Local and global pitch perception in L1 and L2 readers of Dutch

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Prior research showed a relationship between reading skills and pitch perception, however the exact nature remained unclear. By means of reading tests and a pitch perception test, we examined the relation between reading abilities and local and global pitch perception for 92 native Dutch children (mean age = 9.47) and 61 non-native Dutch children (mean age = 9.61). Additionally, for the latter group we examined the role of working memory. In line with prior research with poor readers in a language with a rather transparent orthography by Ziegler, Pech-Georgel, George and Foxton (2012), a relationship is found between reading skills and the ability to detect local changes in pitch, rather than global changes in the melody. Additionally, at least for beginning readers of Dutch as a second language, there is a strong effect of working memory on the relation between reading skills and pitch perception.

Keywords: auditory perception, Dutch, phonological decoding, pitch perception, reading skills, second language learning, working memory

1. Introduction

Reading is the process of understanding speech that is written down (Ziegler & Goswami, 2005) with the goal of accessing meaning. In order to read successfully it is essential for learners to gain insight into the visual symbols connected to units of sound already known and used in speech. This means that beginning readers have to understand that, for example, in Dutch, the symbol 'B' is most of the time pronounced as /b/ at the beginning of a word. This process of mapping orthographic units to phonological units, also called *phonological recoding*, is systematic in most languages (Ziegler & Goswami, 2006) and central to reading development.

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Most studies looking at the relation between sound perception and reading development so far connected the latter to speech perception, represented by *phonological awareness* (i.e., the ability to reflect on the sound structure of words) and *phonological recoding* (Stahl & Murray, 1994; Ziegler & Goswami, 2005; 2006; Whalley & Hansen, 2006; Goswami, 2013). However, not only speech perception, but auditory perception in general appears to be related to reading development. According to the *auditory deficit* theory poorly specified representations of auditory input are the major cause of reading disabilities (Boets et al., 2011; Snowling, 2001; Tallal, 1980).

Possibly the most important aspect of auditory input is *frequency modulation* (FM), which relates to the encoding of information in the sound carrier by varying the instantaneous frequency of the wave. The variation can be local (relevant for fast formant transitions), as well as global (for slow prosodic changes spanning over several hundreds of ms, e.g., creating melody in speech; see Grube, Cooper, Kumar, Kelly, & Griffiths, 2014). Through noticing fast local modulations, the receiver can differentiate for instance between the phonemes /*i*/ and /*a*/ (Hirahara & Kato, 1992). On top of formant differences, the perceptual distinction between the vowels is also due to so-called intrinsic fundamental frequency (F0). As demonstrated in the experimental study by Whalen and Levitt (1995), intrinsic F0 is the necessary result of the production of different vowels in any language and local changes in F0 thus provide important cues for vowel judgment (Turner & Verhoeven, 2011).[1] Global frequency modulations, on the other hand, enable listeners to segment the speech input they are receiving into chunks (Foxton et al., 2003; Whalley & Hansen, 2006; Goswami et al., 2013). In doing so, they become aware of the fact that certain phonological units belong together, which helps them to connect those phonological units to orthographic units. Listeners suffering from congenital amusia (i.e. tone deafness) have shown to perform significantly worse on speech perception tasks that involve global pitch changes (Patel, Wong, Foxton, Lochy, & Peretz, 2008), providing evidence for a link between tune perception and the perception of speech intonation.

Some studies have found that sensitivity to frequency changes was a unique predictor of the variation in speech and language development (Tallal & Piercy, 1974). Importantly, Witton et al. (1998), using pure tone stimuli, reported a lower sensitivity among English-speaking adults with developmental dyslexia for frequency modulation for both low and high FM rates, corresponding both to global and local pitch changes (Grube et al., 2014). For English as well, Foxton et al. (2003) argued that *global* pitch perception is a strong predictor of reading

1. In a recent study of Standard Belgian Dutch, the reported average F0 difference between vowels was 33 Hz (3.28 semitones), see Turner & Verhoeven (2011).

performance in skilled adult readers. For French, on the other hand, findings by Ziegler, Pech-Georgel, George and Foxton (2012) showed that young dyslexic readers appear to have strong deficits in the detection of *local* pitch changes. The opposing findings in these two studies may be due to differences between English and French in the degree of so-called 'consistency' of grapheme-phoneme mappings (De Jong & Van Der Leij, 1999; Sprenger-Charolles, Colé & Serniclaes, 2013; Ziegler & Goswami, 2005).

In consistent languages a particular phonological unit is usually represented by one and the same orthographic unit, and vice versa. Since phoneme awareness is easier to learn if a letter consistently maps onto one and the same phoneme most of the time, children show better recoding skills in consistent languages. In such languages less grapheme-phoneme relations have to be learned. Next to that, children learning to read in consistent languages are more accurate in both word reading and non-word reading (Ziegler & Goswami, 2005). Compared to French, English is a highly inconsistent language (Goswami, 2013; Sprenger-Charolles et al., 2013) in which the correct pronunciation is dependent on digrams or longer sequences of graphemes (corresponding to rimes, syllables, or even words), rather than on a one-on-one grapheme-phoneme relation.

As suggested by Bruck, Genesee, and Caravolas (1997), the high level of inconsistency of English compared to French might be the reason why French children appear to have better reading skills than their English peers, despite the fact that they are provided with relatively little pre-literacy opportunities.[2] With respect to pitch sensitivity, it is thus possible that global changes are more relevant for readers of languages with inconsistent grapheme-phoneme mappings, whereas local pitch changes have a high information value for readers of languages with more consistent orthographies.

In our current study, we explored the relation between reading abilities and local and global pitch perception in typically developing young readers of Dutch (Experiment 1). Since Dutch is a language with high consistency (De Jong & Van Der Leij, 1999), we hypothesized that reading skills will be predicted by a reader's sensitivity to local pitch changes. Next to that, we examined the relation between reading abilities and pitch perception in second language learners of Dutch (Experiment 2). The variation in orthographies of different languages can cause additional difficulties to second language learners, since they need to acquire new phonological rules and reading strategies that may differ from their native language. In learning a second language, new repertoires with phonemes and

2. Comparable results were obtained by Goswami, Gobert, & Barrera (1998) for English, French, and Spanish children, and by Seymour, Aro, & Erskine (2003) who examined 13 European languages, including English, French, and Dutch.

syllables must be learned in order to create correct grapheme-phoneme mappings (Chiappe, Siegel, & Wade-Woolley, 2002). We hypothesized that for this reason both local and global pitch sensitivity would be important predictors of reading skills in second language learners.

Following Foxton et al. (2003) and Ziegler et al. (2012), we made use of a test of local and global pitch sensitivity that involved non-speech stimuli consisting of pure tonal sequences. This choice was motivated by the results of the aforementioned studies, which involved both non-dyslexic and dyslexic participants from different age groups, showing a relation between the perception of pure tonal sequences and reading skills in English and French. Similar results with other types of pure tone stimuli were obtained by Louie, Kroog, Zuk, Winner and Schlaug (2011) who used pairs of tones differing in F0 in a simple perceptual judgment task, showing a link to phonemic awareness in children between 7–9 years old.

Finally, we examined the role of working memory in relation to reading skills and pitch perception. While children learn a second language working memory plays a major role in the acquisition. In particular one subsystem of working memory is concerned with the acquisition of unfamiliar words, namely the *phonological loop* (Baddeley, 2003). The phonological loop stores temporary verbal cues in the form of unfamiliar sound structures, while more permanent, long-time representations are created by the memory. Working memory in general has been connected to the processing of musical, auditory information as well as speech sounds, like pitch heights (Williamson, Baddeley, & Hitch, 2010). When looking at reading development for children learning Dutch as a second language, working memory can be of particular importance for pitch perception and reading skills. The additional hypothesis for the second experiment is therefore that for children learning Dutch as a second language there is a relationship between working memory and reading skills, and working memory and pitch perception. Earlier research on the relationship between pitch perception and reading skills with Dutch L1 readers already showed that for this group there was no relationship with working memory (De Jong, Postma-Nilsenová, & Mos, 2017). Therefore, only the L2 group was tested on working memory.

2. Current study

In order to test the relationship between reading skills and pitch perception, we conducted two studies, consisting of a listening task and two reading tasks, with a Dutch L1 and L2 group. The stimuli for the listening task were based on the description of the experimental material provided by Foxton et al. (2003) and Ziegler et al. (2012), cast as a game of sound-identity detection. The reading tasks were standardized tasks for the Dutch language and measured technical reading skills (Brus & Voeten, 1980; Van Den Bos, Lutje Spelberg, Scheepstra, & De Vries, 2010).

2.1 Experiment 1

In the first experiment we analysed the relationship between reading skills and pitch perception for Dutch children. Since learners focus on phonemes when they read in a consistent language like Dutch, we hypothesized that for this group of Dutch primary school children reading skills can be predicted by sensitivity to changes in local pitch.

2.1.1 *Method*

Participants. The sample consisted of 95 participants, all native speakers of Dutch, recruited from a primary school in Tilburg. Three children did not complete the pseudo-word reading test, which resulted in a sample of 92 participants (54 female) for the analysis. The children's ages ranged from 7 to 12 years old ($M = 9.47$, $SD = 1.30$).

Design and instrumentation. The experiment had a correlational design, with the variables Reading Skills and Pitch Perception. Reading skills was further divided into the variables Word Reading and Pseudo-word Reading. Pitch perception consisted of the variables Global Pitch Perception and Local Pitch Perception.

Reading skills. In order to test the reading skills of participants, two standardized tasks for Dutch were used, namely the 'EMT' (Brus & Voeten, 1980) and the 'Klepel' (Van Den Bos et al., 2010), measuring word and pseudo-word (pronounceable non-words) reading speed and accuracy. The *EMT* measured technical reading skills by asking children to accurately read aloud as many Dutch words from a standardized list as possible in one minute (Brus & Voeten, 1980). Each participant was randomly assigned to version A or B. Both versions consisted of 116 non-related words, increasing in length. The task was assessed and scored following the instructions of Brus and Voeten (1980). The time was kept with a stopwatch from the moment the child was told to start reading. A word was scored as correct if the child proved to be able to decode the word, i.e. if the stress pattern was incorrect or if a word was pronounced in an unusual way, but not in opposition to its orthography, the word was counted as correct (Brus & Voeten, 1980). The rough score of the word reading task was calculated by subtracting the number of inaccurately read words from the total number of words read by the participant. The *Klepel* also assessed technical reading skills by asking children to accurately read aloud as many pseudo-words as possible from a standardized list in two minutes (Van Den Bos et al., 2010). Again, the instructions as described by Van Den Bos et al. (2010) were followed when assessing and scoring the task, which were similar to the procedure of the *EMT.* The pair of tests is based on the dual-route theory of technical reading skills (Siegel, 1993). The first route consists of the conversion of letters and groups of letters into sounds that make up a word, which is called the phonological route. The second, lexical, route comprises the instant recognition of the whole word. During the normal word reading task children could use both routes, whereas the pseudo-word reading task required children to make use of the phonological route. The pseudo-word reading task thus explicitly measured phonological reading skills, since children had to rely on learned associations between letters and phonemes. The pseudo-word reading test has good parallel forms reliability (.89 to .95) as well as good construct validity together with the word reading test (minimum .66) (Van Den Bos et al., 2010).

Pitch Perception Task. The pitch perception task in this study was based on the task used by Foxton et al. (2003) and Ziegler et al. (2012), previously implemented in De Jong, et al. (2017). In order to make the experiment understandable and enjoyable for the participants, we created a computer game in which players were asked to determine whether two animals produced the same or different sound patterns (see Figure 1). The game was implemented in Casanova 2 (Abbadi et al., 2015), a programming language designed for creating serious games for educational and research purposes.

Figure 1. Screenshot of the pitch perception game

The pitch perception task consisted of two types of stimuli, measuring either global or local pitch perception. Participants were presented with 48 pairs of 4-tone sequences. The first sequence was played by a fox on a trumpet, followed by a brief pause after which the second 4-tone sequence was whistled by a bird. The children had to detect whether the second sequence was the same or different from the first one. After a practice session with two pairs of sequences, the actual task started. No feedback was provided during the test.

The sequences of tones were based on the description provided in Ziegler et al. (2012) and consisted of pure tones with the duration of 250 ms per sequence. The pauses between tones, called gating windows, lasted for 20 ms and the tones had frequencies from an atonal scale, taken from a division of an octave into seven equally spaced logarithmic steps. For the starting frequencies, an interval of 250 to 354 Hz was used. For the 'different' pairs, the second or third note of the second sequence was two steps lower or higher than the second or third note of the first sequence (Ziegler et al., 2012; De Jong et al., 2017).

Local pitch perception required the skill to discriminate actual pitch values over time. A change in local pitch did not lead to a violation of the contour, whereas a change in global pitch perception did (see Figure 2).

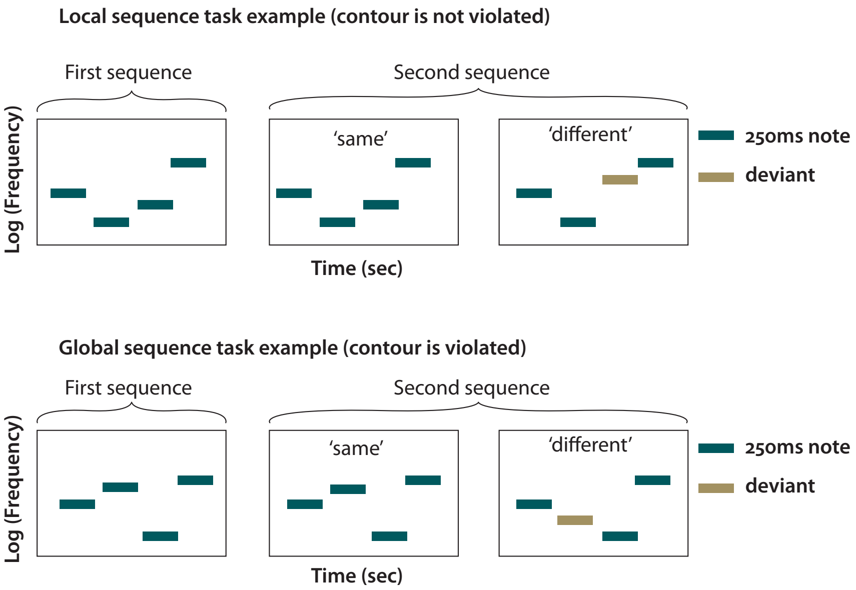

Figure 2. Illustration of the global and local pitch change detection tasks. Reprinted from Ziegler et al. (2012, p. 2).

Procedure and materials. The complete set of tasks was divided into two different test sessions. The first session consisted of the two reading tasks, conducted and assessed in the standard way described in Brus and Voeten (1980) and Van Den Bos et al. (2010). The second session consisted of the pitch perception task. In order to preserve anonymity, a number was assigned to each participant prior to participation.

The first test session was recorded with the freely available software Audacity. This was done so in case of any doubt about the correctness of a read word, the experimenter could listen to the test session again. The time for the reading tests was kept by use of a stopwatch on a mobile phone. A Packard Bell PEW 91 laptop was used in the second test session for the game presentation. Connected to the laptop was a Trust headset (Model HS-2550) via which the stimuli were presented to the participant.

Data analysis. The scores of the reading tasks were calculated by subtracting the number of incorrect words from the total number of words that were read. In case there was doubt about the correctness of a word – even after rechecking the audio recordings – a second judge was consulted with experience in assessing these tasks. The test sequences of the pitch perception task were categorised as either a pair that had the same sequence or a pair that had a different sequence and as either global or local. Proportional scores were calculated indicating the percentage of correct answers in the four categories (Global-Same, Global-Different, Local-Same and Local-Different). Additionally, in the analysis of the pitch perception task, d'-scores were used, which control for bias and sensitivity in participants by giving credits for correct answers and penalties for incorrect answers (Keating, 2005). First, the *hit rate* and *false alarm rate* was computed for both the global as well as the local category. An answer counted as a *hit* when the participant reported to hear a difference between the sequences when there indeed was a difference. Participants got a *false alarm* when they said to hear a difference, when in reality there was no difference. The z-scores of the hit rate minus the z-scores of the false alarm rate led to the d'-score of the pitch perception task for global and local separately.

2.1.2 *Results*

Performance patterns showed that participants scored significantly higher on global pitch perception ($M = 0.70$, $SD = .16$) than on local pitch perception ($M = 0.63$, $SD = .16$), $t(91) = 3.74$, $p < .001$. In order to control for the effect of demographics, correlations between the study measures and age were run as well t-tests for the effect of gender. The results showed that there was no effect of gender on any of the study measures (see Table 1). However, there was an effect of age on the word reading test ($r(90) = .66$, $p < .001$), pseudo-word reading test ($r(90) =.62$, $p < .001$)

and the local pitch perception task ($r(90) = .34$, $p < .001$). No effect was found of age on the global pitch perception task ($r(90) = .09$, $p = .404$).

Table 1. Descriptives of the study measures and correlations with demographics for the L1 group

	Descriptives		Relation with demographic variables	
	Mean	SD	Gender (*t*, *p*)	Age (*r*, *p*)
Word Reading	62.59	20.87	−1.56, .123	.66, <.001
Pseudo-word reading	51.92	20.79	−1.02, .311	.62, < .001
Global d'*	0.00	1.47	0.06, .957	.09, .404
Local d'**	0.00	1.29	−1.39, .167	.34, .001

* Median = −0.01; Range −2.67–2.72
** Median = 0.01; Range −3.24–3.04

In order to test the hypothesis of the first experiment stating that reading skills are predicted by a reader's sensitivity to local pitch changes in typically developing young readers of Dutch, correlations between scores on the reading tasks and d'-scores for global and local pitch perception were run. There was a significant positive correlation between the score on the local pitch perception task and the word reading task ($r(90) = .23$, $p = .027$) and the local pitch perception task and the pseudo-word reading task ($r(90) = .29$, $p = .005$). There were no significant correlations between the reading tasks and global pitch perception.

Table 2. Pearson product correlations between the reading tasks and pitch perception task for the L1 group.

	Word reading (*r*, *p*)	Pseudo-word reading (*r*, *p*)
Global d'	.04, .699	.13, .237
Local d'	.23, .027	.29, .005

2.1.3 *Conclusion*

The results of the first experiment with Dutch children between eight and eleven years old show that for Dutch readers, sensitivity to local pitch perception appears to be related to their reading skills. This was in correspondence to the hypothesis that, based on the consistency of the Dutch language and the resulting focus of readers on phonemes, Dutch readers would rely more on local pitch perception, which is used to discriminate between phonemes.

For second language readers, the variation in orthographies can cause additional difficulties during reading development. New phonological rules and reading strategies must be learnt as well as new repertoires with phonemes and syllables for grapheme-phoneme mapping. Since prior research mainly focused on the relationship between auditory input and reading skills in a first language, we extended the first experiment and replicated the study with children learning Dutch as a second-language.

2.2 Experiment 2

In the second experiment we analyzed the relationship between reading skills and pitch perception for foreign children learning Dutch as a second language. Since second language learners need to learn new rules, strategies and repertoires of phonemes and syllables, we hypothesized that for this group both local and global sensitivity would be important predictors of reading skills. Also, since second language learners need to store the unfamiliar sound structures in their working memory while reading, we hypothesized that for children learning Dutch as a second language there is a relationship between working memory and reading skills, and between working memory and pitch perception.

2.2.1 *Method*

Participants. The sample consisted of 61 participants from five different classes for recently migrated children in the province of Noord-Brabant. Five participants had to be excluded due to incomplete data, which resulted in a final sample of 56 children (32 female). The children's ages ranged from 5 to 13 years old ($M = 9.61$, $SD = 1.68$). One of the classes was situated at a school at an asylum seeker centre, whereas the other classes were located at regular Dutch primary schools. Only children who had mastered the Dutch alphabet, as determined by their teacher, were included in the study. In their daily life, all of the children were multilingual. None of the participants was a native speaker of Dutch. Based on the answers of the children, those who had been at school on average had been attending school for 3.16 years, ranging from half a year to 7 years. The majority of the children came from Somalia and Poland (see Table 3). The period during which the children attended school in the Netherlands ranged from 1 month to 23 months ($M = 8.89$, $SD = 4.20$).

Design and instrumentation. To test whether there was a relationship between reading skills and pitch perception for children learning Dutch as a second language, the same study measures were used as Experiment 1, namely a pitch perception task and two reading tasks (see above). For this study, a digit span task was added as a standardized measure for working memory.

Table 3. Country of origin and prior education of the L2 group

Country of origin	Number of children (*N*)	Percentage of total (%)	Prior education (%)[b]	No prior education (%)[b]
Somalia	16	28.6	12.5	75.0
Poland	15	26.8	80.0	13.3
Syria	4	7.1	100.0	–
Iran	3	5.4	66.7	33.3
Hungary	2	3.6	100.0	–
Netherlands[a]	2	3.6	100.0	–
Kosovo	2	3.6	50.0	50.0
Slovakia	2	3.6	100.0	–
Afghanistan	2	3.6	50.0	50.0
Other[c]	8	14.4	62.50	12.5

Notes

a. These children were born in the Netherlands, but moved to England.

b. Remaining percentages represent missings in the data file.

c. Other countries included: China, Guinea, Latvia, Libya, Lithuania, Serbia, Sierra Leone and Spain.

Digit Span Task. Working memory was tested using an auditorily presented digit span task, which consisted of forward digit repetition and backward digit repetition (Olsthoorn, Andringa, & Hulstijn, 2014). All the children were able to count to ten in Dutch. The experimenter read aloud a sequence of digits (i.e. numbers from 1 to 9) to the participant after which the participant had to repeat the sequence. Two sequences were presented at each length, beginning with a sequence of three digits going up to a sequence of eight digits. The forward digit span test was thus composed of twelve sequences of digits in total. The length increased until both sets of sequences were successively failed or until the last sequence of eight digits was repeated correctly. The backward digit span test resembled the forward digit span test, but started with two digits instead of three. If one series of backward digits was repeated correctly, the number of digits was increased, up to a sequence of seven digits or until both sequences of digits were successively failed. The digit span task is a standardized measure for verbal working memory (Olsthoorn et al., 2014).

Procedure and material. The procedure for the second experiment was the same as in the first experiment, with the following additions. The first session started with a sentence-repetition task during which children had to repeat two Dutch sentences after the researcher. The repetition task was, together with a teacher's judgement on children's ability to participate, used to verify children's ability to participate in the experiment. None of the participants was excluded after this task. The last part of the first session was the digit span task. After the digit span forward, the digit span backward was administered in the same manner with a practice digit prior to the actual test. The scoring was the same as the digit span forward. A Dell laptop with Windows 7 professional (Model E5510) was used for presenting the pitch perception game. Connected to the laptop was a Sennheiser headset (Model PC 320) via which the stimuli were presented to the participant.

Data analysis. The data was analysed in the same manner as in Experiment 1 resulting in two scores for the reading tests (i.e. word and pseudo-word reading) and two scores for the pitch perception test (i.e. global and local pitch perception). Additionally, the digit span task resulted in three scores: one for digit span forward, one for digit span backward and one overall working memory score. The scores on the digit span forward and backward were made up by the total number of sequences repeated correctly with a maximum score of twelve for each task. Overall working memory consisted of digit span forward and backward added together.

2.2.2 *Results*

In the second experiment two hypotheses were tested. Firstly, we hypothesized that for children learning Dutch as a second language, both local and global sensitivity would be important predictors of reading skills. As a second hypothesis, we stated that for these children there would be a relationship between working memory and reading skills and working memory and pitch perception. In order to analyze the results, we performed the same analyses as mentioned above and added working memory as a study measure.

Just as with experiment 1, the results showed that children scored significantly higher on global pitch perception ($M = .67$, $SD = .18$) than on local pitch perception ($M = .57$, $SD = 12$), $t(55) = 4.70$, $p < .001$. Again, in order to control for the effect of demographics, correlations between the study measures and age were run as well as *t*-tests for the effect of gender (see Table 4). The results showed that there was no effect of gender on any of the study measures. However, there was an effect of age on word reading accuracy ($r(54) = .39$, $p = .003$), pseudo-word reading accuracy ($r(54) = .39$, $p = .003$), digit backward ($r(54) = .28$, $p = .036$), and working memory (forward and backward digit span together) ($r(54) = .31$, $p = .019$). Age did not correlate significantly with digit forward, d'-global, and d'-local. The period during which children attended school in the Netherlands also did not correlate to any of the study measures (see Table 4).

Based on the d'-scores of the pitch perception task, the correlation between phonological skills and reading skills was tested (see Table 5). There was a significant positive correlation between the score on the local pitch perception task and the word reading task ($r(54) = .33$, $p = .014$). There was no significant correlation between the pseudo-word reading task and local pitch perception. Finally, there were no significant correlations between the reading tasks and global pitch perception.

Table 4. Descriptives of the study measures and correlations with demographics for the L2 group

	Descriptives		Relation with demographic variables		
	Mean	**SD**	**Gender (*t, p*)**	**Age (*r, p*)**	**Period at school (*r, p*)**
Word Reading	38.52	18.37	0.21, .833	.39, .003	−.10, .448
Pseudo-word reading	50.02	24.29	0.70, .485	.39, .003	−.12, .397
Global d'*	0.00	1.36	0.80, .428	.20, .131	.05, .711
Local d'**	0.00	1.21	−1.29, .202	.15, .258	−.05, .744
Working memory	7.91	2.43	0.24, .814	.31, .019	−.05, .739
Digit forward	4.75	1.72	0.16, .877	.23, .089	.08, .549
Digit backward	3.16	1.29	0.24, .813	.28, .036	−.20, .151

* Median = −0.35; Range −2.75–2.44
** Median = 0.02; Range −3.49–3.46

Table 5. Pearson product correlations and partial correlations between the reading tasks and pitch perception task (r, p) for the L2 group

	Word reading		Pseudo-word reading	
	Pearson	**Partial**	**Pearson**	**Partial**
Global d'	.15, .287	.09, .521	.15, .276	.10, .451
Local d'	.33, .014	.24, .082	.20, .124	.12, .368

Since working memory was added as a variable in the second experiment, Pearson product moment correlations were run to determine the statistical associations between the study measures and working memory (see Table 6). Working memory correlated significantly with the tasks measuring reading skills and local pitch perception. For the reading tasks, this could mainly be attributed to digit span backward, whereas for local pitch perception it could mainly be attributed to digit span forward.

Table 6. Pearson product correlations between the study measures and working memory (r, p) for the L2 group

	Word reading	**Pseudo-word reading**	**Global d'**	**Local d'**
Digit Forward	.23, .083	.13, .327	.12, .362	.28, .037
Digit Backward	.49, < .001	.45, < .001	.12, .361	.17, .211
Working Memory	.43, .001	.33, .012	.15, .257	.29, .032

Considering the finding that working memory had a strong relationship to almost all the study measures, the correlations between the reading tasks and the pitch perception task were also run while controlling for the effect of working memory on these variables. This was done by means of partial correlations with working memory as a control variable (see Table 5 Partial correlations). When doing so, the existing correlation between local pitch perception and word reading became marginally significant ($r(54) = .24$, $p = .082$).

2.2.3 *Conclusion*

The results of the second experiment with children at the early stages of learning Dutch as a second language show that just like for Dutch children, local pitch perception correlated with reading skills. An additional finding of this experiment is that at least for beginning learners of Dutch as a second language, there is a strong effect of working memory on (the relationship between) reading skills and pitch perception. The hypothesis that sensitivity to global pitch would be a predictor to reading skills was not confirmed.

3. General conclusion and discussion

In the current study, the main aim was to test the relationship between reading skills and the perception of global and local pitch for young readers of Dutch as a first or a second language. A secondary aim was to see whether there was a relation between working memory and reading skills and between working memory and pitch perception for the children learning Dutch as a second language. In doing so, 95 children with Dutch as a first language and 56 children with Dutch as a second language completed a pitch perception test and tests measuring reading skills. Additionally, the non-Dutch children completed a digit span task measuring working memory.

In line with prior research with poor readers in a language with a rather transparent orthography by Ziegler et al. (2012), a relationship is found in this study between reading skills and the perception of local pitch. The ability to read aloud words and pseudo-words thus correlates with the ability to detect actual changes in pitch, rather than global changes in the melody. As previously suggested, local pitch perception may be central to the mastering of the Dutch orthographic system, which is highly consistent, compared to languages with inconsistent grapheme-phoneme mappings such as English, where global pitch changes may provide additional information. However, there is reason to suspect that the stimuli involving global pitch changes were too easy for the participants in our study, resulting in a low predictive value of the global d-prime score.

An additional finding is that at least for beginning readers of Dutch as a second language, there is a strong effect of working memory on the relation between reading skills and pitch perception. It could be that the process of phonological decoding relies heavily upon the phonological loop, since that is the system that stores unfamiliar sound structures and retrieves them from memory while reading. However, it can also be that the relationship between the digit span task and the pitch perception task can be attributed to the fact that the latter is a same-different task, meaning that participants need to remember the first sequence, while listening to the second. A same-different task like the pitch perception task relies heavily on the storage of information, which is tested by means of the forward digit span task (Olsthoorn et al., 2014) possibly explaining the relationship between the two.

Furthermore, the current study found a correlation between working memory and reading skills for children learning Dutch as a second language. Prior research showed that verbal working memory is a good predictor of successful second-language learning (for an overview see Olsthoorn et al., 2014). Since second language learners do not have a large vocabulary yet, they cannot appeal to their lexical memory in the way native speakers of Dutch do while reading aloud words. The reading skills of second language learners thus rely heavily upon the phonological route of reading for both words and pseudo-words. Since most words that were part of the word reading task were unknown to the non-native Dutch children, they probably processed them like pseudo-words, which can be supported by the very strong correlation between the word reading task and the pseudo-word reading task ($r = .95$). The finding of a relationship between reading and working memory was consistent with earlier research showing a relationship between reading difficulties and working memory deficits (Swanson & Ashbaker, 2000; Wang & Gathercole, 2013). However, the correlation reported here should be primarily attributed to the backward digit span task since there was no significant correlation between reading and the forward digit span task.

According to Lundberg (2002), the importance of the phonological loop differs when comparing first and second language learning. At a certain age, most of the vocabulary of the first language is familiar and therefore stored in long-term memory. In this case, a reader can (and will) use the lexical route to directly recognize almost all words while reading that language, meaning that any deficits in phonological loop capacities do not hamper his reading performance. However, when the same individual is learning a second language, he will most likely have problems with the acquisition of words due to this deficit in phonological loop capacities. Relating this to reading disabilities, second language learners who have a deficit in their phonological loop may suffer from poor development of second language vocabulary, whereas due to certain compensation strategies, they have fewer problems in their first language (Lundberg, 2002).

For future research, it is thus important to further investigate the role of working memory in pitch perception and reading development especially in the context of children learning Dutch as a second language. Additionally, the possible influence of L1 on this relationship between reading skills and pitch perception should be further analyzed since the granularity and consistency of children's first language can be different, leading to advantages for children who have a mother-tongue comparable to the Dutch language and disadvantages for children with a very different mother-tongue (Ziegler & Goswami, 2006). Also, there can be an advantage in pitch perception for speakers of tonal languages. Research showed that individuals with a tonal native language are better in imitating pitch and in discriminating pitch differences compared to individuals with an intonation native language. In a tone language, pitch changes contribute to word meaning, which makes it more important to be able to detect them. The use of pitch to convey meaning in spoken language facilitates the use of pitch in non-linguistic contexts, resulting in an advantage for tonal language speakers (Pfordresher & Brown, 2009). However, due to the many different nationalities and native languages in the current sample such an in-depth investigation of differences between children was not possible in the scope of this study.

In conclusion, the main question in the current research was whether there is a relationship between reading skills and pitch perception in native and non-native young readers of Dutch. For both groups a relationship was found between the ability to read aloud words and pseudo-words and the ability to detect local pitch changes rather than global changes in the melody. Additionally, for the non-native readers there is a strong effect of working memory on this relationship.

The educational game in this research can be used for early detection of deficits in pitch perception skills in a playful way. Training these pitch perception skills can then lead to fewer chances of reading difficulties at a later age. Additionally, since the game does not test language proficiency, it can also be used to detect pitch perception skills in second language learners of Dutch. Furthermore, the findings of this study can be used to improve the teaching methods in newcomers classes as well as to determine the topic of focus in those classes. Since it is very likely that reading proficiency for this group relies heavily upon (verbal) working memory and (local) pitch perception, training of those skills might result in a higher literacy and faster (second) language acquisition. Research on auditory intervention for children with developmental dyslexia already proved its efficacy (Thomson, Leong, & Goswami, 2013). In order to train pitch perception skills, it is important to provide children with feedback while playing the game, so they become aware of the accuracy of their judgements. A possibility for the future is thus to train children's pitch perception (and working memory) in order to improve their literacy skills and make them active members of the society.

References

Abbadi, M., Di Giacomo, F., Cortesi, A., Spronck, P., Constantini, G., & Maggiore, G. (2015). Casanova: A simple, high-performance language for game development. In S. Göbel, M. Ma, J. Baalsrud Hauge, M. Oliveira, J. Wiemeyer, & V. Wendel (Eds.), *JCSG 2015, LNCS 9090* (pp. 123–134). Bern: Springer.

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, 36(3), 189–208.

Boets, B., Vandermosten, M., Poelmans, H., Luts, H., Wouters, J., & Ghesquière, P. (2011). Preschool impairments in auditory processing and speech perception uniquely predict future reading problems. *Research in Developmental Disabilities*, 32(2), 560–570.

Bruck, M., Genesee, F., & Caravolas, M. (1997). A cross-linguistic study of early literacy acquisition. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 145–162). Mahwah, NJ: Lawrence Erlbaum Associates.

Brus, B. T., & Voeten, M. J. M. (1980). *Eén-Minuut-Test (EMT): Vorm A en B*. Nijmegen, The Netherlands: Berkhout.

Chiappe, P., Siegel, L. S., & Wade-Woolley, L. (2002). Linguistic diversity and the development of reading skills: A longitudinal study. *Scientific Studies of Reading*, 6(4), 369–400.

De Jong, C., Postma-Nilsenová, M., & Mos, M. B. J. (2017). Reading skills and pitch perception in Dutch high-school students. In *Proceedings of the 14th International Congress for the Study of Child Language, Lyon, France*.

De Jong, P. F., & Van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology*, 91(3), 450.

Foxton, J. M., Talcott, J. B., Witton, C., Brace, H., McIntyre, F., & Griffiths, T. D. (2003). Reading skills are related to global, but not local, acoustic pattern perception. *Nature Neuroscience*, 6(4), 343–344.

Goswami, U. (2013). Dyslexia – in tune but out of time. *Psychologist*, 26(2), 106–109.

Goswami, U., Gobert, J. E., & de Barrera, L. C. (1998). Children's orthographic representations and linguistic transparency: Nonsense word reading in English, French, and Spanish. *Applied Psycholinguistics*, 19, 19–52.

Goswami, U., Mead, N., Fosker, T., Huss, M., Barnes, L., & Leong, V. (2013). Impaired perception of syllable stress in children with dyslexia: A longitudinal study. *Journal of Memory and Language*, 69(1), 1–17.

Grube, M., Cooper, F. E., Kumar, S., Kelly, T., & Griffiths, T. D. (2014). Exploring the role of auditory analysis in atypical compared to typical language development. *Hearing Research*, 308, 129–140.

Hirahara, T., & Kato, H. (1992). The effect of F0 on vowel identification. In Y. Tohkura, E. Vatikiotis-Bateson, & Y. Sagisaka (Eds.), *Speech perception, production and linguistic structure* (pp. 89–112). Tokyo: Ohmsha.

Keating, P. (2005). *D-prime (signal detection) analysis*. Retrieved from <http://www.linguistics.ucla.edu/faciliti/facilities/statistics/dprime.htm>

Louie, P., Kroog, K., Zuk, J., Winner, E., & Schlaug, G. (2011). Relating pitch awareness to phonemic awareness in children: Implications for tone-deafness and dyslexia. *Frontiers in Psychology*, 2, 58–62.

Lundberg, I. (2002). Second language learning and reading with the additional load of dyslexia. *Annals of Dyslexia*, 52(1), 165–187.

Olsthoorn, N. M., Andringa, S., & Hulstijn, J. H. (2014). Visual and auditory digit-span performance in native and non-native speakers. *International Journal of Bilingualism*, 18(6), 663–673.

Patel, A. D., Wong, M., Foxton, J., Lochy, A., & Peretz, I. (2008). Speech intonation perception deficits in musical tone deafness (congenital amusia). *Music Perception*, 25, 357–368.

Pfordresher, P. Q., & Brown, S. (2009). Enhanced production and perception of musical pitch in tone language speakers. *Attention, Perception, & Psychophysics*, 71 (6), 1385–1398.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, 94(2), 143–174.

Siegel, L. S. (1993). The development of reading. *Advances in Child Development and Behavior*, 24(2), 63–97.

Snowling, M. J. (2001). Developmental dyslexia. *Current Paediatrics*, 11(1), 10–13.

Sprenger-Charolles, L., Colé, P., & Serniclaes, W. (2013). *Reading acquisition and developmental dyslexia*. Hove: Psychology Press.

Stahl, S. A., & Murray, B. A. (1994). Defining phonological awareness and its relationship to early reading. *Journal of Educational Psychology*, 86(2), 221–234.

Swanson, H. L., & Ashbaker, M. H. (2000). Working memory, short-term memory, speech rate, word recognition and reading comprehension in learning disabled readers: Does the executive system have a role? *Intelligence*, 28(1), 1–30.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language*, 9(2), 182–198.

Tallal, P., & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia*, 12 (1), 83–93.

Thomson, J. M., Leong, V., & Goswami, U. (2013). Auditory processing interventions and developmental dyslexia: A comparison of phonemic and rhythmic approaches. *Reading and Writing*, 26(2), 139–161.

Turner, P. G., & Verhoeven, J. (2011). *Intrinsic vowel pitch: A gradient feature of vowel systems*. Paper presented at the 17th International Congress of Phonetic Sciences, 17–21 August, 2011, Hong Kong.

Van Den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & De Vries, J. R. (2010). *De klepel: Vorm A en B. Een test voor de leesvaardigheid van pseudowoorden: verantwoording, handleiding, diagnostiek en behandeling*. Amsterdamnds: Pearson.

Wang, S., & Gathercole, S. E. (2013). Working memory deficits in children with reading difficulties: Memory span and dual task coordination. *Journal of Experimental Child Psychology*, 115(1), 188–197.

Whalen, D. H., & Levitt, A. G. (1995). The universality of intrinsic F0 of vowels. *Journal of Phonetics*, 23, 349–366.

Whalley, K., & Hansen, J. (2006). The role of prosodic sensitivity in children's reading development. *Journal of Research in Reading*, 29(3), 288–303.

Williamson, V. J., Baddeley, A. D., & Hitch, G. J. (2010). Musicians' and nonmusicians' short-term memory for verbal and musical sequences: Comparing phonological similarity and pitch proximity. *Memory & Cognition*, 38(2), 163–175.

Witton, C., Talcott, J. B., Hansen, P. C., Richardson, A. J., Griffiths, T. D., Rees, A., Stein, J. F., & Green, G. G. R. (1998). Sensitivity to dynamic auditory and visual stimuli predicts non-word reading ability in both dyslexic and normal readers. *Current Biology*, 8, 791–797.

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, 131(1), 3–29.

Ziegler, J. C. & Goswami, U. (2006). Becoming literate in different languages: similar problems, different solutions. *Developmental Science*, 9(5), 429–436.

Ziegler, J. C., Pech-Georgel, C., George, F., & Foxton, J. M. (2012). Global and local pitch perception in children with developmental dyslexia. *Brain and language*, 120(3), 265–270.

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