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Nonverbal Intelligence Does Matter for the Perception of Second Language Sounds

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Abstract: Although there has been considerable research on the interplay between intelligence and second language (L2) learning, research focusing on the intelligence and L2 speech perception link is limited. The present study aims to fill this gap. The native language of the participants was Cypriot Greek and they spoke English as an L2. The participants completed a forced-choice psychoacoustic test in which they discriminated L2 sound contrasts and a nonverbal intelligence test which measured their nonverbal intelligence capacities. They were divided into two groups according to their performance in the intelligence test, namely, a low IQ and a high IQ group. The results showed that the high IQ group discriminated the majority of the L2 contrasts better than the low IQ group. In addition, the degree of perceived difficulty for most L2 contrasts differed between the two groups. It is concluded that nonverbal intelligence is associated with the discrimination of L2 sounds. This can be explained by the possibility that either intelligence triggers the more efficient functioning of other domains, such as information processing and attention, leading to increased speech perception skills, or that it directly affects the categorization of speech sounds resulting in the development of more robust L2 categories.

Keywords: intelligence; speech perception; sound discrimination; second language

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1. Introduction

The perception of a large number of speech sounds across world languages is an easy task during early infancy, but this ability gradually declines after the first few months of life [1,2]. As a consequence, adults cannot easily distinguish the sounds of a second language (L2). This is because the learning of all subsequent speech sounds occurs through the lens of the speakers' first language (L1) (see [3,4]). As speech perception relies on the categorization of L2 sounds to L1 categories [5–7], difficulties may arise when two L2 sounds are mapped to the same L1 category. For example, Georgiou [8], who investigated the perception and production of English vowels /ɪ/ and /iː/ by Cypriot Greek speakers of L2 English, reported that the English vowels were mostly classified in terms of Cypriot Greek category /i/, and therefore L2 speakers could not discriminate this contrast well. Thus, single category mapping may deprive listeners of the ability to accurately distinguish non-native sound contrasts since they perceive the two non-native sounds as being acoustically similar to a single L1 sound.

Variation in the acquisition of L2 sounds led researchers to focus on particular characteristics of listeners which may potentially shape their language acquisition skills. They examined the effect of a variety of factors such as linguistic, sociolinguistic, biological, psychological, etc. on L2 speech perception. A series of studies by Flege and colleagues indicated the importance of several sociolinguistic factors such as the age of L2 learning onset, the length of residence in a foreign country, L1–L2 use, the quality and quantity of L2 input, etc. Flege et al. [9] examined two groups of Italian/English bilinguals who shared an identical (low) age of learning in Canada. The first group used their L1 frequently while the second only rarely. The results showed that bilinguals with frequent L1 use had stronger foreign accent than bilinguals with rare L1 use. McKay et al. [10] observed that L1 influence on the perception and production of English stops was stronger for late bilinguals than early bilinguals due to the lack of quality and quantity as regards the input they received. More recent studies investigated other factors such as vocabulary size and proficiency level. Bundgaard-Nielsen et al. [11] and Georgiou et al. [12] highlighted the role of increased vocabulary size in the perception of phonological L2 contrasts. In particular, Georgiou [12] found that adult learners with a larger vocabulary in English could discern L2 contrasts in a more accurate manner, while this ability was reduced for learners with a low vocabulary in their L2. In addition, Georgiou [13] examined the perception of L2 English vowels by Cypriot Greek child learners of English, concluding that the proficiency level of the learners did not affect the discrimination of L2 contrasts. The author attributed this finding to the absence of pronunciation teaching for these populations. Two recent phonetic training paradigms by Georgiou [14,15] have proven successful for the perception of L2 sounds. For example, Cypriot Greek child and adult learners of English improved their discrimination accuracy over L2 contrasts after receiving some sessions of high variability perceptual phonetic training. Similarly, the discrimination of L2 Cypriot Greek vowel contrasts by Egyptian Arabic learners of Greek was improved after the learners received high variability phonetic training.

Less attention has been paid to the effect of cognitive factors, especially intelligence, on L2 acquisition. Most theories recognize intelligence as a higher-order factor of human abilities [16]. Intelligence refers to the set of cognitive abilities used to perform a wide range of tasks [17]. Cattell [18] distinguished between two types of intelligence: the fluid and crystallized. Fluid intelligence is associated with problem-solving skills and the ability to think flexibly and fast. This type of intelligence is independent of individuals' past experiences. Crystallized intelligence is associated with acculturated knowledge and learnt skills. It is language- and culture-specific and changes over time. Fluid intelligence is assessed through the use of nonverbal measures including visual analogies and matrices based on pattern completion. Among the most popular tests measuring this type of intelligence are the Wechsler Abbreviated Scale of Intelligence (WASI [19]) and the Raven Progressive Matrices [20]. Crystallized intelligence is assessed through verbal measures demanding the formation of verbal concepts and information flow [21].

There is a significant body of research focusing on the interface between nonverbal intelligence and L2 learning. Brooks et al. [22] found that nonverbal intelligence predicted the learning of L2 Russian morphology and the generalization of case-marking inflections to new vocabulary. Schmidt and Blumenthal [23] examined the connection between nonverbal intelligence and the lexical abilities of German learners of English. The results showed that learners with above-average intelligence performed better in receptive English lexical knowledge compared to learners with average or below-average intelligence. Similar results were obtained by Woumans et al. [24]. The authors explored the effect of nonverbal cognitive abilities on L2 acquisition, reporting that intelligence was one of the factors that contributed to L2 learning and specifically the acquisition of L2 Dutch vocabulary. Research about the effect of intelligence on L2 speech acquisition is very limited. Rota and Reiterer [25] examined, among other variables, the association between verbal and nonverbal intelligence and phonetic abilities. The findings demonstrated the absence of a connection between verbal and nonverbal intelligence and pronunciation, while a connection was found only between verbal intelligence and phonetic coding ability. Fodor [26] characterized speech perception as a modular system which functions quickly without the need for conscious attention and the direction of higher-order skills such as intelligence and inductive language learning. This is supported by the fact that phonological processing problems can appear in L2 learners with average or above-average intelligence and that the phonetic coding skills of exceptional L2 learners with below-average intelligence can be strong [27]. However, a recent study by Georgiou and Giannakou [28] provides contradictory findings. The authors found that nonverbal intelligence accounted for the discrimination of the majority of non-native contrasts by Standard Modern Greek speakers of L2 English. This shows that intelligence is somehow positively linked to the perception of L2 sounds.

This study aims to investigate the effect of nonverbal intelligence on the discrimination of L2 vowel contrasts. To the best of our knowledge, the link between the perception of L2 speech sounds and intelligence has received only scarce scientific attention. The participants' native language was Cypriot Greek and they could speak English as an L2. There are considerable differences between the vowel systems of the two languages. Cypriot Greek has a small and simple vowel system consisting of vowels /i e a o u/ [29], while English (Standard Southern British English) has a larger and more complex vowel system consisting of lax vowels /ɪ ʊ e æ ʌ ɒ/ and tense vowels /iː uː ɜː ɔː ɑː/ [30]. Greek speakers encounter difficulties with the discrimination of the majority of English vowel contrasts due to the small size and the limited complexity of their L1 vowel system [31,32] as well as the acoustic-phonetic differences between the L1 and L2 vowel systems [8]. This study followed an experimental protocol using a forced-choice psychoacoustic task for the assessment of speakers' L2 sound discrimination abilities and a psychometric tool for the assessment of speakers' nonverbal intelligence. Participants were divided into two groups (a high IQ group and a low IQ group) according to their performance in the nonverbal intelligence test. The ability of speakers with low intelligence to discriminate L2 vowel contrasts was compared with the corresponding ability of speakers with high intelligence. Although some studies in the literature do not favor the positive impact of intelligence on speech perception, it is assumed that at least some contrasts will be discriminated more accurately than others by speakers with high intelligence compared to speakers with low intelligence. This hypothesis is based on the most recent evidence indicating a positive link between L2 contrast discrimination and intelligence [28], and the findings of previous studies supporting a positive effect of nonverbal intelligence on L2 learning [22–24].

2. Methodology

2.1. Participants

Sixteen Cypriot Greek speakers ($n_{females}$ = 8) with an age range of 20–43 (M = 31.81; SD = 7.94) participated in the study. All participants permanently resided in Cyprus and had a moderate socioeconomic background. They reported knowledge of English at B2/C1 levels and knowledge of some other languages (e.g., French, Italian) at lower levels. In addition, they rated their understanding skills in English as 4.5/5 (SD = 0.63). Their mean English learning onset age was 8.19 years (SD = 1.52), the daily use of English was 1.13 h (SD = 1.31), and the daily input in English was 3.31 h (SD = 2.02) on average. None of them had ever lived for a long time in an English-speaking country. All participants reported healthy vision and hearing and the absence of any cognitive or language disorders. The participants were divided into two groups according to their intelligence capacities (i.e., low IQ/high IQ) after conducting a median split on the raw scores of the nonverbal intelligence test (Mdn = 52.5) (see Section 2.3.2, which describes the procedure of the intelligence test). The low IQ group had an average intelligence raw score of 46.75 (SD = 4.03), while the high IQ group had an average intelligence raw score of 54.88 (SD = 1.25); according to the results of independent t-tests, there were statistically significant differences between the scores of the two groups (t = 5.45, df = 14, p < 0.001). There were no significant differences between the two IQ groups in terms of English learning onset age (t = 0.48, df = 14, p = 0.64), daily use of English (t = 0.37, df = 14, p = 0.72), daily input in English (t = 0.36, df = 14, p = 0.73), or English understanding skills (t = −0.67, df = 14, p = 0.12); this shows that the aforementioned characteristics were similar across the two groups.

2.2. Stimuli

The stimuli of the study consisted of the 11 English monophthongs embedded in monosyllabic /hVd/ words, which were part of the carrier phrase "They say <word> now". These words were hid, heed, head, herd, had, hard, hud, hod, hoard, who'd, and hood, representing English vowels /ɪ iː e ɜː æ ɑː ʌ ɒ ɔː uː ʊ/ respectively. Two adult female English (Standard Southern British English) native speakers were recruited for the production of the stimuli. The phrases were presented on paper using Standard British English orthography. The speakers were asked to produce the phrases as naturally as possible as if speaking to a friend and their output was recorded at a 44.1 kHz sampling rate using a professional audio recorder. The data were normalized for peak intensity using Praat [33].

2.3. Procedure

2.3.1. Discrimination Test

All participants completed a forced-choice AX discrimination test using Praat. The experiments took place in quiet rooms and participants did not have contact with each other. The stimuli were grouped into six "different" pairs and six "same" pairs. The "different" pairs included the following six English contrasts: /ɪ/–/iː/, /iː/–/e/, /ɑː/–/ʌ/, /æ/–/ɑː/, /ɔː/–/ɒ/, and /uː/–/ʊ/. Each of the six "different" conditions contained eight repetitions of the contrastive vowels (4 AB and 4 BA types). Similarly, each of the six "same" conditions contained eight repetitions of the contrastive vowels (4 AA and 4 BB types). Each participant discriminated a total number of 96 items (6 contrasts × 2 conditions × 8 repetitions), which were presented in random order. The stimulus pairs always included recordings from different speakers to avoid solely auditory decisions. Participants sat in front of a PC monitor, maintaining a consistent distance from it. They listened to the stimuli through a set of headphones connected to the PC and were asked to select whether the pair tokens were acoustically the same or different by clicking on the relevant script label ("same" vs. "different"). The interstimulus interval was set at 300 m.s. There was no option to repeat the stimuli and no feedback was given on the participants' responses. In addition, there was an optional five-minute break at the midpoint. Prior to the main experiment, participants completed a familiarization test with four items on the script to ensure that they understood the instructions of the test. Moreover, before the experiment, it was ensured that participants knew the target words. The test lasted about 15 min for each participant.

2.3.2. Nonverbal Intelligence Test

Raven's Standard Progressive Matrices test [20] was used to measure participants' nonverbal intelligence. This test measures abstract reasoning and fluid intelligence and is considered an indicator of general human intelligence [34]. The test was provided in written form and completed individually in quiet rooms. There were 60 black and white items in 5 sets (e.g., A to E) of 12 items (e.g., A1 to A12). The items within a set progressively became more complex, so the information demanded a higher degree of cognitive capacity to encode and analyze. The test was completed within 30–45 min. During the test, there were no breaks and no feedback was given to the participants. The performance of the participants was measured using the raw scores (out of 60).

2.4. Statistical Analysis

A binomial logistic mixed-effects model [35] was fitted in R [36] as the dependent variable, namely, *response,* was dichotomous (correct/incorrect). *Contrast* (/ɪ/–/iː/, /iː/–/e/, /ɑː/–/ʌ/, /æ/–/ɑː/, /ɔː/–/ɒ/, /uː/–/ʊ/), *groupIQ* (low/high), and *contrast* × *groupIQ* were the fixed factors, while *subject* was the random factor. The pairwise comparisons were conducted using the *emmeans* package [37] and the *Tukey* method.

3. Results

The results showed that all contrasts but /iː/–/e/ could be discriminated better by the high IQ than the low IQ group. For the low IQ group, all contrasts but /iː/–/e/ were discriminated below chance (i.e., 50%). In addition, /iː/–/e/ was the most accurate contrast, followed by /ɔː/–/ɒ/, /ɑː/–/ʌ/, /uː/–/ʊ/, /ɪ/–/iː/, and /æ/–/ɑː/. For the high IQ group, only one contrast was discriminated below chance, namely, /ɑː/–/ʌ/. Moreover, similarly to the low IQ group, /iː/–/e/ was the most accurate contrast, followed by /ɔː/–/ɒ/, /ɪ/–/iː/, /uː/–/ʊ/, /æ/–/ɑː/, and /ɑː/–/ʌ/, which was the least accurate one. It can be observed that the discrimination of some contrasts differed between the two IQ groups. Figure 1 illustrates the correct discrimination percentages and *SD*s for all contrasts in the low and high IQ groups. Figures 2 and 3 illustrate the discrimination of contrasts by each subject in the low and high IQ groups.

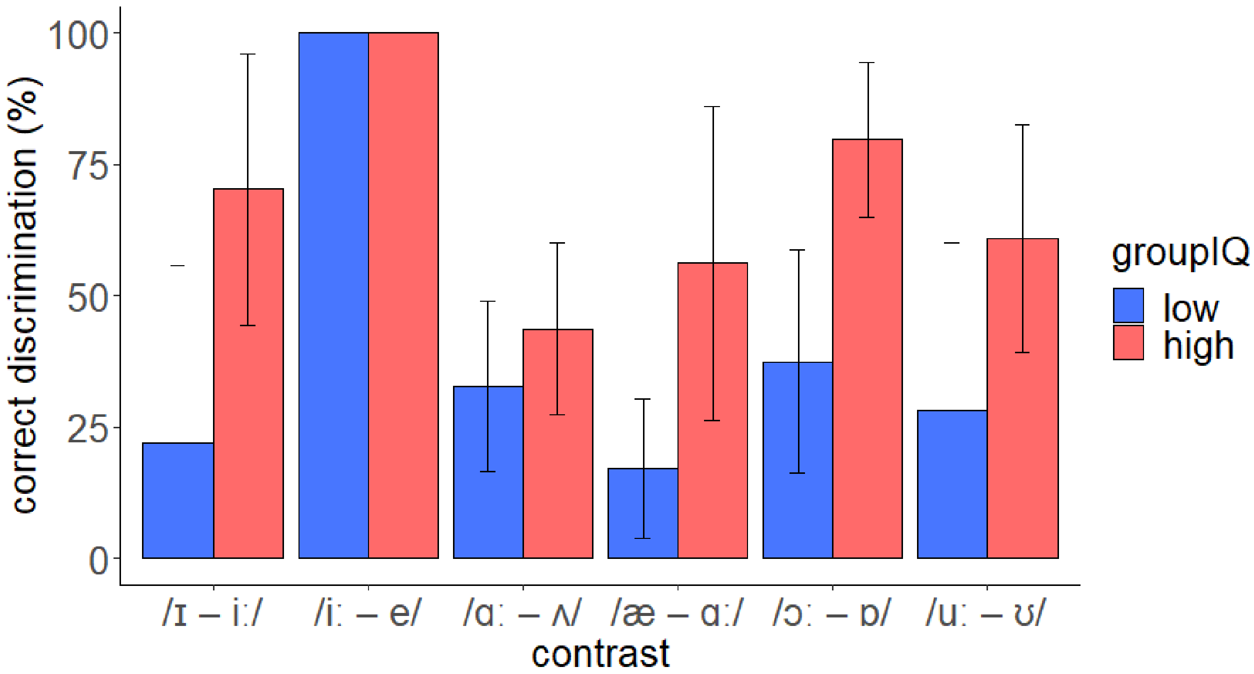

Figure 1. Discrimination of the English vowel contrasts by the low and the high IQ groups.

A binomial mixed-effects model indicated significant differences only between contrast /ɔː/–/ɒ/ and contrast /æ/–/ɑː/ (the Intercept term) ($\beta = 1.16$, $SE = 0.41$, $z = 2.85$, $p = 0.004$) for the high IQ group. In addition, a significant effect of *group.IQ* was observed ($\beta = -1.88$, $SE = 0.47$, $z = -4$, $p < 0.001$), showing that the low IQ group discriminated /æ/–/ɑː/ less accurately than the high IQ group. The *contrast* × *group.IQ* interaction was significant, but only for /ɑː/–/ʌ/ ($\beta = -1.4$, $SE = 0.56$, $z = 2.49$, $p = 0.013$), indicating that the low IQ group discriminated this contrast more accurately than /æ/–/ɑː/ in comparison to the high IQ group. The results of the model are shown in Table 1.

Table 1. Results of the binomial mixed-effects model (Intercept: groupIQ high, contrast /æ/–/ɑː/).

Fixed Effects:				
	Estimate	**Std. Error**	***z*-Value**	***p*-Value**
(Intercept)	0.26286	0.29579	0.889	0.37419
contrast /iː/–/e/	18.34617	170.66971	0.107	0.91440
contrast /ɪ/–/iː/	0.71923	0.38378	1.874	0.06092 .
contrast /ɔː/–/ɒ/	1.16410	0.40858	2.849	0.00438 **
contrast /ɑː/–/ʌ/	−0.52765	0.36523	−1.445	0.14855

contrast /uː/–/ʊ/	0.34287	0.37096	0.924	0.35535
groupIQ low	−1.87632	0.46935	−3.998	6.40E-05 ***
contrast /iː/–/e/:groupIQ low	−13.24089	170.67594	−0.078	0.93816
contrast /ɪ/–/iː/:groupIQ low	−0.41415	0.59285	−0.699	0.48482
contrast /ɔː/–/ɒ/:groupIQ low	−0.07669	0.58861	−0.130	0.89633
contrast /ɑː/–/ʌ/:groupIQ low	1.40324	0.56354	2.490	0.01277 *
contrast /uː/–/ʊ/:groupIQ low	0.30517	0.57257	0.533	0.59405

Signif. codes: 0 '***' 0.001'**' 0.01'*' 0.05 '.' 0.1 '' 1.

Pairwise comparisons of *groupIQ* × *contrast* were used to compare the discrimination of particular vowel contrasts between the low IQ and the high IQ groups. The results revealed that there were significant differences between the low IQ and the high IQ groups for /æ/–/ɑː/ ($\beta = 1.88$, $SE = 0.47$, $z = 4$, $p = 0.004$), /ɪ/–/iː/ ($\beta = 2.29$, $SE = 0.47$, $z = 4.92$, $p < 0.001$), /ɔː/–/ɒ/ ($\beta = 1.95$, $SE = 0.46$, $z = 4.25$, $p = 0.001$), and /uː/–/ʊ/ ($\beta = 1.57$, $SE = 0.44$, $z = 3.58$, $p = 0.02$). In sum, the results indicate that the majority of L2 contrasts were discriminated better by the high IQ group compared to the low IQ group. The results of pairwise comparisons are presented in Table 2.

Table 2. Pairwise comparisons for *groupIQ:contrast*.

groupIQ:contrast	**Estimate**	**Std. Error**	***z*-Value**	***p*-Value**
high /æ/–/ɑː/- low /æ/–/ɑː/	1.8760	0.469	3.998	0.0037 **
high /iː/–/e/- low /iː/–/e/	15.117	170.675	0.089	1.0000
high /ɪ/–/iː/- low /ɪ/–/iː/	2.2900	0.465	4.921	0.0001 ***
high /ɔː/–/ɒ/- low /ɔː/–/ɒ/	1.9530	0.460	4.248	0.0013 **
high /ɑː/–/ʌ/- low /ɑː/–/ʌ/	0.4730	0.426	1.112	0.9943
high /uː/–/ʊ/- low /uː/–/ʊ/	1.5710	0.439	3.582	0.0178 *

Signif. codes: 0 '***' 0.001'**' 0.01'*' 0.05 '' 1.

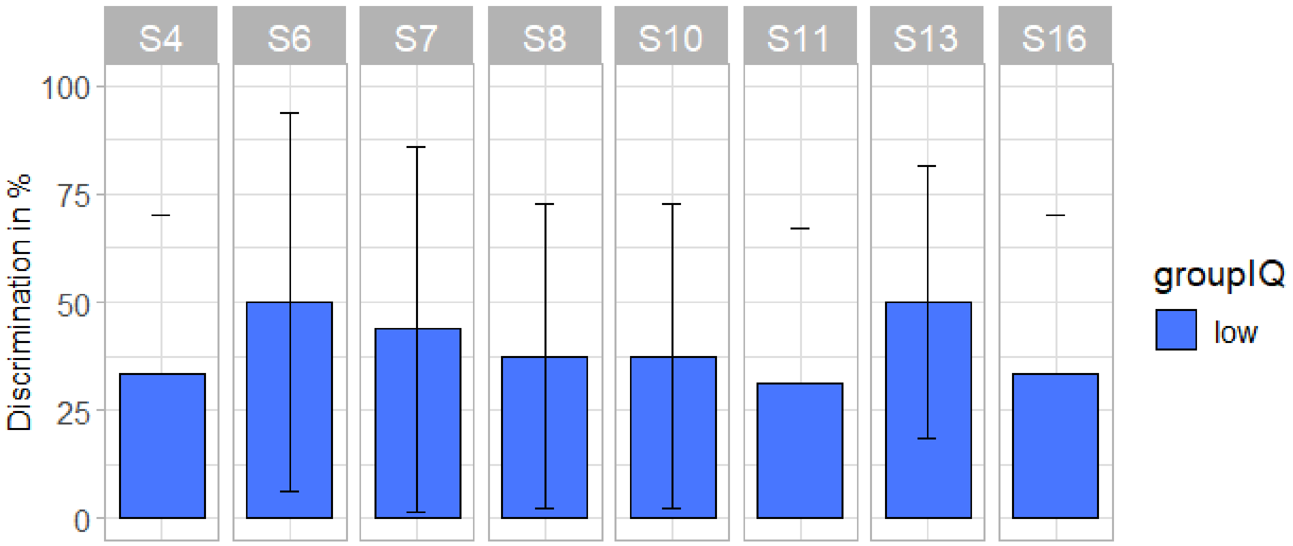

Figure 2. Discrimination of contrasts by each subject in the low IQ group.

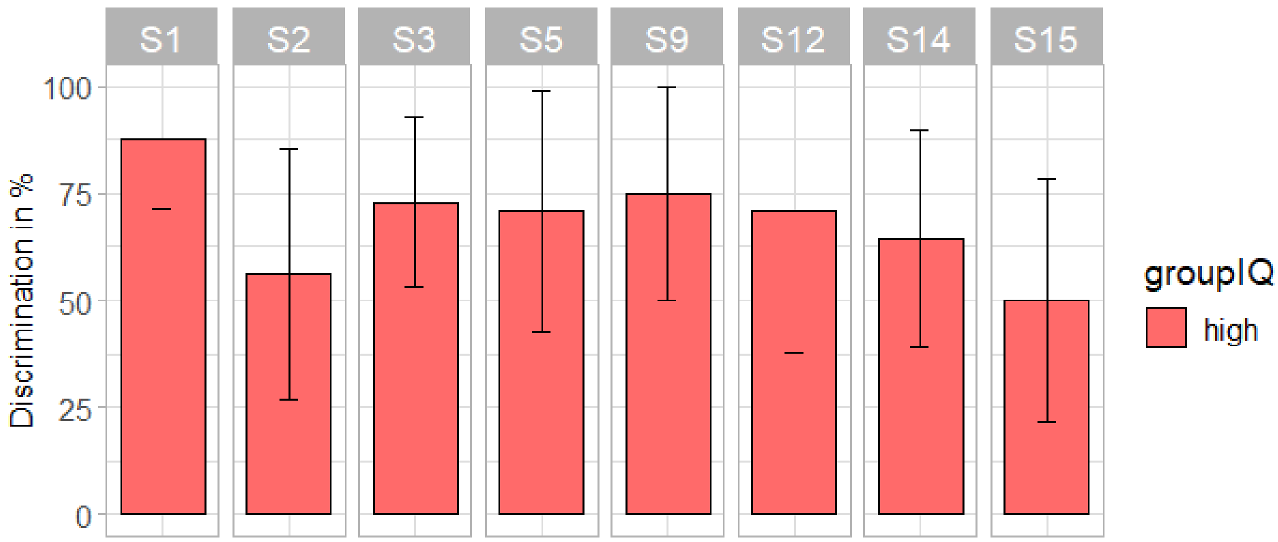

Figure 3. Discrimination of contrasts by each subject in the high IQ group.

4. Discussion

This study aimed to examine the effect of nonverbal intelligence on the discrimination of L2 vowel contrasts. The participants were Cypriot Greek speakers of L2 English, who completed a forced-choice AX discrimination test using a computer-based Praat script and a nonverbal intelligence test on paper. The analysis of data was conducted with the use of a binomial mixed-effects model and pairwise comparisons in R statistical software. According to the results, the high IQ group demonstrated a better performance than the low IQ group for most L2 contrasts. Specifically, English /ɪ/–/iː/, /æ/–/ɑː/, /ɔː/–/ɒ/, and /uː/–/ʊ/ contrasts were discriminated more accurately by the high IQ group. Therefore, the discrimination of L2 vowel contrasts was affected by the intelligence of the L2 speakers. This corroborates the findings of Georgiou and Giannakou [23] who observed such an effect in the discrimination of L2 English contrasts by Standard Modern Greek speakers. However, the results of this study are inconsistent with other findings, which show no connection between nonverbal intelligence and phonetic abilities (e.g., [25]). In addition, it has been proposed that the speech perception mechanism is not associated with intelligence, since perception is instantaneous and fast and does not need the guidance of a cognitive process [26].

The findings of this study may have emerged from an indirect effect of nonverbal intelligence on L2 speech perception. That is, intelligence may have triggered the more efficient functioning of other domains leading to better speech perception skills. For example, intelligence is related to an increased ability to process and learn new information (see [38]). So, intelligent L2 speakers have more advanced processing and learning skills, which can also be employed in speech perception. In addition, intelligence signals better attention control [39], which is crucial for L2 phonological learning. Individuals with advanced attention control skills can extract relevant acoustic information more easily during speech processing, thereby acquiring L2 speech sounds more accurately [40]. A more direct effect of intelligence on L2 speech perception is not precluded. It might be that speech perception is something more than just a simple realization of acoustic events. It has been supported that humans develop speech categories in their minds after extracting acoustic information found in the speech signal [41,8]. Thus, perceived speech features are categorized to particular speech categories. Perhaps, intelligence aids the connection between perceived acoustic information and the development of speech categories resulting in the activation of more robust L2 phonetic categories.

The results indicated that the majority of L2 contrasts (four out of six) were discriminated better by the high IQ group compared to the low IQ group. Nevertheless, the discrimination of two contrasts, that is /iː/–/e/ and /ɑː/–/ʌ/, did not differ between the two groups. The nonsignificant differences in the discrimination of /iː/–/e/ can be explained by the fact that this contrast is an easy distinction for the L2 speakers since both sounds do not acoustically overlap (i.e., they are associated with two different categories of their L1). In terms of the Universal Perceptual Model [7,8], this contrast would be considered nonoverlapping and therefore speakers would not have difficulties in discriminating between the contrast members. It seems that the between-group differences mostly appear in L2 contrasts considered difficult for these speakers. Another important finding is that most contrasts (except /iː/–/e/ and /ɔː/–/ɒ/) exerted a different degree of difficulty for the individuals in each group. For example, /æ/–/ɑː/ was the most difficult contrast for the low IQ group, while /ɑː/–/ʌ/was the most difficult contrast for the high IQ group. The perceived difficulty of particular speech contrasts by the groups differing in intelligence capacities is a matter which requires further investigation.

The study revealed that intelligence is somehow linked to L2 speech perception. However, this is a preliminary finding considering that research on this topic is very limited in the literature. Future studies can employ larger samples and populations with different L1s to examine how L2 speech perception relates to intelligence. It is also of paramount importance to use different tools to measure participants' intelligence. Although there was an attempt to control several factors in this study such as proficiency level, age of L2 English learning onset, L2 use, etc. there might be other factors that potentially affect the results such as phonological short-term memory, attention, motivation toward the learning of the L2, lexical access time, etc. These factors can be considered in future studies.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Department of Languages and Literature at the University of Nicosia.

Informed Consent Statement: All participants were informed about the goals of the study and gave their written consent for their participation in the experiments.

Data Availability Statement: Not applicable.

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Conflicts of Interest: The author declares no conflict of interest.

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