done with children of this age and with these specific language backgrounds. We chose to investigate a well-researched topic, that is, the cue weighting of Dutch /ɑ/ and /a:/, for listeners that have an alternate language with and without duration. A similar study was conducted by Escudero and Boersma (2004) for Spanish and English (one dialect with duration and one without).

Stimuli

For the identification task, a synthetic continuum was created using the Klattgrid synthesiser in Praat (Boersma & Weenink, 2015) based on the acoustic values for Dutch /ɑ/ and /a:/ from Escudero et al., (2009). The F1 and F2 were manipulated, logarithmically, in equal steps for the spectral and durational cue. In total there were 24 test stimuli; the lowest F2 value (1115 Hz) was matched with every durational step (1 × 7), and the highest F2 value (2330 Hz) was matched with every durational step (1 × 7); in addition, every intermediate F2 value was contrasted with the shortest and longest durational value (5 × 2), see Table 2. The vowels were presented in carrier words, the existing Dutch words *mat* [mɑt] ('mat') and *maat* [ma:t] ('mate, friend'). (Note that 'mat' is a meaningful word ('dull') in Turkish; it is possible impact will be taken up in the discussion. In Moroccan Arabic, the verb 'to die' is pronounced with a long vowel [mæ:t], which is too fronted and too raised to cause inference.) The acoustic properties of the word-initial and word-final consonants /m/ and /t/ were kept constant and did not vary in values in any step of the continuum. The consonants were also synthetically generated in Praat, in order to avoid a discrepancy between the synthetically modified vowels and the consonants. Elman et al., (1977) shows that the interaction between synthetic and natural sounds can influence the test subjects. The language setting of the test was engineered to be in Dutch in order to trigger the Dutch language modus (Elman et al. 1977). The students were taken from class where Dutch was spoken to them and the test was

Table 2. Seven-step continuum Dutch short to long /a/.

Steps	Duration	Steps	F2
1	99 ms	1	1115 Hz
2	118 ms	2	1149 Hz
3	137 ms	3	1183 Hz
4	156 ms	4	1219 Hz
5	175 ms	5	1255 Hz
6	194 ms	6	1292 Hz
7	213 ms	7	2330 Hz

entirely conducted in Dutch. The explanation of the test words was also in Dutch and the pictures represented the Dutch lexeme. This was all done to make sure that the language setting was Dutch in order to steer the participants towards their Dutch perception of the vowel contrast in order to gain insight into the possible influence of their alternate L1.

Procedure

The listeners were tested in groups of six. The participants were first shown two images representing the test words *mat* ('mat') and *maat* ('friend') together with their orthographic representations. The participants were asked if they knew what the words meant. This was done to make sure that the test was not compromised due to unfamiliarity with the carrier words. The participants were then handed a scoring sheet, which had two columns with two images representing the test words *mat* ('mat') for /ɑ/ and *maat* ('friend') for /a:/ without their orthographic representations. This was done in order to make sure that the orthographic representations did not influence the participants (Escudero & Wanrooij, 2010). It was explained to the participants that the test would begin, then they would go through a PowerPoint presentation consisting of numbers and sound fragments and were expected to identify the stimuli as sounding more like 'mat' or 'maat'. They were told to make a choice every time and identify which of the two options fitted the stimuli best, even if they doubted which to choose. The participants were reassured that there were no right or wrong answers. All instructions were given in Dutch. The test subjects were tested as a group, but were not allowed to communicate with each other; they heard the test tokens over loudspeakers. The test PowerPoint started with the two images representing the test words *mat* ('mat') and *maat* ('friend'), without their orthographic representations. After the initial images, the slides consisted of numbers followed by the randomised sound fragment. In total, there were 144 stimuli (6 × 24) for the participants to identify. The stimuli were presented in random order, and this was done by using randomising software (https://www.random.org/lists/). The participants filled in their own answer, by ticking a box captioned with one of the two pictures representing the vowels, indicating after each trial whether the test token they heard was more like /ɑ/ or /a:/.

Analysis

The aim of the analysis was to provide insight into the cue weighting behaviour of 2L1 bilinguals for the multiple cued Dutch /ɑ/-/a:/ contrast. In order to do this the most preferred cue (i.e. cue usage) and cue weight were calculated. Individual data was processed in Microsoft Excel and transferred to SPSS for group analysis. For each stimulus, six responses were given per participant and the average result for each stimulus was calculated. The bias towards /a:/ was calculated in

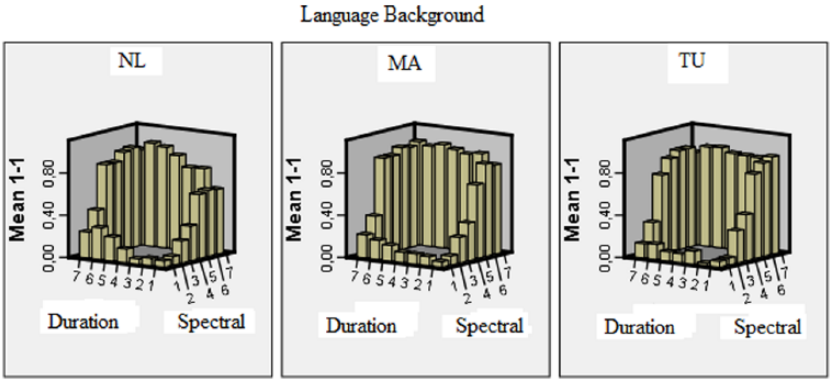

Figure 1. A three-dimensional chart representing cue reliance per language group for durational and spectral cue per step in the seven-step continuum of the Dutch /ɑ/-/a:/ contrast. Created in SPSS based on the average results per language group for each continuum step.

order to control whether there were no outliers. In order to determine cue usage, cue weight and bias towards /a:/, the calculations presented by Giezen and Escudero (2015) were used. To calculate how a participant used the durational or spectral cue, the responses for the sum of the lowest F2 paired with each durational step was multiplied by six and subtracted by the sum of the responses of the highest F2 values paired with each durational step, and then multiplied by 36 (the total number of responses including the four endpoint stimuli that each counted as half). The weight of the durational cue was calculated by dividing the durational cue use score by the identified spectral cue score. To calculate the weight of the spectral cue, the identified spectral cue score was divided by the identified durational cue score. The bias towards /a:/ was calculated by the sum of all given scores per test tokens multiplied times six (rounds), divided by 144 (the total number of stimuli presented). All the results were rounded off to two decimals. Normality tests were used to see if the responses per groups were normally distributed and to check for outliers. A multivariate analysis of variance (MANOVA) was conducted to determine whether there was a significant interaction effect between language background and cue weighting behaviour for the three language groups. When the overall test would indicate a significant (<0.05) effect, Tukey's test for post hoc analysis was used to investigate which groups were significantly different.

Results

Group results

The groups did not show large differences or bias towards /a:/ and could, therefore, be compared. Figure 1 is a three-dimensional (3D) graph that represents the cue usage, spectrally and durationally, per language group for each step of the continuum as provided in Table 2.

Each graph Figure 1 shows how the paired spectral and durational steps (as provided in Table 2) are used by the three language groups. The three graphs in Figure 1 reveal that overall a clear increase in durational reliance with each step occurs, which corresponds with longer duration, yet the spectral cue is used more clearly in the cue weighting behaviour of each group for each paired step. Figure 1 presents a similar pattern in cue weighting behaviour for the MA group compared to the Dutch group (NL), displaying an increase in durational reliance but overall the MA listeners

Table 3. Descriptive statistics for language background and cue usage.

Language background	M (mean weight) for duration (SD)	M (mean weight) for spectral (SD)	*p*-value for difference
Dutch	0.41 (0.21)	0.76 (0.16)	.004
MA	0.33 (0.24)	0.82 (0.23)	.001
TU	0.22 (0.14)	0.83 (0.14)	<.001

assign less weight to this cue compared to the Dutch group. The Turkish group reveals a less reliable tendency to weigh the durational cue and utilises the spectral cue significantly more than the durational cue.

The descriptive statistics show that all three groups utilised the spectral cue more than the durational cue (see Table 3). The differences between cues were significant in all three groups according to paired *t*-tests ($p = 0.004$ or less). The Turkish/Dutch listeners relied most on the spectral cue and least on the durational cue compared to the Dutch listeners and the Moroccan-Arabic/Dutch listeners. The Dutch listeners also used the spectral cue more than the durational cue, but used the durational cue most out of all three groups. The Moroccan-Arabic/Dutch listeners show perceptive behaviour that resembles the Dutch listeners' behaviour, but used the durational cue less on average.

Overall tests in the multivariate analysis suggested a significant difference between at least two groups for at least one cue (*p*-values ranging from 0.01 for Roy Largest Root to 0.07 for the Pillai's Trace method). An association between durational cue usage and language background variables was found ($p = 0.02$) in the Between-subject Effects. A post hoc Tukey honest significant difference (HSD) test was used to determine which language group revealed a significant effect for cue weighting behaviour while adjusting *p*-values for drawing multiple comparisons. The post hoc test only revealed a significant effect for the cue weighting behaviour of the Dutch monolingual control group in comparison to Turkish/Dutch listeners, that is, they weighed the durational cue significantly higher: the difference is 0.19, $p = 0.02$. Results from all Tukey HSD post hoc tests are shown in Table 4 with the significant results in bold.

The influence of bias towards /a:/ and participant age on cue weighting behaviour was assessed in an alternatively fitted MANOVA. For this MANOVA, we fitted another model of language background on both cues but added participant age and bias towards /a:/ as continuous covariates to the model. This MANOVA gave similar results (*p* for Between-subject Effects of language background on duration cue changed from 0.02 to 0.03). For Between-subject Effects on bias score, the *p* values were 0.32 and 0.12 for the durational and spectral cues, respectively. For participant age, *p* values were 0.62 and 0.25. There was thus no significant bias towards /a:/ for cue weighting behaviour nor significant differences between participant ages for cue weighting behaviour.

Individual results

There was no clear trend in advancing age and cue weighting behaviour, which is not surprising considering the sample size of the age groups and the distribution of ages. Unfortunately, this is a question the current study cannot address. Table 5 represents the age distribution of the listeners.

The listeners identified each stimulus with manipulated F2 values and duration as either 0 for /ɑ/ or 1 for /a:/. An ideal listener would score 0 and 1 for the endpoint stimuli, representing the lowest and highest F2 values and the shortest and longest duration, respectively. For the in-between steps, an ideal listener would display a score averaged over the six rounds that gradually increases

Table 4. Multiple-comparison Tukey honest significant difference.

Dependent variable	(*I*) Language background	(*J*) Language background	Mean difference (*I* – *J*)	*p*-value for difference
Duration	DU	MA	0.08	0.52
	DU	TU	0.19	**0.02**
	MA	TU	0.11	0.21
Spectral	DU	MA	–0.06	0.63
	DU	TU	–0.07	0.50
	MA	TU	–0.01	0.99

Table 5. Age distribution amongst participants.

Age (years)	Frequency
8	5
9	5
10	16
11	23
12	3

(from 0 to 1) stepwise over the continuum, essentially following an s-curve, corresponding with the manipulated values for the F2 and/or durational cue (see Table 2). Based on the response pattern, cue weightings for individual participants were calculated. (The method to determine individual cue weightings can be found in Giezen and Escudero, 2015.) The individual results give a general idea of the listening preference and make it possible to statistically analyse the group results. The individual results give a general idea of the listening preference and make it possible to statistically analyse the group results. Furthermore, the individual results provide a more specific look into the perceptual behaviour of the participants, which can shed light on the possible implications and/or limitations of the theoretical models. For the monolingual Dutch listeners, the data showed that 13 out of 15 (86.7%) listeners used the spectral cue to identify a stimulus as either /ɑ/ or /a:/ more than the durational cue. These 13 listeners assign more weight to the spectral cue in their perception of Dutch /ɑ/-/a:/, while the other two listeners assigned more weight to the durational cue. For the Moroccan-Arabic/Dutch bilingual listeners the spectral cue was the most preferred cue. Of the 16 listeners, 14 listeners used the spectral cue more than the durational cue. The other two listeners favoured the durational cue. The results of the 21 Turkish-Dutch bilingual listeners indicate that they all preferred the spectral cue in order to identify the presented stimulus as /ɑ/ or /a:/. Two listeners disregarded the durational cue even when it was overtly present. The Turkish/Dutch assigned most weight to the spectral cue when compared to the monolingual Dutch and Moroccan-Arabic/Dutch listeners.

Findings

The groups' results reveal that the three language groups do not differ significantly from each other in the usage and weighing of the spectral cue. The monolingual Dutch and Moroccan-Arabic/Dutch listeners do not use or weigh either the durational or spectral cues differently. The Turkish/Dutch listeners do not significantly differ in their cue usage and weighting for the spectral cue compared to the monolingual Dutch and Moroccan-Arabic/Dutch listeners. The Turkish/Dutch

listeners do differ significantly in the usage and weighting of the durational cue when compared to the monolingual Dutch group, that is, the lack of durational cue weighting has this impact. The individual results confirm the average group results, showing that all three language groups predominantly use the spectral cue in the perception of the Dutch /ɑ/-/a:/ contrast. The individual results confirm that the monolingual Dutch and Moroccan-Arabic/Dutch bilingual listeners use the durational cue for the identification of this contrast, while the Turkish/Dutch bilinguals exclusively use the spectral cue.

Discussion

Based on the literature review two research questions were constructed that allowed us to test the ability of three theoretical models to predict the perceptive behaviour of bilingual (heritage) listeners.

First: *What influence does simultaneous bilingualism have on cue weighting of spectral and durational cues?* The data shows that the Moroccan-Arabic/Dutch and the monolingual Dutch listeners display fairly similar cue weighting behaviour; the Turkish/Dutch listeners' perceptual behaviour differs significantly from that of the Dutch monolingual listeners. Since Moroccan-Arabic and Dutch both have short and long vowels, both use the spectral and durational cue and both have long /a:/ and short /ɑ/, it was expected that these two groups would behave in a similar fashion, which was supported by the data. The Turkish language does have a marginal durational contrast, but this is not used to distinguish vowel length; hence, in Turkish the spectral cue is critical. For the Turkish/Dutch listeners the durational cue is present in the Dutch language but based on the data these participants maintain a characteristic of their Turkish perceptive behaviour even when listening to Dutch, by using the spectral cue predominantly. The MANOVA and post hoc tests suggested a main effect for cue usage and an interaction between cue usage and language background. These results would indicate that having an alternate language that does not use the same acoustic cues can have an effect on the perceptive behaviour and cue weighting.

Second: *What role does the duration cue play in cue weighting behaviour of simultaneous bilinguals: is it universally accessible or related to the alternate first language?*

The results suggest that duration is not overtly used when presented in the test tokens. The Dutch group uses the durational cue most. The Moroccan-Arabic/Dutch listeners also use the durational cue, but less than the monolingual Dutch listeners. The Turkish/Dutch listeners provide most insight into this question due to the fact that they hardly use the cue even when present in the test words. In a previous study by van Heuven, van Houten, and de Vries (1986), L2 Turkish/Dutch adults over-used the durational cue (even incorrectly); however 2L1, heritage listeners in the current study seem to have developed their perceptual behaviour in a manner that is different from the sequential L2 adults.

Implications

Three theoretical models were considered based on the results of earlier studies in order to predict perceptual behaviour. Model 1 would predict a transfer effect, that is, the bilingual listeners would be expected to project the characteristics of their first (heritage) language onto their other first (dominant) language. In this case Moroccan-Arabic and Turkish are the heritage languages and Dutch the dominant language, so the transfer effect for Moroccan-Arabic would hardly be significant since Moroccan-Arabic and Dutch weigh the short and long /a/ similarly in both languages,

using both the durational and spectral cue. For the Turkish listeners this would be more significant; since Turkish does not have a durational cue, these listeners would be expected to rely exclusively on the spectral cue for the Dutch vowel perception. Model 2 focuses on the durational cue as a universally salient feature that is universally accessible to listeners that do not have this acoustic cue in their native language. Model 3 predicts that because bilinguals rely on a trading relation between durational and spectral information, based on the acoustic landscape of both their L1s, they should use and weight both cues. The data suggest that Model 2 does not fit the perceptual behaviour of the listeners in this study, since duration is not weighed significantly by every language group. Model 3 suggests a trading relation between the cues for the bilingual listeners, which is not supported by the data. Although the Moroccan-Arabic/Dutch listeners do use both cues, this is most likely due to the fact that both cues are present in both languages. The Turkish/Dutch listeners rely on the spectral cue even when the durational cue is present; hence, there is no trading relation between the cues. The collected data suggests that Model 1 is most accurate in its predictions. The listeners in this study are categorised as Dutch-dominant heritage (Moroccan-Arabic or Turkish) bilinguals, who are immersed in Dutch in every formal and informal domain, while their alternate L1s are restricted to their home domains, even though they have been present since birth and during the critical period. The results show that the perceptive behaviour of the Moroccan-Arabic/Dutch listeners is somewhat different from that of the monolingual Dutch listeners; however, this is not significant enough to indicate transfer. The results of the Turkish/Dutch listeners, on the other hand, do suggest a transfer effect. The weighing of the spectral cue and the disregard for durational cue when weighing the Dutch vowels is most likely Turkish cue weighting behaviour projected onto the Dutch language. Benmamoun, Montrul, and Polinsky (2013, p. 18) explain that "once commitment has taken place in each optimal period, the resources dedicated to the original language cannot be reassigned, and the knowledge persists throughout life [which is the Permanence hypothesis]". However, even Benmamoun, Montrul, and Polinsky agree that the research into heritage bilinguals is not as clear cut, having yielded mixed results. Although the current data does not suggest that there is a significant effect between age and perceptive behaviour, this could possbly be observed in a longitudunal study, as seen in Brasileiro (2009). In order to assess the development of the perceptual behaviour, a longitudinal study will have to be conducted, which might also shed more light on the possible influence of exposure, possible language attrition and/or dominance. For example, Brasileiro's (2009) longitudinal study suggests that the use of the durational cue can develop over time, with increased exposure and development of the Dutch language. It stands to reason that the results of the current case study are limited and, in order to make more general claims about the effect bilingualism has on perceptual behaviour, more research needs to be conducted on a larger scale as well as in a longitudinal study.

Potential limitation

There is a potential methodological flaw in the current study that needs to be addressed. (Thanks to an anonymous reviewer for pointing this out to us.) The stimulus 'mat' used in our experiment happens to be a meaningful word ([mɑt] 'dull') in Turkish. Hence, when performing the identification task, the Turkish/Dutch participants may have activated a Turkish lexeme (Dijkstra, Grainger, & van Heuven, 1999; Marian, Blumenfeld, & Boukrina, 2008), which in turn may have foregrounded Turkish perception strategies that may have affected their identification judgements. In particular, since the Turkish lexeme [mɑt] has a (short) back vowel, the Turkish/Dutch participants may have perceived Dutch /ɑ/ as a better example of the corresponding Turkish vowel than Dutch /a:/ (as

predicted, for example, by the Perceptual Assimilation Model; Best & Tyler, 2007). According to the anonymous reviewer, this might have biased their judgements and "skewed their perception of the continuum and explain why they were not prone to using duration, despite having comparable exposure to Dutch as the other bilingual group [=Moroccan-Arabic/Dutch listeners]". Although we agree with the reviewer that perceived similarity of our stimuli with a Turkish lexeme may have affected the Turkish/Dutch listeners' perceptual judgements, we believe that this effect, if it occurred at all, must have had limited impact on their *cue weightings*. Firstly, by using orthographic representations of the Dutch words 'maat' and 'mat', and by asking our participants beforehand whether they knew the meanings of these words, we can be reasonably sure that they entered the experiment in a Dutch language mode. Secondly, the nature of the identification task (a forced choice judgement) was such that it invited attention to the acoustic differences between the stimuli, which participants were free to construe along two dimensions (durational, spectral). Thirdly, if Dutch /ɑ/ was indeed perceived by Turkish/Dutch listeners as a better example of Turkish short back /ɑ/ than Dutch /a:/, causing a response bias towards Dutch /ɑ/, then this bias should have affected the use of cues equally and symmetrically, since the vowel in Turkish [mɑt] matches Dutch /ɑ/ in two respects: durationally *and* spectrally. Hence, we have no reason to believe that bias towards Dutch /ɑ/ should have hampered use of the durational cue *less* than use of the spectral cue.

Conclusion

To conclude, based on previous studies three theoretical models were considered in order to predict the perceptual behaviour of Dutch-dominant heritage bilinguals. The Dutch language uses both the durational and spectral cue for the /a:/-/ɑ/ vowel contrast. Moroccan-Arabic and Turkish are both well-represented alternate L1s in the Netherlands; in this study school-aged children with these language backgrounds were tested in order to study their perceptive behaviour and cue preference for the Dutch vowel contrast. Moroccan-Arabic, similarly to Dutch, uses both the durational and spectral cue for the /a:/~/ɑ/ contrast, whereas Turkish only uses the spectral cue to contrast vowels while otherwise using duration only to a limited extent. It is hypothesised that heritage bilinguals are exposed to both languages from birth but during childhood experience a shift of language dominance in favour of the majority language (Dutch); still, the reorganisation of the first/heritage language may be incomplete, in which case this language possibly influences the acquisition of the alternate first/dominant language. This hypothesis is supported by the data, which suggests a significant difference in the use of the durational cue between the monolingual Dutch listeners (control group) and the Turkish/Dutch listeners, the latter listeners relying on the spectral cue only while not using the durational cue (even when present) in order to identify the Dutch /a:/-/ɑ/ vowel contrast.

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