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Speech breathing behavior during pauses in children

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Abstract

The aim of this paper is to investigate speech breathing behaviors in children during the realization of pauses, breathing pauses or non-breathing pauses, depending on the syntactic location of the pause and the speech task. Thus, we will be able to observe the effects of cognitive-linguistic demands on breathing patterns in children. To do so, 10 French speakers, between 8 and 11 years old, were recorded while reading and spontaneous speech. The variation of respiratory movements was measured using inductive respiratory plethysmography. The respiratory signals were synchronized with acoustic data. The results show an effect of the speech task on the duration of inhalation and, to a lesser extent, on its amplitude. 'Partial inhalations' were observed at the syntactic boundaries, suggesting that they are integrated in the child's respiratory patterns. Finally, we observed occasional cessation of rib cage closure, essentially during non-syntactic pauses.

Index Terms: speech breathing, children, pause, syntactic location

1. Introduction

Studying breathing behavior during pauses is of interest for understanding respiratory functioning in speech, particularly in children, for whom few studies have been conducted on the subject.

Breathing is in constant interaction with the linguistic level, playing an essential role in the demarcation of syntactic units, in the same way as intonation and silent pause. Pauses, with or without inhalation, are mostly realized at the grammatical boundaries [1][2][4].

Breathing pauses are mostly performed at the boundaries of major syntactic constituents [5]. Moreover, the inhalation depth depends on its location within the speech [6] [3]. In reading, it appears that the inspiratory contribution is higher at the borders of paragraphs, and then of utterances. These patterns are not observed in children. Indeed, in young speakers, inspiratory amplitude is not significantly different according to its location at the boundaries of utterances or sequences [7]. Nevertheless, inhalations are less important when they occur outside the syntactic boundaries.

The management of lung volumes did not vary significantly depending on the speech task and the increase in the cognitive-linguistic demands [8]. On the other hand, the speech task had an effect of fluency-related parameters such as the duration of breath groups, the number of syllables per breath group, etc. Furthermore, while no significant difference is observed in the duration of inspiratory movement between reading and spontaneous speech in adults [9], there is evidence that the duration of inhalation is significantly higher in spontaneous speech in children [7].

While speech breathing has been the subject of numerous studies, recent data provide new insights into the analysis of respiratory phenomena in speech. These data reveal the occurrence of 'partial' inhalation, characterized by a reduced or incomplete intake of air compared to a typical full inhalation, in spontaneous speech [10]. The author of this study hypothesizes that these partial inhalations could be associated with disfluencies and/or correspond to a planning time for speech.

In addition, we will also focus on respiratory behaviors during non-breath pauses. Indeed, some data have highlighted the cassation of rib cage closure during the realization of non-breathing pauses [11]. These punctual blocks could be a result of hesitation or high cognitive activity.

The aim of this study is to explore breathing behaviors during breathing and non-breathing pauses, depending on the syntactic structure of utterances and the speech task, in order to supplement the description of breathing patterns in children's speech.

If partial inhalations are related to disfluency and planning phenomena, we hypothesize that they would occur more frequently in spontaneous speech and be more commonly found outside the syntactic boundaries. Furthermore, we hypothesize that an increase of the duration of non-breathing pauses would correspond to a longer inhalation duration. Finally, regarding the non-breathing pauses, the punctual cessation of rib cage closure would be associated with an increase in the cognitive-linguistic demands. Consequently, these interruptions would likely occur during non-syntactic pauses and be more prevalent in spontaneous speech.

2. Method

2.1. Speakers

Our corpus includes recordings from ten children between 8 and 11 years old (mean = 9.71; sd = 0.772) with no reported speech or respiratory disorders. They were native speakers of French. These recordings come from a corpus created for the study by Charuau [11] about speech breathing in children with and without cleft palates.

2.2. Corpus

Each participant was instructed to read the tale *La bise et le soleil* at comfortable speech rate and intensity. This task was repeated once. For the spontaneous speech task, the speakers were asked to carry out a picture-based storytelling activity. An

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example with similar images was provided prior to the recording session.

2.3. Acquisition system

The variation of respiratory movements was measured using Respiratory Inductive Plethysmography (Respitrace system, ADInstruments). Two electromagnetic belts were positioned on the thorax and the abdomen of each speaker. Acoustic data was collected using a Senheiser e835s microphone and a Marantz Professional digital recorder. The children stood upright 30 cm away from the microphone. A marking on the floor was made to maintain this parameter across speakers. The synchronization of the acoustic and respiratory signals was achieved using PowerLab (ADInstruments). The respiratory and speech signals allow observing variations of the thoracic-abdominal perimeter during phonation.

2.4. Data processing

To analyse the breathing movements as a whole, we created a new signal by collapsing the thoracic and abdominal signals (1 Tho + 1 Abd) [12]. The amplitude of respiratory movements was measured in terms of maximum displacement (%MD) [14], which was estimated for each speaker from isovolume maneuvers [12] [13].

The respiratory data, synchronized with the speech signal, was processed using MATLAB software [19]. In addition, the acoustic speech signal was analysed using the Praat software [16], and semi-automatically annotated with EasyAlign [17].

2.5. Speech and respiratory measurements

We were measuring the amplitude inspiratory movement, wich was defined as the difference between the minimum and maximum values of the inspiratory movement [18]. The duration of inhalation was measured as the interval between these two values of movement. The pause duration was the time between the end of the speech and the beginning of the new breath group.

2.6. Labeling of pauses and syntactic analysis

For our analyses, we made a distinction between breathing pauses and non-breathing pauses. Breathing pauses were characterized by a cessation of phonation accompanied by an increase in the respiratory curves.

For the analysis of inspiratory movements, we also differentiated between inspiratory and partial inspiratory, as defined by Weston [10] as 'half the range of the fullest inhalation in the trial'.

Syntactic labelling was performed manually using Praat, based on a method relies on the dependency relations between units, according to the principles of micro- and macro-syntax [18]. Thus, we categorized pauses located at the boundaries of major syntactic units (rection unit), at the boundaries of minor unit (verbal, subject, object, or rule sequences) and non-syntactic pauses located outside these boundaries.

2.7. Statistical analyses

Statistical analyses were performed using RStudio software (version 1.4.1717) [20]. The data were compared using repeated measures analysis of variance (ANOVA). This model has been chosen to examine the impact of intra-subject factors (speech tasks and syntactic location) on the variables under analysis, such as the duration of inhalation and pauses. The overall significance level was set at $p < 0.05$. When significance was indicated, Bonferroni tests were conducted for *post-hoc* comparisons.

3. Results

3.1. Inspiratory and partial inspiratory

Figure 1 illustrates the distribution of partial inhalations and inhalations among the total number of breaths (693 breaths), according to the speech task.

The results show that the frequency of partial inhalations was significantly lower than that of inhalations, both in reading and spontaneous speech (reading: partial inh. = 7.81 %; inh = 92.19 %; spontaneous speech: partial inh = 11.41 %; inh = 88,59 %). While there was a slight increase in the occurrence of partial inspirations during spontaneous speech, although the difference was not statistically significant.

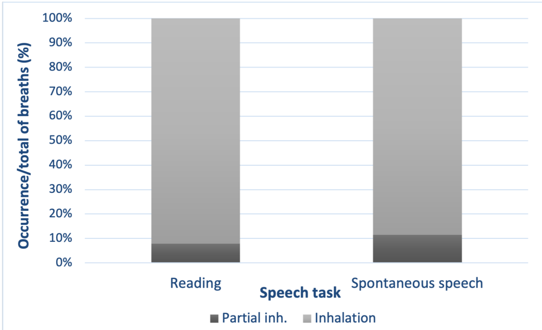

Figure 1: *Distribution of inhalations and partial inhalations according to speech task.*

Figure 2 displays the distribution of partial inhalations and inhalations according to their syntactic location in reading and spontaneous speech.

The results reveal that the majority of inspirations occurred between two major syntactic units, although there is a minor difference between major and minor units in reading.

Most of the partial inhalations were observed at the boundaries of the syntactic constituents, like the 'typical' inhalations. Only a small number of partial inhalations were non-syntactic. In reading, partial inspirations were slightly more frequent at the boundaries of minor syntactic units. On the other hand, in spontaneous speech, they were significantly more important at the boundaries of major syntactic units.

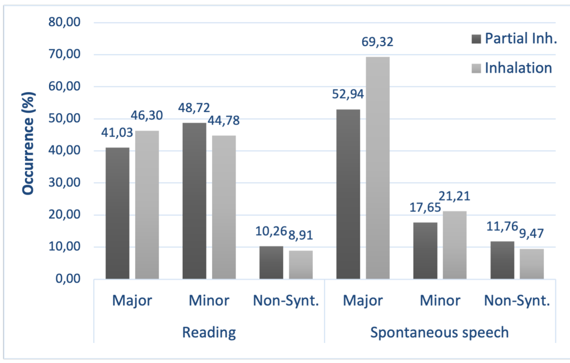

Figure 2: *Syntactic distribution of inhalations and partial inhalations according to speech task.*

3.2. Duration of inspiratory and breathing pauses

Figure 3 shows the distribution of inspiratory duration values in reading and spontaneous speech, according to their syntactic location.

In reading, the duration of inhalation tended to be longer when it occurred at the boundaries of major syntactic units (mean = 0.475 sec), but the difference was not statistically significant (minor = 0.367 sec; non-syntactic = 0.379 sec; p = 0.087). Generally, inspiratory duration was significantly higher in spontaneous speech ($F (1,21) = 36.5$; $p < 0.01$). Additionally, inspiratory movement was significantly longer when it performed outside of syntactic boundaries (non-syntactic = 0.653 sec, major = 0.641 sec; minor = 0.538 sec) ($F (1,21) = 24.707$, $p < 0.001$).

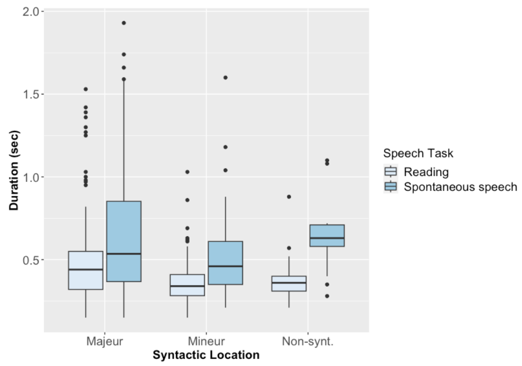

Figure 3: *Distribution of duration values of inhalation according to syntactic location and speech task.*

The duration of breath pauses followed similar patterns as the duration of inhalation, as shown in Figure 4.

In reading, the pause duration was longer when located between two major syntactic units (major = 0.682 sec; minor = 0.473 sec; non-syntactic = 0.509 sec; $p = 0.029$). In spontaneous speech, while the duration of pauses at major boundaries was longer than that of pauses at the ends of minor syntactic units (major = 1.134 sec; minor = 0.808 sec; $p = 0.006$), they were shorter than non-syntactic breath pauses (mean = 1.239 sec), consistent with the observations made for the duration of inhalation.

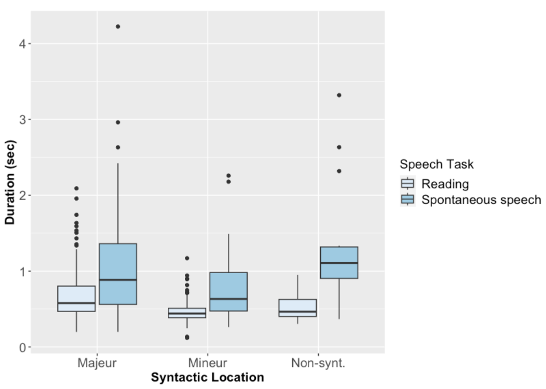

Figure 4: *Distribution of duration of breathing pauses according to syntactic location and speech task.*

Then, we computed the ratio of inspiratory duration to breath pause duration (figure 5).

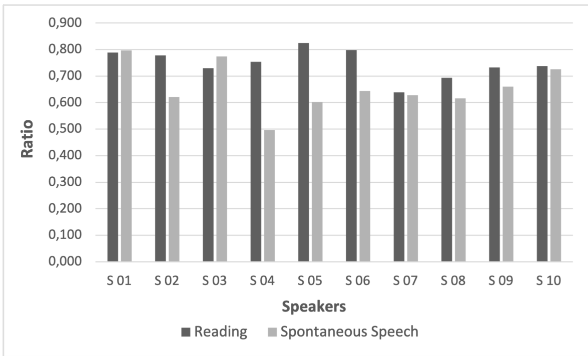

Figure 5: *Ratio of the duration of inhalation to the total duration of the respiratory pause according to the speech task.*

The duration of inspiration relative to the total duration of the respiratory pause was lower in spontaneous speech (reading = 0.732; spontaneous speech = 0.659). Nevertheless, figure 5 shows a inter-individual variability regarding the duration of the pause, suggesting a diversity of strategies operated by the speakers. Although the ratio of duration of inspiration to duration of pause was more important in reading for the majority of speakers, the opposite tendency was observed for others in spontaneous speech.

3.3. Analyses of non-breathing pauses

This section of the study investigates the respiratory behavior during non-breathing pauses. During some non-breathing pauses, the speaker stopped a rib cage closure, leading to stagnant respiratory curves. The blockage of chest may extend throughout part or the entire duration of the pause. On average, the duration of chest blockage accounted for 80% of the total pause duration. Therefore, we consider a non-breathing pause with chest blockage (NBP-B) as a pause in which expiratory flow is stopped for at least 80% of the total pause duration.

The non-breathing pauses characterized by a momentary stop of rib cage closure account for 20.67% of all non-breathing pauses.

Figure 6 illustrates the percentage of non-breathing pauses with (NBP-B) and without arrest of chest closure (NBP).

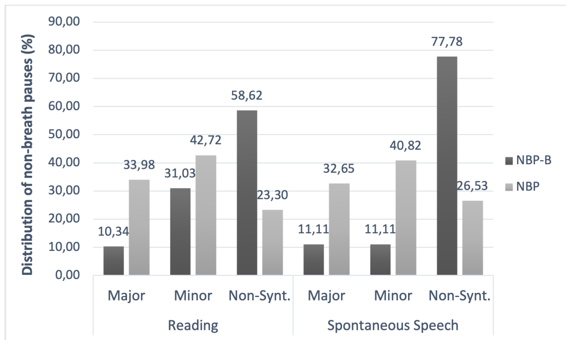

Figure 6: *Distribution of non-breathing pauses with rib cage blocking (NPB-B) and without (NPB), according to the syntactic location and speech task.*

Chest blocking occurred mainly during non-syntactic pauses in both reading (58.62%) and spontaneous speech (77.78%). In reading, 31.03% of non-breathing pauses with ribcage blocking occurred at the boundaries of minor syntactic units. In contrast, in spontaneous speech, there were relatively few pauses with blocking observed at the syntactic unit boundaries.

Non-breathing pauses without ribcage blocking were primarily observed at the boundaries of minor constituents in both reading and spontaneous speech.

4. Discussion

The results obtained provide valuable insights into the organization of respiratory patterns in children with the observation of particular breathing behavior. They also offered new perspectives of research in this area.

In our study, we have considered the presence of 'partial' inspirations, as described by Weston [10]. If these partial inspirations were fewer in number compared to 'typical' inspirations, they were observed in both reading and spontaneous speech. Contrary to the initial hypothesis proposed by Weston [10], these partial inspirations were not systematically associated with hesitation phenomena. Instead, they predominantly occurred at syntactic boundaries, indicating their integration within the child's breathing patterns. Moreover, all of our speakers exhibited at least one partial inspiration during reading and/or spontaneous speech, further suggesting their regular occurrence in children's respiratory behavior during speech production.

Considering the presence of partial inspirations in the study of breathing in speech is important in order to understand the respiratory strategies implemented by speakers, whether in a context of typical speech or of speech disturbances, both natural or pathological. In addition, further investigation into the realization of these inspirations in a larger number of speech types or in the context of speech disorders could provide valuable insights into the emergence of these partial inspirations.

The duration of inhalation, as well as the overall duration of pauses, were longer in spontaneous speech. The higher cognitive-linguistic demands associated with spontaneous speech exerts an influence on the duration of the respiratory movements. Additionally, in spontaneous speech, non-syntactic breaths and pauses are significantly longer than those occurring at the boundaries of syntactic units. The increased cognitive-linguistic demands, and the consequent rise of planning time, may lead to a slowing of the inspiratory movements.

The increase in cognitive-linguistic demands affected not only the duration of inhalation but also the overall duration of pauses. The ratio of the inspiratory duration to the total duration of the pause indicated that the pause was not solely dedicated to inhale both in reading and spontaneous speech. It also appears that, in spontaneous speech, the duration of inhalation relative to the total pause duration tends to be shorter compared to reading. Consequently, the lengthening of the breathing pause in spontaneous speech was not only due to the slowing down of the inspiratory gesture. The speakers used this inspiratory time to plan the upcoming utterance or to search for words, and the other way round.

If the duration of inhalation to the duration of pause was shorter in spontaneous speech than reading, we have observed the opposite phenomenon in some speakers. Indeed, the inhalation time during the pause was lower during reading. This decrease could be due to hesitations related to decoding errors occurring during reading.

The manual verification of the delimitation of inspirations revealed that the beginning and end of an inspiration could be perfectly aligned with the delimitation of the pause. Indeed, for a significant number of respiratory pauses, the inspiration starts at the end of the previous breath group, coinciding with the end of the last sound emitted, and its end corresponds to the resumption of phonation. These findings were consistent with previous research conducted by Godde et *al*. [4].

The thoracic and abdominal breathing behaviors during non-breathing pauses was ignored in literature. However, understanding thoraco-abdominal behaviors during these pauses would contribute to a better understanding of breath control phenomena in speech. Some non-breathing pauses are characterized by the cessation of thoracic cage closure. As expected, the majority of these pauses are non-syntactic. These data suggest the influence of cognitive-linguistic demands on the expiratory movement control during pauses. Chest blocking during a pause can be used as an indicator of elevated cognitive activity, potentially resulting from increased planning effort or encoding error in reading.

Finally, these data encourage us to approach breathing not as a biphasic phenomenon, corresponding only to inhalation and exhalation, but as a process that can involve intermediate phases characterized by a momentary pause in rib cage compression.

The study of respiratory behavior during non-breathing pauses should be further investigated, particularly by considering additional measures such as the amplitude of expiratory movement during a non-breathing pause, or the speed of chest closure during the pause in comparison to the speed of the exhalation per syllable, for example. Such data, alongside an electroglottograph, would provide an overview of the synchronization of respiratory and laryngeal movements. Specifically, it would be necessary to determine whether the blockage of the thoracic cage during the pause concerns only the subglottic respiratory level, or if it is accompanied by a vocal folds closure, or laryngeal obstruction, as in apnea. These data would enhance our understanding of the control of breathing in speech. Moreover, these data would also hold clinical interest for the treatment and rehabilitation of individuals with dysarthria, stuttering, or speech disorders in children.

5. Conclusions

In conclusion, this study highlights the importance to consider new approaches in investigating of speech breathing. Although we have not yet identified the factors behind the emergence of 'partial' inhalations in speech, it appears that these inhalations are incorporated into the respiratory patterns of our speakers. These data should be further verified with a larger panel of children as well as with adults. Additionally, while the speech task and syntactic location did not significantly affect lung volume management, they did influence the duration of inhalation, with the movement slowing down as the cognitive-linguistic demands increased. Finally, we sporadically observed the arrest of rib cage closure, indicating a temporary interruption of the thoracic and abdominal gestures. These blockages occurred mainly during non-syntactic pauses, potentially reflecting heightened cognitive and planning activity. Furthermore, considering the influence of cognitive-linguistic demands on the respiratory control, we suggest that these breathing behaviors could be observed in adults.

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