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Identification and discrimination tasks in auditory and visual perception of linguistic and non-linguistic stimuli

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Abstract

The importance of temporal processing related to age and schooling is explored in this study. The primary goal is to examine the discrimination (same/different) and identification (Temporal Order Judgment) tasks in 334 proficient reading primary school students from first to fifth grade. In this vein, linguistic and non-linguistic stimuli in auditory and visual modalities were used. Results suggest that the tasks' performance has a linear trend regardless of the stimuli and modality. They also reveal that the performance of the tasks is similar in the auditory-non-linguistic stimuli, but in the rest, the Temporal Order Judgment (TOJ) task required more time than the Same/Different task (S/D). The most difficult task was the auditory-linguistic TOJ task. In sum, the identification and discrimination process across the grades seems to be different. The linguistic stimuli seem to show differences throughout primary school grades, but only auditory stimuli reveal an association between tasks and grades.

Keywords: discrimination; identification; reading; temporal processing; visual perception; auditory perception

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Tareas de identificación y discriminación en la percepción auditiva y visual de estímulos lingüísticos y no lingüísticos

Resumen

En este estudio se explora la importancia del procesamiento temporal en relación con la edad y la escolarización. El objetivo principal es examinar las tareas de discriminación (igual/diferente) e identificación (Juicio de Orden Temporal) en 334 estudiantes de primaria de primero a quinto grado que dominan la lectura. Para ello, se utilizaron estímulos lingüísticos y no lingüísticos en las modalidades auditiva y visual. Los resultados sugieren que el rendimiento de las tareas tiene una tendencia lineal independientemente de los estímulos y la modalidad. También revelan que el rendimiento de las tareas es similar en los estímulos auditivos-no lingüísticos, pero en el resto, la tarea de Juicio de Orden Temporal (JOT) requirió más tiempo que la tarea de Igual/Diferente (I/D). La tarea más difícil fue la tarea JOT auditivo-lingüística. En resumen, el proceso de identificación y discriminación en los distintos grados parece ser diferente. Los estímulos lingüísticos parecen mostrar diferencias a lo largo de los grados de primaria, pero sólo los estímulos auditivos revelan una asociación entre tareas y grados.

Palabras clave: discriminación; identificación; lectura; procesamiento temporal; percepción visual; percepción auditiva

Tarefas de identificação e discriminação na percepção auditiva e visual de estímulos linguísticos e não linguísticos

Resumo

Este estudo explora a importância do processamento temporal em relação à idade e à escolaridade. O objetivo principal é examinar as tarefas de discriminação (igual/diferente) e identificação (Julgamento de Ordem Temporal) em 334 alunos da primeira à quinta série do ensino fundamental que são proficientes em leitura. Para isso, foram usados estímulos linguísticos e não linguísticos nas modalidades auditiva e visual. Os resultados sugerem que o desempenho na tarefa tem uma tendência linear independente dos estímulos e da modalidade. Eles também revelam que o desempenho da tarefa é semelhante para estímulos auditivos e não linguísticos, mas para os demais, a tarefa de Julgamento de Ordem Temporal (JOT) exigiu mais tempo do que a tarefa de Igual/Diferente (I/D). A tarefa mais difícil foi a tarefa JOT auditivo-linguística. Em resumo, o processo de identificação e discriminação nas diferentes séries parece ser diferente. Os estímulos linguísticos parecem mostrar diferenças entre as séries primárias, mas somente os estímulos auditivos revelam uma associação entre tarefa e série.

Palavras-chave: discriminação; identificação; leitura; processamento temporal; percepção visual; percepção auditiva

Introduction

When we read, we have to handle both auditory and visual input very quickly. However, linguistic or non-linguistic stimuli using visual or auditory modalities are extremely complex to process by the brain due to the rapid segmentation and integration of different features extracted from each stimulus. This process can be assessed through two tasks: identification and discrimination, which are different processes. As Mody et al. (1997) explain, identifying a stimulus denotes assigning it a specific response, such as pressing a certain button or saying its name. In turn, discriminating stimuli consists of designating that they are different in some respects. Identification, therefore, involves discrimination, but not vice versa. In this train of thought, if we use Temporal Order Judgment (TOJ), discrimination alone will not be enough: identification will be required. If we only use a discrimination task, errors will have ambiguous meanings unless we have independent evidence of correct identification. The difficulty is obvious from the standard format of the TOJ test in which pairs of stimuli (1,2) are presented in different combinations: 1-1, 2-2, 1-2, 2-1. We must take into account that errors of reversal belong to an error of temporal order; meanwhile, errors of the same stimuli are judged as different, or different stimuli are judged as the same, those errors being of identification.

The importance of studies on reading is undeniable. If we want to assess the reading ability in-depth, we have to become aware of the importance of these two concepts. Reading is an achievement of the human being, it accounts for cognitive, cultural, and artistic developments. It is the basis for gaining knowledge of different areas and an essential skill in academic settings, and social interaction, and it is even a key to job success (Klein, 2002). It is difficult to know the origin of the problems that some children present with reading. Overall, problems with reading have been attributed to phonological deficits, and at the same time, some researchers attribute phonological deficits of reading in disabled children to an impaired rate of temporal perception (Vuorinen, 2000). Phonological processing refers to the processing of speech sound, comprising sub-word level lexical units down to phonemes, the smallest meaningful constituents of speech.

However, it is relevant to point out that this approach has been criticized precisely in the concepts mentioned above. Specifically, about linguistic auditory stimuli, Mody and Brady (1997) reported that the difficulties in the identification of temporal changes stem from a deficit in discriminative capacity, not in the temporal processing of acoustic phenomena in general. The deficit in dyslexia is a specific domain and reflects struggles with identifying the phonological categories of speech sounds that resemble one another. To analyze this point of view, Ortiz et al. (2014) examined whether the perceptual phonological deficit in children with dyslexia is explained by a temporal processing deficit with a design that controls the demands of the task and linguistic complexity. In this study, thirteen children with dyslexia and phonological deficits and 13 age-matched normal readers were assessed on Temporal Order Judgment tasks (TOJ) and Same/Different discrimination tasks (S/D). The tasks were based on contrasts between the syllables /ba/-/da/ and / fa/-/la/. They analyzed the effects of the complexity of stimuli (similar versus dissimilar) and tasks (Temporal Order Judgment tasks versus discrimination tasks). The children with dyslexia showed lower performance than

the control group in both pairs of syllables. Children with dyslexia performed significantly worse on the TOJ tasks compared to the control group, but there were no differences between groups in the S-D tasks. These findings highlight the speech perception processing issues in children with dyslexia.

Taking into account the above-mentioned difficulties, the use of both tasks is interesting in the sense that the comparison between them facilitates the study of the temporal processing pure effect (Mody et al., 1997; Ortiz et al., 2014; Tallal & Piercy, 1973). This design has been employed by some researchers focused exclusively on children with reading difficulties. In this regard, linguistic and non-linguistic stimuli in visual and auditory modalities have been examined separately in most of the investigations. In each of them, stimuli have had different features related to the duration of the auditory stimuli or visual stimuli's screen time; thus, input stimuli are not comparable across studies. For example, some studies have centered on auditory-linguistic stimuli (Luque et al., 2011; Ortiz et al., 2014) , auditory-non-linguistic stimuli (Cestnick & Jerger, 2000) , and visual-non-linguistic stimuli (Ison & Korzeniowski, 2016; Skottun & Skoyles, 2010) . Others have evaluated the auditory modality with linguistic and non-linguistic stimuli (Luque et al., 2008; Mody et al., 1997; Muñetón-Ayala et al., 2017) . Yet, studies evaluating both processes in visual and auditory modalities with linguistic and non-linguistic stimuli are scarce (e.g., Ortiz et al., 2014).

Ortiz et al. (2014) examined visual and auditory perception in children at risk of developing dyslexia. They compared preschool children's performance in auditory and visual TOJ and S/D tasks, these participants being not at such risk. Identical visual,auditory-linguistic, and non-linguistic stimuli were presented in both tasks. As a general result, they described a temporal auditory and visual processing deficit in both types of stimuli in children at risk in comparison to those without risk. However, those researches do not address the question of the development of the identification and discrimination processes in primary school.

In sum, the literature showed that most of the research that uses the tasks of discrimination and identification focused exclusively on children with reading difficulties, and those processes are underexplored in individuals without reading difficulties through primary school.

This Study

As mentioned above, studies on discrimination and identification problems have so far been limited in the sense that all the participants report reading difficulties. Due to the lack of evidence on how these processes develop in typical primary school readers, it was of interest to explore them further. Hence, the main objective of this study was to investigate the role of identification and discrimination tasks in auditory and visual modalities of linguistic and non-linguistic stimuli throughout primary school. More precisely, this study allowed examining whether discrimination and identification processes develop in the same way in terms of speed and developmental stages. In this vein, this research used Temporal Order Judgment (TOJ) tasks to assess identification processing and Same/Different (S/D) tasks to assess discrimination processing. One advantage of this study is that the stimuli for both tasks were identical; thus, the comparison of the tasks showed the effect of temporal processing in a more realistic way,

as discussed later.

Based on previous research, better performance for S/D tasks than TOJ tasks in auditory and visual modalities in both kinds of stimuli in each grade was predicted. Two questions were raised:

1. Is the evolution of the S/D tasks similar to the TOJ tasks' evolution in primary school?

In order to answer this question, the trend development of each task was analyzed, and based on this , the developmental stages were identified.

2. Is the development of the tasks dependent on primary school grades?

To answer this question, a two-factor (i.e., grade/task) repeated-measure multivariate analysis of variance was done in each modality and stimulus.

Method

Participants

Three hundred thirty-four students attending public and private schools between first and fifth grades in Medellín (Colombia) participated in the study. All the participants were native speakers of Spanish and had not had any reading difficulty during their education according to their teachers' criteria. Previously, the teachers had taken part in a semi-structured interview to identify students without reading difficulties based on speed and accuracy . Also, parents had consented to their children's participation in the study,[1] according to the Declaration of Helsinki.

Measurements

Psychometric Parameters

General cognitive abilities are involved in the development of literacy (Alloway & Alloway, 2010) as well as in the execution of temporal processing tasks. Thus, relations between temporal processing and literacy might be mediated by these general cognitive abilities. To isolate temporal processing abilities from broader factors, assessments of general intelligence, attention, and memory were conducted and used as covariates for psychometric purposes.The descriptive data of the groups is shown in Table 1.

1 This was approved by the Ethics Committee of Antioquia University (Comité de Bioética de la Facultad de Medicina; see protocol code 022).

Table 1 *Mean and Standard Deviation per Age, IQ, Memory, and Attention by Groups*

	1° n=49		*2° n=61*		*3° n=55*		*4° n=82*		*5° n=85*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age	*5.96*	*.57*	*7.13*	*.64*	*8.11*	*.56*	*9.17*	*.75*	*9.94*	*.64*
IQ	*104.69*	*14.62*	*98.31*	*9.98*	*96.27*	*10.78*	*98.84*	*13.79*	*100.09*	*13.43*
Attention	*.30*	*.47*	*.77*	*.18*	*.73*	*.25*	*.79*	*.20*	*.79*	*.18*
Memory	*8.96*	*2.42*	*11.03*	*2.19*	*12.18*	*2.02*	*13.05*	*2.39*	*13.32*	*2.19*

Source: own elaboration

General intelligence was measured with the G Factor (Cattell & Catell, 2001), making it possible to assess general intellectual ability through non-verbal tasks. Due to the age range used in the sample, two different scales were used. On one hand, Scale 1 was employed with children aged between four and eight. The subtests applied were substitution, identification, labyrinths, and similarities. On the other hand, Scale 2 (form A) was used with schoolchildren from eight to fourteen 14 years of age. The subtests applied for this scale were series, classification, matrices, and conditions.

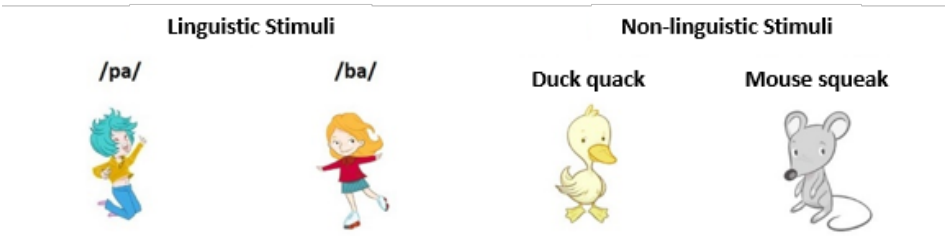
Likewise, the Magallanes Scale of Visual Attention (EMAV) was considered to measure attention (Magaz et al., 2011). Again, two different scales were used. EMAV-1 was employed with children aged between five and eight; in turn, EMAV-2 was used with nine-year-old students and older.

Lastly, the Wechsler Intelligence Scale for Children Digits Subtest (WISC-IV, Wechsler, 2005) was used to measure short-term auditory memory and working memory, thus ruling out problems of this type. In this task, the girl or boy repeated a series of numbers that the evaluator presented verbally. The test started with two digits and increased by one digit until there were two consecutive failures. One series was repeated in the same order, and another series, in reverse order.

Perceptive Processing Stimuli and Tasks

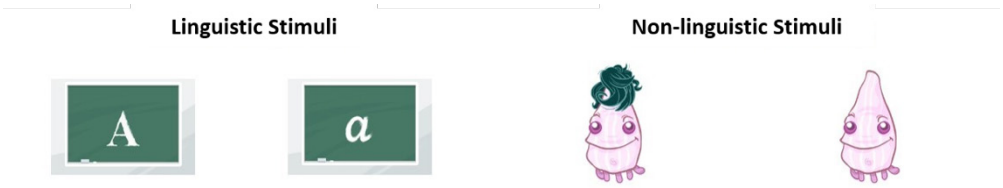
This study used the PRAVI test (Estévez et al., 2011): a validated computer program that evaluates identification and discrimination processes (Muñetón-Ayala et al., 2022). It has Temporal Order Judgment and Similar/Different Tasks. In this research, each of these tasks used auditory (see Figure 1) and visual (see Figure 2) modalities with linguistic and non-linguistic stimuli.

Figure 1 *Images of Linguistic and Non-linguistic Visual Stimuli*



Source: own elaboration

Figure 2 *Images of Linguistic and Non-linguistic Visual Stimuli*



Source: own elaboration

The stimuli used were identical for both tasks. For both modalities, the stimuli each had a 200-millisecond duration and appeared consecutively separated by intervals of 50 ms. Therefore, the PRAVI test had eight tasks, four for TOJ and four for S/D; these tasks were auditory-linguistic, auditory-non-linguistic, visual-linguistic, and visual-non-linguistic, respectively.

The auditory stimuli were matched in intensity. Linguistic stimuli were two spoken CV syllables that differed in voicing (/pa/-/ba/); those were studio recordings of a female voice. Non-linguistic stimuli were a mouse squeak (470 Hz) and a duck quack (260 Hz). In turn, the visual-linguistic stimuli were capital "A" and lowercase letter "ɑ," and the visual-non-linguistic stimuli, two stimuli that differed only in the presence or absence of one visual feature.

Overall, first, the relation between the responses and the different keys (L or S) was established in each task; afterward, example trials were presented to children to learn how to execute the task correctly; finally, participants advanced to the evaluation stage. This test was validated (Muñetón-Ayala et al., 2022) and indicated its suitability for identification and discrimination processes.

In each task, an AX paradigm was presented where participants heard or saw stimulus A followed by a second stimulus X after a 50 ms ISI. Specifically, in the discrimination task (S/D), the second stimulus could be the same as the first one or different. The participants had to indicate whether the two stimuli were identical or different. In the TOJ identification task, the second stimulus was different from the first one. The children had to point out the stimulus presented in the first place. For both tasks, responses were given by pressing a pre-specified key (L or S).

Procedure

A clinical experimental psychologist and ten psychology practitioners conducted all the tests. There were five sessions. In the first one, the psychometric tests were applied. The rest of the sessions, in which the PRAVI tasks were implemented, were tested individually in a quiet room in the participants' school. Each PRAVI session lasted approximately 20–30 minutes.

Data Analysis

To achieve the research aims of this study, different statistical methods were used. A trend analysis was applied to meet the first research aim. In doing so, such an analysis led to checking

whether the auditory and visual-linguistic and non-linguistic stimuli increased per course and whether such an increase was similar or not in all the tasks. Since the number of samples was uneven between the courses, the Games-Howell Pairwise Comparison Test was computed. Furthermore, analysis of covariance was introduced to evaluate and test the difference between both tasks in each modality and type of stimulus while controlling for IQ, attention, and memory. The latency time to correct responses was average for each task.

Results

First, the developmental pattern in each task was observed through a trend analysis; then, to statistically test for differences between the S/D and TOJ task responses in each grade, a MANOVA analysis was conducted.

Trend Analysis

Linguistic Stimuli

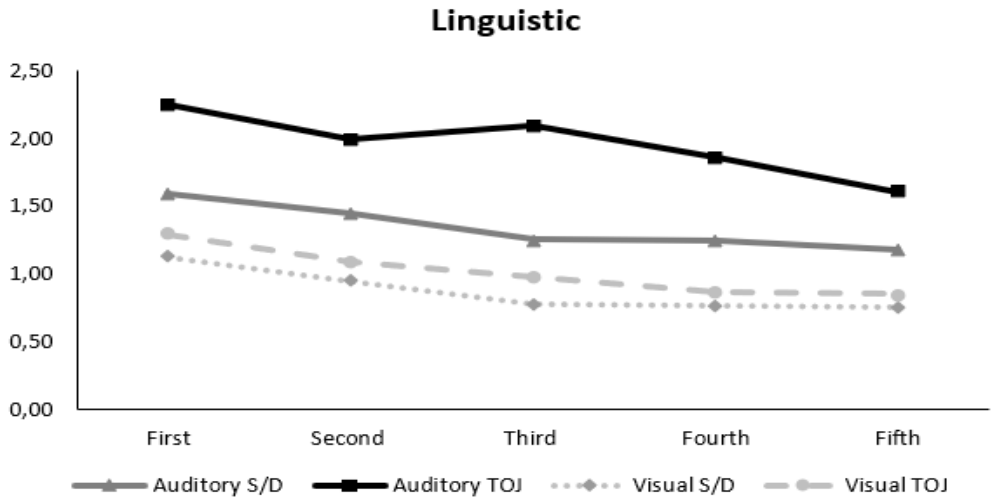
In the first set of analyses, a linear trend analysis was done across groups per task separately. This analysis showed a linear trend using the average calculated for each task: Auditory S/D $F(1,316) = 44.78$, $p < .001$; Visual S/D $F(1,317) = 69.58$, $p < .001$; Auditory TOJ $F(1,317) = 22.92$, $p < .001$; Visual S/D $F(1,326) = 64.12$, $p < .001$. Games-Howell correction for pos-hoc comparison was used to assess the statistical significance of the differences between group pairs in each task (see Table 2 and Figure 3).

Table 2 *Significant Levels (P Values) in the Differences between Groups in the Linear Trend Analysis Regarding Auditory and Visual Modalities in S/D and TOJ Tasks with Linguistic Stimuli*

	Auditory	*Visual*	*Auditory*	*Visual*
	S/D	*S/D*	*TOJ*	*TOJ*
	P	*P*	*P*	*P*
1 vs. 2	*.331*	*.037*	*.481*	*.094*
1 vs. 3	*.001*	*.001*	*.901*	*.001*
1 vs. 4	*.001*	*.001*	*.094*	*.001*
1 vs. 5	*.001*	*.001*	*.001*	*.001*
2 vs. 3	*.096*	*.004*	*.961*	*.463*
2 vs. 4	*.027*	*.001*	*.863*	*.004*
2 vs. 5	*.001*	*.001*	*.013*	*.002*
3 vs. 4	*.100*	*.999*	*.530*	*.218*
3 vs. 5	*.755*	*.978*	*.007*	*.130*
4 vs. 5	*.590*	*.993*	*.126*	*.998*

Source: own elaboration

Figure 3 *Mean Performance of Children in Auditory and Visual Modalities per Task with Linguistic Stimuli*



Source: own elaboration

Non-linguistic Stimuli

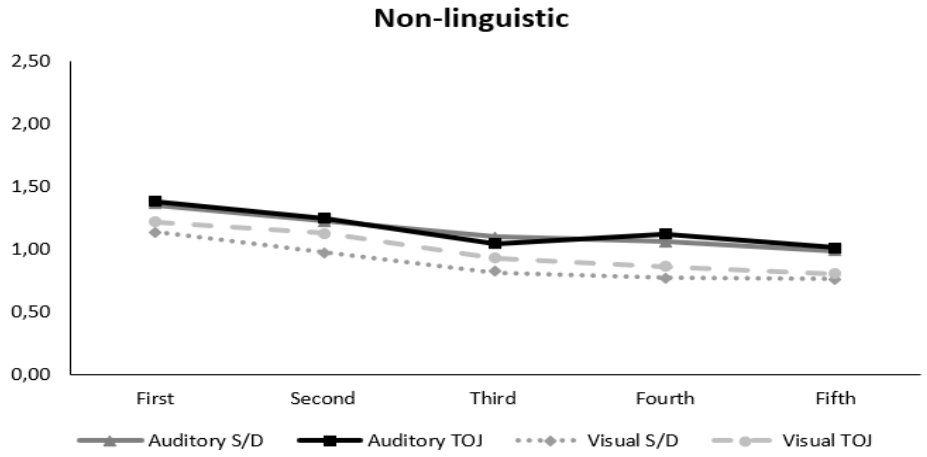
This analysis showed a linear trend using the average weighted for each task: Auditory S/D F (1,320) = 46.69, p < .001; Visual S/D F (1,325) = 71.20, p < .001; Auditory TOJ F (1,325) = 23.42, p < .001; Visual S/D F (1,324) = 64.67, p < .001. Games-Howell correction for post-hoc comparison was used to assess the statistical significance of the differences between group pairs in each task (see Table 3 and Figure 4).

Table 3 *Significant Levels (P Values) in the Differences between Groups in the Linear Trend Analysis Regarding Auditory and Visual Modalities in S/D and TOJ Tasks with Non-linguistic Stimuli*

	Auditory S/D	*Visual S/D*	*Auditory TOJ*	*Visual TOJ*
	P	*P*	*P*	*P*
1 vs. 2	*.290*	*.048*	*.574*	*.745*
1 vs. 3	*.006*	*.001*	*.003*	*.002*
1 vs. 4	*.001*	*.001*	*.021*	*.001*
1 vs. 5	*.001*	*.001*	*.001*	*.001*
2 vs. 3	*.396*	*.056*	*.118*	*.024*
2 vs. 4	*.035*	*.001*	*.478*	*.001*
2 vs. 5	*.001*	*.001*	*.014*	*.001*
3 vs. 4	*.977*	*.851*	*.862*	*.684*
3 vs. 5	*.334*	*.770*	*.992*	*.193*
4 vs. 5	*.389*	*.999*	*.461*	*.811*

Source: own elaboration

Figure 4 *Mean Performance of Children in Auditory and Visual Modalities per Task with Non-linguistic Stimuli*



Source: own elaboration

Differences between Tasks

There were significant differences between groups, such as, memory function (F (4,328) = 37.47, p < .000), attention (F (4,327) = 32.13, p < .000), and IQ (F (4,328) = 3.17, p < .014). A correlation of Pearson analysis was used to determine the strength of the association between these variables and the dependent variables (S/D and TOJ tasks). Results show that there was a significant correlation between the tasks and attention and memory, so they were employed as covariates (See Table 4).

Table 4 *Pearson Correlations between the Task and the IQ, Attention, and Memory Variables.*

Task	*Stimuli*	*IQ*		*Attention*		*Memory*	
Time in ms		*r*	*p*	*r*	*p*	*r*	*p*
S/D	*Auditory-linguistic*	*-.10*	*.071*	*-.20*	*.001*	*-.25*	*.001*
	Visual-linguistic	*-.08*	*.110*	*-.18*	*.001*	*-.29*	*.001*
	Auditory-non-linguistic	*-.11*	*.051*	*-.16*	*.003*	*-.24*	*.001*
	Visual-non-linguistic	*-.09*	*.094*	*-.15*	*.004*	*-.26*	*.001*
TOJ	*Auditory-linguistic*	*.01*	*.835*	*.09*	*.100*	*-.18*	*.001*
	Visual-linguistic	*-.06*	*.231*	*-.06*	*.222*	*-.22*	*.001*
	Auditory -non-linguistic	*-.05*	*.351*	*-.05*	*.350*	*-.22*	*.001*
	Visual-non-linguistic	*-.02*	*.619*	*-.17*	*.002*	*-.22*	*.001*

Source: own elaboration

Linguistic Stimuli

Two-factor repeated measure multivariate analysis of variance was used to examine the effects of Group (1 vs. 2 vs. 3 vs. 4 vs. 5) per Task (TOJ vs S/D) in each Modality (visual vs.

auditory) for every reaction time.

In the auditory modality, there was an interaction between the two factors F (4,304) = 2.56, p < .011, ηp2 = 0.04. The TOJ task performed poorer than S/D in each grade, as follows: first grade F (4,304) = 40.43, p < .001, ηp2 = 0.11; second grade F (4,304) = 25.96, p < .011, ηp2 = 0.08; third grade F (4,304) = 75.70, p < .001, ηp2 = 0.20; fourth grade F (4,304) = 57.02, p < .001, ηp2 = 0.16; fifth grade F (4,304) = 31.75, p < .001, ηp2 = 0.10 (See Table 5).

Table 5 *Mean and Standard Deviation in Linguistic and Non-Linguistic Stimuli in Auditory and Visual Modalities per School Grade*

		Linguistic stimuli				*Non-linguistic stimuli*			
		Auditory Modality		*Visual Modality*		*Auditory Modality*		*Visual Modality*	
Grades		*S/D*	*TOJ*	*S/D*	*TOJ*	*S/D*	*TOJ*	*S/D*	*TOJ*
First	*M*	*1,59*	*2,25*	*1,12*	*1,29*	*1,35*	*1,38*	*1,14*	*1,22*
	SD	*0,38*	*0,89*	*0,32*	*0,43*	*0,31*	*0,48*	*0,30*	*0,41*
Second	*M*	*1,44*	*1,99*	*0,95*	*1,09*	*1,23*	*1,25*	*0,97*	*1,13*
	SD	*0,40*	*0,74*	*0,27*	*0,43*	*0,35*	*0,47*	*0,33*	*0,41*
Third	*M*	*1,25*	*2,09*	*0,77*	*0,97*	*1,10*	*1,05*	*0,82*	*0,93*
	SD	*0,40*	*0,88*	*0,23*	*0,31*	*0,40*	*0,43*	*0,28*	*0,34*
Fourth	*M*	*1,25*	*1,86*	*0,77*	*0,86*	*1,07*	*1,12*	*0,77*	*0,86*
	SD	*0,34*	*0,74*	*0,22*	*0,28*	*0,31*	*0,44*	*0,24*	*0,29*
Fifth	*M*	*1,17*	*1,60*	*0,75*	*0,85*	*0,99*	*1,01*	*0,76*	*0,81*
	SD	*0,30*	*0,62*	*0,24*	*0,28*	*0,25*	*0,38*	*0,24*	*0,29*
Total	*M*	*1,31*	*1,91*	*0,84*	*0,98*	*1,12*	*1,14*	*0,87*	*0,96*
	SD	*0,39*	*0,79*	*0,28*	*0,37*	*0,34*	*0,45*	*0,31*	*0,37*

Source: own elaboration

In the visual modality, there was a main effect of task F (1,312) = 64.26, p < .001, ηp2 = 0.17. Means' comparison showed that the TOJ task (0.98) always required more time than the S/D (0.84) task.

Non-linguistic Stimuli

Concerning auditory stimuli, there were no significant effects. In visual stimuli, the analysis showed that there were significant differences in task F (1,319) = 28.55, p < .001, ηp2 = 0.08. The means comparison indicated that the TOJ task (0.96) required always more time than the S/D task (0.87).

Discussion

The objective of this study was to investigate the role of identification and discrimination processes in auditory and visual modalities in linguistic and non-linguistic stimuli in normal readers from first to fifth school grades. In this vein, it addressed two issues. First, it analyzed

the trend development of the S/D and TOJ tasks in auditory and visual modalities in both kinds of stimuli. Second, it examined whether there were differences between the tasks through the above-mentioned school grades.

With regard to the first issue, results revealed that the stimuli followed a linear trend, where response time is reduced throughout primary school grades: 1) in auditory and visual-linguistic stimuli in S/D task from 1,59 to 1,17, and from 1,12 to 0,75, respectively; 2) in auditory and visual-linguistic stimuli in TOJ task from 2,25 to 1,60, and from 1,29 to 0,85, respectively; 3) in auditory and visual non-linguistic stimuli in S/D task from 1,35 to 0,99, and from 1,14 to 0,76, respectively; 4) in auditory and visual non-linguistic stimuli in TOJ task from 1,38 to 1,01, and from 1,22 to 0,81, respectively. The data suggest that the performance of the processes increased along with the grades and had a similar trajectory. These results agree with studies that have found that older children in upper-school grades have higher performance and shorter times for perceptual tasks than younger children (Domínguez, 2017; Gallegos, 2010).

Additionally, participants consistently spent more time on the auditory-linguistic TOJ task across different grades compared to other tasks. However, this task showed the most significant reduction in response time from first to fifth grades (0.64). This is perhaps because auditory temporal processing is related to the phonological process in this developmental stage. Hence, an advance in reading skills requires an advance in temporal auditory processing (Dominguez, 2017).

In general, related to the linguistic stimuli, it was observed that young children (from first and second grades) had a lower discrimination and identification level than the rest of them, except for auditory-linguistic TOJ tasks, which showed a different pattern. Specifically, the auditory-linguistic S/D task led to two stages: one of them from first to third grades and another one from second to fifth grades. The same pattern was displayed in the visual-linguistic TOJ task. In the visual-linguistic S/D task, changes were faster, and again, two stages were identified: one from first to second grades and another between second and fifth grades. Finally, the development of the auditory-linguistic TOJ task is slower than the remaining tasks. The first change was observed between first and fifth grades; the second one, from second to fifth grades; and the last one, from third to fifth grades.

In summary, the findings show that performance improved significantly up to third grade. Likewise, these indicate that there was no significant improvement except for the auditory-linguistic TOJ where the performance enhanced in fourth grade. Regarding the last result, some studies have pinpointed that children with reading problems perform lower than those without any, with the same chronological age (Muñetón-Ayala et al., 2021; Ortiz et al., 2014; Rey et al., 2002); but they do not differ from children without reading problems with the same reading level in the auditory temporal processing (Chung et al., 2008; King et al., 2008; Muñetón-Ayala et al., 2021). This is interesting because it can be interpreted in terms of the idea that improvement in auditory temporal processing could improve reading ability.

Concerning the second issue, whether there were differences between the tasks through primary school grades, overall, results reveal that the TOJ task is more difficult than the S/D task in linguistic and non-linguistic stimuli, except in auditory-non-linguistic stimuli, where

no significant effects were found.

The task distribution across the grades was not significantly different in the visual-linguistic and non-linguistic stimuli. This finding is brought up to reflect the differences in both tasks throughout the grades. Close inspection of the means in Table 5 reveals that the visual TOJ task required more time than the S/D task in each grade. Because this point is important for the discussion of the development of the processes, the T-test was computed comparing both tasks in each grade in linguistic and non-linguistic stimuli. Concerning linguistic stimuli, results show that there were significant differences in each grade (first grade: t (41) = -2.39, p >.021; second grade: t (59) = -3.06, p >.003; third grade: t (51) = -4.47, p >.001; fourth: t (80) = -3.48, p >.001; fifth: t (83) =-3.67, p >.001). This finding reflects the differences between the tasks in the development stage. In regard to visual non-linguistic stimuli, results indicate that there were no differences in first and fifth grade, but in second, third, and fourth grades there were differences (t (59) =-3.48, p >.001; t (51) =-2.31, p >.025; t (80) =-2.75, p >.007, respectively). This evidences a similarity between the tasks in the initial stage; then, there was a maturity process, and finally, both tasks reached a similar development stage.

Concerning the auditory-linguistic and non-linguistic stimuli, interestingly, data showed an interaction between task and grade only in auditory-linguistic stimuli, indicating that differences between the tasks are associated with the grades. Children spent significantly more time in the TOJ task than the S/D task in each grade, while, in auditory-non-linguistic stimuli, there were no significant differences as observed in Figure 4.

In sum, the identification and discrimination process across the grades seems to be different. The linguistic stimuli seem to show differences throughout primary school grades, but only auditory stimuli reveal an association between tasks and grades. Thus, its development looks as if it were grade-dependent. It makes sense because, as analysis showed before, auditory-linguistic stimuli seem to be related to phonological processes.

A remarkable aspect of perception is its automaticity; otherwise, linguistic identification and subsequent reading comprehension would not be possible (Belinchón et al., 2004; Steinbrink et al., 2014; Valle, 1992). In this way, based on the previous results, it is inferred that children are ready for reading comprehension after fourth grade. It is the moment in which children complete the development of the linguistic auditory temporal perception, which in turn, is related to the reading process.

General Conclusion

The importance of temporal processing related to age and schooling has been shown in this study. The data show the relevant participation of temporal processing in the process of reading, given that reading involves identifying, discriminating, and linking sounds in short segments of time. This fact and the temporal processing relationship with phonological processing may be on the basis of the phonological deficit and reading difficulties. This research shows that the TOJ task used here allows evaluating the temporal processing in different modalities and with different types of stimuli in the school population.

Limitations

The research carried out is not exempted from limitations that, however, can help propose better studies in the future that solve the problems found here: 1) Although a cross-sectional approach is undoubtedly useful, it needs to be completed with a longitudinal study through all primary education that includes participants from various geographic locations and cultural backgrounds. 2) It is necessary to compare the data obtained in this study with the development of individual phonological skills. 3) It would be necessary to analyze whether reading performance increases when children receive training in temporal processing. 4) It is necessary to minimize the differences between the different methodologies used in the field in order to advance the study of temporal processing and its relationship with reading development through primary education. 5) future research could include measures of reading performance to examine how temporal processing skills correlate with actual reading abilities and could incorporate more complex cognitive tasks to better reflect the challenges of reading and language comprehension.

Closing statements

Author Contributions. M.M-A., C.V. and A.E. made a contribution to the study design, data analysis and interpretation, and manuscript drafting and revising. M.M.-A. and C.V. participated in collecting data, coding and analysis, interpretation of the data, as well as manuscript revising. M.M-A., C.V. and A.E. made a contribution to the study design, interpretation of data, manuscript drafting and revising. All authors have read and agreed to the published version of the manuscript.

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