Doctorate Programme in Reading and Comprehension

Reading in students with deafness: An eye movement research

Lectura en estudiantes con sordera: Una investigación con movimientos oculares

DOCTORAL THESIS WITH INTERNATIONAL DOCTORATE MENTION

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mi abuelita y mi abuelito

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Preface

Hard of hearing and deaf students' ability to comprehend written language has improved throughout the last two decades. Yet, there is still much more work to do, as many deaf or hard of hearing students (DHH) still fail to achieve a chronological-age equivalent reading level. Indeed, this was one of the main conclusions drew at the second edition of the International Congress of Written Language and Deafness (Salamanca, 2019). In that Congress current findings were compared with those presented at the first edition of the Congress, twenty years ago. During that lapse of years, many things have changed. One is that some techniques such as eye-tracking, have widely spread and become more user-friendly than decades ago. Nowadays, eye-movements research appears promising for the study of reading as it allows to obtain information directly related to the moment-to-moment reading processing and therefore, makes it possible to tap-into the nature of the reading underachievement or success. In fact, it constitutes an innovative technique and on-growing field of research for studying developmental readers (Schroeder, Hyönä, & Liversedge, 2015).

The present **Thesis** aimed to explore the online reading pattern of students with deafness from 9 to 15 years. It is divided in three chapters: 1) Theoretical Framework (*Marco Teórico*), 2) Empirical Research and 3) General Discussion and Conclusions.

Chapter 1 (*Marco Teórico*) consists of an overview around the topic of reading and deafness. This chapter is divided in three sections. In the first one, we review the literature around the reading comprehension skills of students with deafness, moving from some classical studies (e.g., Conrad, 1979) up to the most recent studies involving students who recceived a cochlear implant at an early age. Then, we briefly explain how the reading comprehension in students with deafness is modulated by factors such as decoding ability, vocabulary and grammar, with particular emphasis on this latter factor, as grammatical processing is one of the core objectives of two experiments of the present **Thesis**. Subsequently, we introduce the reader to the eye-tracking technique and describe the measures commonly used in reading studies. Finally, we briefly present the few studies that relate to the particularities regarding the eye-movement pattern of students with deafness.

Chapter 2 (***Empirical Research***) contains the empirical body of this dissertation. A general methodology section is provided initially, followed by three eye-tracking studies.

The *General Methodology* section is offered in the first place as all the data from the three studies was obtained during a single testing protocol. Because of this procedure, almost the same sample took part in the three studies. We did it this way as it took a long time to find eligible participants for the **Thesis** and because assessments should adapt to the time constraints that involve young school children (e.g., some participants were available for collaborating only during vacations). We anticipated these difficulties during the recruitment process. Thus, we carefully designed the studies in such a way that they could cover the assessment of a wide range of reading related skills to describe the deaf or hard of hearing readers' profile. Within the participant and method sections of each study, we only report the particularities of the sample and procedure of each one.

Regarding our empirical studies, two of them addressed grammatical processing at sentence level (**Study 1** and **Study 2**) whereas the third one, investigated reading comprehension at whole text level (**Study 3**).

In **Study 1**, we compared the time course of grammatical processing between students with deafness and chronological-age matched typically hearing students by means of a grammatical judgment task. We explored the ability of DHH students to detect grammatical incongruences during sentence reading while their eye-movements, especially in the targets areas related to the grammatical incongruences, were monitored.

In **Study 2**, we aimed to examine the extent to which DHH students rely on semantic and syntactic cues during sentence interpretation in comparison to their chronological-age typically hearing peers. To do so, we used a sentence-picture-matching task in which students read sentences with different grammatical structures (most of them with a complex syntactic structure; e.g., passive sentences) and were asked to depict the correct response between pictures that included syntactic and semantic distractors. As a complement to the study, we analyzed the relationships between the online data with some offline measurements.

Study 3 was conceived from a more general perspective. This study explored the eye-movement pattern at text level (not isolated sentences but short written narrative and expository texts). It reports and describes basic characteristics regarding the online reading behavior of students with deafness by using global eye-movements processing measures. We further explored how their reading pattern was modulated by factors such as text genre (narrative versus expository) or varied for each grammatical word class (function words versus content words). Additionally, in this study we examined the correlation of the online reading pattern with a range of individual skills underpinning reading (e.g., receptive vocabulary, working memory, etc.).

By the time of submitting the **Thesis**, **Study 1** has already been published and **Study 2** and **Study 3** have been submitted to peer-review journals so are under revision almost in the same form than they are presented in this **Thesis**.

The last chapter **(Chapter 3)** comprises a general discussion driven by considering the results from the three studies conjointly. Finally, we report the main conclusions, limitations, and practical implications of this research.

Chapter 1

General Introduction

- El Rendimiento lector en Niños y Adolescentes con Sordera: Breve repaso histórico

- Factores que determinan la Comprensión Lectora en Niños y Adolescentes con Sordera.

- El Estudio de la Lectura mediante Medidas de Movimientos Oculares.

1 | 1 El Rendimiento lector en Niños y Adolescentes con Sordera: Breve repaso histórico

La lectura constituye una de las principales vías de acceso al aprendizaje. Mientras que al inicio de la escolaridad el aprendizaje de la lectura es uno de los objetivos principales, la dirección de este objetivo se invierte paulatinamente a medida que se avanza hacia cursos superiores, cambiando el lema “aprender a leer” por el de “leer para aprender”.

Si bien, la importancia de la lectura va más allá del ámbito académico, siendo relevante en otros ámbitos como el socioeconómico y el personal.

En el plano socioeconómico, por ejemplo, los economistas señalan al nivel educativo de un país como un importante predictor de crecimiento económico (Coulombe, Tremblay y Marchand, 2004 citado por OECD, 2017). En el plano personal, la lectura facilita el acceso a la información, constituye un medio de entretenimiento (e.g., lectura de novelas), socialización (e.g., redes sociales) y de participación en aspectos cotidianos de la vida diaria (e.g., comprender las instrucciones de funcionamiento de un electrodoméstico, entender un prospecto médico). Sin ir más lejos, durante el confinamiento por COVID-19, los adultos españoles e italianos han aumentado significativamente el tiempo de lectura semanal, especialmente la lectura recreativa y de noticias, con respecto a antes del confinamiento (Salmerón et al., en prensa). Además, también tiene un papel relevante en el acceso y progreso en el mercado laboral (e.g., uso profesional de la lectura, OECD, 2017). De hecho, los adolescentes ya identifican durante su etapa escolar algunos de estos beneficios. Por ejemplo, de acuerdo con el reciente informe de Hábitos de Lectura y Compra de Libros en España (Federación de Gremios de Editores de España [FGEE], 2019), la gran mayoría de estudiantes adolescentes (entre 10-14 años) reconocen la lectura como una herramienta clave para su futuro laboral, estando de acuerdo en afirmar que “leer les ayudará a encontrar un mejor trabajo en el futuro”.

Sin embargo, cabe matizar que en estas afirmaciones está implícito el hecho de que cuando hablamos de la lectura no sólo nos referimos a la capacidad del estudiante para “descifrar” el código escrito, sino que además incluimos dentro del concepto la habilidad para *comprender*, esto es, aludimos a la *comprensión lectora*. Es en este último constructo (la comprensión lectora) en el que se centrará la **Tesis**.

Una vez puesta en contexto la importancia de la lectura en la vida social y académica de los individuos en general, nos centramos en la población con sordera, que ha sido objeto de estudio en diversas investigaciones por lo que refiere a la comprensión lectora en virtud de diferentes razones que iremos desgranando a lo largo de este capítulo.

El estudio de Conrad (1979) constituye uno de los trabajos clásicos que informan acerca del bajo rendimiento lector en estudiantes con sordera. Entre sus hallazgos destaca el bajo porcentaje de alumnos con sordera que logran alcanzar un nivel de lectura funcional a la edad de 15-16 años. Durante décadas, otros estudios se han hecho eco de estas dificultades, corroborando que el bajo rendimiento lector en alumnado con sordera no solo es evidente, sino que persiste a lo largo (e incluso más allá) de la escolaridad. Destacaremos a continuación algunos de estos trabajos.

En un estudio a gran escala, Wolk y Allen (1984) evaluaron la comprensión lectora de 1664 estudiantes de EE.UU. con sordera en dos periodos de tiempo con un intervalo de 5 años. Al igual que la mayoría de los estudios a gran escala realizados con población sorda estadounidense, se sirvieron de los resultados en distintas versiones adaptadas para alumnado con sordera del Stanford Achievement Test (Test Standford en adelante), una prueba ampliamente utilizada en este país para obtener información sobre el rendimiento en diversas habilidades académicas. En particular, Wolk y Allen (1984) observaron que los estudiantes con sordera mejoraban su nivel de comprensión lectora con mayor lentitud respecto a los estudiantes normoyentes. Los progresos producidos en 5 años por alumnado con sordera correspondían únicamente a un tercio de la mejora en comprensión lectora observada en los estudiantes normoyentes.

Por su parte, Allen (1986) reportó que el nivel promedio de competencia lectora de los estudiantes con sordera de 15 años era aproximadamente 6 cursos inferior al de los estudiantes normoyentes. El sentido de estos resultados seguía corroborándose a través de más estudios con el paso del tiempo. Por ejemplo, partiendo nuevamente de los resultados en el Test Standford de 6500 estudiantes con pérdida auditiva de 8 a 20 años, Holt (1993) expuso que el rendimiento de alumnado con sordera de 17 años era equivalente en promedio al de alumnado normoyente de 4º curso de Primaria. A una conclusión similar llegaron otros estudios (e.g., Allen, 1994 [citado por Parault y Williams, 2010]; Holt, Traxler y Allen, 1997). Más adelante, Traxler (2000) proporcionó datos normativos de 4808 estudiantes con sordera entre 8 y 18 años con la novena edición del Test Stanford (Harcourt Educational Measurement, 1996). Los estudiantes que participaron en su estudio tenían sordera prelocutiva de grado entre severo y profundo en su mayoría. Nuevamente, los resultados constataban un "estancamiento" de la competencia lectora en habilidades propias de 4º curso de Primaria. Únicamente la mitad de los estudiantes con sordera que finalizaban la escolaridad obligatoria entre 15-18 años disponían a esas edades de un nivel de lectura funcional, si consideramos como tal un dominio lector propio de un alumno normoyente de entre 11-12 años.

Los hallazgos a partir de participantes españoles han mostrado una tendencia similar a la expresada por los trabajos recién citados. En este contexto se enmarca el estudio de Asensio (1989) (citado por Asensi, 2004) donde, a partir de una muestra de 106 escolares con sordera de 1er curso de Primaria a 2º curso de Secundaria, se observaba que el rendimiento en comprensión lectora de los estudiantes con sordera de 2º curso de Secundaria no era superior al de estudiantes normoyentes de 3[er] curso de Primaria. Algo más tarde, Villalba, Ferrer y Asensi (1999) observaron que en población con sordera adulta que aspiraba a cursar estudios universitarios mediante vías de acceso extraordinarias para personas mayores, se observaban niveles de compresión lectora muy alejados de los referidos por estudiantes normoyentes.

De esta forma, en consonancia con los resultados de otros estudios (e.g., véase para una revisión Qi y Mitchell, 2012[1]), la competencia lectora de los estudiantes con sordera ha estado durante décadas caracterizada por un estancamiento o "efecto techo" (*glass ceiling* [Easterbrooks y Beal-Alvarez, 2012]), siendo su nivel de compresión lectora equivalente al de estudiantes normoyentes de 4º curso de Primaria.

Si bien, cabe considerar con relación a las dos últimas décadas que los continuos avances en el ámbito sanitario (screening universal neonatal), tecnológico (audífonos digitales, implante coclear), terapéutico y educativo (estimulación temprana) han hecho posible que las personas con sordera dispongan de un acceso al input auditivo de forma temprana que era impensable años atrás. Esta situación ha generado altas expectativas en el ámbito educativo, donde se esperaba que las personas con sordera alcanzaran un nivel de consecución de hitos de lectura superior al reportado en estudios previos. Así, los resultados parecen ser algo más positivos en la actualidad. Algunos estudios han demostrado que el nivel lector de los estudiantes con sordera va más allá del "efecto techo" tradicionalmente reportado (Easterbrooks y Beal-Alvarez, 2012), de manera que se han observado resultados más favorables, muchos de ellos ligados a población equipada con implante coclear. Ejemplo de ello es el estudio realizado por Mayer, Watson, Archbold, Yen y Mulla (2016) en que el 75% de participantes con sordera de 9 a 16 años (todos ellos usuarios de implante coclear) obtuvo resultados acordes a la media de población normoyente en comprensión lectora.

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[1] En la revisión llevada a cabo por Qi y Mitchell se reportan gráficamente los resultados de comprensión lectora obtenidos por los estudiantes con sordera en el Test Stanford en estudios a gran escala publicados entre los años 1974-2003.

No obstante, otros estudios como el de Edwards, Aitkenhead y Langdon (2016) indican que el nivel de comprensión lectora de los estudiantes con sordera con implante coclear de 12 a 18 años todavía resulta inferior en promedio al de los estudiantes normoyentes, lo que sugiere que las diferencias en comprensión lectora todavía persisten en muchos casos a pesar de las mejoras protésicas.

Uno de los factores que puede explicar el desacuerdo entre estudios es la disparidad del grado de pérdida auditiva que se observa en los participantes con sordera, así como el tipo de ayuda protésica o edad de implantación en el caso de implantes cocleares (IC en adelante). Algunos estudios reportan un mejor dominio de la comprensión lectora en estudiantes equipados con IC frente a aquellos estudiantes con sordera sin IC (Rezaei, Rashedi y Morasae, 2016; Vermeulen, van Bon, Schreuder, Knoors y Snik, 2007). Estos resultados más favorables se observan especialmente en casos donde la implantación se ha llevado a cabo de manera temprana, no más allá de entre los 2-3 años (Domínguez, Pérez y Alegría, 2012; Figueroa, Darbra y Silvestre, 2020; Guerzoni et al., 2020; Sarant, Harris y Bennet, 2015).

Sin embargo, no es posible afirmar que recibir un IC de manera temprana asegure per se el desarrollo de un nivel de comprensión de textos acorde a la edad cronológica (Marschark, Sarchet, Rhoten y Zupan, 2010; Barajas, González-Cuenca y Carrero, 2016). Es cierto que la evidencia científica apunta hacia resultados más positivos (próximos a los normoyentes) en comprensión lectora para estudiantes con IC temprano. Por ejemplo, Sarant et al. (2015) observaron que gran parte de los participantes con sordera (un 67% que se correspondía con los implantados precozmente) demostraban un rendimiento en habilidades lectoras similar al de sus iguales normoyentes, mientras que el 33% restante que no contaba con esta característica exhibía un rendimiento por debajo de lo esperado para su edad cronológica. Sin embargo, los datos que se obtienen en diferentes estudios aconsejan matizar el efecto positivo de la implantación precoz sobre la comprensión lectora pues no se cumple en un porcentaje considerable de los casos.

Mayer y Trezek (2018) realizaron una revisión de los estudios llevados a cabo entre 1997 y 2016 que proporcionaban información sobre el nivel de comprensión lectora de estudiantes con sordera equipados con IC. De la revisión se concluyó que los resultados obtenidos en comprensión lectora en los estudiantes con IC representaban una mejora sustancial respecto al panorama presentado décadas atrás, obteniéndose en algunos casos resultados próximos a los niveles de lectura de estudiantes normoyentes. Sin embargo, los autores destacan dos aspectos que no han de ignorarse: 1) existe todavía una gran variabilidad en el rendimiento de los estudiantes con IC en las tareas que evalúan comprensión lectora y lenguaje; 2) los resultados próximos a los normoyentes en muchos casos no se mantienen en cursos superiores.

Un ejemplo de la variabilidad a la que aluden Mayer y Trezek, es el estudio de Mathews y O'Donell (2020). En él, los autores registran el nivel en decodificación (mediante lectura de pseudopalabras) y la comprensión lectora de 40 niños con pérdida auditiva (21 de grado severo y profundo, 15 de ellos equipados con IC). Los resultados en ambas áreas reflejaron la gran variabilidad interindividual de la población con sordera. En el caso de las habilidades de decodificación se obtuvo puntuaciones estándar inferiores a 65 y puntuaciones superiores a 130. Algo similar ocurrió con la comprensión lectora, donde las puntuaciones estándar oscilaron entre 70 y 125. El hecho de que se incluyeran estudiantes con distintos grados de sordera (desde leve a profunda) y distinto equipamiento podría llevar a plantear al investigador si las puntuaciones de los estudiantes con IC podrían situarse en el límite superior o inferior del rango de resultados.

Según sugieren los resultados de algunos estudios, la variabilidad parece estar condicionada por factores que trascienden el tipo de prótesis y el momento de colocación del

IC. Por ejemplo, Harris y Terlektsi (2011) evaluaron la competencia en lectura de palabras y en habilidades relacionadas con la comprensión lectora (e.g., comprensión de sintaxis y vocabulario) en 86 estudiantes con sordera divididos en tres grupos en función del tipo de ayuda auditiva (IC vs. audífono) y del momento de adaptación del IC (temprano vs. tardío). Los autores observaron una gran disparidad de puntuaciones en los tres grupos. El rango y la desviación típica en los tres casos fueron amplios. Mientras que las puntuaciones de algunos estudiantes superaban lo esperado para su edad cronológica, en otros casos el rendimiento se situaba sustancialmente por debajo de la media. Los resultados de este último estudio corroboran la variabilidad inherente a esta población.

Otro factor relevante que considerar cuando se juzgan los avances actuales en competencia lectora de los estudiantes con sordera comparado con los estudiantes normoyentes es el relativo al mantenimiento del nivel a lo largo de los años. Diversos estudios reflejan cómo las dificultades en competencia lectora de los estudiantes con sordera se incrementan a medida que los estudiantes avanzan en su escolaridad. Por ejemplo, Harris, Terlektsi y Kyle (2017) evaluaron en tres momentos (con un año de diferencia) lectura de palabras y comprensión lectora con un grupo de 41 niños (de 5 a 7 años) con sordera prelocutiva de grado profundo. Los participantes diferían en el equipamiento protésico, de manera que 22 de ellos estaban equipados con IC y el resto (19) con audífonos. Los participantes procedían de entornos comunicativos diversos: mientras que algunos utilizaban la lengua de signos (37%), otros se comunicaban principalmente mediante lengua oral (44%) y otros utilizaban ambos (lengua de signos y lengua oral, 19%). El rendimiento fue comparado con el de un grupo de 32 niños normoyentes de 5 a 6 años. Por lo que refiere a los resultados, los escolares normoyentes mejoraron anualmente tanto en lectura de palabras como en comprensión lectora. En cambio, los estudiantes con sordera mejoraron la lectura de palabras, pero no se observó un cambio en los resultados en comprensión lectora entre la segunda y tercera evaluación. Dicho con otras palabras, en un periodo de un año los estudiantes con sordera no progresaron en el dominio de la comprensión lectora.

La manera en que las dificultades en comprensión lectora de los estudiantes con sordera se mantienen o aumentan a lo largo de la escolaridad ha sido documentada en estudios que recogen medidas de distintos cursos.

Recientemente, Antia et al. (2020) evaluaron mediante un estudio longitudinal las habilidades lingüísticas y lectoras (comprensión de frases entre ellas) de un grupo de 336 niños con pérdida auditiva de entre 5 y 9 años. Los participantes procedían de tres cursos académicos distintos (preescolar, 1º curso de Primaria y 2º curso de Primaria) y fueron evaluados dos veces en el mismo curso escolar (en primavera y en otoño). Se realizaron tres grupos en función de la modalidad comunicativa de preferencia (e.g., oral, lengua de signos y bimodal). Los resultados indicaron que las habilidades de comprensión lectora se distanciaban más de las de los normoyentes conforme se avanzaba en curso escolar. El efecto se observó en los tres grupos, independientemente de la modalidad comunicativa. De esta forma, los estudiantes que asistían a 2º curso de Primaria obtuvieron puntuaciones estándar significativamente inferiores respecto a las obtenidas por los estudiantes en preescolar, con una diferencia próxima a 16 puntos en el caso de aquellos estudiantes que únicamente se comunicaban mediante lenguaje oral (97 preescolar vs. 81 en 2º curso de Primaria).

En el caso de la etapa de Educación Primaria, Rezaei et al. (2016) evaluaron las habilidades lectoras de 48 estudiantes de 2º y 3er curso de Primaria con sordera profunda ($n=24_{IC}$; $n=24_{\text{audífonos}}$) y las compararon con un grupo de estudiantes normoyentes del mismo curso académico. Respecto a los resultados, se observó que los estudiantes normoyentes de 3º de Primaria obtenían resultados significativamente superiores a los estudiantes de 2º curso de Primaria en todas las habilidades lectoras evaluadas (lectura de palabras, lectura de pseudopalabras y comprensión lectora en palabras y textos). Sin embargo, en el caso de los estudiantes con sordera únicamente se percibió tal mejora en lectura de palabras, mientras que no se observó un aumento en el rendimiento en comprensión lectora y lectura de pseudopalabras en los alumnos de 3º curso de Primaria respecto a los de 2º curso.

Existe evidencia adicional con muestra española. Recientemente González-Cuenca, Lavigne-Cerván y Prieto-Cuberos (2020) analizaron el rendimiento académico en lectura y en matemáticas de un grupo de 46 niños españoles con sordera prelocutiva de grado severo a profundo con edades entre 6-13 años. Los participantes pertenecían a diferentes niveles de Educación Primaria y estaban equipados con audífonos bilateralmente (*n*=22) o con IC unilateral (*n*=24). Se obtuvo medidas que reflejaban el rendimiento académico, incluyendo de manera independiente el rendimiento en comprensión auditiva, comprensión lectora, expresión oral y expresión escrita mediante cuestionarios dirigidos a profesores. De los resultados cabe destacar que, en el caso de la comprensión lectora, el porcentaje de alumnos con sordera que obtenía un rendimiento inferior al de alumnos normoyentes aumentaba a lo largo de la escolaridad. En concreto, durante el 1er ciclo de Primaria (de 6 a 8 años) el 42% de los participantes con sordera tenían un rendimiento en comprensión lectora inferior al de los estudiantes normoyentes, este porcentaje se incrementaba en 2º Ciclo (de 8- 10 años) hasta un 64% y en 3º Ciclo (10-12 años) alcanzaba el 75%.

En un estudio longitudinal, Geers, Tobey, Moog y Brenner (2008) evaluaron en dos momentos (primero en 2º ciclo de Primaria y posteriormente en Secundaria) las habilidades lectoras de un grupo de 85 estudiantes con sordera en su mayoría prelocutiva (*n* = 66) equipados con IC. La evaluación en lectura integraba una tarea de lectura de palabras y una tarea de comprensión lectora de frases. De los resultados cabe destacar que, aunque en Secundaria el 44% de los estudiantes con sordera alcanzaron puntuaciones adecuadas para su edad cronológica, las puntuaciones estándar obtenidas en esta etapa (*z*=83) fueron significativamente inferiores a las obtenidas en la evaluación previa en Educación Primaria (*z*=88). Este decremento en el rendimiento lector comparado se observó en un 60% de los casos de estudiantes con sordera. En cuanto al resto de los participantes con sordera, un 20% mejoraron sus puntuaciones respecto a las obtenidas en Educación Primaria y el otro 20% mejoraron su rendimiento en comparación a los estudiantes normoyentes.

Otros estudios añaden evidencia sobre el retraso que se observa en secundaria a pesar de las mejoras protésicas. Harris y Terlektsi (2011) evaluaron la lectura de 86 estudiantes de 12 a 16 años con sordera prelocutiva con unos umbrales de pérdida superiores a 85dB, documentando que incluso los estudiantes con IC temprano obtenían resultados por debajo de los esperados para su edad cronológica en comparación con normoyentes.

En el caso de población española, Moreno-Pérez, Saldaña y Rodríguez-Ortiz (2015) evaluaron mediante una tarea de comprensión de frases la eficiencia lectora (velocidad de lectura y comprensión) de 27 estudiantes con sordera prelocutiva de severa a profunda, gran parte de ellos estudiantes de Educación Secundaria con una edad media de 14 años. La mayoría de los participantes se comunicaban mediante el lenguaje oral y, en general, estaban equipados con audífonos; únicamente 9 participantes eran usuarios de IC. Los resultados de los estudiantes con sordera fueron significativamente inferiores a los obtenidos por un grupo de estudiantes normoyentes equiparados en edad cronológica.

Las diferencias en comprensión lectora entre estudiantes adolescentes con sordera y normoyentes observadas a partir de frases se trasladan de modo lógico al plano de la comprensión de textos, tal y como apuntan Figueroa et al. (2020). Nuevamente, los resultados ponen en evidencia que el rendimiento lector de los estudiantes con sordera es inferior al de estudiantes normoyentes con una edad cronológica similar. No obstante, este estudio encontró un efecto positivo del uso temprano de prótesis en comprensión de textos pues cuando dividieron los grupos según la edad de implantación, no observaron diferencias entre los estudiantes normoyentes y los estudiantes con sordera e IC temprano.

Por lo que refiere a estudiantes con sordera y estudios superiores (e.g., universitarios), las dificultades en el dominio de la comprensión lectora continúan estando presentes. Actualmente existe un porcentaje de adultos con sordera que obtienen un buen rendimiento lector, si bien hay otros que, a pesar de alcanzar estudios postobligatorios todavía manifiestan dificultades impidiéndoles avanzar en su formación académica. A esta problemática aludían Villalba et al. (1999) que analizaron el dominio en comprensión lectora de 16 estudiantes universitarios con deficiencia auditiva, la mayoría prelocutiva (*n*=9) y con un grado de pérdida severo a profundo (*n*=12). A su vez, evaluaron a 7 personas con sordera profunda que no habían logrado, a pesar de intentarlo, acceder a la universidad. Los resultados de ambos grupos fueron comparados con el de 16 estudiantes normoyentes. Los estudiantes universitarios con deficiencia auditiva obtuvieron resultados similares al grupo de participantes normoyentes en comprensión lectora de textos. En cambio, el otro grupo de personas con deficiencia auditiva obtuvo resultados significativamente inferiores a los estudiantes normoyentes. De esta forma, parecía evidente que el bajo dominio lector era uno de los factores decisivos que dificultaba el acceso a niveles de formación superior a algunas personas con deficiencia auditiva.

Más recientemente, Domínguez, Carrillo, Pérez y Alegría (2014) evaluaron las estrategias de lectura de 26 adultos con sordera prelocutiva profunda usuarios de lengua de signos española que habían alcanzado estudios postobligatorios (formación profesional en algunos casos, estudios universitarios en otros), observando que un 65,38% de los participantes con sordera con estudios superiores no habían alcanzado un nivel lector equivalente a 5º o 6º curso de Primaria en normoyentes. Resultados similares obtuvieron Parault y Williams (2010), los cuales reportaron que el nivel de comprensión lectora de 24 estudiantes universitarios con sordera residentes en EE. UU. (2 de ellos graduados), equivalía en promedio al de estudiantes normoyentes de 11 años. A pesar de los estudios citados, la evidencia disponible es limitada;

se requiere de estudios que describan con qué nivel de comprensión lectora llegan los estudiantes con sorderas prelocutivas y con IC a estudios postobligatorios.

En resumen, a pesar de la mejora llevada a cabo en las últimas décadas en detección y atención temprana, así como en la del equipamiento protésico, la población con sordera (ya sean o no usuarios de ICs) continúa exhibiendo dificultades para alcanzar un nivel de comprensión lectora acorde a su edad cronológica. Algunos estudiantes con sordera pueden haber logrado alcanzar un nivel próximo al de sus iguales normoyentes (especialmente aquellos que reciben un IC de manera temprana) (e.g., Figueroa et al., 2020; Guerzoni et al., 2020, Sarant et al., 2015), pero se observa una clara variabilidad en los resultados tanto por lo que refiere a la comprensión lectora (Mathews y O'Donnell,2020; Mayer y Trezek, 2018) como a los beneficios en el rendimiento lector que pudiera derivar del tipo y momento de equipamiento protésico (Marschark et al., 2010). Mientras que algunos estudios sugieren que los estudiantes con IC en algunos casos obtienen resultados en lenguaje y en lectura próximos a lo esperable para su edad cronológica (e.g., Mayer et al., 2016; Sarant et al., 2015) otros informan todavía de un bajo nivel respecto a los normoyentes (e.g., Barajas et al., 2016; Edwards et al., 2016; Rezaei et al., 2016). Además, la distancia en aptitudes lectoras tiende a incrementarse con la edad en cuanto se compara con la de normoyentes (Antia et al., 2020; Domínguez et al., 2014; Geers et al., 2008; González-Cuenca et al., 2020; Moreno-Pérez et al., 2015; Rezaei et al., 2016). La documentación científica ha analizado esta cuestión tanto estudiando habilidades directamente relacionadas con el proceso lector (i.e., decodificación), como estudiando la manera en que el desarrollo del lenguaje (e.g., fonología, léxico y gramática) influye en el dominio de la comprensión lectora. Conocer los factores que explican las dificultades en comprensión lectora se convierte en condición necesaria para dar respuesta en aquellos casos cuyos resultados son sustancialmente inferiores a lo esperable para su edad cronológica. La manera en que estos factores influyen en la comprensión lectora de los estudiantes con sorderas prelocutivas de grado severo a profundo se desarrollará en el siguiente apartado.

1 | 2 Factores que determinan la Comprensión Lectora en Niños y Adolescentes con Sordera.

El “modelo” o concepción simple de la lectura (*Simple View of Reading*, Gough y Tunmer, 1986; Hoover y Gough, 1990) define la comprensión lectora (L) como el producto de dos factores: la decodificación (D) y la comprensión del lenguaje (C) (D x C = L). Esto implica que la comprensión lectora no será posible o se verá afectada en caso de que el lector carezca o tenga dificultades en una de las dos habilidades (manteniendo el paralelismo con la fórmula matemática planteada, cuando uno de los dos elementos es “0”, el resultado también lo es). Este planteamiento ha sido ampliamente utilizado en la investigación en lectura, ya que describe de una manera sencilla el concepto *comprensión lectora*.

Si bien, aunque útil, el planteamiento no es perfecto. Una de sus limitaciones es que el lenguaje oral y escrito, salvada la decodificación, no son exactamente iguales (ver revisión de Cain, 2010). El lenguaje escrito es permanente mientras que el oral es temporal, los lectores pueden volver atrás en el texto, pero no en el discurso oral; en el lenguaje oral hay más claves no verbales que en el lenguaje escrito, el vocabulario en el texto escrito suele ser más rico y variado que en el lenguaje oral y, por último, las estructuras sintácticas, así como la longitud oracional, suelen ser más complejas en el discurso oral que en el escrito.

Por otro lado, Castles, Rastle y Nation (2018), critican la falta de precisión del Modelo Simple de Lectura al no describir en detalle algunos conceptos y al no explicar cómo los procesos cognitivos participan en esta ecuación, destacando la naturaleza multifacética de la comprensión lectora. Según estos autores, la comprensión lectora quedaría definida como “the orchestrated product of a set of linguistic and cognitive processes operating on text and interacting with background knowledge, features of the text, and the purpose and goals of the reading situation” [el producto orquestado de un conjunto de procesos lingüísticos y cognitivos que operan a nivel de texto e interaccionan con el conocimiento previo, las características del texto y la intención y objetivos de la situación de lectura.] (Castles et al.,2018, p.28). Más acorde con esta definición estarían los modelos de representación de textos que entienden que los lectores construyen una representación dinámica o modelo mental del texto más que una simple descripción de este como son la Teoría de Modelos Mentales de Johnson-Laird (1983) y el Modelo de Construcción e Integración de Kintsh (1998). Según este último, la comprensión de textos implica dos fases: construcción e integración. Durante la fase de construcción, se activan los significados de las palabras, se forman las proposiciones[2] y se realizan inferencias necesarias para generar coherencia local (se consigue cuando los significados de oraciones adyacentes se pueden conectar entre sí). Durante la fase de integración, se realizan inferencias para establecer la coherencia global del texto entendida como el momento en el que el significado de las oraciones se conecta entre sí y con un tema general, para lo cual se incorpora información recuperada de la memoria a largo plazo de los lectores (conocimiento general y experiencia).

Este proceso de comprensión-integración no es lineal sino cíclico y requiere que el lector lea, relea, vuelva atrás, active sus conocimientos previos y genere inferencias recursivamente. Como veremos al describir el **Estudio 3** de la presente **Tesis**, tal proceso puede quedar reflejado en medidas de procesamiento on-line cuando se usa el texto completo como unidad de análisis.

[2] El significado del texto se expresa como una lista estructurada de proposiciones. Nos referimos a las proposiciones como las unidades mínimas que aportan significado dentro del texto. Cada proposición incluye un predicado y uno o más argumentos. Los argumentos de cada proposición cumplen con varias funciones por ejemplo la de agente u objeto. En un texto, las proposiciones se presentan siguiendo una secuencia lógica (Kintsch y Van Dijk, 1978).

No obstante, pese a sus limitaciones, el marco teórico que propone la concepción simple de la lectura resulta tremendamente útil para describir, a grandes rasgos, el rendimiento lector de los estudiantes con sordera (Antia et al., 2020). Más allá de las típicas diferencias interindividuales, la ponderación que adquiere cada factor puede ser bien distinta cuando se trata de comparar el caso de estudiantes normoyentes y el de estudiantes con sordera ya que estos últimos cuentan con déficits evidentes en el acceso y desarrollo del lenguaje oral a causa de la deficiencia sensorial auditiva. De este modo, el resultado de ese producto, la competencia lectora, vendrá mucho más determinada por la calidad de acceso al lenguaje oral, o al lenguaje en general (vía incluso la lengua de signos, véase por ejemplo Alegría y Domínguez, 2009) [3], que tenga cada caso de sordera.

La especificidad del desarrollo lector en niños con sordera puede apreciarse bien a través de estudios como el de Nittrouer, Caldwell, Lowenstein, Tarr y Holloman (2012) en el que se analizaron las habilidades que predecían el dominio lector en 27 niños con sordera severa-profunda equipados con IC y 17 escolares normoyentes que acababan de finalizar la etapa de educación infantil. En el caso de los niños normoyentes, el vocabulario expresivo fue la variable que mejor explicó la varianza en comprensión lectora. En cambio, en el grupo de niños con sordera las variables que explicaron mayor parte de la varianza de los resultados en comprensión lectora fueron las habilidades narrativas, la comprensión auditiva y la rapidez de denominación. Este estudio ilustra cómo la predicción del rendimiento en comprensión lectora de los estudiantes normoyentes puede ser completamente diferente en comparación a cómo se configura para el caso de la sordera donde no necesariamente tienen idéntico poder explicativo

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[3] Por ejemplo, tanto la lengua de signos como el lenguaje oral proporcionan al niño la base lingüística en términos de léxico para el desarrollo de la lectura. Es decir, ambas constituyen un soporte semántico y conceptual para la lectura. No ocurre así con otras dimensiones lingüísticas (fonología y morfosintaxis), donde la relación lengua de signos y lengua escrita es discutible. Esta última afirmación requeriría de un extenso debate si bien, dado que no es el objetivo, no se abordará en la presente **Tesis**. Para una revisión invitamos a la lectura del trabajo llevado a cabo por Alegría y Domínguez (2009).

las mismas variables. A lo largo de este capítulo se expondrá la manera en que ambos factores (decodificación y comprensión del lenguaje) se relacionan con la comprensión lectora en estudiantes con sordera. Cabe insistir en que, a pesar de su ineludible importancia, no se ha considerado el papel de la lengua de signos en nuestra revisión de la literatura. De esta forma, en gran parte de las secciones hemos limitado la extensión de la **Tesis** doctoral a literatura que principalmente hiciera referencia a población más afín a la incluida en el trabajo empírico, es decir, población con sordera que se comunica principalmente mediante lenguaje oral, evitando que la **Tesis** resultara excesivamente extensa. En cada sección se sintetizará la relación entre el factor o nivel lingüístico correspondiente y la comprensión lectora en los niños normoyentes. Seguidamente, se desarrollará la evidencia existente en torno a cómo dicho factor interacciona con la comprensión lectora en alumnado con sordera.

De acuerdo con Alegría y Domínguez (2009), y en sintonía con la concepción Simple de Lectura, entendemos por *aspectos específicos de la lectura* aquellos que implican exclusivamente mecanismos de identificación de la palabra escrita. Por ejemplo, la capacidad de conectar letras y fonemas para decodificar una palabra y acceder a su significado es una habilidad que se pone en práctica únicamente durante la lectura. Por otra parte, constituyen *aspectos no específicos de la lectura* aquellas habilidades lingüísticas generales que permiten no solo el acceso al significado de una palabra sino también a la comprensión de frases y textos presentados de manera oral. Es decir, para comprender una frase se requiere, entre otras habilidades, entender el significado, disponer de un conocimiento previo acerca del contenido del tema a tratar, saber establecer las relaciones entre las palabras que componen la frase (morfología y sintaxis) y conocer los elementos pragmáticos que la integran. En caso de no disponer de los recursos necesarios, la comprensión de la frase puede verse afectada tanto de manera oral como escrita. Los aspectos no específicos afectan por tanto a la comprensión en ambos contextos (oral y escrito), son necesarios para la comprensión del lenguaje, pero no son exclusivos (o específicos) de la lectura. En consonancia con las edades y el contenido empírico de la **Tesis**, trataremos de forma más amplia el dominio del léxico y la sintaxis por lo que refiere a los aspectos no específicos de la lectura y daremos un mínimo repaso a las habilidades discursivas.

1|2 .1 Aspectos Específicos de la Lectura: Decodificación

De acuerdo con Castles et al. (2018), entendemos por decodificación el proceso mediante el cual el lector transforma los grafemas en fonemas. Si precisamos un poco más la definición, el término *decodificación* haría referencia a la habilidad del lector para reconocer palabras descontextualizadas, y no solo a la capacidad para simplemente verbalizar los sonidos que representan los grafemas, pues tal y como señalan Gough y Tunmer (1986), esta última habilidad se consideraría una forma más primitiva o inicial de decodificación. En consecuencia, las habilidades de decodificación podrían evaluarse mediante la lectura de palabras (Hoover y Gough, 1990) o pseudopalabras (Gough y Tunmer, 1986) aisladas de contexto.

Evidentemente, la fonología es uno de los motores que guían el proceso de decodificación. En el caso del lector con desarrollo típico, acceder al código escrito implica ser capaz de analizar la palabra a nivel fonémico y así enlazar la representación fonológica de la palabra con la representación escrita de la misma (Domínguez, Alegría, Carrillo y González, 2019). Si bien, aunque el desarrollo de la fonología sea condición *sine qua non* para la adquisición de la lectura en el estudiante con desarrollo típico, tal y como sugiere la concepción simple de lectura la decodificación en ausencia de la comprensión del lenguaje carecería de sentido. Así, por ejemplo, un lector de origen hispánico con buenas habilidades de decodificación podrá reproducir de manera oral la frase en finés: “et voi käyttää puhelinta luokassa” pero a menos que comprenda el vocabulario y la gramática del finés, no logrará entender su significado (que no se le permite utilizar el teléfono en clase).

El papel que las habilidades de decodificación ejercen en la comprensión lectora en lectores normoyentes varía en función de diversos factores como la etapa de lectura o el nivel de escolaridad. De este modo, sabemos que la relación entre decodificación y comprensión lectora decrece a medida que se avanza en escolaridad, mientras que la relación entre habilidades lingüísticas y comprensión lectora aumenta en etapas superiores (Castles et al., 2018; Ripoll, Aguado y Castilla-Earls, 2014).

Otra variable que influye en el peso que juegan las habilidades de decodificación en la comprensión lectora es el grado de transparencia de la ortografía. De esta forma, en idiomas con ortografías más opacas como el inglés se ha observado que las habilidades de decodificación constituyen un fuerte predictor de la comprensión lectora en segundo curso de Primaria mientras que en idiomas con ortografías más transparentes (e.g., español, checo y eslovaco) el valor predictivo de las habilidades de decodificación es moderado (Caravolas et al., 2019).

Dado que la pérdida auditiva puede generar dificultades de acceso a la forma fonológica de las palabras, las habilidades de decodificación podrían constituir un factor todavía más determinante para el desarrollo lector de los niños con sordera. La manera en que las habilidades de decodificación influyen en la lectura de los estudiantes con sordera es motivo de un extenso debate (véase Andrews y Wang, 2015), dando lugar a posturas contrapuestas (González y Domínguez, 2019). Mientras que unos autores defienden que el papel que juega la fonología en la comprensión lectora de los estudiantes con sordera es distinto al de los estudiantes normoyentes, otros sostienen que es equiparable.

Aquellos que defienden que la fonología tiene un peso distinto en los estudiantes con sordera parten de la premisa de que el alumnado con sordera tiene un acceso limitado al desarrollo de representaciones fonológicas estables a través de la vía auditiva (debido a las limitaciones sensoriales auditivas). Siguiendo este argumento, la construcción de las representaciones fonológicas depende de factores directamente ligados a la calidad del input auditivo y, en ausencia de éste, los lectores se convierten en aprendices “visuales” (e.g., Miller y Clark, 2011). Es decir, acceden al código escrito mediante la conversión del texto a señas visuales (dactilología o lengua de signos), procesando directamente la representación ortográfica de las palabras sin hacer uso de la fonología (véase los estudios con población adulta de Fariña, Duñabeitia y Carreiras, 2017 [en español]; Bélanger, Baum y Mayberry, 2012 [francés]). Desde este punto de vista, la fonología que refiere al lenguaje oral no tendría un papel fundamental para leer, a diferencia de lo que ocurre en los estudiantes normoyentes en las primeras etapas.

Sin embargo, en el caso del alumnado con sordera el desarrollo de la fonología no es exclusivamente auditivo y tiene un carácter de tipo auditivo-visual, lo que hace posible que estudiantes con un nivel de sordera no funcional (con restos auditivos que no permiten diferenciar con precisión los sonidos del lenguaje oral a través de la audición), puedan acceder a la fonología a pesar de sus restricciones en la vía auditiva (Mayer y Trezek, 2014). Así pues, los sistemas aumentativos que completan la información fonológica a través de la vía visual como, por ejemplo, la lectura labiofacial (Rodríguez-Ortiz, Saldaña y Moreno-Pérez, 2017) y la palabra complementada (Torres, Rodríguez, García-Orza y Calleja, 2008; Trezek, 2017) benefician al desarrollo lector de los estudiantes con sordera (Alegría y Domínguez, 2009; Torres et al., 2008); mientras que en el caso de los estudiantes normoyentes la percepción visual del lenguaje oral, aunque también es posible y se da a través de la lectura labiofacial, no ejercería un papel tan relevante. A este respecto, Rodríguez-Ortiz et al. (2017) analizaron cómo la lectura labiofacial contribuía a la lectura en 27 adolescentes y adultos jóvenes de 11 a 27 años con sordera prelocutiva de grado severo-profundo cuyo modo de comunicación era el lenguaje oral. Sus resultados mostraban que el nivel de lectura labiofacial correlacionaba positivamente con las habilidades de conciencia fonológica únicamente en el grupo de participantes con sordera, mientras que en el caso de participantes normoyentes equiparados en edad cronológica no se apreciaba una correlación significativa a pesar de tener un nivel de lectura labiofacial similar.

Dado que las habilidades de conciencia fonológica en el estudiante con sordera no están limitadas al canal auditivo y también pueden desarrollarse a través del canal visual mediante la ayuda de sistemas aumentativos como la lectura labiofacial y la palabra complementada, es posible que los estudiantes con deficiencia auditiva adquieran una mejor competencia en conciencia fonológica al recibir instrucción en el uso de estos sistemas. De hecho, existen estudios, que confirman su utilidad para acceder a la representación del lenguaje oral y que destacan la importancia de la fonología en el aprendizaje lector de los estudiantes con sordera (véase Alasim y Alqraini, 2020, para una revisión).

Además, muchos estudiantes con un elevado grado de sordera (e.g., pérdidas auditivas de grado severo o profundo), disponen de un mejor acceso a la señal auditiva gracias a la posibilidad del IC, lo que facilitaría el desarrollo de unas representaciones fonológicas de mayor calidad (González y Domínguez, 2018).

El acceso a la fonología durante la lectura por parte de lectores con sordera ha sido reportado. En el caso de participantes españoles podríamos citar los estudios de Domínguez et al. (2019) y de González y Domínguez (2019) cuyos resultados sugieren que los estudiantes con sordera prelocutiva moderada y profunda (tanto equipados con IC como con audífonos) desarrollan representaciones de las palabras basadas en la fonología de la lengua oral. También cabe citar los estudios de Gutierrez-Sigut, Vergara-Martínez, Marcet y Perea (2018) y de Gutierrez-Sigut, Vergara-Martínez y Perea (2017) que, a través de la medición de los tiempos de reacción (Gutierrez-Sigut et al., 2018, 2017) y el registro de la respuesta cerebral (Gutierrez-Sigut et al., 2017), demuestran que los adultos con sordera profunda o severa prelocutiva acceden a la fonología de manera automática. Estas conclusiones se obtuvieron a partir de comparar los efectos de *primming* fonológico y ortográfico de los adultos con sordera con los de adultos normoyentes en una tarea de decisión léxica. Los adultos con sordera respondieron al *primming* fonológico de manera similar a como lo hicieron los normoyentes (Gutierrez-Sigut et al., 2018), siendo más rápidos en responder cuando la palabra iba precedida por una pseudopalabra que mantenía similitud fonológica con la palabra target (e.g., cosa-kosa) que cuando la palabra era precedida por una pseudopalabra ortográficamente similar (e.g., cosa-tosa). Si bien, mientras que estos resultados correlacionaban con diversas medidas en lectura (en concreto, eficiencia lectora en frases) en los estudiantes normoyentes, no se observó tal correlación en el caso de los participantes con sordera, lo que llevó a los autores a determinar que pese a acceder al código fonológico, la fonología no sería tan determinante para el éxito lector de los adultos sordos.

La manera en que las habilidades de decodificación explican el bajo rendimiento en lectura se ha analizado en diversos estudios. Uno de ellos que ha recibido una considerable atención es el trabajo de Mayberry, Del Giudice y Lieberman (2011) que consistió en el desarrollo de un metaanálisis con el objetivo de analizar el papel que tenían las habilidades de conciencia fonológica en la lectura de los estudiantes con sordera. A partir de las investigaciones incluidas, los autores indicaron que las habilidades de conciencia fonológica explicaban el 11% de la varianza de los resultados en lectura, mientras que las habilidades lingüísticas (analizadas en 7 de los 57 estudios) predijeron el 35%. A partir de sus resultados concluían que las habilidades de conciencia fonológica no jugaban un papel tan relevante en el dominio de la lectura como hasta el momento se había pensado.

Sin embargo, el estudio de Mayberry et al. (2011) no está exento de limitaciones (Domínguez et al., 2019, 2012; González y Domínguez, 2019; Mayer y Trezek, 2014). En primer lugar, el porcentaje de varianza explicado por la conciencia fonológica en el metaanálisis no sería tan distinto al reportado en estudios con normoyentes (Domínguez et al., 2019, 2012). Por otra parte, el rango de edad seleccionado en el metaanálisis es muy amplio (5 a 37 años) y solamente son 4 los estudios incluidos que se centran en casos de lectores menores de 8 años, etapa en la que las habilidades de conciencia fonológica son fundamentales para el dominio de la mecánica lectora (Mayer y Trezek, 2014). Finalmente, la manera en que Mayberry et al. delimitaban el término "habilidades metafonológicas" no contemplaba la inclusión en el metaanálisis de datos referentes a habilidades estrechamente relacionadas con el dominio de la decodificación en los estudiantes con sordera (e.g., lectura labial) (Domínguez et al., 2019; González y Domínguez, 2019).

En resumen, todavía se observa una falta de consenso acerca del papel que adopta la fonología en la lectura de los estudiantes con sordera en relación con la eficiencia en decodificación. Lo cierto es que los resultados que se obtienen en un determinado grupo con sordera son difícilmente generalizables a todos los casos, pues la población con sordera constituye una población en la que diversas variables (e.g., tipo de prótesis auditiva, momento de implantación, intervención recibida) pueden modificar la manera en que los estudiantes acceden a la fonología. En cualquier caso, el peso que tiene la fonología o, más concretamente las habilidades metafonológicas en la comprensión lectora de los estudiantes con sordera, varía en función de la etapa de aprendizaje lector en la que se encuentre el alumno, adoptando un papel más relevante en etapas iniciales y perdiendo peso en etapas posteriores, una vez el alumno ya ha aprendido el código alfabético. Cuando este aprendizaje ocurre, son los factores lingüísticos y los cognitivos los que principalmente determinan el éxito lector (Castles et al., 2018; Domínguez et al., 2012).

El peso que ganan otras habilidades lingüísticas a medida que avanza la escolaridad queda reflejado en el estudio de Moreno-Pérez et al. (2015). Esto autores analizaron la relación entre el nivel de eficacia lectora (entendiendo como tal la habilidad para comprender un texto a una velocidad adecuada y de manera precisa) y diversas habilidades relacionadas con la lectura (precisión de lectura de palabras y pseudopalabras, conciencia fonológica, velocidad lectora, vocabulario receptivo y lectura labiofacial) en 27 adolescentes y adultos jóvenes de 9 a 25 años con sordera prelocutiva de grado severo-profundo. Los resultados fueron comparados con dos grupos de estudiantes normoyentes: un grupo emparejado al grupo con sordera en edad cronológica y otro equiparado en edad lectora. El nivel de eficiencia lectora de los estudiantes con sordera resultó significativamente inferior al de los estudiantes normoyentes equiparados en edad cronológica, si bien, estas diferencias no se explicaron por dificultades en decodificación ya que los tres grupos alcanzaron una puntuación techo en precisión de lectura, lectura de palabras y pseudopalabras y conciencia fonológica. Uno de los componentes con mayor poder predictivo en su estudio fue el vocabulario. Este estudio demuestra cómo ciertas habilidades lingüísticas (no ligadas a aspectos específicos de la lectura) adoptan un papel más relevante en el desarrollo de la comprensión lectora una vez el lector ya ha adquirido las habilidades de decodificación necesarias para descifrar el código escrito de manera automática.

En soporte a esta afirmación cabe recordar el estudio de Mathews y O'Donnell (2020) que, tras examinar las habilidades de decodificación (lectura de pseudopalabras) y comprensión lectora de 40 estudiantes con deficiencia auditiva (rango de edad = 7 a 13 años), observaron que: (1) el número de estudiantes que exhibía un pobre rendimiento en comprensión lectora, doblaba en número al de estudiantes que demostraron bajas habilidades de decodificación, (2) algunos estudiantes obtenían resultados deficientes en comprensión lectora a pesar de puntuar muy alto en decodificación. Dada la discrepancia entre los resultados en comprensión lectora y decodificación, los resultados invitan nuevamente a concluir que la baja competencia en comprensión lectora por parte de los estudiantes con sordera debe ser explicada por otros factores adicionales, más allá de la decodificación (p.ej. vocabulario y gramática), tal y como también sugieren Moreno-Pérez et al. (2015) y otros estudios donde se observa cómo la mayoría de estudiantes con dificultades en comprensión de textos demuestran habilidades de decodificación acordes a la normalidad (e.g., Barajas et al., 2016).

En resumen, al menos por lo que refiere al desarrollo de la comprensión lectora de los estudiantes con sordera prelocutiva que se comunican principalmente a través del lenguaje oral, las habilidades fonológicas tendrían un papel relevante en edades tempranas. Si bien, en el momento en que el lector es competente en su dominio, son aspectos no específicos de la lectura (e.g. léxico, gramática o habilidades discursivas; Cain, 2010) los que explicarían un mayor porcentaje de la variabilidad en los resultados en comprensión lectora. El siguiente apartado profundizará en el análisis de cómo el dominio léxico, gramatical y discursivo se relaciona con la comprensión lectora.

1 | 2.2 Factores No Específicos de la Lectura: Comprensión del Lenguaje.

1 | 2.2.1 Vocabulario.

Conocer el significado de las palabras que integran un texto se convierte en una condición necesaria para comprenderlo y elaborar una representación mental del mismo. Algunos autores indican que se requiere conocer al menos un 90% de las palabras de un texto para poder entenderlo (Nagy y Scott, 2000). Esta relación entre comprensión lectora y vocabulario es recíproca, pues si resulta difícil comprender un texto sin conocer el significado de las palabras que lo integran, también un bajo nivel de competencia lectora va a dificultar la adquisición de nuevas palabras a través de la lectura (Oakhill, Cain y Elbro, 2019). La competencia lectora (así como las habilidades lingüísticas que la subyacen) mantendría una relación bidireccional con la práctica lectora, de manera que aquellos lectores que disponen de buenas habilidades lingüísticas y una mayor competencia en comprensión lectora, aumentan la frecuencia de su práctica lectora.

La relación entre comprensión lectora y vocabulario se mantiene a lo largo del desarrollo. En las etapas iniciales el vocabulario es importante para facilitar el reconocimiento léxico y las habilidades de comprensión, asimismo, también contribuye de manera relevante al desarrollo de la comprensión lectora en etapas más tardías (Verhoeven, van Leeuwe y Vermeer, 2011). De acuerdo con Oullette y Beers (2010), a medida que se aumenta en escolaridad el vocabulario gana en importancia para la comprensión lectora. Según su estudio, el vocabulario explica gran parte de la varianza de los resultados en comprensión lectora en niños normoyentes de sexto curso de Primaria, mientras que no lo hace en estudiantes de primer curso. Este resultado, como se ha indicado en el apartado anterior, podría deberse a que en los cursos superiores los estudiantes normoyentes sin dificultades lectoras ya deben haber automatizado las habilidades de decodificación y se enfrentan a textos con un vocabulario más complejo (Oakhill et al., 2019).

Diversos estudios han observado una correlación positiva entre comprensión lectora y vocabulario en estudiantes normoyentes (p.ej. Simpson, Moreno-Pérez, Rodríguez-Ortiz, Valdés-Coronel y Saldaña, 2020). Los modelos recientes sobre el léxico sugieren la distinción de dos dimensiones de conocimiento de vocabulario. Por un lado, la *amplitud de vocabulario* (*vocabulary breadth*) implica una comprensión superficial de la palabra e incluye la capacidad de la persona para reconocer distintas palabras (Oakhill et al., 2019). La amplitud de vocabulario se mide con tareas como por ejemplo el Test de Vocabulario en Imágenes Peabody (Dunn, Dunn y Arribas, 2006) donde se le pide al participante que identifique la imagen que corresponde a la palabra target entre varias imágenes. Por otro lado, el término *profundidad de vocabulario* (*vocabulary depth*) alude a un conocimiento en detalle del significado de la palabra. Es decir, presupone que el lector es capaz de establecer relaciones entre la palabra propuesta y otras relacionadas. En el caso del español, una de las pruebas que miden este constructo es la Prueba de Vocabulario (VOC) integrada en la Batería PEALE (Pruebas de

Evaluación Analítica de la Lengua Escrita; Domínguez, Alegría, Carrillo y Soriano, 2013), la cual fue diseñada para valorar principalmente a niños con sordera. En esta prueba se le pide al participante que señale, entre tres opciones, la palabra que guarda una mayor relación con el significado de la palabra target (e.g., ante la palabra “mucho” el estudiante debe seleccionar entre las opciones “peor”, “demasiado” y “nunca” [Domínguez et al., 2013]).

En resumen, en el caso de los niños normoyentes el vocabulario constituye un predictor relevante de la comprensión lectora (Simpson et al., 2020). Además, su validez predictiva se incrementa a medida que aumenta la escolaridad (Oakhill et al., 2019; Oullette y Beers, 2010) y cabe tener en cuenta la dimensión del vocabulario (amplitud o profundidad) que se contemple pues resulta relevante a la hora de considerar su relación con la comprensión lectora.

Considerando que el vocabulario adopta un papel relevante en los casos de los niños normoyentes, ¿qué podríamos esperar de los niños con sorderas prelocutivas de grado severo-profundo? Según Kyle, Campbell y MacSweeney (2016), el vocabulario correlaciona con la comprensión lectora tanto en estudiantes normoyentes como en estudiantes con sordera. Desde hace años, las mediciones del léxico de los estudiantes con sordera han evidenciado que este se caracteriza por ser reducido, tardío en su aparición (véase la revisión de Luckner y Cooke, 2010) y con un ritmo de aprendizaje más lento en comparación a los estudiantes normoyentes (e.g., Harris et al., 2017). El rendimiento en vocabulario ha mejorado con la aparición del IC, sin embargo todavía dista de la normalidad en un alto porcentaje de casos (Geers, Moog, Biedenstein, Brenner y Hayes, 2009).

Desde hace décadas algunos estudios han apuntado que existe una alta correlación entre el nivel de vocabulario de los estudiantes con sordera y su rendimiento en comprensión lectora (e.g., Paul, 1996). Dicha relación se ha puesto de manifiesto en estudios más recientes tanto por lo que refiere al vocabulario expresivo (Harris et al., 2017; Kyle et al., 2016; Kyle y Harris, 2010; 2011) como a la validez predictiva del vocabulario receptivo (Wass et al., 2019).

Las habilidades léxicas predicen los resultados en lectura de los estudiantes con sordera tanto a nivel de un conocimiento más superficial (amplitud de vocabulario) (Moreno-Pérez et al., 2015) como a un nivel de conocimiento más elevado (profundidad de vocabulario) (Domínguez et al., 2014). Por ejemplo, Moreno-Pérez et al. (2015), mediante el Test de Vocabulario en Imágenes Peabody (Dunn et al., 2006) evaluaron la amplitud del vocabulario de 27 estudiantes con sordera de 9 a 25 años. Los estudiantes con sordera obtuvieron unos resultados significativamente inferiores en términos de vocabulario que los dos grupos de estudiantes normoyentes (grupo con edad cronológica similar y grupo equiparado en edad lectora). Además, en el caso de los estudiantes con sordera, el vocabulario fue la variable que mejor predijo los resultados en eficiencia lectora, explicando un 55,6% de la varianza. Por otra parte, Domínguez et al. (2014) evaluaron la profundidad de vocabulario de un grupo de 26 adultos con sordera prelocutiva profunda. Sus participantes, excepto en tres casos, no estaban equipados con prótesis auditivas (IC o audífonos), su modo de comunicación principal era la Lengua de Signos (LS) y todos ellos habían alcanzado o estaban cursando estudios superiores a la Educación Secundaria Obligatoria (universidad o Formación Profesional). Los resultados fueron comparados con los de un grupo de estudiantes normoyentes de 6 a 18 años (N= 521). Tal y como se esperaba, los participantes con sordera obtuvieron un rendimiento inferior a los estudiantes normoyentes en profundidad de vocabulario a pesar de tener mayor edad y haber accedido a estudios postobligatorios. Estos hallazgos también se replicaban en un estudio posterior (Domínguez, Carrillo, González y Alegría, 2016) en el que se incluyeron niños con IC (temprano y tardío), observando además que la diferencia entre estudiantes con sordera y normoyentes aumentaba con la edad.

Otro de los aspectos a destacar del estudio de Domínguez et al. (2014) fue el hecho de que, mientras que el vocabulario mejoró a medida que lo hacía el nivel lector, las habilidades sintácticas no lo hicieron. Este hecho llevó a los autores a centrar la atención sobre las habilidades sintácticas, en concreto al uso que los estudiantes con sordera hacían de las mismas durante la lectura como potencial variable explicativa de las dificultades de comprensión lectora de los estudiantes con sordera, más que a centrarse en los aspectos léxicos.

Por su parte, Kelly (1996) estudió la interacción entre el vocabulario y la sintaxis en la comprensión lectora de los estudiantes con sordera. De acuerdo con su trabajo, las limitaciones en sintaxis dificultan la puesta en marcha de los recursos necesarios por parte del lector para mejorar el vocabulario. De esta forma, las habilidades sintácticas ejercerían un efecto de "cuello de botella" (Kelly, 2003b) en la comprensión lectora y la adquisición de léxico. Este efecto podría explicarse (1) porque el lector interpreta incorrectamente la estructura de la frase y esta "interpretación fallida" lleva a un procesamiento del vocabulario erróneo, (2) porque debido a la falta de conocimiento sintáctico el análisis resulta más costoso y el lector emplea recursos cognitivos adicionales para llevarlo a cabo, recursos que en ausencia de estas dificultades se dedicarían, entre otros, al procesamiento léxico.

En resumen, los estudiantes con sordera prelocutiva severa-profunda aún equipados con IC exhiben un rendimiento inferior en vocabulario respecto a sus iguales normoyentes. Las dificultades léxicas son evidentes en ambas dimensiones (amplitud y profundidad del vocabulario). El vocabulario constituye un predictor a considerar en las dificultades en comprensión lectora, así y todo, cabría considerar el papel de esta variable en conjunción con las habilidades gramaticales como potenciales predictores de la comprensión lectora en estudiantes con sordera. Dos motivos resultan relevantes para centrarse en el papel de las habilidades gramaticales en la comprensión lectora: (1) el aparente "estancamiento" en su desarrollo, tal y como reportan Domínguez et al. (2014), (2) el hecho de que las dificultades gramaticales puedan interferir en el aprendizaje del vocabulario, limitando la adquisición de nuevas palabras (Kelly, 1996). Como veremos, el **Estudio 1** de la presente **Tesis** alude en sus resultados a esta segunda propuesta, matizando que el efecto "cuello de botella" generado por las dificultades gramaticales podría ser descrito por un efecto en cascada, de manera que éstas no llegaran a bloquear el acceso al léxico sino a que los eventos subsiguientes tuvieran lugar de manera deficiente.

1 | 2.2.2 Gramática.

Habilidades gramaticales y comprensión lectora en estudiantes normoyentes.

La competencia gramatical hace referencia a la comprensión y uso de la morfología y la sintaxis en el lenguaje. Dicho con otras palabras, alude a cómo las palabras cambian su forma y se combinan con otras palabras para generar frases (Grammar, 2019). Tanto el dominio de la morfología como el de la sintaxis interaccionan entre sí para contribuir a la competencia gramatical. Por ejemplo, para transformar una oración activa a pasiva (p.ej. "Juan pinta el cuadro" – "El cuadro es pintado por Juan") se requiere cambios en las palabras tanto en el orden (sintaxis) como en su morfología (pinta-pintado). A pesar de la distinción entre morfología y sintaxis, en la mayor parte de los estudios reportados se hace uso del término *sintaxis* para referirse a ambos constructos, por lo que a lo largo de la presente **Tesis** también los usaremos como sinónimos distinguiéndolos solo si fuera necesario.

Diversos estudios han analizado cómo las habilidades gramaticales interactúan con la comprensión lectora en estudiantes normoyentes, siendo que las dificultades gramaticales pueden situarse en la base (aunque no siempre) de un bajo rendimiento en comprensión lectora.

Centrándonos en la relación entre comprensión lectora y sintaxis, Brimo, Lund y Sapp (2018) llevaron a cabo un metaanálisis cuyo objetivo era determinar si las habilidades sintácticas orales varían en función del grado de competencia en comprensión lectora en población normoyente. En el análisis se incluyeron 14 estudios en los que se evaluaron las habilidades sintácticas orales de estudiantes normoyentes de 6 a 15 años. Los resultados demostraron que, efectivamente, los estudiantes con mayor y menor rendimiento lector diferían en cuanto a sus habilidades sintácticas orales. Más recientemente, Simpson et al. (2020) en una muestra de 234 alumnos de cuarto curso de Primaria de la región de Andalucía (España) observaron que las habilidades sintácticas orales y el nivel de vocabulario receptivo fueron las variables que mostraron una mayor correlación positiva con la comprensión lectora en comparación con otras variables (eficiencia lectora, inteligencia no verbal y decodificación). Además, las habilidades sintácticas mostraban valor predictivo con relación a los resultados en comprensión de textos, si bien con un porcentaje explicativo pequeño.

Algunos estudios, sin embargo, no identifican que las habilidades de comprensión de sintaxis oral sean el predictor más potente de la comprensión de textos en normoyentes, tal es el caso del trabajo de Oakhill y Cain (2012) con estudiantes de 7 a 11 años. En este trabajo se documentaba que, si bien existe relación entre las habilidades de comprensión de sintaxis oral y la comprensión de textos, otras habilidades lingüísticas como el vocabulario fueron las que contribuyeron a predecir mayor porcentaje de varianza.

En resumen, el procesamiento gramatical, al igual que el léxico, parece ser una habilidad fundacional que permite al lector establecer relaciones entre los elementos que constituyen la oración, posibilitando la elaboración del significado y, posibilitando finalmente crear representaciones cohesionadas de un texto o discurso escrito. El procesamiento sintáctico debe automatizarse, de esta forma se liberan recursos cognitivos para hacer posible la puesta en marcha de procesos o acciones de alto nivel, necesarias para la comprensión de textos más complejos (e.g., realizar inferencias, monitorizar la lectura, hacer uso del conocimiento previo para comprender el texto; Kelly, 2003a). Las habilidades gramaticales, y más concretamente la sintaxis pueden contribuir a explicar los resultados de estudiantes normoyentes con bajo rendimiento en comprensión lectora, aunque según algunos estudios (e.g., Oakhill y Cain, 2012) su papel en la comprensión lectora no sea tan determinante. En cambio, en el caso de los estudiantes con sordera, las habilidades gramaticales han sido señaladas como un factor explicativo de mayor poder para explicar la baja competencia en comprensión lectora, cuestión esta que se abordará en el siguiente apartado.

Habilidades gramaticales y comprensión lectora en estudiantes con sordera.

Partiendo de la idea de que las habilidades gramaticales constituyen un factor clave a la hora de predecir los resultados en comprensión lectora de los estudiantes con sordera, se han desarrollado múltiples estudios en este tipo de población. Así, Barajas et al. (2016) llevaron a cabo un estudio con 47 niños hispanohablantes con sordera de 6 a 13 años, la mayoría de ellos (*n*=26) equipados con IC unilateralmente y los restantes (*n*=21) equipados con audífonos en ambos oídos. En su estudio se valoró la comprensión de textos y se llevaron a cabo evaluaciones de diferentes variables implicadas en la lectura (decodificación, vocabulario receptivo y comprensión gramatical [oral]). A su vez, se consideraron variables externas al proceso lector: tipo de equipamiento protésico, edad de implantación o colocación de la prótesis, nivel socioeconómico y curso escolar. Los estudiantes fueron clasificados en dos grupos según su rendimiento en la tarea de comprensión lectora. Más de la mitad de los estudiantes (55,3%) manifestaron dificultades severas para comprender textos. Además, los participantes de ambos grupos (con o sin dificultades de comprensión de textos) demostraron habilidades de comprensión gramatical y léxica que en promedio correspondían a una edad equivalente por debajo de la esperada. Si bien, los estudiantes con dificultades de comprensión lectora obtuvieron resultados todavía más bajos (Gramática = 4,73 años [rango = 4 - 7]; Léxico = 5,53 años [rango = 2,5 - 8,6]) que aquellos sin dificultades en comprender textos (Gramática = 6,34 años [rango = 4 - 9]; Léxico = 6,96 años [rango = 3,9 – 9,9]). El resultado más destacable se obtuvo a partir de los resultados en el análisis de regresión logística en que se observaba cómo el conocimiento sintáctico predecía un gran porcentaje de la varianza de los resultados (41%). La variable “habilidades gramaticales” permitía agrupar al 84,6% de los estudiantes del grupo con dificultades en comprensión de textos y al 71,4% de participantes del grupo sin dificultades de comprensión lectora.

Recientemente, González-Cuenca y colaboradores (2020) exploraron la relación entre las habilidades gramaticales (conocimiento sintáctico) y el léxico (amplitud de vocabulario) con respecto al rendimiento académico tanto en matemáticas como en comprensión lectora. El estudio maneja prácticamente la misma muestra que el recién citado (Barajas et al., 2016), aunque a diferencia de este, el rendimiento en comprensión lectora no se obtuvo a partir de medidas directas del rendimiento de los estudiantes sino a partir de cuestionarios de rendimiento académico dirigidos al profesorado. En dichos cuestionarios, los profesores debían informar en qué punto se situaba el estudiante con sordera en comparación con sus iguales normoyentes en cada habilidad consultada. El rendimiento en comprensión lectora se estimaba a partir de la apreciación sobre un conjunto de aptitudes (lectura de textos con precisión, entonación y ritmo; comprensión de las ideas principales en el texto; secuenciación de las partes de la narración e interés por la lectura). Los profesores de estudiantes con sordera indicaron que estos presentaban mayores dificultades que los estudiantes normoyentes a nivel léxico y gramatical, siendo éstas más evidentes a nivel gramatical. Además, según los docentes, aquellos estudiantes con sordera que fueron calificados como de mayor rendimiento académico, eran los que mejor puntuaban en compresión de oraciones sintácticas complejas. Por último, la distancia entre el nivel de edad cronológica y la edad lingüística aumentó progresivamente tanto en léxico como en gramática a medida que avanzaba la escolaridad. Los resultados de este estudio podrían ser considerados como evidencia complementaria al estudio de Barajas y colaboradores (2016), enfatizando ambos la importancia de las habilidades gramaticales en el desarrollo de la comprensión lectora en niños con sordera.

Otros estudios, realizados con participantes hispanohablantes (e.g., González y Domínguez, 2018) así como en otros idiomas (e.g. inglés [Quigley y King, 1980], turco [Miller, Kargin y Guldenoglu, 2013] y persa [Pooresmaeil, Mohamadi, Ghorbani y Kamali, 2019]), también sitúan a las habilidades gramaticales como elemento clave en el desarrollo de la competencia lectora de los niños con sordera.

Se han formulado diferentes hipótesis sobre el origen y la naturaleza de las dificultades sintácticas en los estudiantes con sordera prelocutiva. Algunas de éstas proponen que el conocimiento sintáctico de los estudiantes con sordera profunda prelocutiva es limitado y, consecuentemente, la interpretación del texto se ve afectada por esta carencia. Otros estudios proponen que la comprensión lectora se ve influida por la conjunción de dos factores: un nivel de habilidad sintáctica insuficiente y el uso de estrategias de lectura ineficaces que relegan el uso de las claves sintácticas del texto a la hora de construir un significado (Miller, 2000, 2005, 2006, 2010; Miller et al., 2013, 2012). A continuación, analizamos algunas de estas propuestas.

Hipótesis/factores que contribuyen al déficit en habilidades sintácticas

*Insuficientes habilidades sintácticas***.** El bajo dominio sintáctico exhibido por los estudiantes con sordera se ha investigado y reportado a nivel oral (Boons et al., 2013), estando presente tanto en el plano comprensivo como en el productivo (Friedmann y Szterman, 2006; González, Silvestre, Linero, Barajas y Quintana, 2015).

Las dificultades en comprensión gramatical también son evidentes durante la lectura. Partiendo de las habilidades que contribuyen al procesamiento sintáctico (Cuetos, 1990), observamos que los estudiantes con sordera tienen dificultades en, al menos, dos de las claves fundamentales para el procesamiento sintáctico de la oración: la interpretación de palabras función y el manejo adecuado del orden de las palabras o estructura de la oración.

Dificultades en el manejo de palabras función. Las palabras contenido o de clase abierta (e.g., adjetivos, verbos, sustantivos), a diferencia de las palabras función o de clase cerrada (e.g., preposiciones, pronombres, conjunciones, o determinantes), aportan información de carácter principalmente léxico-semántico. Ahora bien, las palabras función son relevantes para la comprensión ya que contienen gran parte del significado que aporta el contenido gramatical de las oraciones (véase Corver y van Riemsdijk, 2001 para una descripción más detallada). Diversos estudios han evidenciado que los estudiantes con sordera tienen dificultades en la comprensión y uso de las palabras función (e.g., Domínguez et al., 2016; Gheitury, Ashraf y Hashemi, 2014; Monsalve, Cuetos, Rodríguez y Pinto, 2002). Las palabras función resultan más complicadas para los estudiantes con sordera por distintos motivos. Por una parte, suelen tener una duración más corta en el contexto del discurso oral al que somos expuestos desde el inicio del desarrollo y adquisición del lenguaje (generalmente son monosílabas o bisílabas) y son menos salientes desde el punto de vista perceptivo, de manera que los estudiantes con sordera tienen más dificultad para percibirlas oralmente y, por tanto, para familiarizarse y aprender con precisión su significado (Trezek, Wang y Paul, 2010). La aparición de los ICs ha supuesto una mejora en la percepción auditiva de las personas con sordera, por lo que *a priori* deberían ser más capaces actualmente de percibir este tipo de palabras. A pesar de ello, las dificultades a la hora de procesar palabras función se mantienen (Alegría, Carrillo, Rueda y Domínguez, 2020; Domínguez et al., 2016). Además, mientras que el aprendizaje de las palabras contenido puede responder a una instrucción directa, el aprendizaje de las palabras función es más dependiente de la exposición incidental, siendo más complicado adquirir un buen dominio de su uso sin una exposición al lenguaje de calidad desde una edad temprana o "baño lingüístico", como así ocurre en los estudiantes con sordera prelocutiva a causa de sus limitaciones en la vía auditiva (Alegría et al., 2020).

Una explicación alternativa o complementaria tendría que ver con las limitaciones de los estudiantes con sordera con relación a la profundidad de vocabulario ya comentadas en el apartado anterior (Domínguez et al., 2014). Las palabras función pueden tener diferentes usos y significados. Por ejemplo, la preposición "en" puede tener un carácter temporal (e.g., en diez minutos llegaré a casa) o bien locativo (e.g., en la estantería encontrarás el libro que buscas) (Trezek et al., 2010). La capacidad para percibir estas sutilezas en el uso de la palabra son las que permiten al individuo asociar un significado correcto en función del contexto. Sin embargo, gran parte de este aprendizaje se produce en edades tempranas a partir de situaciones que dependen en su mayor parte de la capacidad auditiva (e.g., las interacciones orales, oportunidades de escucha incidental) (Alqraini y Paul, 2020) y más adelante a partir de la lectura (Oakhill et al., 2019). Este hecho dificulta por tanto el aprendizaje en el caso de los niños con sordera cuya exposición al lenguaje oral es más reducida y que, además, suelen exhibir dificultades en la comprensión lectora.

En definitiva, las limitaciones con el uso de palabras de función podrían conllevar que los estudiantes con sordera sobreutilicen las palabras de contenido. Esto es lo que lleva al grupo de Alegría y Domínguez a proponer la hipótesis de preferencia por palabras clave (*Key Word Strategy*, *KWS*) en lectores con sordera a la hora de comprender textos. Esta estrategia se podría definir de la siguiente forma:

> Consiste en identificar las palabras clave de la frase, generalmente palabras frecuentes con contenido semántico pleno y elaborar sobre esta base un significado global. Considerando el ejemplo… *Ir a mucha velocidad con el coche por carretera es…*, la lectura de palabras clave de esta frase consistiría en identificar las palabras *coche* y *carretera* e ignorar las demás. Un lector que use la estrategia de palabras clave aceptaría que palabras como *viaje* o *camino* son adecuadas para completar la frase. Solamente un análisis exhaustivo de la frase que implicara procesar las palabras funcionales, permitiría al lector excluir esas soluciones y adoptar la palabra *peligroso* como correcta gramaticalmente (González y Domínguez, 2018, p.3).

El procesamiento diferencial entre palabras función y de contenido es, de hecho, uno de los fenómenos que a lo largo de los tres estudios que comprenden esta **Tesis** tratamos de vislumbrar, analizando la preferencia o anomalías a la hora de procesar palabras función o claves gramaticales frente a claves semánticas.

Orden de las palabras. Especialmente, en el caso del inglés, los estudiantes con sordera parecen asignar por defecto una estructura Sujeto-Verbo-Objeto (SVO) a las oraciones cuando las interpretan (véase Cannon y Kirby, 2013, para una revisión más extensa). El abuso de esta estrategia llevaría a los estudiantes con sordera a interpretar erróneamente aquellas oraciones en las que la asignación de roles temáticos en la oración no sigue un orden canónico, como sucede por ejemplo en frases pasivas y en oraciones donde se produce una interrupción en el procesamiento de la estructura SVO por la inserción de elementos adicionales (e.g., frases de relativo – "El coche que tiene los asientos de cuero se ha estropeado"). Los estudios que Cannon y Kirby (2013) citan para sostener este argumento no son recientes (e.g., Berent 1993, 1996) y, por tanto, se podría pensar que la situación actual podría haber cambiado (véase Gheitury et al., 2014). Sin embargo, hoy en día los estudiantes con sordera equipados con IC y que utilizan el lenguaje oral como principal modo de comunicación continúan exhibiendo dificultades para comprender frases que implican la interpretación de estructuras sintácticas de mayor complejidad y que no siguen un orden canónico (Lee, Sung y Sim, 2018; López-Higes, Gallego, Martín-Aragoneses y Melle, 2015; Piñar, Carlson, Morford y Dussias, 2017; Szterman y Friedman, 2014; Traxler, Corina, Morford, Hafer y Hoversten, 2014). Esta dificultad podría no resultar tan evidente en algunos casos con mejor situación protésica. Por ejemplo, el estudio de López-Higes et al. (2015) mostraba que los estudiantes que reciben IC antes de los 24 meses comprenden mejor las oraciones que no siguen un orden canónico que aquellos estudiantes implantados en edades más tardías.

Los estudiantes con sordera pueden ser, por tanto, sensibles a la complejidad de la oración. Si bien, su rendimiento decrece a medida que se incrementan las demandas en el procesamiento de la oración (Gallego, Martín-Aragoneses, López-Higes y Pisón, 2016) (e.g., al aumentar la longitud o el número de cláusulas de las oraciones [Kelly 2003b; Miller et al., 2013]). Este aspecto se ha contemplado en el diseño del **Estudio 2** de la **Tesis**, donde se analiza el uso de claves semánticas y sintácticas por parte de los estudiantes con sordera ante frases que, en su mayoría, debido a su estructura sintáctica, comportan una mayor dificultad de procesamiento sintáctico (e.g., oraciones pasivas, oraciones de relativo y oraciones de complemento focalizado). Además, a esta dificultad en procesar correctamente oraciones complejas pueden subyacer dificultades en la automatización del procesamiento sintáctico (Kelly, 2003b).

Dificultades para automatizar el procesamiento sintáctico. Citando literalmente a Kelly (2003b), la *automatización en el procesamiento* se define como "la habilidad para completar ciertas operaciones básicas de la lectura como el reconocimiento léxico y la unión de conjuntos de palabras, en frases con significado con un esfuerzo cognitivo mínimo" [the ability to complete certain basic operations of reading, such as recognizing individual words and chunking sets of words into meaningful phrases, with a minimum of intentional mental effort] (Kelly, 2003b, p.230). Según el autor, en condiciones normales el procesamiento sintáctico se lleva a cabo de manera automática, sin necesidad de que el lector realice un esfuerzo cognitivo extra. Sin embargo, cuando esto no ocurre, se genera un "efecto de cuello de botella" (Kelly, 1996) que dificulta la puesta en marcha de las operaciones restantes. En este último caso, los esfuerzos del lector se concentrarán en suplir las limitaciones de un proceso de bajo nivel (procesamiento sintáctico) que debiera actuar automáticamente y, consecuentemente, no dispondrá de los recursos suficientes para llevar a cabo los procesos restantes de alto nivel (comprensión lectora) que hubieran requerido de parte de estas habilidades cognitivas.

En esta línea, Kelly (2003b) se centró en analizar si el bajo rendimiento en comprensión lectora en la población con sordera se debía o no a una falta de automaticidad en el procesamiento sintáctico. En su estudio participaron 30 adultos con sordera prelocutiva de grado severo a profundo cuyo modo de comunicación principal era la lengua de signos. Los participantes fueron divididos en dos grupos de acuerdo con su rendimiento lector en comprensión lectora utilizando como criterio la medida *Degrees of Reading Power* (College Board, 1986). De esta forma, la competencia media en comprensión lectora del grupo de participantes con buen nivel lector era superior al rendimiento de estudiantes universitarios de primer curso, mientras que la del grupo de participantes con bajo rendimiento lector se asemejaba en promedio a la de estudiantes de 5º curso de Primaria. Se aplicaron diversas tareas valorando, entre ellas, la comprensión de frases. Los participantes debían leer oraciones y seguidamente responder a preguntas de verdadero/falso para verificar su comprensión, registrando el tiempo de lectura en cada estímulo. Se manipuló el modo de presentación y la complejidad sintáctica de las oraciones. En cuanto a la complejidad sintáctica, se presentaban frases simples y frases complejas (de relativo). Se partía del hecho de que, generalmente, los lectores tienden a aumentar el tiempo de lectura ante oraciones sintácticamente complejas, reducción en velocidad lectora que es interpretada como una disminución de la automaticidad del procesamiento que supone una adaptación con relación a la complejidad que requiere mayor esfuerzo cognitivo. Por tanto, comparar los tiempos de lectura en frases simples y complejas permitía verificar si esta dificultad en el procesamiento de oraciones complejas contribuía a una disminución de la automaticidad en la lectura (en una lectura más lenta) o no en población con sordera. Además, se pretendía observar si a esa disminución en automaticidad le acompañaba una buena ejecución (si los participantes invertían más recursos, pero continuaban comprendiendo bien) o si, por el contrario, las demandas desbordaban la capacidad del lector y por tanto resolvían peor las oraciones a pesar de haber invertido más recursos cognitivos (tiempo) en la comprensión. Con relación a la manipulación de complejidad, se destacan los siguientes resultados:

(1) El tiempo de lectura empleado en la tarea fue inferior en los participantes con alto rendimiento en comprensión lectora frente a aquellos con bajo rendimiento. Incluso en las oraciones simples donde el rendimiento en comprensión de ambos grupos fue similar (90% de aciertos) las diferencias en tiempo de lectura entre grupos se mantuvieron. De acuerdo con los autores, estos resultados podrían sugerir que el procesamiento en el primer grupo está más automatizado que en el segundo y, por ello, requieren de menor tiempo de lectura para resolver las oraciones correctamente.

(2) Ambos grupos (participantes con sordera con mayor y menor rendimiento lector) aumentaron su tiempo de lectura, fueron más lentos, en las oraciones complejas frente a las simples. Ello indica que ambos grupos fueron sensibles a la complejidad sintáctica, pues la automaticidad del procesamiento se redujo en ambos grupos para ajustarse a las mayores demandas de esfuerzo cognitivo que conllevaba el procesamiento de oraciones complejas. Si bien, este ajuste no llevó a un buen resultado en los dos grupos. Los participantes con un buen rendimiento lector redujeron su velocidad de lectura en las oraciones complejas pero su comprensión no decreció, es decir, obtuvieron un porcentaje de aciertos similar en las oraciones complejas respecto a las oraciones simples. En cambio, los participantes con un rendimiento lector bajo, redujeron su velocidad de lectura en las oraciones complejas respecto a las simples, pero comprendieron peor estas oraciones que las simples; en otras palabras, en este grupo no fue suficiente con reducir la velocidad de lectura y emplear más recursos cognitivos para comprender mejor.

En cuanto al modo de presentación, las frases se presentaron en dos condiciones, en una aparecía la frase completa, mientras que en la otra condición se mostraba la frase palabra a palabra. Se esperaba que el modo de presentación de la frase "palabra a palabra" dificultara más la resolución por la mayor carga en memoria de trabajo que implica esta modalidad. Esta manipulación permitía discriminar si las diferencias en rendimiento en comprensión de oraciones en los estudiantes con sordera se explicaban por limitaciones en la automatización del procesamiento sintáctico, si se debían a dificultades en el almacenamiento temporal de la información (memoria de trabajo) o bien si eran consecuencia de ambos factores. En el caso de que las dificultades fueran motivadas principalmente por dificultades en memoria de trabajo, la comprensión lectora disminuiría en la condición en que se presentaban las oraciones palabra a palabra en comparación a la condición donde aparecía la frase completa. En total se presentaron 4 condiciones (frases simples - presentación por palabra, frases simples - frase completa, frases complejas - presentación por palabra, frases complejas - frase completa). Atendiendo a los resultados, no se observaron diferencias significativas en el porcentaje de aciertos entre las oraciones presentadas palabra a palabra y las oraciones presentadas de manera completa en ninguno de los dos grupos, lo que conducía a descartar la memoria de trabajo como principal factor explicativo de las diferencias en comprensión lectora de oraciones.

Los resultados de este estudio son un claro ejemplo de cómo factores más allá del bajo conocimiento sintáctico per se (en este caso las dificultades en automatización) pueden subyacer a las deficiencias gramaticales y, por tanto, contribuir a explicar mejor las dificultades en comprensión lectora en población con sordera. Sin olvidar, por supuesto, que habrá ocasiones en las que no sea la baja automaticidad en el procesamiento sintáctico el principal obstáculo para la comprensión lectora, sino que también influirán en el rendimiento lector las limitaciones en memoria de trabajo, el deficiente uso de estrategias metacognitivas y el conocimiento lingüístico (conocimiento previo y léxico) del individuo (Kelly, 2003b).

Otra de las propuestas planteadas por diversos estudios se basa en que los estudiantes con sordera adoptan un patrón de lectura estratégico ineficaz, cuestión en la que se profundizará a continuación.

Uso de estrategias ineficaces

Según Miller (2000), se podría decir de forma simplificada que la comprensión lectora resulta de la interacción del procesamiento *bottom-up* (abajo-arriba) y *top-down* (arriba-abajo), véase Kintsch (2005) para una revisión sobre el tema. El primero, incluye procesos de "bajo-nivel" como las habilidades de decodificación o el procesamiento sintáctico, mientras que el procesamiento *top-down* engloba actividades que refieren a procesos de "alto-nivel" como la activación del conocimiento previo, la monitorización del proceso lector y la realización de inferencias durante la lectura (Kelly 2003a). Según Miller (2000), las limitaciones en uno de los niveles de procesamiento (en concreto el procesamiento *bottom-up*) se situaría en la base de las dificultades en comprensión lectora.

Miller y colaboradores desarrollaron esta línea de investigación implementando diferentes estudios en que se explora el papel del procesamiento semántico y sintáctico en la comprensión lectora de los estudiantes con sordera en diversos idiomas (hebreo [Miller 2000, 2005, 2006, 2010; Miller et al., 2013, 2012], árabe, inglés y alemán [Miller et al., 2012]), a partir de la manipulación de la plausibilidad de las oraciones. La lógica de esta manipulación fue la siguiente: para comprender correctamente las oraciones plausibles semánticamente (e.g., "la mujer que cuidaba del bebé estaba leyendo [*The woman who watched the baby was reading*]", Miller, et al., 2012, p.441), basta con enlazar la información proporcionada por las palabras contenido (pues expresan un significado congruente y predecible con lo que se esperaría comprender basándose en la experiencia previa). Es decir, para comprender las oraciones semánticamente plausibles basta con un procesamiento *top-down*. En cambio, las oraciones semánticamente implausibles (e.g., "la mujer que cuidaba del bebé estaba llorando [*The woman who watched the baby was crying*]", Miller et al., 2012, p.441) no podrían resolverse sin la mediación del procesamiento sintáctico (*bottom-up*) pues el significado al que se refieren puede contradecir lo esperado a partir de la experiencia previa del lector. Por tanto, la discrepancia entre un buen rendimiento en oraciones semánticamente plausibles y los resultados (sustancialmente inferiores) en las oraciones semánticamente implausibles en la mayoría de los participantes con sordera de los estudios de Miller et al. llevó a concluir que la lectura de gran parte de éstos se describe por la preferencia de un procesamiento *top-down* durante la comprensión de oraciones. No obstante, Miller et al. (2012) puntualizan que los resultados no necesariamente implican que los estudiantes con sordera ignoren o eviten procesar sintácticamente las oraciones, ya que es posible que los participantes de su estudio se basaran en normas sintácticas de una manera ineficiente o muy “simplista” durante su lectura. Además, no todos los participantes mostraron un perfil congruente con una estrategia basada en el procesamiento preferentemente *top-down* (Miller 2005, 2010; Miller et al., 2012); algunos mostraron perfiles diferentes, como un buen rendimiento tanto en oraciones plausibles como implausibles (lectores con perfil sintáctico) o un bajo rendimiento en ambos tipos de oraciones.

Siguiendo un argumento similar de preferencia por un procesamiento *top-down*, el conjunto de investigaciones desarrolladas por el equipo de Jesús Alegría de la Universidad Libre de Bruselas y de Ana Belén Domínguez de la Universidad de Salamanca buscaron evidenciar la preferencia por el procesamiento de las claves semánticas durante la lectura en población con sordera frente al uso de claves sintácticas.

En uno de sus primeros estudios en torno a esta cuestión, Soriano, Pérez y Domínguez (2006) evaluaron el uso de estrategias semánticas y/o sintácticas en estudiantes hispanohablantes (*N*=71) de 6 a 16 años con sordera profunda prelocutiva y con diferente tipo de equipamiento protésico, y lo compararon con un grupo de 326 lectores normoyentes del mismo rango de edad. Para ello utilizaron una tarea de completamiento de frases por selección múltiple denominada “Prueba de Evaluación de Estrategias Sintácticas” (Soriano et al., 2006). La tarea consistía en seleccionar la palabra que mejor completaba la oración entre 4 opciones que resultaban semánticamente plausibles en el contexto de la frase. Por ejemplo, para la frase "El edificio nuevo se …" (Soriano et al., 2006, anexo), las opciones propuestas serían "vive", "quemó", "bonito", "reciente". Como se puede observar, todas las opciones son semánticamente plausibles, pero la única opción correcta atendiendo a las claves sintácticas es la palabra "quemó", debiendo el lector recurrir al pronombre reflexivo "se" para contestar correctamente. La tarea estaba compuesta por 64 oraciones y debía llevarse a cabo con una limitación de tiempo de 5 minutos. El bajo rendimiento por parte de los estudiantes con sordera frente a los estudiantes normoyentes justifica el uso de esta tarea en estudios posteriores donde se exploró la preferencia de los estudiantes con sordera por las claves semánticas a la hora de elaborar el significado de frases.

Posteriormente, Alegría, Domínguez y van der Straten (2009), administraron la misma tarea a dos grupos de adultos con sordera (hispanohablantes y francófonos, considerados buenos lectores), comparando nuevamente su rendimiento con dos grupos de estudiantes normoyentes. Los autores observaron que los adultos con sordera obtenían un rendimiento inferior en la tarea de evaluación de estrategias sintácticas (también denominada "prueba de detección de estrategias semánticas" [Alegría et al., 2009, p.64]) aun cuando eran comparados con estudiantes normoyentes con un nivel lector equivalente, hecho que llevó a los autores a concluir que los adultos con sordera construían el significado de la oración basándose en la información semántica de la oración, considerando principalmente las palabras contenido. Esto es, usaban la ya comentada "estrategia de palabras clave".

A esta misma conclusión llegaron en estudios posteriores, tanto en población adulta (Domínguez y Alegría, 2010; Domínguez et al., 2014) como infantil (Alegría et al., 2020; Domínguez et al., 2016, 2012; González y Domínguez, 2018) y aunque se ha examinado su uso en estudiantes con dislexia, no se ha encontrado evidencia que la sostenga para este caso (Alegría et al., 2020).

A pesar de que los estudios de Domínguez y colaboradores emplean una muestra extensa y el uso de la estrategia de palabras clave ha sido documentado en diversos estudios, no toda la literatura científica está completamente de acuerdo con esta hipótesis.

Uno de los argumentos para sostener el desacuerdo es que la tarea que utilizan Domínguez y colaboradores para deducir que las personas con sordera hacen uso de esta estrategia no deja lugar a otro tipo de estrategia en caso de no ser eficiente en el uso de la sintaxis. Es decir, en caso de que un participante cometa un error en la tarea éste se deberá inequívocamente a la selección de una palabra sintácticamente incorrecta, sin permitir que afloren otro tipo de errores que pudieran derivar de un uso (aunque poco preciso) de claves sintácticas. Siguiendo esta idea, Gallego et al. (2016) adaptaron la tarea empleada por Domínguez y colaboradores para explorar el uso de la estrategia de palabras clave en 38 estudiantes con sordera prelocutiva de grado severo a profundo (la mitad equipados con IC de manera temprana y el resto de manera tardía) y en 19 estudiantes normoyentes (rango de edad de 8-12 años). Los autores modificaron la tarea de evaluación de estrategias sintácticas (Soriano et al., 2006) añadiendo un distractor sintáctico. De esta forma, en lugar de descartar 3 palabras sintácticamente implausibles, pero semánticamente plausibles para elegir la opción correcta, los participantes debían descartar dos palabras implausibles desde el punto de vista sintáctico pero plausibles semánticamente (distractores semánticos) y una palabra implausible desde el punto de vista semántico pero plausible sintácticamente (distractor sintáctico). Por ejemplo, en la frase "*La tormenta provocó un …*" las opciones eran: "*truenos*" (distractor semántico), "*lluvias*" (distractor semántico), "*desastre*" (target) y "*bastón*" (distractor sintáctico). Por lo que refiere a los resultados, ambos grupos de estudiantes con sordera realizaron más errores al seleccionar el distractor semántico que los normoyentes. Sin embargo, cuando aparecían errores, tanto el grupo de estudiantes normoyentes como el grupo de estudiantes equipados con IC temprano seleccionaron en mayor proporción los distractores sintácticos frente a los semánticos. El grupo de estudiantes implantados tardíamente, a diferencia de los anteriores, cuando erraron seleccionaron en una proporción similar los distractores semánticos y sintácticos. Los autores concluyeron que los estudiantes con IC temprano hacían uso de las claves sintácticas. En cambio, con relación al grupo de estudiantes con IC tardío concluyeron que la inconsistencia en sus respuestas (seleccionar indistintamente el distractor semántico y sintáctico) podría ser consecuencia de un patrón de respuesta errática o al azar. De esta manera, los autores descartaron la hipótesis de que el patrón de lectura de los estudiantes con sordera se rigiera por el uso exclusivo de las claves semánticas (Estrategia de Palabras Clave) en ambos grupos evaluados (estudiantes con sordera usuarios de IC temprano y tardío).

Hasta el momento no existe un acuerdo por parte de la literatura presentada acerca de cómo los estudiantes con sordera procesan las claves sintácticas durante la lectura. No en vano estos estudios derivan las conclusiones a partir de medidas fundamentalmente off-line; es decir, obtienen información sobre el producto de ese procesamiento. En cambio, otros autores han analizado el procesamiento sintáctico de las personas con sordera principalmente a partir de medidas on-line.

En esta línea se inscribe el trabajo llevado a cabo por Coulter y Goodluck (2015) que estudiaba el patrón lector de 16 adultos con sordera prelocutiva (educados en entornos oralistas) y lo comparaba con los tiempos de lectura de 16 adultos normoyentes durante la lectura de oraciones de distinta complejidad. Otros estudios ya habían hecho mención de las posibles diferencias en el patrón lector y de las limitaciones en el procesamiento sintáctico de las personas con sordera (e.g., Miller, 2000), si bien en el caso de Coulter y Goodluck se examinaba si dichas diferencias se reflejaban en un patrón diferencial de lectura de oraciones a partir del registro de lectura online. Las oraciones se presentaron palabra a palabra y el tiempo de lectura se registró para cada una de las unidades léxicas que componían la oración. Los autores llevaron a cabo tres experimentos, si bien, únicamente haremos alusión a los dos primeros dado que son los que guardan relación con los efectos que pretendemos destacar.

En el primer experimento se compararon los patrones lectores de ambos grupos en oraciones simples declarativas. Los autores partían de evidencia previa en normoyentes donde se sugería que los tiempos de lectura y de reacción eran menores para las palabras función (e.g., el /la [*the*, en inglés]) que para las palabras contenido (Aaronson y Scarborough, 1976). De acuerdo con dicha literatura, el patrón lector en oraciones declarativas se caracteriza por un conjunto de transiciones en el que se observa un continuo incremento y decrecimiento de tiempos de lectura entre palabras de dichas clases gramaticales ("*rise and fall pattern*", Coulter y Goodluck, 2015; p.74). Por lo que refiere a los resultados, los lectores con sordera mostraron tiempos de lectura inferiores en las palabras función frente a las palabras contenido. De esta forma, si imagináramos la frase como una secuencia temporal, observaríamos cómo el tiempo de reacción aumentaba de los determinantes a los sustantivos y decrecía de los verbos a los determinantes (véase Figura 1 para un ejemplo). En cambio, en el caso de los participantes normoyentes, los tiempos de reacción se mantuvieron constantes al largo de la oración, sin observarse cambios significativos entre la mayoría de las transiciones de palabras. A pesar de las diferencias observadas en el patrón lector entre ambos grupos, los autores concluyeron que los tiempos de reacción de los estudiantes con sordera eran congruentes con lo esperado dada la literatura previa (aumento de tiempo de lectura en palabras contenido y disminución de éste en palabras función, Aaronson y Scarborough, 1976) y que en el caso de los participantes normoyentes este efecto no se había observado a consecuencia de las condiciones experimentales, ya que las preguntas de comprensión a las que se enfrentaba a los participantes (con respuesta "sí/no") suelen inducir a tiempos de reacción más rápidos y perfiles lectores más "suavizados" (véase Coulter y Goodluck, 2015). Por último, los participantes normoyentes mostraron un efecto de cierre o *wrap up*[4] de la oración, aumentando su tiempo de reacción al final de la frase. En cambio, este efecto no estuvo presente en el caso de los participantes con sordera.

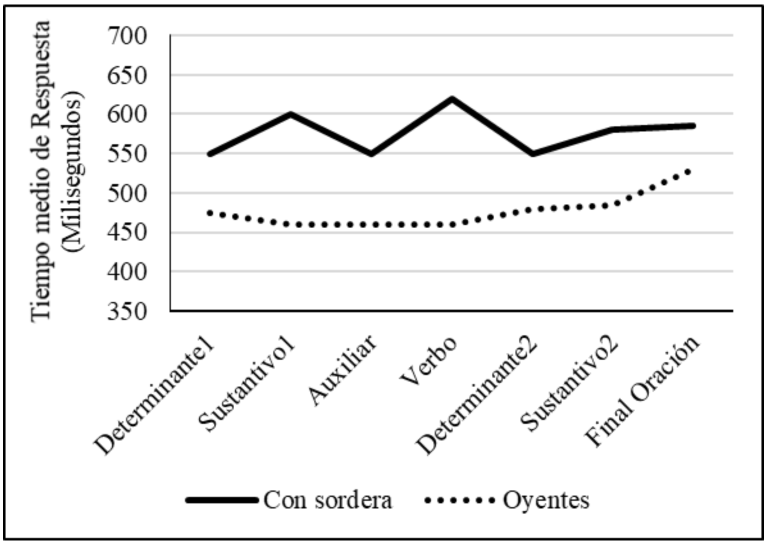

Figura 1*. Tiempo Medio de Respuesta por Grupos en Oraciones Declarativas (Experimento 1).*

Nota. Figura traducida y adaptada a partir de Coulter y Goodluck, 2015, (Figura 2, p. 76). Los valores representados han sido determinados a partir de la gráfica original y, por tanto, no son exactos.

En un segundo experimento estudiaron el efecto *garden-path*[5] a partir de la manipulación de la complejidad de la frase. En cuanto a las oraciones más complejas (con una partícula interrogativa), se presentaron oraciones de dos tipos. Por un lado, se mostraron frases que requerían procesar la partícula interrogativa (a) "*El chef se preguntó con qué cocinaría el cordero esa noche* [*The chef wondered what he would cook the lamb with that night*]", y por

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[4] El efecto *wrap up* (Just y Carpenter, 1980) se refleja en una pausa más larga o aumento del tiempo de lectura en la última palabra de la oración. Generalmente el lector utiliza los finales de la oración para resolver las ambigüedades o procesar las inconsistencias halladas durante la lectura. El efecto *wrap up* por tanto, suele reflejar procesos de integración.

[5] El efecto *garden-path* se produce cuando el texto induce inicialmente al lector a un análisis incorrecto de la oración (metafóricamente lo conduce por la senda errónea). Este análisis se restaura una vez que el lector se encuentra con la partícula desambiguadora. Por ejemplo, si atendemos a la oración: "*The chef wondered what he would cook the lamb with that night"* (Coulter and Goodluck, 2015, p.77), el lector detectaría que su análisis no era correcto al encontrarse con "the lamb" y resolvería la oración tras enlazar la preposición "with" con la información anterior (en concreto la palabra "what"). Este proceso se reflejará en un mayor tiempo de lectura para resolver la frase.

otro oraciones en las que la partícula interrogativa era sustituida por la preposición "si" (b) "*El chef se preguntó si cocinaría el cordero con patatas asadas esa noche* [*The chef wondered if he would cook the lamb with roast potatoes that night*]", (Coulter y Goodluck, 2015, p.77*).* Se esperaba que las oraciones que incluían una partícula interrogativa (ejemplo a) requerirían de mayor tiempo de reacción que las segundas (ejemplo b). Ambos grupos se mostraron sensibles a la dificultad de las oraciones, de manera que tanto los participantes con sordera como los normoyentes mostraron tiempos de reacción más largos en las oraciones que incluían la partícula interrogativa y, por tanto, conllevaban una mayor dificultad en el procesamiento. Sin embargo, se observaron patrones de reacción diferentes para cada uno de los grupos. Mientras los adultos normoyentes aumentaban el tiempo de reacción desde el verbo hacia el determinante (*the*) y de éste hacia las palabras contenido (*lamb*) y función (*with*) contiguas, los adultos con sordera invirtieron más tiempo en las palabras contenido (en este caso en el verbo [*cook*] y sustantivo [*lamb*]), demostrando un patrón semejante al observado en el experimento anterior con oraciones declarativas (véase Figura 2).

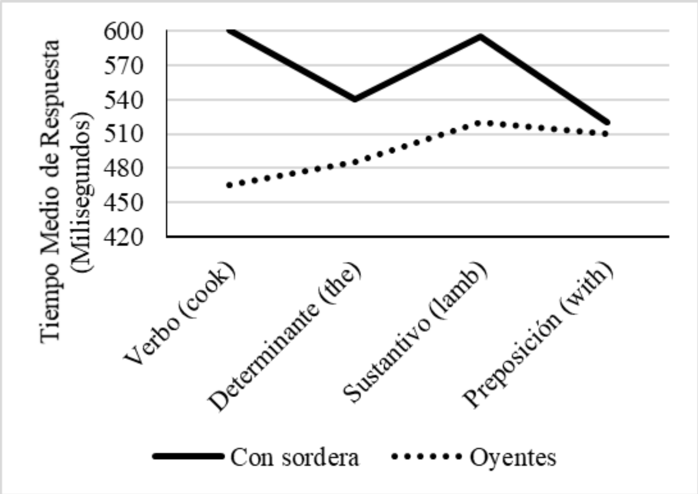

Figura 2*. Tiempo Medio de Respuesta por Grupos en Oraciones con Partícula Interrogativa (Experimento 2).*

Nota. Figura adaptada a partir de Coulter y Goodluck, 2015, (Figura 5 y 6, p. 79 y 80). Los valores representados han sido determinados a partir de la gráfica original y, por tanto, no son exactos.

Los resultados de ambos experimentos llevan a concluir que existen diferencias entre los lectores con sordera y los normoyentes en cuanto al procesamiento online de oraciones (tanto simples como complejas). Tal y como se deduce al comparar los resultados de ambos grupos: ausencia de efecto *wrap up* (Experimento 1) y *garden-path* (Experimento 2), así como aumento de tiempo de lectura en palabras contenido frente a palabras función (Experimento 1 y Experimento 2) en participantes con sordera.

Otros autores se han servido de medidas de procesamiento on-line para analizar la sensibilidad a las claves sintácticas por parte de la población con sordera. Así por ejemplo, Piñar et al. (2017) y Traxler et al. (2014) analizan la sensibilidad de los adultos con sordera a claves sintácticas a partir del aumento en tiempo de lectura que se produce como consecuencia de la *penalización por objeto* en oraciones de relativo (*The object-relative penalty*, [Traxler, Morris y Seely, 2002]) y del efecto que ejerce en dicha penalización el hecho de que los sustantivos que constituyen la oración sean animados o inanimados (Traxler, et al., 2002; Traxler, William, Blozis y Morris, 2005).

La *penalización por objeto* consiste en el aumento en el tiempo de lectura y de regresiones en las oraciones relativas de objeto frente a las de sujeto (Traxler et al., 2014) que se observa en lectores normo-oyentes. Así por ejemplo, una oración relativa de objeto como "*El abogado al que el banquero enfadó presentó una demanda judicial* [*The lawyer that the banker irritated filed ahefty lawsuit*]", Traxler et al., 2002, p.69) se lee con más lentitud que una oración relativa de sujeto como "*El abogado que enfadó al banquero presentó una demanda judicial* [*The lawyer that irritated the banker filed ahefty lawsuit*]", Traxler et al.,2002, p.69).

Sin embargo, Traxler et al. (2002; 2005) demostraron que esta penalización estaría modulada por características de los agentes que participan en la acción, en concreto, si estos son animados o inanimados. Por ejemplo, la oración (a) " *La pistola que el vaquero dejó caer permaneció en el salón* [*The pistol that the cowboy dropped remained in the saloon*]" (Traxler et al., 2014, p.99) en la que el sujeto de la oración principal es inanimado (pistola) y el sujeto de la oración subordinada es animado (vaquero) resulta más sencilla de procesar que (b) "El vaquero al que la pistola hirió permaneció en el salón [*The cowboy that the pistol injured remained in the salón*]*"* (Traxler et al., 2014, p.99) donde el sujeto de la oración principal es animado y el de la oración subordinada es inanimado. Por tanto, según este paradigma, la mayor probabilidad de que un sustantivo inanimado ejerza el papel de sujeto (de la oración principal) disminuye la dificultad de procesamiento. Esta condición propone una particularidad interesante, pues el éxito del lector vendrá determinado no solo por el uso de pistas sintácticas (que le ayudarán a resolver la oración relativa de objeto) sino por la integración de las pistas sintácticas con el uso de pistas semánticas (sujeto inanimado – sujeto animado) que le ayudarán a reducir la dificultad de procesamiento sintáctico que resulta de la interpretación de una oración de relativo de objeto.

Con estas tareas, Traxler et al. (2014) analizaron la interacción entre claves sintácticas (orden o complejidad sintáctica) y semánticas (sujeto animado o inanimado) en adultos con y sin sordera. Los participantes con sordera fueron distribuidos en tres grupos en función del grado de conocimiento de la lengua de signos. Los resultados de éstos se compararon con los de dos grupos de lectores normoyentes bilingües y monolingües. Los autores llevaron a cabo dos experimentos, en el primero de ellos, partieron del paradigma *penalización por objeto*. En el segundo experimento, analizaron los patrones de lectura en frases activas y pasivas, pronosticando que si los lectores con sordera eran sensibles a la estructura sintáctica se observaría un aumento en el tiempo de lectura de las oraciones pasivas frente a las activas a consecuencia de la mayor demanda de procesamiento que imponen las oraciones que no siguen un orden canónico. En ambos experimentos las oraciones eran presentadas palabra a palabra a la vez que se registraba el tiempo de lectura.

En cuanto a los resultados, se observó que los lectores con sordera son sensibles a las claves sintácticas ya que requirieron más tiempo para procesar las oraciones relativas de objeto que de sujeto. Ello indica que el procesamiento sintáctico de los participantes con sordera se asemeja a los normoyentes, ya que el efecto de penalización por objeto también estuvo presente en su lectura. Sin embargo, los resultados también sugirieron que los lectores con sordera no son tan eficientes como los lectores normoyentes para procesar este tipo de oraciones, pues invirtieron más tiempo que los normoyentes en procesar frases relativas de objeto. Por último, los participantes con sordera integraron las claves sintácticas y semánticas en su procesamiento, ya que la presencia de un sujeto inanimado facilitó la interpretación de las oraciones subordinadas de objeto.

Los resultados del segundo experimento (oraciones pasivas vs. activas) llevaron a una conclusión similar. En este caso, los participantes con sordera invirtieron más tiempo en la lectura de oraciones pasivas que simples, reflejando nuevamente su sensibilidad a la complejidad sintáctica. Además, realizaron más errores en las oraciones pasivas que los adultos normoyentes, lo cual nuevamente indica que son menos eficaces que los normoyentes en este tipo de tareas.

La investigación de Traxler et al. (2014), especialmente el Experimento 1, contrarresta aquellas hipótesis hasta el momento planteadas mediante medidas off-line que abogan por un procesamiento lector basado principalmente en la información semántica. Sin embargo, tanto el estudio de Coulter y Goodluck (2015) como el de Traxler et al. (2014) presentan un par de limitaciones importantes ligadas a la metodología empleada para la presentación y registro del patrón lector. En primer lugar, la presentación de los estímulos "palabra a palabra" genera una lectura poco natural, en la que el lector "forzosamente" se enfrenta a todas las palabras. Es posible que en una situación de lectura natural donde no se fuerza al participante a visualizar todas las palabras, el lector ni tan siquiera atendiera a éstas (tal y como propone la estrategia de palabras clave). En segundo lugar, la tarea impide que el lector pueda volver a atrás para leer algunas palabras; consecuentemente, se pierde información que podría ayudar a definir mejor el patrón de lectura. Dadas las limitaciones en el modo de presentación y registro, así como la amenaza relativa a la validez ecológica de la tarea, los resultados de Traxler et al. (2014) y los de Coulter y Goodluck (2015) serían discutibles. De esta forma Piñar et al. (2017) trataron de replicar los resultados obtenidos en el estudio de Traxler et al. (2014) introduciendo dos modificaciones. Por una parte, en lugar de presentar las oraciones palabra a palabra emplearon el registro de movimientos oculares o "*eye-tracking*"; de esta forma los efectos de complejidad sintáctica podrían observarse mediante indicadores adicionales más allá del tiempo de lectura de la palabra (e.g., regresiones). Por otra parte, a diferencia de Traxler et al. (2014) evaluaron el nivel de comprensión lectora en textos de los participantes y consideraron esta variable en los análisis. Los resultados demuestran la presencia de ambos efectos reportados previamente por Traxler et al. (2014), observándose tanto la penalización por objeto (mayor tiempo de lectura de oraciones relativas de objeto frente a relativas de sujeto) como la reducción de dicho efecto cuando se incluía un sujeto inanimado. De este estudio se concluye que tal y como Traxler et al. (2014) anticipaban, los adultos con sordera son sensibles tanto a las claves semánticas como a las sintácticas e integran la información de ambas claves para comprender las oraciones.

Hasta el momento, gran parte de los estudios presentados que hacen referencia al procesamiento sintáctico de la población con sordera mediante medidas de procesamiento on-line se han llevado a cabo con población adulta. No disponemos pues de conocimientos que informen de estas medidas desde un corte más evolutivo. Uno de los estudios que analiza esta cuestión es el de Breadmore, Krott y Olson (2014).

Breadmore et al. (2014) analizaron las habilidades morfosintácticas de 19 estudiantes con sordera, de 11 a 16 años, a partir de la manipulación de la concordancia de sujeto-verbo mediante medidas on-line (en este caso, registraron el tiempo de lectura utilizando la técnica de *self-paced reading*, presentando los estímulos palabra a palabra) con el uso de dos tareas. En una de ellas, los estudiantes debían leer oraciones que contenían incongruencias gramaticales (se registraron los tiempos de lectura) mientras que en la otra los participantes debían corregir los errores gramaticales que encontraron en las oraciones. Los participantes con sordera fueron sensibles a las manipulaciones de concordancia gramatical (en la primera tarea lograron detectar las frases gramaticalmente incongruentes). Si bien, la sensibilidad a la manipulación reflejó patrones distintos de procesamiento, mientras que los estudiantes normoyentes se percataban del error en el verbo (V) o en la palabra contigua (V +1), los estudiantes con sordera lo hacían en la palabra que seguía al verbo (V+1) o en la subsiguiente (V+2). En cuanto a la segunda tarea, a diferencia de los estudiantes normoyentes, los participantes con sordera no fueron capaces de detectar y corregir los errores gramaticales en las oraciones. A pesar de que el estudio de Breadmore et al. (2014) es uno de los pocos estudios que analiza el procesamiento morfosintáctico mediante medidas on-line en niños y adolescentes, no está exento de las limitaciones que ya señalamos para los estudios en población adulta (Piñar et al., 2017; Traxler et al., 2014), principalmente por el modo de registro mediante la técnica *self-paced reading* que simula una situación de lectura poco natural.

Hasta el momento, desconocemos la existencia de evidencia adicional que evalúe el procesamiento sintáctico mediante medidas de registro on-line, obteniendo datos de una mayor validez ecológica a la que se consigue mediante la técnica *self-paced reading*. Por otra parte, aquellos pocos estudios que exploran la cuestión mediante *eye-tracking* evalúan población principalmente adulta (e.g., Piñar et al., 2017). Algunos trabajos han estudiado aspectos relacionados con el procesamiento online de palabras función, sin embargo, el paradigma del que se parte trasciende al ámbito de la lectura (e.g., Krejtz, Szarkowska y Łogińska, 2016; Schouwenaars, Finke, Hendriks y Ruigendijk, 2019) o bien carecen metodológicamente de la información necesaria para extraer conclusiones válidas (e.g., Tomasuolo, Roccaforte y Di Fabio, 2019).

En conclusión, a través de la revisión efectuada hemos observado que las habilidades gramaticales parecen contribuir en gran medida a explicar las dificultades en comprensión lectora de los estudiantes con sordera. Parece ser un hecho que los estudiantes con sordera desarrollan sus habilidades gramaticales con dificultad. Esta baja habilidad se observa cuando los estímulos a procesar demandan una mayor capacidad de manejo de la información gramatical (e.g., ante oraciones complejas), aunque también se observan dificultes en aspectos particulares que generalmente se obtienen por mera exposición al lenguaje oral (e.g., manejo de palabras función). Dadas las características que definen el bajo rendimiento gramatical en los estudiantes con sordera, estas limitaciones podrían verse reflejadas en un patrón de lectura distinto al de los normoyentes. Actualmente, existe una falta de consenso en la literatura que ha explorado esta cuestión mediante medidas offline. Por otra parte, la evidencia online es todavía escasa, limitándose en su mayoría a población adulta.

En consecuencia, el objetivo general de esta **Tesis** será contribuir a la evidencia acerca de patrones de procesamiento durante la lectura de estudiantes (niños y adolescentes) con sordera a partir de medidas de registro de procesamiento on-line, en concreto mediante la monitorización de movimientos oculares (*eye-tracking*). En la Sección 3 de este mismo capítulo ("El Estudio de la Lectura mediante medidas de movimientos oculares"), se pretende explicar en qué consiste esta técnica, qué ventajas tiene y cómo complementa a las medidas off-line, sintetizando las medidas generalmente utilizadas en la investigación en el ámbito de la lectura.

1 | 2.2.3 Habilidades discursivas.

Además de las habilidades lingüísticas citadas, existen otras habilidades que contribuyen a la comprensión del discurso y, por tanto, a la elaboración de un modelo mental del texto (Kintsch, 1998). En concreto, haremos referencia a tres de estas habilidades: capacidad para generar inferencias, la monitorización del proceso lector y el conocimiento de la estructura textual (Landi y Ryherd, 2017; Oakhill y Cain, 2012).

La *capacidad para generar inferencias* refiere a la competenica para generar ideas que no están explícitamente expresadas en el texto y que van desde una simple inferencia local entre dos oraciones interpretando un pronombre a inferencias más globales o elaborativas en las que se usa el conocimiento semántico o pragmático. Generar inferencias resulta necesario para construir un modelo de texto coherente. La capacidad para desarrollar inferencias tiene lugar incluso antes del aprendizaje formal de la lectura, pues esta competencia no solo sirve para comprender un texto, sino que también ayuda a comprender mejor el entorno. Dicha habilidad se mantiene en desarrollo de forma más acentuada desde los 6 a los 15 años aproximadamente (Oakhill et al., 2019). Varios factores contribuyen a su desarrollo (Oakhill et al., 2019). En concreto, la memoria de trabajo ayuda a que el lector recuerde con precisión ciertas partes del texto, el vocabulario (especialmente profundidad del léxico) y conocimiento previo sobre el tema también son de relevancia. Finalmente, los estándares de coherencia del lector contribuyen a que éste ajuste su lectura a las exigencias de la tarea (e.g., no es lo mismo leer con una finalidad de entretenimiento que leer con un objetivo de aprendizaje).

En el caso de los estudiantes con baja competencia en comprensión lectora, parte de las dificultades en elaboración de inferencias surge a consecuencia de que no atienden a las palabras que advierten de la necesidad de generarlas (Sullivan, Oakhill, Arfé y Gómez-Merino, 2020). Generalmente esto suele ocurrir en referencias anafóricas, en palabras como pronombres que hacen referencia a una entidad que las precede en orden de aparición en el texto o en conectores, palabras que sirven de enlace entre oraciones, es decir, de nuevo palabras de función más que de contenido como destacábamos en la sección anterior.

Los estudiantes con sordera parecen presentar limitaciones en la elaboración de inferencias. Tal y como concluyen Sullivan et al. (2020) éstos son capaces de generarlas, si bien resultan más lentos y, por tanto, menos eficientes en su elaboración. La evidencia por lo que refiere a este tema es todavía escasa (Edwards, Marschark, Kronenberger, Crowe y Walton, 2020). Algunos de los estudios se hacen eco de estas dificultades a nivel de comprensión del lenguaje oral (e.g., Mastrantuono, Saldaña y Rodríguez-Ortiz, 2019), siendo pocos los estudios que exploran y documentan diferencias entre estudiantes con sordera y oyentes a nivel de texto escrito (e.g., Kyle y Cain, 2015). El hecho de que usualmente esta población tenga dificultades en procesar durante la lectura palabras función (Domínguez et al., 2016), utilizadas generalmente para elaborar inferencias locales (e.g., pronombres o conectores, véase Sullivan, Oakhill, Arfé y Boureux, 2014) podría explicar por qué en ocasiones los estudiantes con sordera manifiestan mayores dificultades que los normoyentes en este dominio. La baja habilidad en otros factores a los que se ha aludido previamente, también podrían justificar un bajo rendimiento por parte de los estudiantes con sordera a la hora de elaborar inferencias. En concreto, la capacidad de memoria de trabajo (Garrison, Long y Dowaliby, 1997) o las limitaciones en vocabulario y conocimiento previo (e.g., Convertino, Borgna, Marschark y Durkin, 2014), podrían justificar también la presencia de dificultades a este nivel. En relación con la capacidad o disponibilidad de conocimiento previo, cabe añadir que tal y como sugiere Oakhill et al. (2019), el problema puede no solo encontrarse en la capacidad o disponibilidad de conocimiento previo sino también en la velocidad o facilidad de acceso a dicho conocimiento.

Monitorización de la lectura. Monitorizar la lectura implica ser consciente y controlar la comprensión durante el proceso lector (Oakhill et al., 2019). Este proceso posibilita al lector competente detectar fallos durante la comprensión de un texto y le permite poner en marcha las acciones necesarias para reparar dichos fallos (e.g., releer el texto, mirar adelante, mirar atrás [The National Reading Panel, 2000]). Como veremos en el **Estudio 3** de la presente **Tesis**, estas acciones también quedan reflejadas en diversas medidas de movimientos oculares (e.g., proporción de fijaciones regresivas y progresivas en el texto).

De acuerdo con Sullivan et al. (2020) monitorizar la comprensión lectora implica: saber cuándo comprendes, saber qué comprendes, conocer qué conocimiento necesitas adquirir para comprender el texto y, finalmente, saber cómo recurrir a estrategias que ayuden a mejorar la comprensión. Para ello, el lector debe contar con una serie de recursos (entre ellos atención, memoria y teoría de la mente) que le permitan llevar a cabo dicha monitorización.

Esta habilidad se evalúa de diferentes formas. Una de las más comunes consiste en la detección de inconsistencias en un texto. Utilizando este paradigma se ha identificado a lo largo de diversos estudios cómo la población con bajo rendimiento lector también suele tener dificultades en este nivel. Véase como ejemplo el estudio de Tavares, Fajardo, Ávila, Salmerón y Ferrer (2015, Experimento 2), en el que, partiendo de una tarea de detección de inconsistencias anafóricas y acompañándola del registro de movimientos oculares se evalúa la habilidad de resolución de anáforas en textos en un grupo de 12 estudiantes normoyentes con discapacidad intelectual (entre 16 y 23 años). Los autores observaron que los participantes con discapacidad intelectual únicamente detectaban un pequeño porcentaje de las inconsistencias en los textos (22%). Dicha conclusión fue reforzada por los resultados obtenidos a partir de movimientos oculares donde los participantes no modificaron su patrón ocular (no realizaron más relecturas) en las secciones del texto donde se situaban las inconsistencias. De esta forma, los autores concluyeron que este tipo de lectores manifestaban dificultades en las habilidades metacognitivas de lectura, lo cual incluiría a las dificultades de monitorización.

Las dificultades en monitorización también han sido reportadas en población con sordera. Si bien, de nuevo la evidencia en torno a esta cuestión es escasa. Como ejemplo citaremos el estudio de Strassman (1992) en el que, a partir de una muestra de 29 estudiantes con sordera, (entre 14 y 19 años) usuarios de lengua de signos, se evidencia una estrategia de aproximación a la lectura meramente "mecánica" (Sullivan et al., 2020). Esta conclusión deriva de la interpretación de las respuestas producidas a partir de una entrevista que revelaba que únicamente el 21% de los estudiantes con sordera identificaba la relectura como una estrategia de mejora de la comprensión del texto, mientras que el 48% la concebían como una actividad encaminada a facilitar el recuerdo de la información.

Los lectores con sordera manifiestan una baja habilidad en algunos factores indicados de los que dependen las habilidades de monitorización, algunos de ellos ya han sido comentados (e.g., memoria de trabajo) mientras que otros no tanto (e.g., habilidades de teoría de la mente). A este último aspecto hacen referencia algunos estudios recientes (e.g., Figueroa et al., 2020). En este caso, tras evaluar la comprensión lectora y las habilidades de teoría de la mente en 36 estudiantes con sordera e IC (entre 12 y 16 años) se observaba cómo las habilidades de teoría de la mente predicen de manera significativa, junto a las habilidades sintácticas, los resultados de comprensión lectora de los estudiantes con sordera, mientras que las habilidades en teoría de la mente no lo hacen en el grupo de estudiantes normoyentes.

Finalmente, dentro de las habilidades discursivas cabe hacer mención al *conocimiento de la estructura del texto* que también se relaciona con la comprensión lectora (Oakhill et al., 2019; Sullivan et al., 2020). Si el lector conoce o está familiarizado con diversos géneros textuales le resultará más sencillo encontrar la información en el texto y elaborar un modelo mental sobre él. Además, se crea unas expectativas que le ayudan a regular su proceso lector. Por ejemplo, si se enfrenta a un texto narrativo esperará encontrarse con una estructura de descripción (donde conocerá a los personajes), nudo y desenlace.

Los autores que han examinado el conocimiento de la estructura del texto en estudiantes con sordera lo han hecho a partir del análisis de narraciones escritas producidas por estudiantes con sordera, observándose en la mayoría (aunque no en todos los casos) limitaciones en comparación con los normoyentes (véase Sullivan et al., 2020, para una revisión).

La manera en la que el género textual influye en el patrón ocular de lectura de los estudiantes con sordera se abordará en el **Estudio 3.**

1 | 3 El Estudio de la Lectura mediante medidas de movimientos oculares.

La técnica de *eye-tracking* o *seguimiento ocular* constituye un instrumento en auge en la investigación de diversas disciplinas (usabilidad, psicolingüística, psicología cognitiva, neuropsicología, etc.) (Holmqvist et al., 2011). Esta metodología permite obtener evidencia acerca de cómo las personas atienden y procesan la información a partir de la monitorización y registro de los movimientos oculares. De esta forma, es posible inferir lo que ocurre mientras tiene lugar el procesamiento (durante una fase on-line) y completar por tanto la información proporcionada por otras medidas (p.ej. aciertos/errores en una tarea) que basan sus conclusiones en el resultado obtenido tras el procesamiento (durante una fase off-line). Esta característica convierte al *eye-tracking* en una metodología interesante para el estudio de la lectura (Rayner, 1998), actividad en la que participan distintos procesos cognitivos para confluir en un resultado: la comprensión del texto escrito.

La información que se obtiene mediante el seguimiento del movimiento ocular toma como referencia el reflejo corneal generado a partir de la luz infrarroja emitida a través del equipo de registro o rastreo ocular (*eye-tracker*), proporcionando como resultado diversos datos que ilustran los eventos relacionados con el comportamiento ocular durante el desarrollo de una tarea. Esta información es almacenada y codificada por el sistema, facilitando medidas de diversos tipos.

La lógica de utilizar el *eye-tracking* como medida de procesamiento radica en la relación que el foco de fijación mantiene con el procesamiento cognitivo. Esta relación es especialmente clara para el caso de la lectura, en que el lector puede modificar su conducta a voluntad para gestionar la información textual que se le ofrece o *input* (p.ej. releyendo, realizando pausas más largas en ciertas secciones o palabras…) (Just y Carpenter, 1980).

Una de las limitaciones de las medidas de movimientos oculares es su interpretación. El registro de los movimientos oculares por sí solo no es suficiente para otorgar a los datos una interpretación inequívoca a la luz del procesamiento cognitivo que pueda estar teniendo lugar detrás del mismo (Holmqvist et al., 2011). Por ejemplo, se puede observar un cambio en el patrón ocular en un área, bien porque ésta haya llamado la atención o interés del participante o bien porque el contenido de esta resulte difícil de procesar (Hyrskykari, Ovaska, Majaranta, Räihä y Lehtinen, 2008). Los mismos datos pueden llevar por tanto a dos conclusiones contrapuestas. Así pues, mientras que en el primer caso los movimientos oculares reflejarían que el participante es sensible a la tarea, en el segundo caso los movimientos oculares reflejarían las dificultades de éste durante su desarrollo. De este modo, para que la interpretación tenga sentido cabe considerarla teniendo en cuenta el diseño y el objetivo del estudio, deduciendo de manera indirecta los cambios en el comportamiento ocular que se generan a partir de las cuidadas manipulaciones experimentales que se planteen. El paradigma del que se parta, la manipulación experimental realizada y la unidad de análisis (palabra, frase o texto) determinarán los cambios a observar y las medidas adecuadas para capturar los efectos.

Para una mejor comprensión de los estudios planteados en este trabajo se describirán a continuación las medidas más utilizadas en el estudio de la lectura y su relación con el procesamiento cognitivo cuando se intenta decodificar y comprender texto escrito.

Medidas de movimientos oculares.

Por lo que refiere a las medidas, se distinguen dos grandes eventos: *fijaciones*, definidos como periodos de tiempo en que los ojos permanecen relativamente estáticos en un área del texto, y *sacadas*, movimientos rápidos que permiten que los ojos naveguen de una palabra a otra (Hyönä y Kaakinen, 2019). A diferencia de las fijaciones, durante la sacada no es posible obtener información nueva (Rayner, 1998) aunque el procesamiento cognitivo no se detiene durante este lapso (Rayner, Schotter, Masson, Potter y Treiman, 2016).

A partir de estos dos eventos, se derivan una serie de medidas secundarias, si bien su significado cognitivo y utilidad no siempre es claro (Holmqvist et al., 2011). Muchos investigadores parten de un procesamiento secuencial del lenguaje a la hora de interpretar los resultados. Por ejemplo, se asume que en circunstancias normales de lectura la identificación léxica se produce en un estadio inicial para ser sucedida por la categorización sintáctica y su integración en la oración. Tomando como base esta línea de pensamiento, las medidas de movimientos oculares harían referencia a distintas etapas secuenciales de procesamiento lingüístico: aquellas medidas más iniciales (e.g., duración de las primeras fijaciones) reflejarían estadios de procesamientos temprano (identificación léxica), mientras que aquellas etapas de procesamiento lingüístico posteriores (e.g., procesamiento del discurso, semántica) quedarían representadas en medidas más tardías en aparición (p.ej. aquellas que incluyen tiempo de revisión del texto) (Rayner y Liversedge, 2011). Resulta tentador tratar de establecer una correspondencia inequívoca entre las medidas de movimientos oculares y etapas específicas del procesamiento (p.ej. afirmar que la duración de las primeras fijaciones se corresponde indudablemente con procesos de acceso al léxico). Sin embargo, esta relación no es siempre tan clara pues diferentes tipos de manipulaciones pueden generar efectos en la misma medida. Por ejemplo, puede haber variaciones en la duración de la primera fijación a consecuencia de la manipulación léxica, pero también puede ocurrir ante una manipulación sintáctica (Rayner y Liversedge, 2011). También sucede a la inversa, es decir, una misma manipulación puede producir variaciones tanto en medidas que representan etapas de procesamiento tempranas (e.g., duración de la primera fijación) como en medidas que corresponden a etapas de procesamiento más tardías (e.g., duración de fijaciones en una fase de revisión del texto) (Clifton, Staub y Rayner, 2007; Rayner y Liversedge, 2011). A favor de este argumento cabe señalar el estudio de Rayner, Warren, Juhasz y Liversedge (2004), donde se analizaron los movimientos oculares a partir de la manipulación de plausibilidad semántica en oraciones, observándose efectos en medidas de movimientos oculares representativas de diferentes etapas de procesamiento en función del grado en que la plausibilidad de la oración se veía comprometida. Así por ejemplo, ante oraciones que reproducían situaciones prácticamente imposibles (e.g., "John usó un inflador para hinchar las grandes zanahorias para la cena [*John used a pump to inflate the large carrots for dinner*]" Rayner et al., 2004, p. 1292) se generaban efectos en medidas iniciales, generalmente asociadas a etapas tempranas del procesamiento, mientras que ante oraciones extrañas pero no imposibles (e.g., "*John usó un hacha para trocear las grandes zanahorias para la cena* [*John used an axe to chop the large carrots for dinner*]" Rayner et al., 2004, p. 1292), los efectos eran más evidentes en medidas asociadas a etapas más tardías de procesamiento. De hecho, diversos estudios con otras poblaciones (con normoyentes con desarrollo típico [Joseph y Liversedge, 2013; Liversedge, Paterson y Pickering, 1998] o con autismo [Au-Yeung, Kaakinen, Liversedge y Benson, 2015; Micai, Joseph, Vulchanova y Saldaña, 2017]) señalan que las medidas que indican reanálisis resultan de utilidad a la hora de distinguir distintos patrones de lectura. En consecuencia, ambos tipos de medidas (que refieren a etapas de procesamiento temprano y tardío) se utilizarán para describir el patrón lector de estudiantes con sordera ante frases en que se manipula la congruencia gramatical (**Estudio 1**).

Otro factor por considerar cuando se trata de investigar con *eye-tracking* es que, a pesar de que existe un consenso general con relación a las medidas más comunes, la nomenclatura puede variar en función del equipo o modelo que se utilice. Para evitar confusiones, resulta de utilidad la propuesta de Holmqvist et al. (2011) que agrupan las medidas en 4 categorías: medidas de movimiento, medidas de posición, medidas de numerosidad y medidas de latencia. De manera sintética, se presentan a continuación las medidas que mantienen una mayor relación con los estudios planteados en esta **Tesis**.

Medidas de movimiento. Hacen referencia a las características del movimiento (dirección, amplitud, velocidad y aceleración). En este caso, destacaremos la *amplitud o longitud de la sacada*.

La amplitud de la sacada se define como la distancia que recorre la sacada desde su comienzo hasta su final (Holmqvist et al., 2011). Generalmente se representa en forma de ángulos visuales (◦) o píxeles, aunque también es frecuente reportarla haciendo referencia al número de caracteres que implicaría esa distancia (véase Rayner, 1998). Generalmente la amplitud de la sacada aumenta a medida que lo hace la edad cronológica. De esta forma, cuando los niños se inician en la lectura, la amplitud de la sacada es menor y aumenta progresivamente. Entre los 7 y los 11 años la amplitud de sacada se sitúa entre 6-7 caracteres (véase la revisión realizada por Blythe y Joseph, 2011), mientras que en el caso de los adultos, en condiciones de lectura normal y en silencio, comprende aproximadamente 8 caracteres (Rayner, 1998).

El tipo de tarea (Kaakinen y Hyönä, 2010), la habilidad lectora y la complejidad del material también influyen en esta medida. Generalmente, la amplitud de la sacada es menor en lectores menos competentes o en lectores con dislexia (véase a nivel de palabra De Luca, Borrelli, Judica, Spinelly y Zoccolotti, 2002). Si bien, tal y como se ha apuntado previamente, la interpretación cabe considerarla en conjunción con otras medidas que informen acerca de la ejecución (precisión) del participante en la tarea y del tipo de material empleado para la lectura, pues una disminución de la amplitud de la sacada refleja también una lectura más cauta y puede reflejar una buena práctica lectora. En este sentido, los lectores más competentes suelen regular su lectura de acuerdo con las exigencias del texto, mientras que aquellos con un bajo nivel lector tienen mayores dificultades para adaptar su lectura a las exigencias de la tarea (Kraal, van den Broek, Koornneef, Ganushchak y Saab, 2019). Cabe tener en cuenta este tipo de factores para evitar caer en una interpretación errónea de los resultados.

Medidas de posición. Con el fin de limitarnos al contenido de la **Tesis** nos referiremos a las medidas de duración de la posición. Estas medidas describen los rasgos temporales que caracterizan los eventos delimitados en un espacio o área en concreto (Holmqvist et al., 2011). Entre ellas, destacamos el tiempo total de fijación *(total fixation time)* y el total (*dwell time).*

Tanto el tiempo total de fijación como el *dwell time* se definen como la suma de la duración (en milisegundos) de todas las fijaciones realizadas en un área de interés (incluidas las revisitas al área de interés). La diferencia entre ambas medidas estriba en que el *dwell time* incluye la duración de las sacadas mientras que el tiempo total de fijación las excluye. Otras medidas de duración recogen solamente parte del tiempo invertido en el área de interés, entre ellas destacamos: (a) Duración de la primera fijación o *first fixation duration* (b) duración de la primera pasada o *first-pass gaze duration* (también *gaze duration* cuando la unidad de análisis es la palabra; Rayner, 1998) (c) duración de la segunda pasada o *second-pass gaze duration.* Para una descripción y mejor comprensión de las medidas de duración de posición véase la Tabla 1 y la Figura 3.

Como se ha indicado anteriormente, durante la lectura los incrementos en la duración de las fijaciones se asocian a un mayor esfuerzo de procesamiento (Hyönä y Kaakinen, 2019). Asimismo, la duración de las fijaciones decrece a medida que aumenta la edad cronológica (véase para una revisión Blythe y Joseph, 2011). Generalmente, en el caso de los adultos las fijaciones tienen una duración aproximada de 250 milisegundos, sin embargo, existe una gran variabilidad al respecto, de manera que esta medida puede variar en función de diversos factores como por ejemplo aquellos asociados a la legibilidad de los estímulos (e.g., contraste), complejidad lingüística del material (e.g., frecuencia de las palabras), las características del lector (e.g., habilidad lectora) y el tipo de tarea (Rayner et al., 2016).

Tabla 1. *Resumen y Descripción de Medidas de Movimientos Oculares de Duración de Posición.*

Medida	Unidad de análisis habitual	Representa efectos	Definición
First fixation duration	Palabra	Inmediatos	Duración de la primera fijación en la palabra target durante la primera pasada, independientemente del número de fijaciones.
Single fixation duration	Palabra	Inmediatos	Duración de la primera fijación en la palabra target cuando es la única realizada durante la primera pasada.
Gaze duration / First-pass fixation duration	Palabra / región	Inmediatos	La suma de la duración de las fijaciones realizadas en la palabra target durante la primera pasada.
Second-pass gaze duration	Región	Tardíos	Tiempo empleado en releer la palabra target después de la primera pasada.
Regression path / go past time[b]	Palabra /región	Inmediatos y tardíos	Tiempo de lectura invertido en un área de interés antes de visitar las áreas siguientes (antes de salir por la derecha), también incluye el tiempo de relectura en áreas previas (Rayner, Warren, Juhasz y Liversedge, 2004)
Total fixation time / Total text time	Palabra / texto/región	Inmediatos y tardíos	Tiempo total empleado en la lectura de una palabra target (suma de la duración de las duraciones de la primera pasada pasada [Gaze duration] y de la segunda pasada [Second-pass gaze duration]).
Average fixation duration[a]	Palabra	Tardío	Es el promedio de duración de todas las fijaciones realizadas en un área de interés determinada (Ahn, Kelton, Balasubramanian y Zelinsky, 2020)

Nota. Tabla y contenido adaptado a partir de Hyönä, Lorch y Rinck (2003); Juhasz y Pollatsek (2011).

[a] Esta medida se suele utilizar como descriptor general de la lectura.

[b] Esta medida no se utiliza en la **Tesis** puesto que el programa no permite obtenerla.

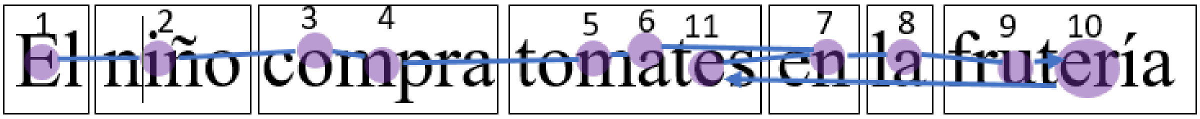

Figura 3. *Representación de Medidas de Movimientos Oculares de Duración de Posición.*

Nota. Los círculos indican fijaciones y su tamaño la duración de la fijación. Las líneas representan la dirección de la sacada y los números el orden de las fijaciones, así por ejemplo, la fijación (5) sería la *first fixation en* la palabra *"tomates"* ; la fijación (1) sería un ejemplo de *single fixation* en la palabra "*El*" ; las fijaciones (5+6) serían el *first-pass gaze* sobre la palabra "*tomates*"; la fijación (11) ilustrará el *second-pass* sobre esta misma palabra; las fijaciones (5+6+11) representan el total de fijaciones que se usarían para calcular el *total fixation time*; y, por último, el *go past time* sobre la palabra "*frutería*" vendría determinado por la suma de la duración de las fijaciones (9+10+11).

Medidas de numerosidad. Entre ellas se incluye el número de fijaciones y la proporción de fijaciones regresivas y progresivas. El número de fijaciones constituye una medida general (Holmqvist et al., 2011) que, generalmente, se incrementa ante áreas que son más difíciles de procesar (Hyönä y Kaakinen, 2019). Las fijaciones pueden definirse mejor en función de la dirección de la que provienen. En este sentido, la proporción de fijaciones progresivas hace referencia a aquellas fijaciones que han sido precedidas por una sacada progresiva (hacia adelante), mientras que las fijaciones regresivas corresponden a fijaciones que se han producido después de una sacada regresiva (hacia atrás). Estas últimas pueden reflejar dificultades durante la lectura (p.ej. el lector vuelve atrás porque tiene dificultades para procesar la información de manera lineal), pero a la vez también reflejan procesos de integración de la información (Hyönä, 1995). Ambas medidas se utilizarán para describir el patrón lector en el **Estudio 3**. También se han usado estas medidas de dirección de la lectura junto con los tiempos de lectura para identificar patrones diferenciales de lectura en textos (e.g., Hyönä, Lorch y Kaakinen, 2002; Hyönä y Nurminen, 2006).

Medidas de latencia y de distancia. Este tipo de medidas hacen referencia al lapso temporal o espacial que sucede desde el inicio o finalización de un determinado evento y el comienzo de otro. Por ejemplo, la latencia voz-vista (*eye-voice latency*) indicaría el espacio de tiempo desde que el participante ha iniciado la fijación en el estímulo hasta que lo ha verbalizado. Existen diferentes medidas agrupadas en esta clasificación, sin embargo, no extenderemos su descripción puesto que no haremos uso de ellas a lo largo de la **Tesis**. Véase Holmqvist et al. (2011) para mayor detalle.

Finalmente, cabe mencionar otro de los eventos que Holmqvist et al. (2011) definen como básicos: la proporción de *skipping* o la probabilidad de no fijar una palabra. Recogemos esta medida al tratarse de una variable utilizada en el **Estudio 3** con el fin de analizar el efecto de la clase gramatical de la palabra sobre el comportamiento lector. De acuerdo con Rayner et al. (2016), aproximadamente un tercio de las palabras no reciben ninguna fijación. Sin embargo, esto no significa que estas palabras no se procesen, aunque se ha observado en algunos estudios cómo la supresión de palabras que tienden a no recibir fijación afecta a la comprensión lectora (Fisher y Shebilske, 1985, citado en Rayner et al., 2016). Diversos factores (e.g., la frecuencia, la predictibilidad [Rayner, Chace, Slattery, & Ashby, 2006]) influyen en el hecho de que una palabra reciba fijaciones o no. En este sentido, a medida que decrece la longitud o aumenta la frecuencia y la predictibilidad de una palabra, la probabilidad de que el lector no realice una fijación en esa palabra se incrementa. Otra de las variables que influye en que una palabra reciba o no fijaciones es la clase gramatical. Algunos estudios de corte clásico (e.g., Carpenter y Just, 1983) indican que las palabras función (preposiciones, conjunciones o pronombres) tienden a no recibir fijaciones con mayor frecuencia a lo observado en las palabras de contenido (adjetivos, sustantivos y verbos).

Medidas de movimientos oculares en función de la unidad de análisis.

La unidad de análisis y el tipo de procesamiento por examinar determinará en gran medida el tipo de medidas a utilizar (Hyönä et al., 2003). Generalmente, cuando el nivel de análisis se reduce a la unidad léxica (la palabra) y se pretende analizar procesos léxicos, las medidas que suelen ser objeto de análisis son aquellas que reflejan etapas iniciales de procesamiento: *single fixation duration*, *first fixation duration* o *skipping probability* (Cook y Wei, 2019). En cambio, cuando se pretende estudiar el procesamiento sintáctico (*parsing*), la unidad de análisis puede variar. De acuerdo con Hyönä et al. (2003), son 4 las unidades que se suelen explorar en este caso: (1) la palabra (en la que se espera que se produzcan efectos a consecuencia de la manipulación experimental), (2) el sintagma, (3) la cláusula y (4) la oración completa. Cuando la unidad de análisis es mayor a la unidad léxica y, por tanto, se sitúa a un nivel supra-lexical, resulta más lógico optar por medidas como *first-pass gaze duration* (duración de la primera pasada), *second-pass gaze duration* (duración de la segunda pasada) o el tiempo total de fijación (Rayner, 1998: Rayner et al., 2006). En el **Estudio 1** de la presente **Tesis**, aunque evaluamos el procesamiento sintáctico a nivel de oraciones aisladas, usamos como unidad de análisis tanto la palabra (una palabra target que corresponde a una incongruencia gramatical, y la palabra posterior –post-target) como el sintagma (que denominamos pre-target por aparecer antes de la palabra target y que consiste en todas las palabras que van desde el comienzo de la oración hasta la palabra target).

Cuando se trata de comprender un texto que implica elaborar una representación mental coherente del mismo (Kintsch, 1998), el tipo de medidas ha de variar. El patrón de movimientos oculares cambia ligeramente cuando se evalúa la lectura a partir de un texto y no de una serie de frases inconexas (Hyönä y Kaakinen, 2019). En el caso de los textos, la duración de la primera pasada (*gaze duration*) en cada palabra es más corta que en el caso de las frases (Radach, Huestegge y Reilly, 2008, citado en Hyönä y Kaakinen, 2019). Ocurre a la inversa en el caso de la amplitud de la sacada y del tiempo total de fijación (*total fixation time*) donde los valores son superiores en los textos frente a las frases (Hyönä y Kaakinen, 2019).

Los estudios que analizan los movimientos oculares durante el procesamiento global de un texto constituyen una minoría (Hyönä et al., 2003). Algunos estudios han analizado el patrón lector en textos partiendo de algunas de las medidas de movimientos oculares "estándar" presentadas en esta sección como longitud de la sacada, proporción de regresiones regresivas y progresivas, tiempo total de lectura del texto, etc. Éstas les han servido como referencia para mostrar la manera en que el patrón de movimientos oculares varía en respuesta a distintas variables como las características propias del texto (e.g., dificultad del texto) (Kraal et al., 2019; de Leeuw, Segers y Verhoeven, 2016a, 2016b; Rayner et al., 2006); o del lector (e.g., habilidad lectora) (Kraal et al., 2019; de Leeuw et al., 2016a; 2016b). Asimismo, otros autores en alguna ocasión han optado por un análisis más cualitativo, utilizando un análisis tipo cluster para identificar distintos tipos de perfiles de lectura en textos (Véase Hyönä et al., 2002; Hyönä y Nurminen, 2006). En el **Estudio 3** de la presente **Tesis** se examinará el patrón lector de los estudiantes con sordera teniendo en cuenta la influencia de variables propias del texto (e.g., género textual).

Particularidades del patrón ocular durante la lectura en población con sordera.

Tal y como se ha mencionado anteriormente, los estudios que utilizan los movimientos oculares para definir el patrón lector de la población con sordera son más bien escasos por el momento. Si bien, algún estudio ha explorado de forma comparada los parámetros mediante *eye-tracking* del comportamiento lector de población sorda y normoyente. En este sentido, se ha señalado cómo la duración de las fijaciones varía en función de variables como el nivel lector, la frecuencia y la predictibilidad de las palabras de manera similar a lo que sucede en los adultos normoyentes (Bélanger y Rayner, 2013). Por otra parte, diversos estudios proponen que los lectores con sordera son más eficaces a la hora de procesar estímulos visuales cuando éstos se hallan todavía en una región parafoveal, encontrándose diferencias en el tamaño del *span perceptual*[6].

Bélanger, Slattery, Mayberry y Rayner (2012), utilizando *el paradigma de ventana-móvil*, hallaron evidencia de que el *span perceptual* de buenos lectores adultos con sordera era más amplio que el de los participantes normoyentes. Más adelante, Bélanger et al. (2018) examinó esta cuestión con niños y adolescentes con sordera. En este caso, la muestra estuvo compuesta por 24 estudiantes (rango de edad = 7 a 15 años) con sordera prelocutiva (en su mayoría severa o profunda) que se comunicaban principalmente en lengua de signos americana. Pese a estar equiparados en edad cronológica, el nivel de comprensión lectora de los estudiantes con sordera era sustancialmente inferior al de los normoyentes, así que los autores elaboraron 4 subgrupos, 2 de ellos permitían clasificar a los estudiantes con sordera según su rendimiento lector mientras que los otros dos consistían en un grupo con sordera y un grupo normoyente de 13 estudiantes, cada uno emparejados en comprensión lectora. Estos dos últimos les permitirían comparar el patrón lector de estudiantes con sordera y normoyentes con un nivel lector similar. El patrón ocular se registró durante la lectura de frases, manipulando el número de caracteres visibles según condición. Además, los estudiantes debían responder a preguntas de “sí/no” tras la presentación de cierto número de frases, asegurando que los participantes leían para comprender. En cuanto a los resultados, los estudiantes con sordera mostraron un *span perceptual* más amplio que los estudiantes normoyentes de la misma edad lectora, replicando los resultados obtenidos en estudios previos con adultos. Asimismo, los estudiantes con sordera demostraron una mayor velocidad de lectura que sus iguales normoyentes emparejados en edad lectora. En cambio, la proporción de regresiones fue similar en ambos grupos. Según Bélanger

[6] El *span perceptual* se define como “la región en la que los lectores utilizan y procesan la información visual con el fin de guiar los movimientos oculares [the region in which readers use and process visual information in order to guide their eye movements]” (Bélanger, Lee y Schotter, 2018; p.292).

et al. (2018), el tiempo de privación auditiva podría ser la causa de las diferencias en el patrón ocular, ya que debido a esta resultan más eficaces en la distribución de recursos atencionales visuales en la región periférica. El hecho de que las personas con sordera sean más eficaces en procesar información visual en la región periférica no ha sido replicado en un estudio reciente (Zeni et al., 2020). En este caso, la tarea no se relaciona con la lectura y los autores exploran esta cuestión durante la percepción de escenas. Si bien, es necesario tener en cuenta que por lo que refiere a la lectura, hasta el momento, esta cuestión no ha sido explorada en participantes con sordera en los que el tiempo de privación auditiva haya sido menor al haber sido equipados con IC de manera temprana.

Como describiremos en su momento, en la presente **Tesis** también se ha usado una medida similar al *span perceptual* (amplitud de la sacada, descrita inicialmente) aunque con un paradigma de tarea de lectura diferente al usado por Bélanger et al. (2018), como explicaremos en su momento (**Estudio 3**).

Esta breve revisión sobre el uso de la técnica de eye-tracking en el área de la lectura, nos permite apreciar la versatilidad de esta para completar las clásicas e inestimables medidas de comprensión offline con medidas online que finalmente nos servirán en la presente **Tesis** para completar un dibujo lo más preciso posible de las características lectoras de los niños y adolescentes con sordera.

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Chapter 2

Empirical Research

- Summary
- General Methodology
- Empirical Studies

2 | 1 Summary

As it had been documented in Chapter 1, researchers have widely shown the low reading achievement exhibited by students with a prelingual severe-to profound deafness compared to their typically hearing peers (e.g., Conrad, 1979; Geers, Tobey, Moog & Brenner, 2008; Harris & Terlektsi, 2011; Moreno-Pérez, Saldaña, & Rodríguez-Ortiz, 2015; Qi & Mitchel, 2012; Traxler, 2000). In this regard, Harris, Terlektsi and Kyle (2017) recently conducted a longitudinal study with children with severe-to profound prelingual hearing loss and children with typical hearing (TH) matched on non-verbal IQ. Participants in the age range of 5-7 years old were asked to complete a set of reading related tests at three time points, 1 year apart (T1–T3): single word reading, reading comprehension, English vocabulary, phonological awareness and speech reading. Their results showed no growth in reading comprehension from T2 to T3 in deaf and hard of hearing children (DHH), regardless of the hearing device used (cochlear implant or hearing aids), whereas TH children's reading progressed according to their chronological age.

However, the systematic review of Mayer and Trezek (2018) illustrated an encouraging trend shift. They analyzed the results of 21 studies over a 20-year time period (1997–2016), on the literacy outcomes of deaf students with cochlear implants (CIs in advance). The review focused on two types of literacy outcomes: reading comprehension and written expression. With respect to reading comprehension, their review pointed out that the majority of DHH students with CIs (from primary to secondary school) were in the average range. Only three studies (out of 14 that included standard scores) showed that participants with DHH were significantly below the average.

Despite this promising trend in the reading comprehension performance of DHH students with CIs, Mayer and Trezek (2018) highlighted that there was a lack of research about the factors that modulate the impact of CIs in the acquisition and development of reading comprehension skills in DHH students, such as communication modality or linguistic abilities before implant.

In this regard, linguistic factors such as phonological coding abilities or vocabulary have been found to predict the reading achievement among individuals with prelingual deafness (Harris et al., 2017; Mayberry, Del Giudice, & Lieberman, 2011; Moreno-Pérez et al., 2015). However, grammatical skills seem to play a more critical role in it (e.g., Barajas, González-Cuenca, & Carrero, 2016; Miller, Kargin, & Guldenoglu, 2013).

There is no doubt about the relevance of the studies mentioned above, however, a perfectible issue is that they have used standardized tests or output measures to assess reading proficiency so they look at the product of reading rather than the process. Examining the process of reading in students with DHH may help to identify exactly where and when reading comprehension breaks down, providing a better understanding of what might be the best focus of reading intervention practices.

The present dissertation was aimed at analyzing the eye movement patterns during reading comprehension of DHH students (age range: 9-15 years) in relation to a TH chronological age-matched control group.

As we advanced in the Preface section, the dissertation is composed of three studies. For **Study 1** and **2**, reading comprehension was analysed at the sentence level while for **Study 3**, reading was analysed at the global text level.

As the Table 2 resumes, in **Study 1**, the use of grammatical cues during sentence processing was assessed by means of a grammatical congruence judgement task. In **Study 2**, the processing of both semantic and grammatical cues was evaluated by means of a multiple-choice sentence reading task. Finally, in **Study 3** the processing of both semantic and grammatical cues was again analysed, but at the global text level instead of at the sentence level. In addition, the effect of text genre (expository versus narrative) and grammatical word class (content words versus function words) was analysed in **Study 3**.

Throughout the three studies, additional exploratory analyses were conducted in order to analyse the association between the individual factors (mainly language related) underpinning the reading ability of both TH and DHH readers on the one hand, and accuracy and eye-movement patterns during text comprehension, on the other.

Table 2. *Overview of Main Design Features of the Three Studies that Composed the Present Thesis.*

Study name	Unit of analysis	Task	Factors manipulated	Assessment format	Skill/knowledge/ Processing level assessed	Off-line measures	On-line measures	
							Areas of Interest (AOIs)	**Eye-movements' variables**
Study 1	Single simple sentence	Incongruence detection task	Grammar congruence of a target word within the sentence	Yes/No questions	Syntactical skill/awareness	Accuracy	Target word Post-target word Pre-target words	First fixation duration. First-pass duration. Second-pass duration. Visits. Revisits.
Study 2	Single complex sentence	Sentence picture-matching task	Type of cue provided by pictures choices (lexical vs. syntactical)	Multiple-choice questions	Lexical and syntactical skill	Accuracy Errors analyses	Target picture and distractor pictures	Total fixation duration. Visits.
Study 3	Whole text or discourse	Reading for comprehension	Text genre (narrative vs. expository) Grammatical Word class (function word vs. content word)	Open-ended inferential questions	Text genre/Text structure knowledge Lexical and syntactical skill Monitoring	Accuracy in inferential questions	Whole text	Saccade amplitude. Average fixation duration. Progressive and regressive fixations. Total reading time.
							Content/function words	Total Fixation Duration. Skipping probability. Visits.

2 | 2 General Methodology

The project was approved by the Research Ethics Committee of Human Beings from the University of Valencia (H1469443238331) and a collaborating hospital, the "Hospital Universitario y Politécnico de La Fe" of Valencia (Spain) (2017/0622).

Methods

Participants

Two groups of students were approached for the present **Thesis**: A group of DHH students as a clinical group (26 in total), a group of students with TH as control group (48 students) and as sample for piloting experimental material (268 in this last case). The whole set of experimental tasks and its procedure was also piloted with six adults (3 of them university students and 2 relatives) and one adolescent (13 years old) with typical hearing.

All participants had to meet the following criteria: 1) showing a nonverbal IQ on average for their chronological age (≥85), 2) not showing word decoding difficulties (word and non-word reading's standard scores 70 or above at the Word and non-Word test of the PROLEC battery (Cuetos, Rodríguez, Ruano, & Arribas, 2007; Ramos & Cuetos, 1999). Additionally, they all showed an intact or corrected-to-normal vision and reported no additional difficulties that could interfere with their performance on the study tasks. Although Valencia is a bilingual region of Spain (Valencian and Spanish are the two official languages), we checked that all participants had used Spanish as one of the instructional languages in primary and secondary schools.

Participants who were deaf or hard of hearing (DHH): Twenty-six participants (range 9.6 – 15.17 years) with a pre-lingual and bilateral severe-to profound hearing loss (Bureau International d'Audiophonologie's criteria, BIAP, 1997) were recruited from different audiology services of public hospitals, educational centers (mainstream schools with special units for students with hearing loss) and associations of people with hearing loss in Valencia (Spain). All DHH students were orally educated and used spoken language as their preferred means of communication. None of them had knowledge about sign language except for a few students who were children of deaf parents and were finally excluded from the final sample because they did not fulfill the inclusion criteria.

As we said above, twenty-six participants with DHH were initially selected. Of these, two were excluded because of visual difficulties (squint), two because of comorbidities (Usher Syndrome, Hydrocephaly and truancy) reported at time of testing, one for using Spanish as a second language and one due to lack of information on educational background as consequence of a late adoption. Additionally, one student with deafness was excluded from **Study 3** due to an interruption during the experimental task. The type of hearing stimulation and degree of hearing loss of the participants of the DHH group are summarized in Table 3.

Table 3. *Age and Hearing Loss Characteristics of the DHH Participants*

Participant	Age	Age of implantation	Stimulation type	Degree of HL
1[a]	13.6	≤2	CI bilateral	Profound
2	11.5	≤2	CI bilateral	Profound
3	11.7	≤2	CI unilateral	Profound
4	12.8	≤2	Bimodal[b]	Profound
5	14.8	≤2	CI unilateral	Profound
6	12.4	>2	Bimodal	Severe
7	14.9	>2	Bimodal	Profound
8	11.5	≤2	CI unilateral	Profound
9	10.3	>2	CI bilateral	Profound
10	15.0		Hearing Aids	Profound
11	15.2	≤2	CI bilateral	Profound
12	9.6	>2	CI bilateral	Profound
13	13.8		Hearing Aids	Severe
14	10.6		Hearing Aids	Severe
15	11.8	≤2	CI bilateral	Profound
16	12.7		Hearing Aids	Severe
17	13.5	≤2	CI bilateral	Profound
18	10.3	>2	CI bilateral	Profound
19	11.3	≤2	Bimodal	Profound
20	12.3	>2	CI unilateral	Profound

Note. Age= Ages are in years; Degree of HL= Degree of Hearing Loss; CI= Cochlear Implant, HA= Hearing Aids; Bimodal= *HA + CI*; ≤ 2= implantation prior or at two years old, >2= implantation after two years old.
[a] Participant 1 was excluded from the Study 3 due to an interruption during the experimental task.
[b] In this context the term "*bimodal*" refers to the type of prosthesis, that is, the student uses a combination of both stimulation types, a Cochlear Implant in one side and a Hearing Aid in the other.

Participants with typical hearing (TH): The typically hearing students were matched to the students with hearing loss on chronological age and nonverbal IQ following a group matching procedure. A total of 7 students with TH were recruited from one of the educational centers were some of the participants with DHH had been recruited. As a greater sample was needed, also participants' attending to different schools were included. A total of 48 TH participants were recruited. However, 25% of the sample (*n*=12) did not performed well at the assessment (i.e., they obtained low scores on tasks related to decoding skills, low reading comprehension or receptive vocabulary). Therefore, a total of 36 participants were finally available. Yet, it should be noted that further exclusions were conducted depending on the data quality on each eye-tracking task. Our intention was to compare the DHH students' performance on reading with a group of TH students of the same reading age and with a group of TH students of a similar chronological age. However, the first comparison was not possible as many DHH students exhibited reading comprehension levels that were even at a lower level of the youngest TH students assessed (3rd graders).

Background Assessments

Participants completed a battery of language and reasoning tests. The results from these assessments were used to describe the sample´s characteristics and to verify the inclusion and matching criteria of the study. Before each test (described below), the instructions were presented both in written and oral form.

Non-Verbal IQ*:* The "Matrices" sub-test from the Kaufman Brief Intelligence Test (K-BIT) (Kaufman & Kaufman, 1997) was used to ensure that nonverbal IQ was within normal range (SS $\geq$ 85). All participants of both groups fulfilled this criterion.

Reading skills: The word decoding skills were measured with the Word and non-Word test of the PROLEC battery (Cuetos et al., 2007; Ramos & Cuetos, 1999); students completed the versions matched to their grade level (PROLEC-R for students attending up to 4th grade and PROLEC-SE for students from 5th to 11th grade). Participants with DHH and TH were in the normal range (SS $\geq$ 70, that is, within two standard deviations from the mean). In addition, they completed the reading comprehension subtest of the Magallanes scale of Reading and Writing TALE 2000 (Toro, Cervera, & Urío, 2000). This is an untimed reading comprehension test where students have to answer a multiple choice format questionnaire based on the information from the text. Students are allowed to check for information in the text if they need to. The test is composed of three different texts addressed to the following grade levels: Text 1 (1st-3rd grade), Text 2 (4th-6th grade), and Text 3 (7th to 10th grade). Because the students with

DHH were reported to have low reading comprehension ability, they were all required to start from Text 2. Students who had obtained an average score in Text 2 and attended grades higher than 6th, were asked to read Text 3. The TH group completed the text matched on grade level.

Receptive Vocabulary: The Peabody Picture Vocabulary Test (Dunn, Dunn, & Arribas, 2006) measures the receptive vocabulary of individuals. The examiner asks the participant to select from four pictures the image that matches with the word pronounced by the examiner. In order to prevent the results from being affected by poor auditory perception, we adapted the task so that the student could also read the word.

Syntactic Abilities: Syntactic Ability Test (SAT) (Domínguez, Alegría, Carrillo, & Soriano, 2013) measures the syntactic abilities of the participants by means of a multiple-choice task. The test consists of 64 sentences with a missing word. Students choose from among four options the correct function word for each sentence. The task was presented in a paper and pencil format.

Expressive language. The subtest of Formulated Sentences from the CELF-4 (Semel, Wiig, & Secord, 2006) was used to measure expressive language skills. Participants are shown a picture (26 in total) and based on the content of the picture, they are asked to formulate one spoken sentence containing a target word or phrase (e.g., third, when, because, etc.) provided by the examiner. The task gives information about the ability of the participants to formulate spoken complex sentences, semantically and grammatically correct. In order to score the responses, the interpretation guidelines of the CELF-4 manual were followed.

Reading span. Finally, an adaptation of the Spanish version of the Daneman and Carpenter's (1980) reading span test was used in a computerized form to measure verbal working memory. There were two versions, one for students from 1st to 6th grade [Carriedo & Rucián, 2009] and one for students from 7th to 10th grade [Elosúa, Gutiérrez, Madruga, Luque, & Gárate, 1996]). Results from this task were only considered for **Study 2** and **Study 3**.

Procedure

The students' assesment was conducted in 2 to 3 sessions, depending on the child's compliance with the tasks. Prior to the assessment, the tutors and parents of all participants were given information sheets and gave their explicit written consent. They also received a report of their results on the standardized tasks used in the study to thank them for their participation. In addition, written consent was obtained from participants older than 12, as the Research Ethics Committee of a collaborating hospital did require. During the first session, participants completed only the off-line tasks (receptive vocabulary, syntactic ability test, reading comprehension test, expressive language, and non-verbal IQ test). In each session, pauses were allowed to let the participants rest. Therefore, this background assessment took up to two sessions.

The last assessment session, lasting no longer than 50 minutes, was performed with the eye-tracker. During this session, the experimental tasks (the sentence judgement task [**Study 1**], the sentence-picture matching task [**Study 2**], the text reading task [**Study 3**]) and two off-line tasks (the reading span and word decoding tasks) were administered. The experimental tasks were applied in the same order to all participants: the sentence picture-matching task (**Study 2**) was completed first, followed by the text reading task (**Study 3**) and by the sentence judgment task (**Study 1**). There were short breaks between each task and participants were calibrated each time they started a new experimental task.

Apparatus

Stimuli were presented on a 15.6- inch ASUS connected to a 18.5" monitor at a resolution of 1366 x 768 pixels. Participants' eye movements during the experimental tasks were tracked using an SMI eye tracker with a recording sampling rate of 60Hz. A head-chin rest system was used to minimize head movements. Participants sat at 60 cm from the screen. In order to ensure a good recording, a 9-point calibration was used. Eye-movements were recorded from the right eye only, although viewing was binocular (Rayner, Chace, Slattery, & Ashby, 2006). An overview of the design and eye-movements variables registered is showed in Table 2.

Analysis

Throughout the **Thesis** we used general linear mixed models to analyse the eye-movement data. This type of analyses allowed us to control for variability related to random variance from participants or items (see Traxler, 2017).

2 | 3 Empirical Studies

Study 1 | *Simple Sentence Comprehension: Processing of Grammatical Incongruences.*

Study 2 | *Complex Sentence Comprehension: Processing of Lexical and Syntactic Cues.*

Study 3 | *Text comprehension: Effects of Text Genre and Grammatical Word Class.*

Study 1 | *Simple Sentence Comprehension: Processing of Grammatical Incongruences.* *

* The content of this section has been adapted from the published work under the reference:

Gómez-Merino, N., Fajardo, I., Ferrer, A., & Arfé, B. (2020). Time-Course of Grammatical Processing in Deaf Readers: An Eye-Movement Study. *The Journal of Deaf Studies and Deaf Education*, *25*(3), 351-364. doi: 10.1093/deafed/enaa005

Abstract

Twenty participants who were deaf or hard of hearing (DHH) and 20 chronological age-matched participants with typical hearing (TH) (mean age: 12 years) were asked to judge the correctness of written sentences with or without a grammatically incongruent word while their eye-movements were registered. TH participants outperformed DHH participants in grammaticality judgment accuracy. For both groups, first-pass, and total fixation times of target words in correct trials were significantly longer in the incongruent condition than in the congruent one. However, whereas TH students showed longer first-pass in the target area than DHH students across congruity conditions, DHH students made more fixations than their TH controls. Syntactic skills, vocabulary and word reading speed (measured with additional tests) were significantly lower in DHH students, but only syntactic skills were systematically associated to the time-course of congruity processing. These results suggest that syntactic skills could have a cascading effect in sentence processing for DHH readers.

Background

Previous studies have suggested that children and adults with deafness are sensitive to morphological and syntactic cues during sentence reading (Breadmore, Krott, & Olson, 2014; Piñar, Carlson, Morford, & Dussias, 2017). However, the time-course of grammar processing could differ in comparison to TH peers (Breadmore et al., 2014).

Therefore, the present study aimed to investigate the time-course of grammatical processing during sentence reading of DHH children and adolescents. By using both off-line (accuracy) and on-line (eye-movements) measures of reading comprehension, we attempted to carry out a more comprehensive analysis of this phenomenon.

Grammatical Skills and Reading Comprehension in Deaf Students

Grammatical competence means the understanding and use of morphology and syntax in a sentence, that is, how words change their form and combine with other words to make sentences (Grammar, 2019). Although morphology and syntax interact (e.g., to convert a passive sentence into an active sentence, both types of changes, morphological and syntactical are needed), the term "syntax" is typically used to refer to both terms in the literature reviewed in this study.

Quigley and King (1980) conducted one of the first large scale studies on grammar competence in deaf students by means of a standardized test of English syntactic abilities. They found that deaf children (10 to 18 years old) had difficulties understanding different syntactic structures compared to their TH peers. Later, Kelly (1996), using a standardized test designed by Quigley, Steinkamp, Power and Jones (1978), observed a "bottleneck effect" of syntax in reading comprehension for readers with DHH. Around 400 adolescents and young students of secondary and postsecondary programs with severe-to profound hearing loss were asked to complete three linguistic tests, assessing respectively syntax, vocabulary and reading comprehension. The results showed that only those DHH participants in the highest quartile of syntactic skills were able to use their vocabulary competence to comprehend the text. Thus, unless participants had a sufficient level of syntax competence (between 84% and 100% of correct answers in the Quigley et al.'s [1978] test), other linguistic skills involved in reading comprehension, such as lexical knowledge, could not be brought into play for DHH students.

More recently, Miller and collaborators (e.g., Miller, 2000, 2010; Miller et al., 2013), based on results of a series of controlled experiments, found that a structural (syntactic) knowledge deficit was the main factor related to the poor comprehension skills of prelingually deaf individuals in languages different from English, such as Hebrew and Turkish. The experimental series was aimed not only to test the syntactic knowledge deficit in DHH students, but also if they compensated such a deficit by showing a preference for a top-down processing of content words during sentence comprehension as described below.

In the most recent study, Miller et al. (2013) asked a group of Turkish readers (from 3rd to 10th grade) with severe-to profound hearing loss and a control group of readers with TH, matched with regard to their level of education and average chronological age, to complete a sentence comprehension test. The test consisted of written sentences varying in syntactic complexity (one relative clause versus two relative clauses) and semantic plausibility (plausible versus implausible), each followed by a multiple-choice comprehension question. The processing of semantically implausible sentences (e.g., *the policeman who was stealing a gun*) required syntactic bottom-up[7] processing of the words (both content and function words), while

[7] According to Kelly (1995), readers:

> Construct mental productions of text that integrate their knowledge of English letter combinations, phonology, syntax, semantics, pragmatics, discourse structure, episodic knowledge, and domain knowledge. The kinds of information appearing early in the preceding taxonomy -- letter combinations, phonology, and syntax -- are frequently referred to as "bottom-up" constraints. These are the specific visual data that readers actually perceive on the printed page. The types of information later in the taxonomy are often characterized as "top-down." Once activated in the mind of a reader, these concepts work "downward" to guide interpretation of the detailed information on the printed page. (p.319)

the semantically plausible sentences (e.g., *the thief who was stealing a gun*) could be correctly interpreted if readers used just a top-down processing of content words. As mentioned earlier in the General Introduction of this **Thesis** (see section 1.2.2.2 "*Gramática"*) semantically plausible sentences do not contradict common assumptions. Thus, if the reader possesses an adequate prior knowledge, he will get to the meaning by understanding the content words and inferring the meaning based on his/her experience. By contrast, when sentences convey a semantically implausible meaning, as they contradict common assumptions, prior knowledge, by itself is not sufficient for understanding the sentence properly (or in other words, top-down processing will not be enough). In these cases, the reader will need to process the syntactic structure (which includes function words) to derive the meaning correctly (bottom-up processing). Students with DHH tend to struggle with syntactic processing (Barajas, et al., 2016; Cannon & Kirby, 2013; Kelly 2003b), specially when the structure of the sentence is more complex (see for example Friedmann & Szterman, 2006; Lee, Sung, & Sim, 2018). Hence, it was expected that the syntactic complexity would affect more prelingually DHH participants, particularly in the implausible condition where the top-down processing was not usable and a proper syntactic processing (that includes bottom-up processing) was required. As anticipated, sentence syntactic complexity affected the DHH group more than the TH group, but the semantic plausibility effect did not interact with hearing status. Overall, participants comprehended semantically plausible sentences to a greater extent than semantically implausible ones. This finding supported the hypothesis of a deficit in syntactic competence of Turkish DHH readers from 3rd to 10th grade. However, the DHH students did not seem to compensate for their lack of syntactic cue understanding by using a top-down processing of content words, since their performance remained below the one of the control groups in both plausibility conditions.

With regard to Spanish, Domínguez and collaborators (e.g., Domínguez, Pérez, & Alegría, 2012; Soriano, Pérez, & Domínguez, 2006) have postulated the “Key Word Strategy” hypothesis in deaf readers that is similar to the hypothesis of top-down processing strategy (Miller, 2000). In their experimental series with deaf and DHH participants (e.g., Domínguez, Carrillo, González, & Alegría, 2016), they used the Syntactic Strategies Assessment Test (SSAT) in which participants complete the last word of a sentence with one of four options: the target word (semantic and syntactically appropriate) or three semantic distractors (semantically plausible but syntactically incorrect). As Gallego, Martín-Aragoneses, López-Higes, and Pisón (2016) noted:

> The rationale of the test is that selecting the proper alternative (target word) requires the use of syntactic and semantic cues. If the reader selects a wrong alternative, this indicates that the sentence is being processed superficially because the reader is guided solely by global semantic cues related to the meaning of some word in the sentence. Errors are thus interpreted as a preference for using semantic strategies as opposed to an accurate analysis of the syntactic relationships among the content words. However, the test has a drawback in that the alternatives to the correct answer are all semantic foils [distractors]. (p. 156)

Therefore, in order to overcome this limitation, Gallego et al. (2016) modified the test of Soriano et al. (2006) by adding a syntactic distractor (an option syntactically correct but semantically implausible). They found that neither DHH nor TH students (8-12 years old) showed a preference for semantic distractor. They interpreted such finding as a lack of support for the Key Word Strategy and Miller’s (2000) hypothesis of top-down processing preference in DHH children.

Also, in Spanish, Barajas et al. (2016) examined the factors influencing reading comprehension skills among 47 Spanish 6 to 13-year old students with a severe-to profound prelingual deafness. Their analysis focused on both the impact of external variables (type of assistive technology, age at fitting, family socioeconomic status and school age) and variables internal to the reading process (decoding, vocabulary and receptive grammar) in reading comprehension. The most interesting result for the issue we are discussing here was that receptive grammar was the only variable that significantly contributed to explaining the differences in text comprehension performance within the DHH group.

In a recent study, Pooresmaeil, Mohamadi, Ghorbani and Kamali (2019) analyzed the relationship between the receptive syntactical skills and reading comprehension abilities in Persian. Their participants were 15 deaf students (from 3rd to 5th grade) with CIs and 15 TH controls. Regression analysis showed that in Persian, reading comprehension increases with the increase of syntactic comprehension for both participants with CIs and participants with TH, whereas the age of receiving a CI and the duration of the speech therapy did not predict reading comprehension in the CIs group.

To sum up, studies conducted in different languages (e.g., English, Persian, Turkish and Spanish) suggested that the syntactic deficit of DHH students could be one of the most significant contributors to their reading comprehension difficulties. However, it is not evident whether they simply ignore grammatical cues during reading or if they process these cues in a different manner. A limitation of revised empirical studies is that they have focused on the output of grammatical understanding rather than on the process, that is, how the morphosyntactic cues are processed when they are encountered in a sentence. The next section focuses on the time-course processing of grammatical cues in DHH readers, the focus of this study.

Time-course of Grammatical Processing in DHH Readers

To our knowledge, only two studies to date (Breadmore et al., 2014; Piñar et al., 2017) have investigated how DHH students process syntactic anomalies while they read sentences (online processing).

In the study by Breadmore et al. (2014), the sample was composed of three groups: 1) deaf adolescents (users of a combination of both British Sign Language and oral English as communication modes in school); 2) a chronological-age (CA) matched TH group and 3) a reading-age (RA) matched TH group. In the first experiment, participants carried out a self-paced sentence reading task (with words presented one at a time, without the possibility to revisit previously read words) with two types of agreement violations (grammatical, subject-verb number-agreement versus semantic, implausible noun-verb combination). In the second experiment, participants had to explicitly detect and correct agreement violations in sentences. The results of the first experiment showed that all three groups were sensitive to semantic implausibility, presenting the same time-course of effects: increment in reading times started in the verb (V) and continued in the subsequent words, called V+1 (first word after the verb) and V+2 (second word after the verb). Although deaf participants were sensitive to subject-verb number agreements, they were so in a different manner than the control group. While the CA-and RA matched children's reading time increased immediately on the verb where the error was (with a small increment on the next word to the verb, that is, V + 1, for the CA group), deaf children's reading times did not increase until V + 1 and V + 2. The authors suggested that, although students with deafness were able to detect the agreement errors, the way they processed the agreements differed from that of TH readers, because they did it later in time (in the post-target region [V1 and V2] instead of in the target region). In the second experiment, the same groups of participants were requested to explicitly detect and correct the grammatical violations in the sentences of experiment 1. The TH participants, but not the deaf participants, were able to solve the grammatical errors. Thus, deaf adolescents demonstrated implicit sensitivity to grammatical agreement, but less robust explicit knowledge of it. Breadmore et al. (2014) concluded that deaf adolescents appeared to adjust to a semantic-first account (the analysis of the semantic cues initiated earlier than the syntactic one). However, TH children, especially in the case of mature readers like adolescents, adjusted to a grammatical-first account, that is, a grammatical agreement assessment would precede or, at least, finish before the semantic analysis ends (Kenney & Wolfe, 1972).

The second recent examination of the online processing of syntactic and semantic cues during reading by deaf readers was the study by Piñar et al. (2017). They asked thirty- nine young adults (18 – 33 years old) who were bilingual in American Sign Language (ASL) and English spoken language to read sentences with relative clauses while their eye-movements were recorded. Two variables were manipulated: 1) the role of a Noun Phrase (NP) (subject versus object of the verb inside a relative clause) and 2) the animacy of the NP (animated NP [e.g., *hiker*] versus inanimate NP [e.g., *avalanche*]). Specifically, the following 4 types of relative clauses were used (Piñar et al., 2017, p. 983-984).

(1) Subject-animate: The hikers that fled the avalanche appeared on the six o'clock news.

(2) Object-animate: The hikers that the avalanche buried appeared on the six o'clock news.

(3) Subject-inanimate: The avalanche that buried the hikers appeared on the six o'clock news.

(4) Object-inanimate: The avalanche that the hikers fled appeared on the six o'clock news.

The critical region for analysis was the relative clause region following the relative pronoun that. According to a previous finding with TH readers (Traxler, Corina, Morford, Hafer & Hoversten, 2014), object relative sentences are more difficult to process than subject relative sentences (as evidenced by slower reading times of the critical region in the former) but only with the animated NP (*hiker*), which is not expected to occupy an object position. Traxler et al. (2014) suggested that such an interaction between animacy and role of the NP demonstrated the interplay of syntactic and semantic cues in written sentence processing. Consequently, Piñar et al. (2017), predicted that if deaf readers made use of syntactic and semantic information as TH readers, they would show longer reading times and more eye-movement regressions in the object relative clause sentences, but only with the animate NP (example 2). Indeed, results showed that bilingual deaf adults showed longer total reading times in the target region (the relative clause region following the complementizer *that*) for animate object relative clauses compared to animate subject relative clauses, whereas no differences between object vs. subject conditions were found for inanimate NP sentences. Therefore, these findings suggest that deaf readers, like TH readers, are sensitive to both syntactic and semantic elements of sentences.

To sum up, the aforementioned studies seem to confirm that children, adolescents and young adults with DHH (both sign language users and bilinguals [oral language and sign language users]) are sensitive to morphological and syntactic cues during reading (Breadmore et al., 2014; Piñar et al., 2017). Thus, **Study 1** aimed to further explore the time-course of syntactic cue processing during sentence reading in children and adolescents with DHH, overcoming some limitations of the studies discussed here. First, the procedure used in the study by Breadmore et al. (2014), where words were presented one at a time, does not allow drawing inferences on natural reading processes in which readers are exposed to the full text and can read back and forth. Unlike Breadmore et al. (2014), we used an in toto presentation mode (the whole sentence is displayed in the screen instead of presenting one word at a time), which allows analyzing re-reading behavior (once the reader encounters a difficult word in a text or sentence) (Au-Yeung, Kaakinen, Liversedge, & Benson, 2015; Joseph & Liversedge, 2013; Liversedge, Paterson, & Pickering, 1998; Micai, Joseph, Vulchanova, & Saldaña 2017).

Second, the lack of a TH control in the study of Piñar et al. (2017) makes it difficult to determine if the interaction between semantic and syntactic cues observed in DHH readers were specific of this group of readers or, alternatively, differed in magnitude with regard to TH readers. Focusing only on syntactic cues, we have added to our design a TH control matched on chronological age, in order to identify differences, if any, in magnitude and/or time-course between DHH and TH readers in the processing of these types of cues during reading.

Third, in constrast to Breadmore et al. (2014) and Piñar et al. (2017), who investigated the reading processes of adolescents and adult readers, we aimed at studying the online processing of grammatical cues in primary and secondary students who were still developing their reading strategies. Moreover, unlike prior studies, our participants were mainly CI users who, in general, received an oral education and were exposed primarily to oral language.

To recap, prelingually DHH students have reading comprehension difficulties directly related to a difficulty with grammatical information. Nevertheless, it remains unclear if this difficulty makes them use an alternative strategy in sentence processing, where they skip or "ignore" the information provided by grammatical cues in sentences, as suggested by the "Key Word Strategy" (e.g., Domínguez et al., 2016, 2012) or if they simply put more effort into processing this information compared to their TH peers, due to their low grammatical ability.

Study 1

The purpose of this study was to examine the reading behavior of young orally educated DHH students by analyzing their eye-movements while taking part in a grammatical judgment task during sentence reading.

Our research questions were as follows: 1) Are orally educated DHH children and adolescents as accurate as TH students when detecting sentences with grammatical incongruence? 2) Do they use the same online processing behavior as TH students when reading sentences to judge their correctness?

Based on prior studies, we made the following predictions: 1) DHH readers would be less able than TH readers to detect the grammatical incongruence of the sentences read (e.g., Barajas et al., 2016; Breadmore et al., 2014; Kelly, 1996; Pooresmaeil et al., 2019) and 2) DHH readers' sentence processing would differ from that of TH readers for sentences with grammatical incongruences. Specifically, we expected no immediate significant effects of grammatical violations on the target area (incongruent word) for the DHH readers (similar number and duration of fixations), but delayed effects in terms of number and duration of visits and revisits to pre- and post-target areas. This prediction of a delayed effect of grammatical congruity in the post-target area was based on previous findings by Breadmore et al. (2014). His results found that deaf participants were sensitive to grammar errors but later in time compared to TH readers. Whereas TH readers spent longer time reading the word that contained the grammar error (the verb region), deaf readers increased their reading time of the subsequent two words after the grammatical error. These results suggested that grammatical analysis happened later in deaf readers than in TH readers. As mentioned, no previous research has explored the processing and re-analyses of pre-target areas (area before the grammar error) in DHH readers. However, earlier studies with other populations (Au-Yeung et al., 2015; Joseph & Liversedge, 2013; Liversedge et al.,1998; Micai et al., 2017) suggest that any kind of sentence re-analysis measures (specifically, eye-movements measures), which serves as an index of what the reader does when he/she encounters a difficult word, could help to distinguish different reading patterns.

Methods

Participants

Participants who were deaf or hard of hearing (DHH): The final sample of DHH students included 20 participants (12 females, 8 males) with a mean age of 12.5 (range 9.6-15.2 years) from 4th to 10th grade. Of the 20 DHH participants included in the study, the majority (n=16) had profound hearing loss and four had severe hearing loss, as reported in their clinical or school records. Twelve participants were fitted with CIs (8 bilateral and 4 unilateral), 4 were fitted with Hearing Aids (HA) and 4 received a bimodal stimulation (HA + CI). Regarding those participants who were fitted with CI, 10 received their first CI before the age of two, and 6 after that age, with the mean age of first implantation being 3 years and 2 months.

Participants with typical hearing (TH): Twenty students (11 girls) with TH and a mean age of 12.00 (range 8.10 – 17 years) from 3th to 11th grade comprised the control group. All had Spanish as their first language, normal or corrected-to-normal vision and were not reported to present learning disabilities or developmental disorders.

Background Assessments

In Table 4, we report the standard scores (SS) for age that followed the IQ scale with a mean of 100 and a standard deviation of 15. When the test manual did not provide age-specific standard scores, we used raw scores (RS).

Table 4. *Background Characteristics of DHH Participants and TH Participants.*

Group	DHH (*N*=20, 12 girls)		TH (*N*=20, 11 girls)		Comparisons between groups			
Background measures	*Mean*	*SD (range)*	*Mean*	*SD (range)*	*F*	*U*	*p*	*r*
CA (months)	149.70	20.45 (114-182)	144.75	25.25 (106-204)	0.53		.503	0.11
Non Verbal IQ (SS)[a]	103.20	9.12 (87-118)	109.25	10.85 (86-126)	0.16		.064	-0.29
Word Reading Accuracy (SS)[a]	106.85	8.23 (86-115)	107.07	8.07 (80-115)		198.50	.967	-0.01
Non Word Reading Accuracy (SS) [a]	109.51	9.41 (82-121)	108.75	7.24 (91-121)		172.50	.456	0.05
Word Reading Speed (SS) [b]	107.51	10.86 (80-123)	115.99	7.36 (100-130)		106.00	.010	-0.42
Non Word Reading Speed (SS)[a]	111.78	10.18 (82-127)	113.46	7.69 (101-127)		190.50	.797	-0.09
Text Reading Comprehension (SS)	87.50	19.18 (50-124)	103.90	6.65 (90-115)		80.00	.001	-0.50
Receptive Vocabulary (SS)	76.86	20.9 (55-117)	105.45	9.10 (85-115)		55.50	< .001	-0.66
Syntactic Ability Test (RS)	43.65	13.55 (15-59)	52.00	11.09 (27-64)		125.00	.042	-0.32
Expressive Language (RS)	35.90	8.06 (19-48)	43.45	5.90 (31-50)		87.00	.002	-0.47

Note. CA= Chronological Age; RS= Raw Scores; SS= Standard Scores

[a] All participants of both groups fulfilled the inclusion criteria, that is, SS =>70

[b] All participants of both groups fulfilled the inclusion criteria, that is, SS =>70 but, in average, the TH group were faster or more accurate significantly than the DHH group.

Experimental Task

Participants silently read 24 sentences written in Spanish (12 congruent and 12 incongruent ones). A target word was manipulated in order to generate a grammatical incongruence in half of the trials (e.g., *la hija*/*la padre* - *the daughter*/ *the father* - in this case, the noun "padre*"* *(father),* which is the target word, is not congruent in gender with the determiner "la" in Spanish). Grammatical incongruence was presented in a random order and manipulated along several dimensions: article-noun gender or number agreement, verb tense and presence/absence of preposition.

Stimulus construction: Taking the Syntactic Strategies Assessment Test (SSAT) (Soriano et al., 2006) as a basis, our material was elaborated ad hoc for the experiment. The incongruent word was associated semantically with the congruent one according to the free Spanish association norms (Fernández, Díez, & Alonso, 2012). The target words were also matched in length, number of syllables (congruent: *Mdn*= 2; incongruent: *Mdn*=2; *U*= 276 *z*=-.30, *p*= .758, *r*= .04), number of characters (congruent: *Mdn*= 5.5, *SD*= 1.35; incongruent: *Mdn*= 5; *U*=282, *z*=-.12, *p*=.898, *r*= -.01) and written word frequency (*z*=-.52, *p*=.959, *r*= -.07), according to the ESPAL database (Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013).

Stimulus evaluation: Sentence congruity was checked in a pilot study carried out with 88 TH students of primary (3rd and 5th graders) and secondary school (7th and 10th graders) who did not take part in the eye-tracking experiment. Students had to rank using a 3 point Likert scale if a set of 30 sentences selected and modified from the SSAT test (Soriano et al., 2006) was correct or not: seemed 1 (*correct*), 2 (*uncertain*), or 3 (*incorrect*). Based on the results of this pilot, we selected the items that were considered congruent (those with a mean under 2) and incongruent (those with a mean equal or above 2). According to the results of this first pilot, we modified the test sentences or added new sentences. In order to test the plausibility and validity of the new sentences we conducted another pilot study with 180 students (from 4th, 6th, 8th and 10th grades). We used the same Likert scale as in the first pilot to rank the congruity of the sentences.

As a result, 24 congruent and 72 incongruent sentences were selected. In order to select the best incongruent sentences, we selected the ones in which the manipulated word had a higher semantic association to the sentence context according to a Spanish version of the Latent Semantic Analysis (Landauer & Dumais, 1997).

Thus, our experimental material consisted of 24 pairs of sentences: each one with 2 versions: congruent or incongruent. Two lists (A and B) of 24 sentences (half-congruent and half-incongruent) were designed in such a way that only one version of each sentence appeared in each list. Lists A and B were assigned alternatively to participants and each list was viewed by the same number of participants in both groups (DHH and TH). Within each group, the order of sentence presentation was randomized by participant.

Interest Areas for eye-movements analysis: Sentences were divided into three main areas of interest (AOIs). All sentences began with a pre-target region (PRE), which was composed of all the words that preceded the target region (TAR). The TAR was the word that had been manipulated in order to generate the incongruences. Following the TAR, we defined a post-target region (POST) to capture spatially delayed effects in participants' judgments (Breadmore et al., 2014; Godfroid et al., 2015). The POST displayed the word next to the TAR, but if the word contained fewer than 5 characters the POST was extended to a second word in order to reduce skipping behavior of short words (Godfroid et al., 2015; Rayner et al., 2006). Interest areas are shown in examples (1a) and (1b) (target region in bold). The examples represent a congruent sentence (1a: The noun "*hija*" is feminine in Spanish so it agrees with the feminine article “la”) and an incongruent one (1b: The noun “padre” is masculine in Spanish so it disagrees with the feminine article “la”).

1a.	La madre quiere a la	**hija**	mucho.	(Congruent)
	(The mother loves the	***daughter***	*a lot).*	
	PRE	**TAR**	POST	
1b.	La madre quiere a la	**padre**	mucho.	(Incongruent)
	(The mother loves the	***father***	*a lot).*	
	PRE	**TAR**	POST	

Eye-movement measures: Different eye-tracking measures inform about the stages of the reading processes. Although, to our knowledge, there is not a systematic list that determines the exact measures that correspond to each stage of processing, this correspondence can be partly inferred from previous literature (Clifton et al., 2016; Liversedge et al., 1998). Measures such as *first fixation duration* or *first-pass gaze duration* are indicative of early processes, that is, when the word is first encountered (referring to lexical access). On the other hand, late measures could reflect integration processes, such as re-reading patterns and reanalysis (e.g., Liversedge et al., 1998). Measures such as *second-pass gaze duration* or *regressions into AOI* are classified into this group. Other measures that inform about the general process, such as fixation time and fixation count, could also be classified into late processing measures.

In the target (TAR) and post-target (POST) AOI’s, the following early and late processing measures were analyzed: *First-pass time* or *first-pass gaze duration* (Sum of fixation durations from the first entry into an AOI until the eye leaves it in any direction), *second-pass time* or *second-pass gaze duration* (Sum of fixation durations from the second entry into an AOI until the eye leaves it in any direction) and *fixation count* (total number of fixations within the area of interest taking into account both first-pass and second-pass). Trials with no fixations in TAR were excluded from the analysis.

Focusing on the pre-target region (PRE), both grammatical congruity conditions were identical until the TAR area, so only second pass gaze duration as a reflex of late processing was considered in the analyses. Second-pass gaze duration in this area was calculated in a similar way to what other authors call "re-reading time" and is meant to provide an index of the time a participant spent detecting a problem and re-reading the text (for a more detailed description, see Liversedge et al., 1998). As items differ in the number of words of the pre-target area, the number of words for each item was averaged in the second-pass.

Procedure

In the experimental task, participants were requested to judge if the sentences displayed one by one on a computer screen were correct or not while at the same time their eye-movements were recorded. Before the recording, students completed 4 practice trials to verify that they understood the task, all the instructions were presented orally as well as in written form and, if necessary, instructions were repeated before the recording began. A fixation point in the middle-left corner of the screen preceded each sentence. Participants had to look at it and contingent on their gaze the sentence appeared (Micai et al., 2017). The students had to read in silence the sentence and immediately after reading it, the question, "Is the sentence correct?" appeared on the screen. Participants had to give a yes/no answer by clicking on the chosen option.

Results

Accuracy

Since accuracy scores were not normally distributed, non-parametric tests (Mann-Whitney test - Wilcoxon rank-sum tests) were applied. Differences in the percentage of correct responses between groups (DHH and TH) and between conditions (congruent – incongruent) were examined. Our criteria for correct answers on sentence grammaticality were: "no" when sentence was incongruent, and "yes" when congruent.

Our findings confirmed that DHH students showed greater difficulties detecting grammatical incongruence than TH students. Differences between the two groups were significant for accuracy (U = 77.50, z = - 3.32, p =.001, r = - .52), with DHH students showing a significantly lower percentage of correct responses (M =77) than the TH students (M=90) in the grammatical judgment task.

The effect of grammatical congruity was not significant neither for the DHH group (z = - 1.60, p = .109, r = - .36) nor for the TH group (z = - 1.54, p = .122, r = - .34).

Time-course processing: Eye-movements

Data preparation and analysis: Fixations shorter than 80 ms and longer than 1200ms were excluded from the data set (Joseph et al., 2008). For each eye-movement time measure, the cells that were either > 2.5 *SD*s above or below each participant mean for each condition, were excluded from the analyses (following Micai et al., 2017).

Only trials with correct answers were analysed. We used the lmer program of the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) in the R environment (R Core Team, 2019) to perform linear mixed effects analyses of the relationship between each time eye- movement measure, congruity and group. We used mixed models in order to account for random variance associated with items (sentences) and participants.

With regard to categorical fixed effects, we entered group, congruity, and their interaction term into the model. Groups were matched on chronological age and IQ but differed in other background measures (Table 4). Therefore, we also added as continuous control variables, word reading speed (standard score), vocabulary (standard score), syntactic skill (percentage of correct answers), and chronological age (which ranged largely within groups) and computed their interaction terms with group and congruity. The variable word reading speed was included since participants from both groups differed on it, whereas vocabulary and syntactic skills were added to the model as according to previous literature both domains appear to be related to DHH students' sentence reading performance (see Domínguez et al., 2016; Moreno-Pérez et al., 2015). The aim was to explore whether any of these continuous variables could affect variance in the eye-movement measures and highlight potential confound variables. Both groups also differed significantly in expressive language skills, however, this measure was not introduced as a control variable because it is related to language production rather than receptive language. Therefore, these results were disregarded although we inform about it for the sake of transparency. Because these analyses were conducted in an exploratory manner, we did not have specific predictions about the effect of continuous variables on eye movements. We did not formulate hyphotheses in this case in order to keep the analyses simple and to reduce extension, otherwise the interpretation of the study would have exceeded our intentions and could have deviated the reader from the focus of the study. All continuous variables were centered (by subtracting the mean of the variable from each variable) to reduce the effects of collinearity between main effects and interactions.

For random effects in the mixed models, we had intercepts for subjects and items, as well as by-item and by-participants random slopes for all fixed effects (see Barr, Levy, Scheepers, & Tilly, 2013). When the full random structure did not converge, we excluded the random effects that explained the least amount of variability. Each reduced model was tested against the previous one using a chi-square test of model fit with the ANOVA function in R. Only converged models are reported (see further details about the fitted models in Appendix). Time measures were log-transformed, and effect coding was used to contrast categorical fixed effects. Effects were considered as significant if $t \geq 2$. Note that in the next Result sections, we provide *b* and *SE* values in milliseconds (ms) that are computed for fixed effects on raw data to facilitate interpretation, however, the *t* and *p* values correspond to the effects computed on log-transformed measures. The *b*, *SE*, *t* and *p* values of the fixed effects computed with transformed variables are provided in the Appendix.

For the non-continuous variable (Fixation Counts), generalized mixed models were computed with the glmer function ('lme4' R package). Model fitting protocol was similar to that of time variables. Effects for non-continuous variables were considered as significant when $z \geq 2$.

Table 5 shows the means and standard deviations for eye-movement results produced for each of the three regions of interest (only correct answers) per group and congruity conditions. Note that, in order to aid the interpretation of this Table, non-log transformed data have been reported.

Table 5. *DHH and TH students' Performance in Congruent and Incongruent Conditions: Eye-movement Measures for Target, Post-target, Pre-target AOI (Means and Standard Deviations in Parentheses).*

			DHH		**TH**		**Both Groups**	
		DHH /TH	**Congruent *M* (*SD*)**	**Incongruent *M* (*SD*)**	**Congruent *M* (*SD*)**	**Incongruent *M* (*SD*)**	**Congruent *M* (*SD*)**	**Incongruent *M* (*SD*)**
Accuracy (per)		20/20	71.7 (17.7)	82.3 (15.1)	86.2 (15.3)	94 (7.3)	79 (18)	88.1 (13.1)
Target								
	First-pass gaze duration (ms)	20/20	420.40 (36.62)	532.71 (34.09)	501.91 (47.66)	654.43 (45.78)	461.15 (42.14)	593.57(39.93)
	Second-pass gaze duration (ms)	20/20	599.45 (77.89)	867.56 (84.98)	644.46 (144.79)	877.97 (137.96)	621.96 (111.34)	872.77 (111.47)
	Fixation count	20/20	2.57 (0.07)	2.86 (0.06)	2.14 (0.07)	2.50 (0.06)	2.36 (0.07)	2.68 (0.06)
Post-target								
	First-pass gaze duration (ms)	20/20	557.24 (47.88)	422.72(47.57)	693.87 (64.02)	463.82 (64.29)	625.56 (55.95)	443.27 (55.93)
	Second-pass gaze duration (ms)	18/19	647.01 (81.73)	635.58 (87.31)	671.79 (126.84)	518.99 (128.99)	659.40 (104.29)	577.29 (108.15)
	Fixation count	20/20	2.07 (0.07)	1.9 (0.07)	2.00 (0.07)	1.73 (0.07)	2.03 (0.07)	1.82 (0.07)
Pre-target								
	Second-pass gaze duration (ms)	20/20	417.7 (32)	514 (31.2)	462 (30.8)	558.7 (30.3)	439.9 (31.4)	536.4 (30.8)

Note. per= percentage of correct responses.

Target AOI. The target area was the part of the sentence that had been manipulated to generate the incongruence. Regarding the first-pass time (see model in Table A1 in Appendix), the effect of congruity (b = - 65.72; SE = 17.69; t = -2.60; p = .009), group (b = -51.64; SE = 21.57; t= -2.57; p = .014) and syntactic skill (b = -4.50; SE = 1.58; t = -2.63; p = .012) were significant. Participants made longer first-pass in the incongruent condition than in the congruent one (see Figure 4), TH participants made longer first-pass than DHH participants across congruity conditions (see Figure 4) and those participants with higher syntactic skills made shorter first-pass than those with lower syntactic skills in the target region. No other main effects or interactions were significant (see Table A1 in Appendix).

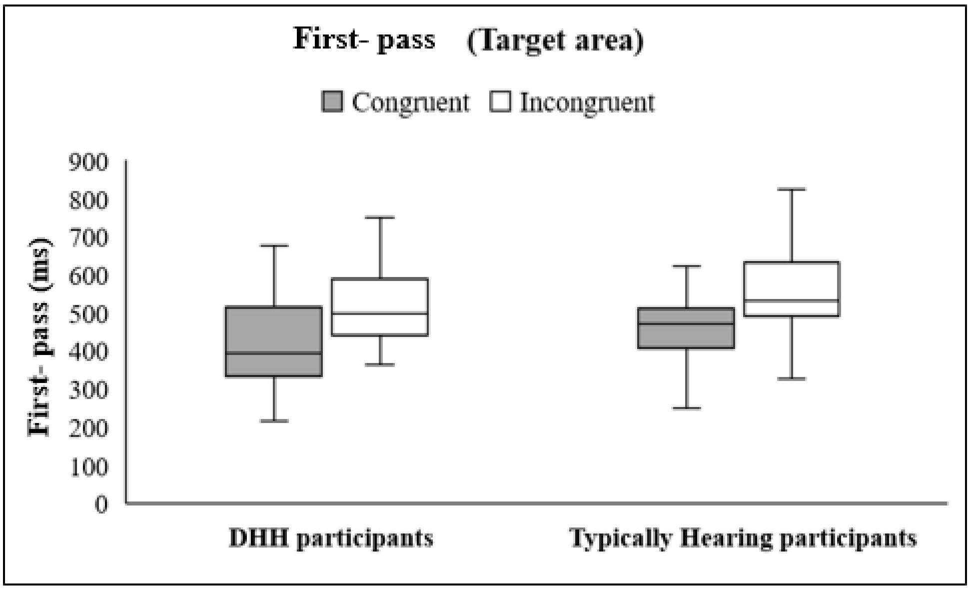

Figure 4. First-pass in milliseconds in the TAR area per congruity condition and participant group.
Note. Non-transformed means were used for making the graphic easier to interpret.

Also, with regard to second-pass fixation duration, the effect of congruity was significant (b = -120.11; SE = 45.82; t = -3.27; p = .002). In particular, participants made longer second-pass fixation in the incongruent condition than in the congruent one across groups, confirming that both DHH and TH students invested more time during their revisits to the target area with incongruence (see Figure 5). The main effect of word reading speed was also significant (*b* = - 6.23; *SE* = 5.34; *t* = -2.09; *p* = .044), such that higher word reading speed was associated with a lower second-pass fixation in both congruity conditions and groups. No other main or interaction effects were reliable (see model, means and *t* values for non-reliable effects in Table A2 in Appendix).

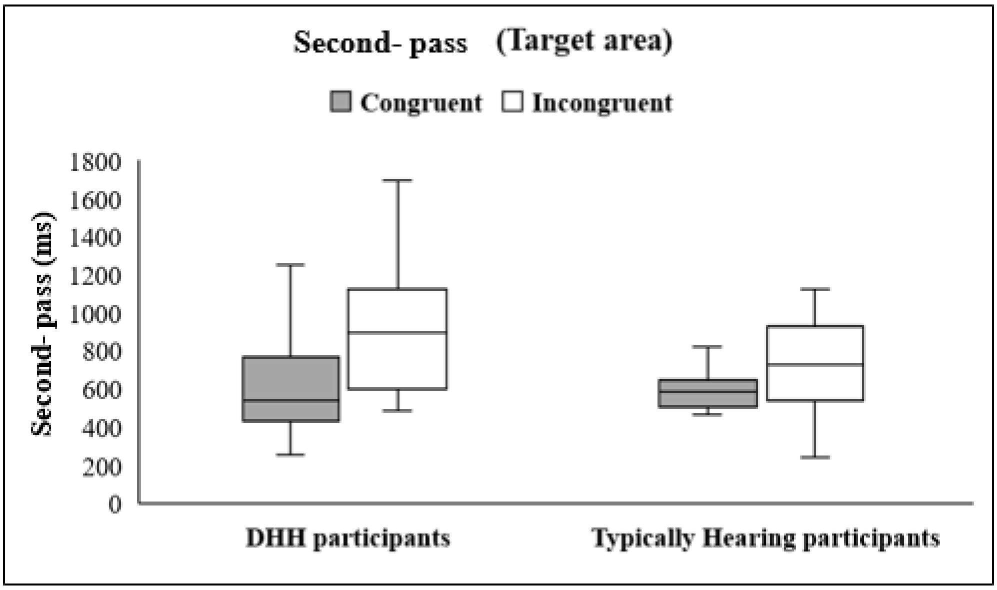

Figure 5. Second-pass in milliseconds in the TAR area per congruity condition and participant group. *Note*. Non-transformed means were used for making the graphic easier to interpret.

Finally, regarding the fixation count, the model with all fixed effects did not converge so we tried different models with the categorical factors, Group and Congruity, as fixed effects, plus one continuous variable each time. Only the model with Group, Congruity and Chronological Age as fixed effects converged (see details for the model with fixed and random effects in Table A3 in Appendix). This model showed that the effect of congruity (*b* = - 0.07; *SE* = 0.02; *t* = - 2.66; *p* = .007) and group (*b* = 0.08; *SE* = 0.03; *t* = 2.24; *p* = .025) were significant in the target area. Participants made more visits in the incongruent condition than in the congruent condition and DHH participants made more visits than TH participants to the target area (see Figure 6). Neither the effect of Chronological age nor any interaction between

Group, Congruity and Chronological age were significant (see model in Table A3 of Appendix).

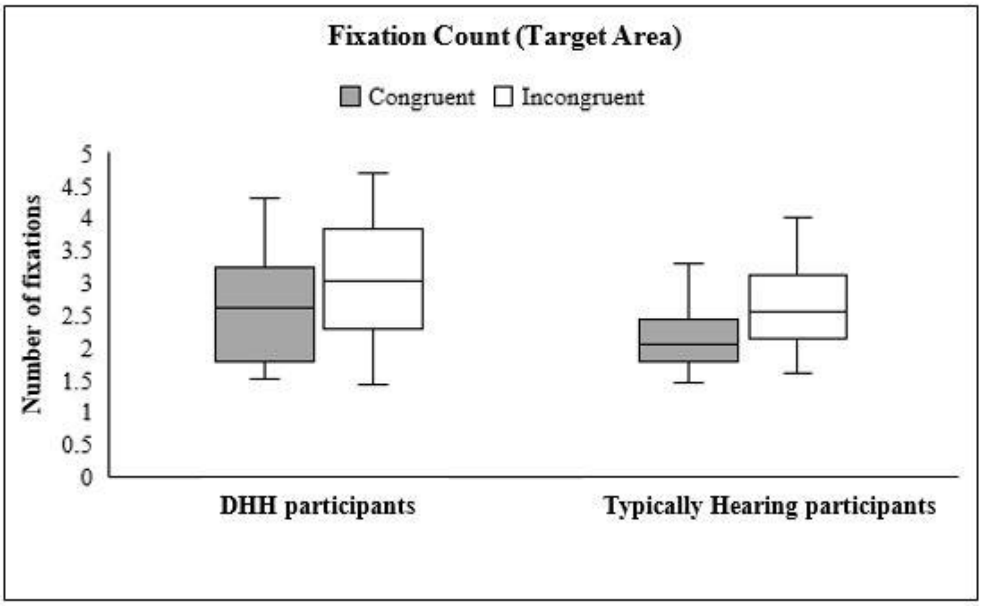

Figure 6. Fixations count (number of total visits) in the TAR area per congruity condition and participant group.

Note. Non-transformed means were used for making the graphic easier to interpret.

Hence, the results in the TAR area revealed that both groups made more fixations in this region, and showed longer first-pass and second-pass fixation durations for the incongruent condition than for the congruent one, which means that they were sensitive to the grammatical congruity manipulation at these points of the sentence processing. However, our findings also evidenced some differences between groups in this area. Whereas TH students showed longer first-pass fixations than DHH students across congruity conditions, the DHH students made instead more fixations in this area (also across congruity conditions). Therefore, DHH students seem to show a preference for doing more but shorter fixations while TH students made fewer but longer fixations in this area. In addition, those participants (of both groups) with higher syntactic knowledge and word reading speed tended to make shorter first-pass and second-pass respectively in this area across congruity conditions.

Post-target AOI. The POST area was defined as the next word with at least 5 characters following the TAR region. Means and standard deviations per condition and group are presented in Table 5.

Regarding the first-pass time, the effects of congruency (b = 92.42; SE = 17.29; t = -4.56; p <.001) and syntactic skill (b = - 6.67; SE = 2.50; t = 2.36; p = .025) were significant. In the case of congruity, however, the pattern was different than in the TAR region, that is, participants did longer first-pass fixations for the congruent condition than in the incongruent condition. Regarding syntactic skills, similar to the TAR region, those participants with higher syntactic skills made shorter first-pass than those with lower syntactic skills. No other main or interaction effects were reliable (see Table A4 in Appendix for details).

With regard to second-pass time, neither main effects nor interaction effects were significant (Table A5 in Appendix). Finally, regarding fixation counts, only the effect of congruency was significant (b = 0.06; SE = 0.03; t = 2.06; p = .039 (Table A6 in Appendix). Consistent with the first-pass pattern, congruent condition received more fixations than the incongruent condition.

Pre-target AOI. The PRE area comprised all the words before the area where the incongruence was generated (TAR area). In this case, only one late measure related to re-reading (second-pass time) was analyzed. Second-pass time reflected what happened in this area once the target area, which contained the incongruence, had been processed. For each item, second-pass time was averaged by number of words. Means and standard deviations for each condition and group for this area are shown in Table 5 (see Table A7 in Appendix for details).

No main effects were significant, but the interaction of congruity by syntactic skills yielded a significant result (*b* = 2.97; *SE* = 3.3; *t* = 2.68; *p* =.007), as in the case of the first-pass, in the TAR and POST regions. The analysis of simple effects with Bonferroni adjustments ("phia" package, De Rosario-Martinez, 2015) showed that the slope of syntactic skills was higher in the incongruent condition than in the congruent one ($\chi^2(1) = 7.19$; *p* = .007), such that those participants with higher syntactic skills made shorter second-pass to the pre-target area in the incongruent condition than those with lower syntactic skills. However, the slope of syntactic skills did not affect the congruent condition, or in other words, syntactic skills did not affect participants' performance in the congruent condition.

Moreover, the third order interaction of congruity by group and vocabulary level (SS) was significant (*b* = - .7; *SE* = 2.9; *t* = - 2.41; *p* = .016). Formal statistical analyses to explore this interaction were not possible due to the reduced sample size of this study, but the visual analysis of the interaction between vocabulary and congruity per group showed that TH participants with higher vocabulary level invested longer second-pass fixations in the congruent condition than in the incongruent condition (see Figure 7). By contrast, vocabulary level seems to affect DHH participants similarly in both congruity conditions. Specifically, DHH readers with lower vocabulary level (SS < 80) invested longer second-pass in both congruity conditions. There were no TH participants with very low vocabulary levels (SS < 80) as in the case of DHH participants, so the direct comparison cannot be performed.

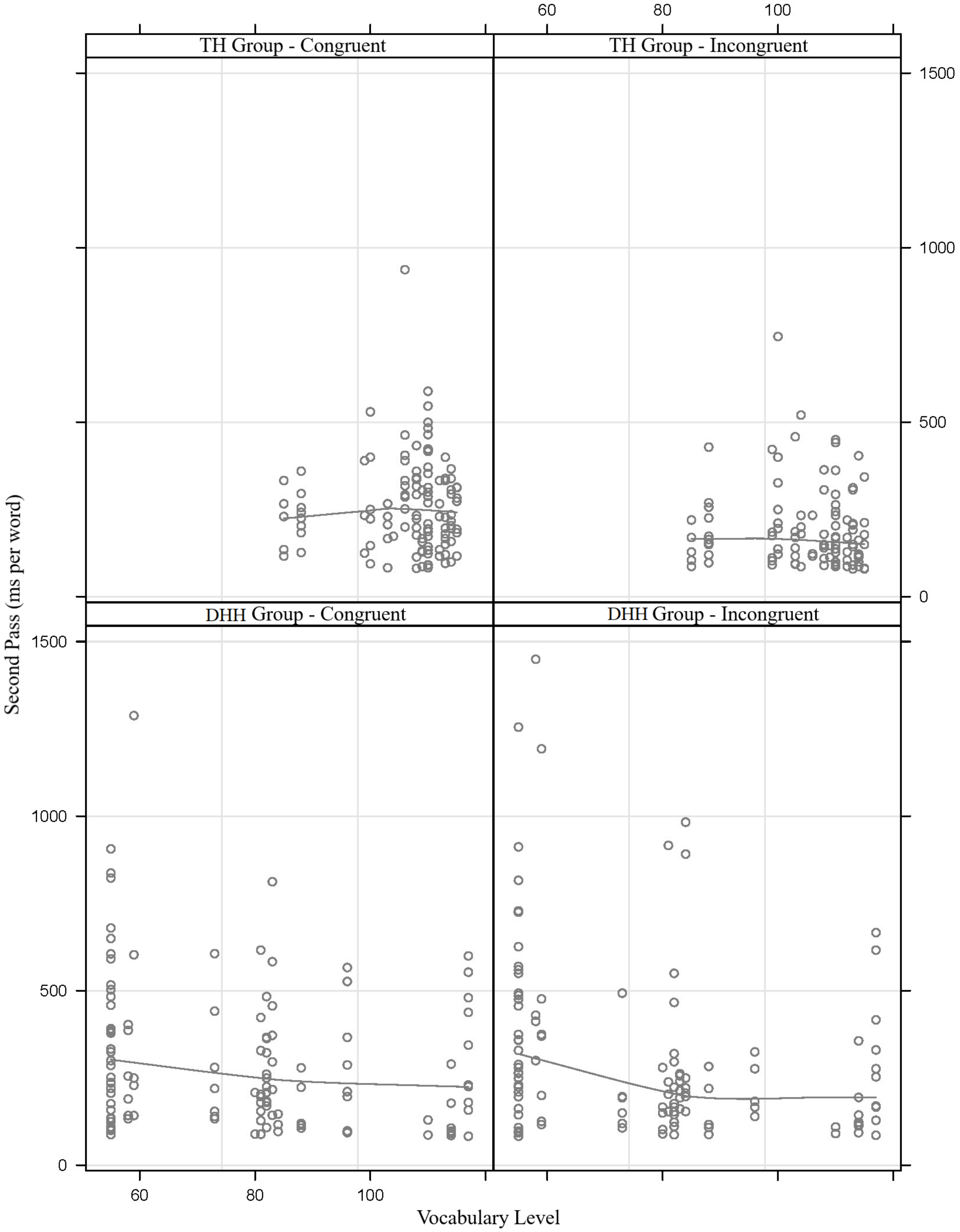

Figure 7. Second-pass (milliseconds per word) in the PRE region as a function of vocabulary level per each participants group (TH and DHH) and congruity condition (Congruent and Incongruent).

Discussion

Based on previous findings that suggested that poor grammatical skills could explain deaf children's reading comprehension deficits (e.g., Barajas et al., 2016), the aim of this study was to examine how deaf students processed and used syntactic cues during reading. In this regard, deaf and TH participants matched on chronological age (mean age: 12 years) were asked to perform a (correctness) judgment task after reading sentences with and without grammatical violations. Participants' eye-movements over the target area (the area that contained the grammatical incongruence), and the pre- and the post-target areas were registered and analyzed. According to earlier findings, we could expect differences in performance and in the time-course of processing of sentences with grammatical incongruences between DHH and TH participants'. With regard to performance, DHH readers would be less capable than TH readers to detect the grammatical incongruence of the sentences. Concerning eye-movements, no effects of grammatical violations for DHH readers on the target area but delayed effects in terms of number and duration of visits and revisits to pre- and post-target areas could emerge (Breadmore et al., 2014).

Between Group Differences in Accuracy

Regarding accuracy in the judgment task, our first prediction was supported. TH students obtained significantly more correct responses than DHH participants across congruity conditions (90% and 77% respectively). These findings are consistent with those of Breadmore et al. (2014), which revealed that deaf adolescents showed less ability to detect and correct subject-verb incongruence in sentences relative to both CA and RA adolescents (Experiment 2; Breadmore et al., 2014). The contribution of our study is that this accuracy effect covers a wider age range since some of our participants were younger (range 9-17 years) than the participants in the Breadmore et al. study (11.9 to 16.3 years old). Nevertheless, it is important to highlight that our findings showed a great variability within the DHH group, with some participants scoring close to chance level (50%) (see Table 5 for standard deviation by group and condition). It is also important to underline that, in our study, DHH participants not only detected syntactic incongruence less frequently than TH participants did, but they also made more "false positives" in congruent trials, that is, they judged as "incorrect" sentences which were congruent more often than TH. This profile might suggest that they were answering in a more random way or felt more insecure about their grammar competence, so they tended to acquiesce.

Between Group Differences in the Time-course of grammatical processing

Regarding the online processing of sentence grammaticality, we predicted: a) no effects of grammatical violations for DHH readers on the target area and b) delayed effects of congruency manipulation in terms of number and duration of visits and revisits to pre- and post-target areas (Breadmore et al., 2014).

a) No effects of grammatical violations for DHH readers on the target area

In contrast with our first prediction regarding the target area, both participating groups appeared to be sensitive to grammaticality manipulation, showing more fixations and longer first-pass and second-pass time in incongruent sentences than in congruent ones. These early grammar effects found in our DHH children and adolescents are consistent with the findings obtained by Piñar et al.'s (2017) and Traxler et al. (2014) with DHH adults and TH adults, respectively. In particular, Piñar et al. (2017) found that adult DHH readers showed longer reading times in the target areas of syntactically complex sentences (animated object relative clauses) than in syntactically simpler sentences (animated subject relative clauses) as was found for TH adults in a previous study by Traxler et al. (2014). However, our results differed from the findings of Breadmore et al. (2014), which found early reading time effects of grammatical incongruence in the target area for the TH readers (CA and RA) but not for the DHH readers group.

Although the effect of congruity was similar in both groups in our experiment, DHH participants differed from TH participants in number and durations of fixations across conditions. DHH students seem to show a preference for doing more but shorter fixations while TH students made fewer but longer fixations in this area.

b) Delayed effects of grammatical violations in pre- and post-target areas

Our second prediction regarding time-course processing stated that there would be differences between groups for the pre- and post-target areas.

With regard to the post-target area and in contrast to our prediction, both TH and DHH participants showed effects of grammatical congruity (though in the opposite direction compared to those produced in the target) for both first-pass time and fixation count (i.e., longer first-pass time and more fixations for the congruent condition than for the incongruent one). This effect for both groups contrasts again with the results of Breadmore et al. (2014), who found delayed effects of grammatical incongruence for deaf adolescents in the post-verb region, but not for the TH controls. Significantly, our findings revealed that congruity manipulation had a delayed effect in the post-target area for all participants. This result was contrary to what we anticipated.

This unexpected effect could be an experimental artifact of our study, which was not present in the study by Breadmore et al. (Experiment 1). We asked participants to judge, explicitly, the correctness of written sentences, whereas Breadmore et al. used an implicit self-paced reading task to measure reading times on sentences containing grammatical errors. They assumed that if participants were sensitive to grammatical errors, they would slow down when encountering them. However, in our experiment, participants might have continued searching for incorrectness until the post-target area, resulting in delayed effects.

Focusing on the pre-target area, no effects of congruity, group or interaction were found, so our prediction about delayed effect for DHH participants was not supported. However, we found an interesting effect of participants' syntactic skills that was also present in the target and post-target area. In particular, those participants with higher syntactic abilities made shorter second-pass of the pre-target area in the incongruent condition than those with lower syntactic skills, whereas the readers' syntactic skills did not affect the congruent condition. Similarly, those participants with higher syntactic skills made shorter first-pass in the target and post-target areas than those with lower syntactic skills across congruity conditions. The significantly lower level of syntactic skills of the DHH readers could be a main contributor for the differences in sentence processing between DHH and TH readers (except in the case of the fixation count in the target area where the group effect remains after controlling for syntactic skills).

In sum, in our experiment, both DHH and TH students showed early detection of grammar errors in the target area (albeit a different pattern of eye-movements). However, they both showed longer first-pass time and more fixations in the post-target area of congruent sentences than in the post-target area of incongruent sentences, suggesting a late confirmation of sentence correctness. Finally, syntactic skills, significantly lower in the DHH group, seem to predict time spent in the relevant areas of the sentence.That is, as syntactic skills have been systematically related to the amount of time spent on each area (pre-target [second-pass], target and post-target [first-pass]) at least for the incongruent condition throughout the experiment, the fact that in this Study participants (DHH-TH) differed in this variable could potentially influence the differences in reading time (and maybe in performance) for DHH readers.

These findings would be, to some extent, in line with previous studies that indicated that DHH individuals have greater problems in making use of morpho-syntactic cues when reading sentences (Domínguez & Alegría, 2010; Domínguez et al., 2016; Miller, 2000).

However, in our study, the DHH group did not completely ignore morpho-syntactic cues as suggested by the "Key-Word strategy" of Domínguez and Alegría (2010) or the "top-down preference" hypothesis of Miller (2000). In correct trials, they actually used morpho-syntactic cues very early as can be inferred from the grammaticality effects in the target region (longer first-pass in the incongruent condition). Notably, our experiment did not allow us to infer if a less efficient use of morpho-syntactic markers could lead DHH students to make a more generalized use of semantic cues as previously suggested, since we did not use a control condition with only semantic violations as Breadmore et al. (2014) or different syntactic and semantic distractors (Gallego et al., 2016).

By contrast, our findings would be compatible with the bottleneck effect of syntactic skills proposed by Kelly (1996), which suggests that, unless DHH participants achieved a reasonable level of syntactic competence, they seem unable to use their vocabulary competence to comprehend the text. This conclusion is supported by the fact that while syntactic skills appeared consistently related to reading times throughout the experiment, vocabulary skills did not (only a third order interaction was found). Again, our study design and analyses did not allow us to establish the level of syntactic competence needed for vocabulary knowledge to be used, such as Kelly did. Consequently, the bottleneck interpretation should be taken with caution. In fact, we could replace the "bottleneck" metaphor with a "cascading" metaphor. The latter term suggests the idea of a "chain of events", in such a way that if the first event (syntax) is not working properly, it would affect the functioning of subsequent events (vocabulary) but not totally block them (as the "bottleneck" metaphor would suggest). Actually, the third order interaction between hearing status, congruity and vocabulary in the pre-target area (Figure 7) seems to suggest that re-visiting the pre-target area in search for congruity or incongruity confirmation is associated to vocabulary knowledge in both, DHH and TH students.

Finally, all other factors used as continuous variables in the linear mixed-effects analyses (chronological age, vocabulary and word reading speed) did not have any systematic effect on eye-movements measures across areas of interest as syntactic competence did. Only word reading speed predicted the second-pass time in the target area. Hence, a higher word reading speed was associated with a lower second-pass in both congruity conditions and groups. This result would suggest that the duration of the revisits in the target area was a lexical effect rather than a sentence integration effect because word reading speed (significantly lower in DHH students) is an index of lexical access. That is, those participants who were slower in lexical access, tended to revisit longer the target area presumably in search of a lexical confirmation that was not complete during the first-pass of the word. This interpretation would be compatible with the fact that DHH participants made more, but shorter, fixations than TH participants during the first-pass of the word.

Conclusions

We have shown that eye-tracking techniques combined with an appropriate task paradigm can provide valuable information both on the causes of DHH readers' reading difficulties and on the nature of their strategies and reading processes as showed in previous research in TH children and adults (Joseph & Liversedge, 2013; Joseph, Liversedge, Blythe, White, & Rayner, 2009). Specifically, we found that deaf readers make more, but shorter, fixations in the target area than TH participants when trying to judge for sentence correctness (regardless of the congruity of the sentence).

Although relevant findings regarding the processing of grammatical cues have been obtained so far, it is not possible to draw a complete picture describing the time-course processing of students with deafness, as no control condition including semantic cues was considered in this study. This limitation has been considered in the next study, where both, grammatical and semantic cues have been included in the assessment. In addition, as it will be exposed in **Study 2's** introduction, more complex sentences were used in **Study 2** (Passive sentences, Focalized complement sentences and Subordinate clause sentences) than in **Study 1** (mainly single sentence in active form).

“Take Home Messages” from Study 1

- DHH participants performed more poorly than chronological age-matched TH participants when detecting sentences with grammatical incongruences.
- However, they were sensitive to grammatical cues, as concerning the area where the manipulation was made (target) they invested more time and made more fixations in the incongruent than the congruent sentences (as TH participants also did).
- DHH students made more but shorter fixations while TH students made fewer but longer fixations in the target area.
- Syntactic skills appeared to be consistently related to reading time at the incongruent sentences (higher syntactic skills – lower reading time). Lower ability on written syntax could potentially explain differences in the online reading pattern of DHH participants.
- No main effects emerged for Vocabulary skills and eye-movement measurements. These results suggest that syntactic skills could have a cascading effect in sentence processing for DHH readers, affecting the rest domains but not “blocking” them (as the “bottleneck” metaphor suggested).

Study 2 | *Complex Sentence Comprehension: Processing of Lexical and Syntactic Cues.* *

* The content of this section is a manuscript submitted for publication to a peer review journal by the following authors (Nadina Gómez-Merino, Inmaculada Fajardo and Antonio Ferrer)

Abstract

The aim of this study was to examine differences in the processing of syntactic versus semantic cues during sentence reading among students with severe-to-profound prelingual deafness (DHH) (mean age = 12.48) compared to chronological age matched students with typical hearing (TH). Readers' eye movements were registered as they read sentences with different grammatical structures and selected the picture (out of four) that best matched their meanings. The type of cues provided by picture options was manipulated in such a way that the target picture was presented together with lexical and syntactic distractors. Results showed that TH readers outperformed DHH participants in all type of sentences except in active ones. In correctly answered trials, both DHH and TH participants made longer and more fixations in the target than in the syntactic distractor and made longer and more fixations in the latter than in the lexical distractor. In addition, in correctly answered trials, DHH participants made longer fixations to lexical distractors than students with TH. When making errors, students with DHH chose the syntactic distractor in a higher percentage than students with TH, although both groups selected more and made more and longer fixations in the syntactic distractor than in the lexical one. Altogether, our results do not support a preference for lexical or semantic cues in DHH readers in a strict way. Instead, they suggest an inefficient use of syntactic cues and a slightly higher preference for lexical cues in DHH readers than in TH readers.

Introduction

Let us imagine that we asked Joan, a primary student, to answer the question "Did the wolf frighten the three little porks?" Joan would probably say inmmediatly "Yes, the wolf did it" based on the previous knowledge of the classic tale that even elementary students know. Let us imagine now that this question is formulated after the child read the sentence "*The wolf was frightened by the three little porks*". If Joan just used his lexical knowledge and his previous knowledge of the classical tale, the answer would be wrong so he should perform a grammar analysis of the sentence to interpret correctly the "*counterintuitive*" information that it conveys. As this evoked situation illustrates, some comprehension questions presented to children after text or sentence reading could be easily answered by means of their previous lexical or world knowledge. However, when answering questions after reading tricky sentences or texts about unfamiliar topics, which is a common issue in academic settings (e.g., Piece of text: "*Sancho Panza was encouraged by Don Quixote to fight the giants* [...]". Question: "*did Sancho Panza encourage Don Quixote to fight the giants?"*), lexical and world knowledge would not be enough, so morpho-syntactic cues need to be used to disambiguate the meaning of the sentence or text.

As we have mentioned in the previous study (**Study 1**) it seems that students with DHH often manifest difficulties in grammatical performance throughout their academic lifetime (see Cannon & Kirby, 2013; Figueroa, Darbra, & Silvestre, 2020 for Secondary school; Pooresmaeil et al., 2019 for Primary school). Such difficulties might be hindering their reading comprehension in a kind of cascading effect (see **Study 1** of the present dissertation; also see Kelly, 1996). In fact, grammatical knowledge correlates positively with reading comprehension in Spanish typically hearing students (Simpson, Moreno-Pérez, Rodríguez-Ortiz, Valdés-Coronel, & Saldaña, 2020). In the case of prelingually DHH students, several studies have pointed out that grammatical skills (either grammatical spoken comprehension

[Barajas et al., 2016; Friedmann & Szterman, 2006] or reading related syntactic processes [Figueroa et al., 2020; **Study 1** of this **Thesis**]) constitute a good predictor of text comprehension.

The complexity of the syntactic structures seems to be highly related with sentence comprehension. In that sense, the comprehension of sentences with complex structures (e.g., reversible passives: *La niña es empujada por el niño* [*The girl is pushed by the boy*] or reversible predicative sentences: *El ratón persigue al gato* [*The mouse chases the cat*]) contribute to explain greater variance in the text comprehension abilities of students with DHH than simple sentence structures (e.g., non-reversible predicative forms: *La niña ve la televisión* [*The girl watches TV*]; Barajas et al., 2016). What is unclear from previous literature is whether the process of comprehending sentences with different structural complexity might vary between students with DHH and TH during reading (i.e., if DHH's rely more on contextual than on syntactic cues than TH students). As Piñar et al. (2017) noted, "it is possible that whether deaf readers' processing patterns are similar or not to those of hearing readers might depend on the particular structure that is being processed" (p. 982). This is a relevant aspect to investigate given that as noted in the General Introduction section of this **Thesis** (see section 1.2.2.2 "*Gramática*"), the comprehension of complex sentences seems to predict reading academic achievement in DHH (González-Cuenca, Lavigne-Cerván, & Prieto-Cuberos, 2020) and so far, results from some recent grammar-based intervention studies are null (See Cannon et al., 2020). We consider that a better description of the online processing of DHH students during complex sentences reading could aid intervention studies to get directly to the focus of the problem.

As we have pointed in previous sections of this **Thesis**, some researchers indicate that, when reading sentences, students with DHH show a preference for using semantic cues and ignore syntactic cues such as function words (Domínguez et al., 2016, 2012; González & Domínguez, 2018). In contrast, **Study 1** as well as more recent studies have shown that DHH readers (children and adolescents) actually do use syntactic cues during sentence comprehension as TH students do, although they might recognize ungrammaticalities later in time (Breadmore et al., 2014) and require a higher number of fixations than students with TH to do so (see **Study 1**).

The present study goes deeper into this subject by analyzing the eye movement patterns of DHH and TH readers while fixating syntactic and semantic cues in a sentence picture-matching task.

Additionally, we explore the relationships between eye-movement data and individual skills such as syntactic skills [Barajas et al., 2016; **Study 1** from this **Thesis**], receptive vocabulary [Gallego et al., 2016; Lee et al., 2018, Moreno-Pérez et al., 2015]) or working memory [Gallego et al., 2016; Lee et al., 2018]) that have been linked to text and complex sentence comprehension.

The Role of Semantic and Syntactic Cues in Sentence Comprehension by Readers with DHH.

Semantic processes cooperate along with syntactic analyses during meaning construction. The interplay between these processes can be disrupted if the grammatical knowledge is limited (Kelly, 1996). Considering that students with DHH often demonstrate low grammatical skills (Cannon & Kirby, 2013; González, Silvestre, Linero, Barajas, & Quintana, 2015), the use of semantic and morpho-syntactic cues during reading may vary as a function of hearing status. In that sense, as noted in the introduction of this study, some previous findings indicate that students with DHH employ a cursory or inaccurate processing during sentence comprehension. In particular, students with DHH may be using an inefficient strategy kwon as "Key Word Strategy" (KWS). Although this theory has been already presented when describing **Study 1** and in the General Introduction of the present **Thesis** (Chapter 1), we consider convenient to refresh the basis of this assumption. According to the KWS hypothesis, when students with

DHH construct the meaning of written sentences, they rely mostly on semantic cues and overlook syntactic information (i.e., function words). Domínguez and colleagues, drew this conclusion by using the “Syntactic Strategies Assessment Task” (Soriano et al., 2006) along a set of studies (Domínguez et al., 2016, 2012; González & Domínguez, 2018). This task required readers to select the missing word in a set of 64 sentences (e.g., “*The storm released a ________*”). There were two types of answer choices, one correct choice (that fitted semantically and syntactically to the sentence [e.g., *catastrophe*]), and three incorrect choices consisting in words that were semantically related to the sentence but were not syntactically appropriate (e.g., *rains*, *thunders*, *wind*). In order to answer correctly the students needed to consider the syntactic cues (mainly function words) otherwise, any option would be equally appropriate. The authors assumed that if the students with DHH obtained lower scores than students with TH of the same reading age, it would indicate that students’ DHH sentence comprehension was driven predominantly by semantic cues. In fact, this was the case, once reading age was considered, the results of students with DHH in the task reflected a larger delay (in terms of accuracy on the task) in comparison to students with TH (Domínguez et al., 2012), even in the case of students that were CI users from an early age (Domínguez et al., 2016; González & Domínguez, 2018). Hence, this observed tendency to over-rely on semantic cues during reading was taken by Domínguez and colleagues as an evidence for the preference for the KWS in DHH readers.

Running alongside, Gallego et al. (2016) applied the same task as Dominguez et al.’s to a group of students with TH and two groups of students with CI. Participants with DHH were divided according to the moment that they were implanted (i.e., early-CI versus late- CI). In contrast to Domínguez and colleagues that only allowed to test the over-reliance on semantic cues, Gallego et al. modified the task by substituting one of the syntactically implausible words for a word that fitted syntactically in the sentence but did not fit it semantically (e.g., *The storm* *released a* ________[*walking stick*]). This modification would allow them to test if readers showed a preference for semantic (as the KWS postulates) or syntactic cues by means of error analysis. If the readers tended to select the syntactically implausible words (what they called *semantic foils*), it would evidence a preference for semantic cues. On the contrary, if readers tended to select the word that fitted syntactically in the sentence but did not fit semantically (the *syntactic foil*), it would indicate a preference for syntactic cues.

Results showed that both TH and early CI-DHH students chose the syntactic foil more often than the semantic ones, which indicates that they relied more on syntactic cues during the task. However, late CI-DHH students chose the syntactically implausible and the semantically implausible option in a similar proportion; that is, they did not show a preference for any type of cues. Consequently, the authors concluded that these results were not supporting the use of the KWS for neither early nor late CI-DHH students. The study of Gallego et al. led to further interesting results related to accuracy on the task. In particular, participants with DHH (late-CI versus early-CI) differed in their pattern of correct responses when the complexity of sentences in terms of word length and frequency were considered. Whereas students with late-CI obtained lower scores than TH regardless of sentence complexity, students with early-CI obtained similar results than TH in all types of sentences except in the more complex ones, that is, sentences with long and infrequent words.

In line with this last result of Gallego et al. (2016), further studies reveal that the processing differences of syntactic cues between students with DHH and students with TH (or between skilled and less skilled DHH readers [Kelly, 2003b]) might arise as the complexity of the sentence increases. Whereas students with DHH often seem to obtain results close to their TH peers in the comprehension of simple structured sentences, their results tend to differ when it comes to interpret written sentences with a complex structure (Szterman & Friedman, 2014; Lee et al., 2018). This is the case for sentences where thematic role assignment requires necessarily to analyze a more infrequent syntactic structure of the sentence, namely: object relative clauses (Piñar et al., 2017; Szterman & Friedman, 2014, Traxler et al., 2014), passives (Lee et al., 2018) and semantically reversible sentences (where either the object or the subject are eligible to carry out the action) (López-Higes, Gallego, Martín-Aragoneses, & Melle, 2015). Therefore, a limited ability to understand complex sentences during reading might stem from an inefficient management of syntactic cues as well.

This was in turn, one of the focus of López-Higes et al (2015)'s study. They explored morpho-syntactic comprehension in students with DHH, by assessing thematic role assignment among sentences with different structures (mainly complex structured sentences). Three groups of students took part in the study (Age range: 8-12 years), students with DHH formed two of the groups while the third group was composed by students with TH (n=19). The students with DHH were divided according to their age of implantation, that is, an early CI group (implanted before 24 months of age; $n_{\text{early-CI}}$=19) and a late CI group (implanted after 24 months of age; $n_{\text{late-CI}}$ =19). The students' grammatical comprehension was assessed by means of an adaptation of a sentence-picture verification task (López-Higes et al., 2015). In the sentence-picture verification task, the student was confronted with sentence-picture pairs that require verification, that is, the student was asked to confirm whether the picture represents the sentence meaning or not. The test assessed comprehension on 12 sentence structures, all of the sentences were semantically reversible (e.g., *The dog is chased by the cat*), and some of them did not fit the canonical order Subject-Verb-Object (e.g., passives, relative clauses, focalized object sentences, etc.). Each sentence structure was presented in three occasions; a different type of picture accompanies the sentence structure in each presentation. Thus, the sentences were presented with a target picture (that represented the meaning of the sentence) or with a picture containing a lexical or a syntactic distractor. While the lexical distractor included an element or argument that was not mentioned in the sentence (e.g., For the sentence "*The girl* *kissed the boy*", the picture could show a girl talking to a boy), the syntactic distractor represented the meaning of the sentence with the thematic roles inverted (e.g., For the sentence "*The girl kissed the boy*", the picture could show the boy kissing the girl). Regarding the results, the analyses on the type of responses revealed that accuracy rates in the syntactic distractor condition were similar for both the group of DHH with early-CI and the group of students with TH. That is, students with early-CI were as efficient at detecting the incorrectness of "syntactic distractors" as students with TH. The authors interpreted this finding as evidence suggesting that students with DHH and early-CI were relying on syntactic cues during their judgments (otherwise, they would not have noticed about the inversion of the thematic roles). In contrast, students with late-CI underperformed students with TH in the syntactic distractor condition but they had a similar performance in the lexical distractor condition. As the authors suggested, these latter results could be indicating that students with late-CI were applying an inefficient strategy during their reading or that, in the absence of semantic cues, they simply struggled with thematic role assignment. Altogether, the results from López-Higes et al. bring into question the use of the KWS by students with DHH during sentence reading.

In line with López-Higes et al. (2015)'s offline findings, most of the current evidence using online measures suggests that DHH are sensitive to syntactic cues during complex sentence reading (see Piñar et al., 2017; Traxler et al., 2014). However, these studies are limited to adult population. As noticed earlier, only two studies have examined the reading pattern of children and adolescents with DHH in real time with a self-paced reading task (Breadmore et al., 2014) and eye movements (**Study 1** of this **Thesis**) respectively. Regarding **Study 1**, eye movements allowed registering in a more natural reading context (the whole sentence was displayed at once) than a word-by-word sentence presentation. Both of them agreed that students with DHH appeared to be sensitive to syntactic cues but, that DHH students differed in their online reading patterns from TH regarding syntactic cues (Breadmore et al., 2014;

Study 1 from this **Thesis**) but not semantic ones (Breadmore et al.,2014). However, the online results cannot be extended to the reading comprehension of complex sentences, as both studies focused on the detection of inconsistencies in sentences with a very simple structure.

To overcome this limitation, the present study was designed to measure how DHH readers use both semantic and syntactic cues while monitoring their comprehension after reading sentences of varying syntactic complexity by means of a sentence picture-matching task.

Study 2

The aim was to examine differences in the processing of syntactic versus semantic cues during sentence reading among students with severe-to-profound prelingual deafness (DHH) compared to children and adolescents with TH. We registered readers' eye movements as they read sentences with different grammatical structures and while selecting the picture (out of four) that best matched their meanings. The type of cues (semantic –or lexical- versus syntactic) provided by picture options were manipulated. Specific hypotheses will be developed after presenting the experimental task, as they are intimately related to it.

Method

Participants

Twenty students with a prelingual bilateral severe-to profound deafness (DHH) (age range = 9.6 – 15.17 years; 4th to 10th graders) and 20 students with TH (age range = 8.83 -14.83 years; 3rd to 10th graders) constituted the final sample of this study.

Regarding the group of students with DHH, all of the students in the previous study (**Study 1**) were also included in this one.

Background measurements

Results from this set of measurements can be found in Table 6

Table 6. *Means, Standard Scores and Between Group Comparisons in Demographic Variables and Background Measurements.*

	DHH (*n* = 20, 12 girls)		**TH** (*n* = 20, 11 girls)		Between Group Comparisons			
Background measures	*M*	*SD (range)*	*M*	*SD (range)*	*F*	*U*	*p*	*r*
Chronological Age (years)	12.48	1.70 (9.6 -15.17)	11.71	1.83 (8.83-14.83)	.11		.179	.22
Non Verbal IQ (SS)	103.20	9.12 (87-118)	108.75	11.05 (86-126)	.41		.091	.27
Word Reading Accuracy (SS)	106.85	8.23 (86-115)	105.52	10.72 (76-115)		191.50	.817	-.04
Non Word Reading Accuracy (SS)	109.51	9.41 (82-121)	108.18	7.57 (91-121)		166.50	.364	-.14
Word Reading Speed (SS)	107.51	10.86 (80-123)	116.55	6.44 (104-130)		99.00	.006	-.43
Non Word Reading Speed (SS)	111.78	10.18 (82-127)	112.7	8.92 (93-127)	.00		.755	.05
Text Comprehension (SS)	87.50	19.18 (50-124)	104.63	6.47 (90-115)		73.00	.001	-.54
Receptive Vocabulary (SS)	76.86	20.91 (55-117)	106.85	8.45 (85-116)		52.00	<.001	-.63
Written Syntax/Syntactic Ability Test (RS)[a]	43.65	13.55 (15-59)	50.75	11.58 (27-64)		141.00	**.110**	-.25
Expressive Language (RS)[b]	35.90	8.06 (19-48)	42.90	5.88 (31-50)		94.50	.004	-.45
Reading Span (RS)	2.38	1.07 (0-4.5)	3.00	0.63 (2-4)		126.00	.041	-.32

Note. Values from this table change slightly in comparison to Table 4 (**Study 1**). This is because due to data loss or unsuccessful calibration, participants with typical hearing from **Study 2** were not exactly the same as in the previous Study. Between-group effects that differ in terms of statistical significance from **Study 1** appear bolded. Results from the Reading Span task have been included in this case.

SS=Standard Scores; RS= Raw Scores.

[a] Number of correct responses with respect to the total test (Maximum score 64).

[b] Number of correct answers with respect to the total sub-test (Maximum score 52).

Experimental Task: The Sentence Picture-Matching Task

Students' eye movements were monitored while participants completed an adapted version of the Grammatical Structures task of the PROLEC-R battery (Cuetos et al., 2007). This task assesses the syntactic processing of students by means of sentences with different grammatical structure.

Moreover, it is important to note that the students who participated in López-Higes et al.'s study (previously described) also completed the Grammatical Structures Task (Cuetos et al., 2007). Although results from this latter task were not reported in their study, they were highly correlated (.74) with the sentence-picture verification task that they used.

Concerning the Grammatical Structures task, readers are asked to select the picture option (out of four) which best matches the sentence meaning. We made some adaptations and did not follow some administration recommendations of the PROLEC-R's authors, consequently, we only used raw scores but not standarized ones. Our main adaptations of the task were:

1) Pictures and sentences were not presented to the students at the same time as in the original task. Instead, each sentence was dysplayed alone on the screen, and once it disappeared the 4 pictures were conjointly presented (See Figure 8). This modification allowed us to obtain clearer data, as it avoided that fixations on the pictures overlapped with fixations on the sentences. In the original version of the task, pictures appear close to each of the corners of the paper-sheet and the sentence appears at the remaining blank space at the center of the page. In our case, we needed to ensure as much distance as possible between the text and the pictures dysplayed, given that if calibration was not optimal at some point during the testing there was a risk of attributing fixations that did not belong to the corresponding stimulus (picture).

2) The position of the picture options (target, syntactic distractors and lexical -or semantic- distractors) was counterbalanced throughtout the experiment and the order of presentation of the items was randomized by participant.

3) The task was applied to an older population than the recommended by the PROLEC-R's authors (from 1st to 6th grade). The reason was that, although some of the participants with DHH attended higher grades, we assumed that the level of the task would be appropiate for them as we expected that they would struggle with this type of task.

As the original Grammatical Structures task of the PROLEC-R, our adapted version comprised 16 items that included a sentence (that the student reads) and 4 picture choices. There were four types of sentences (note that the examples are invented to protect the Copyright of the PROLEC-R's editorial [TEA Ediciones]): 1) Active sentences, with a simpler grammatical structure as the elements follow a canonical order (e.g., *La niña está acariciando al niño* [*The girl is caressing the boy*]); The remaining types of sentences follow a non canonical structure, namely, 2) Passive sentences (e.g., *El bombero es salvado por el niño* [*The fireman is saved by the boy*]); 3) Focalized complement sentences (e.g., *Al niño le ayudó el padre* [*To the son, the father helped],* note that this sentence structure does not exist in English and it means that the father helped the son emphasizing the son role); 4) Subordinate clause sentences (e.g., *El policía que lleva un uniforme blanco arrestó al bailarín*, [*The policeman who wears a white suit arrested the dancer*]). There were four items per sentence type and all sentences are semantically reversible, yet, some convey a more plausible meaning (e.g., *El profesor es dibujado por el estudiante* [*The teacher is drawn by the student*]) than others (e.g., *El lobo feroz es asustado por los tres cerditos* [*The big bad wolf was frightened by the three little porks*]). The sentence type was not considered for predictions regarding eye movements. Therefore, for online measures, data from the 16 items was averaged without considering their syntactic complexity.

Regarding the picture choices, one picture (*target*) corresponds to the meaning of the sentence while the rest were given as distractors. The distractors were classified into two types:

Syntactic distractor: In these pictures the thematic roles were exhanged with respect to the meaning of the sentence. Students could easily select this distractor if they constructed the meaning of the sentence by relying solely on semantic cues (as the same elements that appear in this picture appear also in the correct one). For example, the passive sentence "*The big bad wolf was frightened by the three little porks [el lobo feroz es asustado por los tres cerditos]*" would be followed by the pictures on Figure 8. As can be seen, there were two options (picture number 2 and 3) where the elements (the wolf and the porks) appeared. Thus, if the student did not consider the morphosyntactic cues of the sentence (specifically those that rule thematic role assignment in the sentence – such as the preposition "*por*" (by) in this case), either the correct picture (2) or the wrong one (3) would have the same probability to be chosen.

Lexical distractor: The other picture options (picture 1 and 4, Figure 8) included a new element that had not been presented in the sentence (i.e., the sheeps). These type of pictures could be easily discarded by considering only the semantic cues of the sentence.

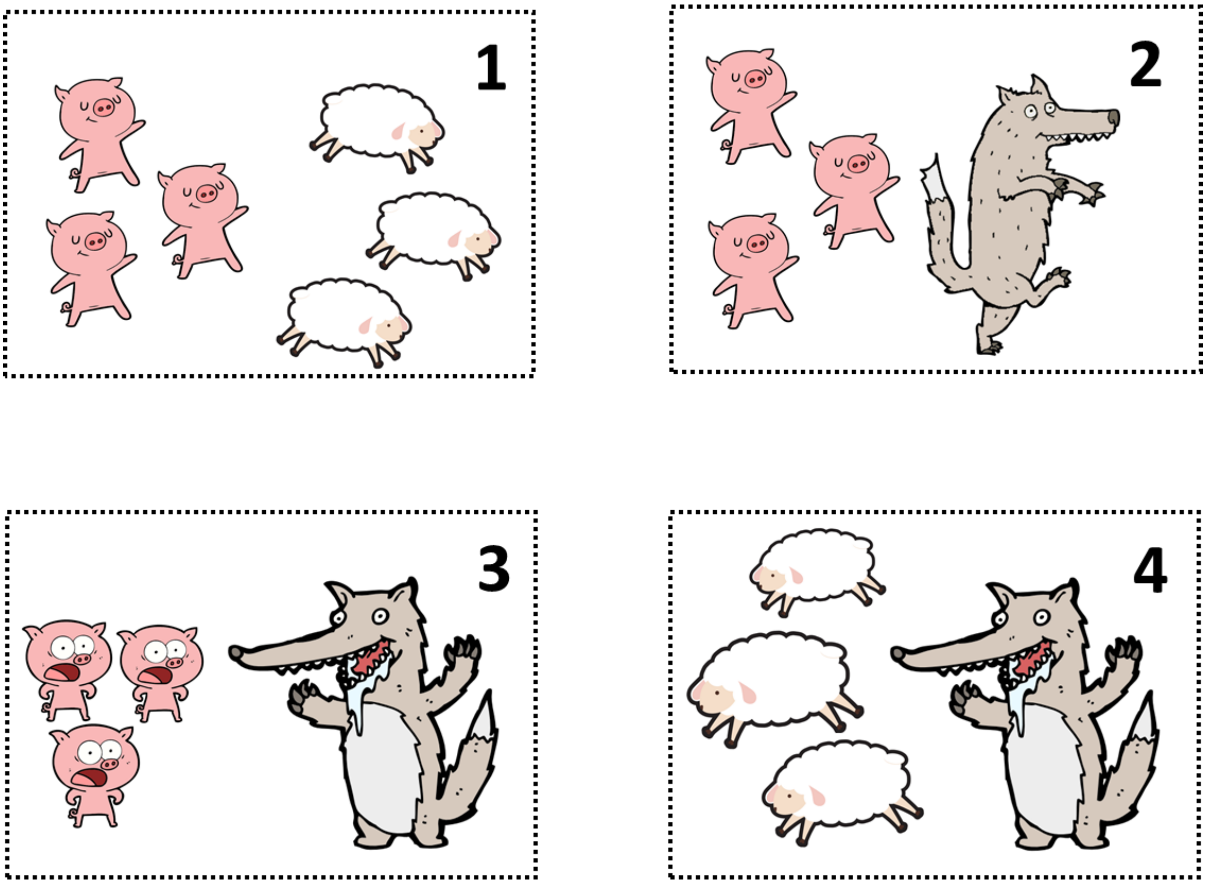

Figure 8. Example of Stimuli Used in the Experimental Task.

Note. Dash lines represent the space limited for each Area of Interest, considering the sentence "*The big bad wolf was frightened by the three little porks*" pictures would be defined as: Target (2); Lexical distractors (1,4); Syntactic distractor (3). This is an invented example, it has not been used in the experiment and it is not part from the PROLEC-R test (Cuetos et al., 2007).

Procedure

Participants' eye movements were monitored while they completed the Sentence Picture-Matching Task. In this case, participants read each sentence silently and indicated orally when they had finished reading. Each sentence was presented alone and in a single line. Once they finished reading, the sentence disappeared, and four pictures were displayed. Participants indicated orally the number of the picture that represented the meaning of the sentence. Before presenting the stimuli, participants completed the examples. Once participants had understood the task, a nine-point calibration preceded the presentation of the stimuli. Sentences were presented in black font on a light grey background. Each sentence was preceded by a trigger asterisk.

Hypotheses

Related to Response Accuracy:

1. It was predicted that students with DHH would obtain lower scores in comparison to TH participants, mainly, in sentences with a more complex structure (passives, focalized complement and relative clause sentence).
2. Regarding alternatives of response. The Key Word Strategy (KWS) hypothesis suggests that when students with DHH construct the sentence meaning, they rely mostly on semantic cues and overlook syntactic information (i.e., function words) (Domínguez et al., 2016). According to this claim:

    a. If students with DHH tend to ignore syntactic cues[8], they would choose the target picture and the syntactic distractor (same elements but reversed roles) in a similar proportion, as the thematic roles are similar and these alternatives of response only differ if syntactic cues are taken into account.

    b. Regarding the type of errors, we expected that participants with DHH would choose the syntactic distractor more than the lexical distractor as the latter can be easily discarded based only in lexical/semantic cues.

    c. Students with TH would show a more homogeneous distribution of the errors between distractor options.

[8] We know from **Study 1** that students with DHH are sensitive to grammatical cues. Yet, in constrast to **Study 2**, in **Study 1**, we did not include a control condition with only semantic incongruences, and students were tested with simple sentences. Moreover, our studies were not conducted one after the other but in parallel so as we did not know the results from **Study 1** before applying this task, hypotheses were formulated according to previous literature. This second study should be considered an extension of the previous one, where we just elucubrate that with more complex sentences and different types of distractors, the tendency to ignore syntactic cues could be higher.

Related to Eye Movements

3. *Pictures*:

a. In the case of correct responses, we expect that both TH and DHH participants spent longer fixation time and a higher number of fixations on the target picture than on the distractors. These measures have shown to be sensitive to processing variations in studies using visual stimuli (Schumacher et al., 2015).

b. In the case of correct responses, we predicted that participants with DHH would spend longer fixation time and a higher number of fixations on the Syntactic distractors in comparison to Lexical distractors.

c. In the case of correct responses, students with TH would show a more homogeneous distribution of the time and number of fixations throughout distractors (as accuracy-based descriptive results from López-Higes et al., 2015, suggested).

Results

Sentence Picture-Matching Task: Accuracy

Nonparametric analyses (Mann-Whitney U-Test and Wilcoxon signed-rank test) were performed in order to study differences in the percentage of correct responses between groups (DHH and TH).

As predicted, groups differed in the percentage of correct responses on the Sentence Picture-Matching Task (U = 58.50, z = - 3.89, p < .001, r = - .62) so that the percentage was lower for students with DHH (M = 72.40; SD = 18.77; range = 38-100) in comparison to students with TH (M = 94.06; SD = 5.54; range = 81-100), confirming the first part of H1. It is important to note, that the lower score obtained by TH was 81% whereas half of the sample of students with DHH did not reach the 70% of correctly answered-items (See Figure 9).

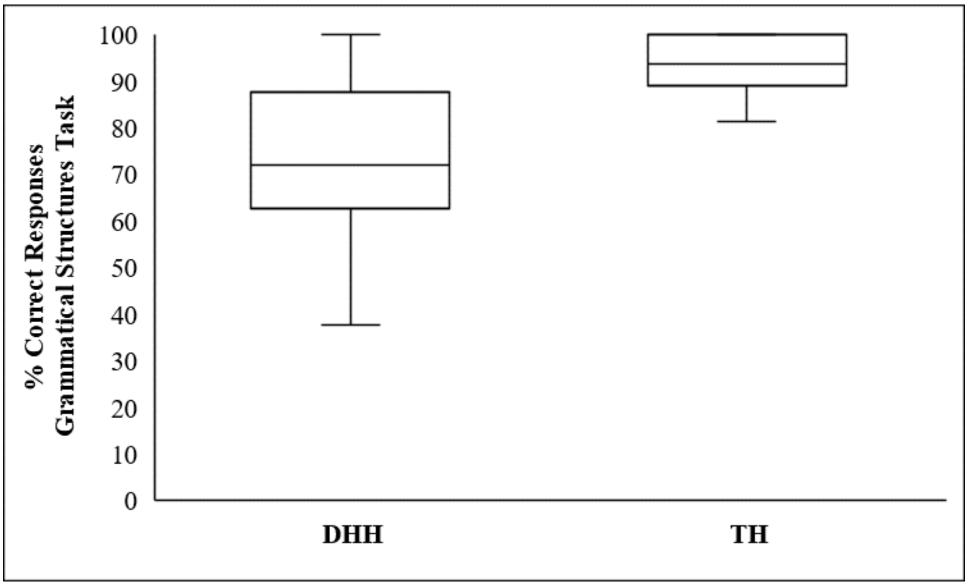

Figure 9. Percentage of Correct Responses in the Sentence Picture-Matching Task.

Regarding the type of sentence, the analyses revealed between-group differences in sentences with a complex syntactic structure. Students with DHH performed more poorly than students with TH in all sentences with a complex syntactic structure, namely: sentences with a focalized complement (M_{DHH} = 52.50, SD_{DHH} = 31.31; M_{TH} =85.00, SD_{TH} = 14.96; $\chi^2(1) = 21.45$, p < .001); passives (M_{DHH} = 66.25, SD_{DHH} = 37.41; M_{TH} = 96.25, SD_{TH} = 9.16; $\chi^2(1) = 22.5$, p <.001) and sentences with a relative clause (M_{DHH}= 83.75; SD_{DHH}=20.31; M_{TH}= 98.75; SD_{TH} = 5.59; $\chi^2(1) = 13.82$, p <.001). Yet, no differences were found for sentences with a simpler syntactic structure; that is, active sentences (M_{DHH} = 90.00; SD_{DHH} = 14.96; M_{TH} = 96.25, SD_{TH} = 12.23; $\chi^2(1) = 1.70$, p = .191), which confirms the second part of H1.

Finally, we analyzed the type of responses given by participants (H2a, H2b and H2c). As the probability of randomly choosing a lexical distractor was twice that of selecting the syntactic distractor (there were 2 lexical distractors but one syntactic distractor per item), the mean proportion of selection of each option type was used as dependent variable in a set of Wilcoxon signed-rank tests by group (e.g., considering the whole task there were 16 syntactic distractors whereas the total number of lexical distractor was 32 [2 for each item], therefore the percentage of selection for each option was calculated accordingly, taking into account the total number of chances for selecting that picture). The results showed that the syntactic distractor selection rate was significantly lower than the target selection rate for both TH (T_{TH} = - 3.95, p < .001) and DHH (T = - 3.61, p < .001) (see descriptive statistics in Table 7 and Figure 10). The selection of the lexical distractor was also significantly lower than the selection of the target for both groups (T_{DHH} = - 3.92, p < .001; T_{TH} = - 3.95, p < .001). Consequently, H2a is not confirmed, that is, it seems that DHH participants did not ignore syntactic cues to answer sentence comprehension questions since they were able to discriminate between the target and the syntactic distractor, which only differed syntactically (in the order of thematic constituents).

Table 7. *Mean Proportion of Selection of the Target, the Syntactic Distractor, and the Lexical distractor by Hearing Status.*

	Type of Picture		
Hearing Status	**Target**	**Syntactic Distractor**	**Lexical Distractor**
DHH	72.40 (18.77)	25.63 (18.79)	0.78 (1.39)
TH	94.06 (5.54)	4.69 (5.32)	0.63 (1.28)

Note. Standard Deviations in parentheses.

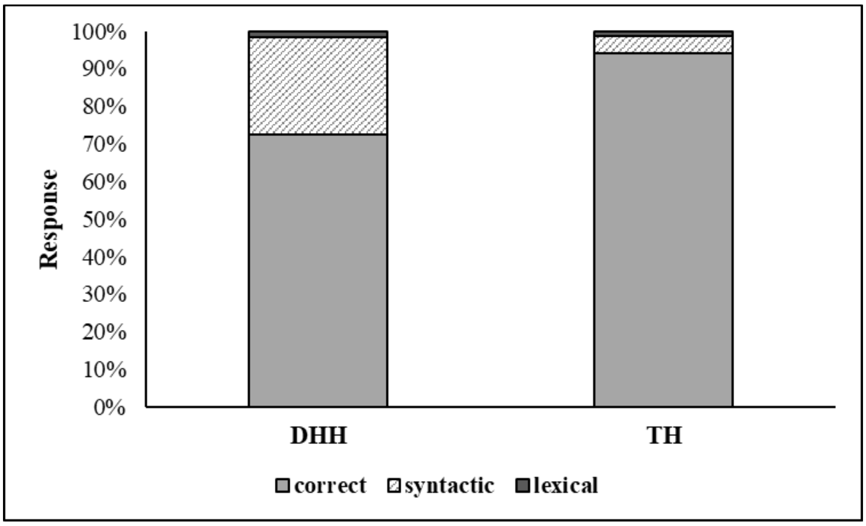

Figure 10. Mean Proportion of Selection by Type of Picture and Hearing Status.

Regarding the distractors' comparison, the mean proportion of selection of the lexical distractor was significantly lower than the syntactic distractor for both groups (T_{DHH} = -3.73, p < .001; T_{TH} = -2.87, p = .004). That is, as expected (H2b), participants with DHH easily discarded the lexical distractor and were more confused by the syntactic distractor. However, the same pattern was true for TH participants, so the last prediction (H2c) cannot be confirmed as TH participants did not show a homogeneous distribution of the errors between distractor options.

Further analyses of the type of errors revealed that students with DHH chose the syntactic distractor in a higher percentage than students with TH (U= 62, z = - 3.83, p < .001) but they did not differ in the proportion of selection of the lexical distractor (U= 190, z = - 0.37, p = .799).

Sentence Picture-Matching Task: Eye movements on picture alternatives.

Areas of interest and Eye Movements Measures

Each picture option was defined as an area of interest (See Figure 8) and was classified in three types: the target picture, the syntactic distractor, and the lexical distractor. In order to explore the use of syntactic and semantic cues during sentence comprehension, *total fixation time* (total amount of time spent on the picture including revisiting time) and *fixation count* (number of fixations made in each area of interest) were analyzed.

Outlier Identification

Each trial was visually inspected and those items that had not been properly recorded were excluded. After visual inspection, 0.16% of the data was removed from the analyses. Additionally, cells where fixation time was represented by zero values were substituted by empty cells. Following Micai et al. (2017) those cells that were > 2.5 SDs below or above each participant mean and condition (target, syntactic distractor, and lexical distractor) were removed from the analyses.

Analyses

In order to check our hypotheses, we first analyzed the eye movements obtained only from correct responses and additionally we conducted further analyses including only errors. This allowed us to explore if a different pattern of results emerged when participants made errors.

For each type of answer separately (correct responses and errors), we performed linear and generalized mixed-models using the lmer and glmer functions of the lme4 package (Bates, et al., 2015) in R (Version 3.6.3, R Core Team, 2019).

We entered group, picture type (syntactic distractor, lexical distractor, or target) and their interaction term as fixed categorical effects. We did not introduce sentence type (active, passive, relative clause and focalized complement) in the model, as in that case the resulting model would appear too complex given the small sample size. Regarding random effects, we kept the most complete logical structure (Barr et al., 2013) including intercepts by participant and by item (in our case, we consider "item" each one of the 16 sentences presented to participants). When the full model failed to converge, random effects were factored out in the following order until the model converged (see Howard, Liversedge, & Benson 2017): interactions between random slopes by stimulus, random slopes by stimulus one by one, according to how much variance they accounted for, that is, first group (lower sum of squares according to the analysis of variance [ANOVA] without random effects), then type of picture (highest variance) and random slope by participants. We only report data from the models that finally converged. Regarding fixed factors, we followed the procedure of Breadmore & Carrol (2018) so that the significance of each factor was calculated using likelihood ratio tests comparing full and null models with the same random structure. The procedure was as follows: 1) the significance of the interaction was assessed by comparing the full model to a model without the interaction term (ANOVA (Full Model, Null Interaction Model)); 2) Fixed effects of Picture Type and Group were compared to the model with additive fixed effects, except for the interaction, so that the main effect of Picture Type was assessed by (ANOVA(Null Interaction Model, Null Picture Model)) and the main effect of Group was assessed by (ANOVA (Null Interaction Model, Null Group Model)).

Total fixation time was log-transformed before conducting analyses. Linear mixed-effects (LME) summary statistics of the full model can be found in Table 8. Thus, *t* and *p* values reported in this table correspond to the analyses using the log-transformed variable. Yet, untransformed descriptive data, *b* and *SE* values are reported in Table 9 and 8 respectively for the ease of interpretation (The *b*, *SE, t* and *p* values of the fixed effects computed with transformed variables are provided in Appendix [Table A8 and Table A9]). As noted by Breadmore & Carrol (2018), it is important to highlight that these *t*-values obtained with the summary () function in R offer an alternative measure to the likelihood ratio tests of effects' significance. Finally, effect coding was used to contrast categorical fixed effects. Therefore, the baseline for the fixed effect of group was "TH" and the baseline for the fixed effect of Picture Type was "Target" (order of contrast coding was Target, Syntactic distractor, Lexical distractor). Consequently, the estimated coefficient (*b*) for the *intercept* can be interpreted as TH readers average total fixation time/visits on the Target. The sum of intercept *b* plus DHH *b* reflects DHH readers' average total fixation time/visits on the Target. The interpretation logic is similar for the rest of effects showed in Table 8.

With regard to fixation count, we followed similar fitting model procedures for both random and fixed effects as that of the total fixation Time, yet, in this case, the variable was not log-transformed and generalized mixed models were conducted using the glmer() function ("lme4" R package) rather than the lmer() function.

Consequently, the initial model formulas used in R were respectively:

lmer(fixation_time_log~group*picture_type+(picture_type|participant)+(group*picture_type|item), data=data)

glmer(nfixations~group*picture_type+(picture_type|participant)+(group*picture_type|item), data=data)

Total Fixation Time for Correct Responses. When only data from correct responses was considered in the analyses**,** the effect of group (DHH versus TH) was significant (χ^2 (1) = 5.18; p = .023) (see Table 8 and Table 9). Students with DHH invested on average more fixation time on the pictures than students with TH.

The main effect of picture type was also significant ($\chi^2(2) = 1185.6$; $p < .001$) so that, participants spent more time in the Target, followed by the Syntactic distractor and finally the Lexical distractor. The time invested in each alternative differed significantly for all participants (See Figure 11, Table 8 and 9).

The interaction between group and type of pictures was also significant (χ^2 (2) = 8.28; p = .016) (see Table 8). The analysis of simple effects was performed with Bonferroni adjustments ("phia" package, De Rosario-Martinez, 2015). As expected (H3a), both DHH and TH participants showed significantly higher fixation times in the Target than in the Syntactic distractor (χ^2_{DHH} (1) = 221.70; $p < .001$; χ^2_{TH} (1) = 388.86; $p < .001$) and in the Target than in the Lexical distractor (χ^2_{DHH} (1) = 602.23; $p < .001$; χ^2_{TH} (1) = 1033.43; $p < .001$) (See Figure 11).

In addition, both, DHH and TH participants made longer fixations in the Syntactic than in Lexical distractors (χ^2_{DHH} (1) = 55.41; $p < .001$; χ^2_{TH} (1) = 85.05; $p < .001$). So that, our predictions were supported for DHH participants (H3b) but not for TH participants (H3c) as we expected a more homogeneous distribution of the time between distractors for this group.

In order to check more exhaustively the interaction between group and type of picture, we checked the difference between groups per picture type which resulted significant for lexical distractor ($\chi^2(1) = 7.91$; $p = .015$), with DHH students investing more fixation time in the lexical distractor than TH students (see Figure 11). With respect to the other alternatives, students from both groups invested similar fixation times either on the syntactic distractor ($\chi^2(1) = 4.92$; $p = .079$) or on the target ($\chi^2(1) = 0.60$; $p = 1$).

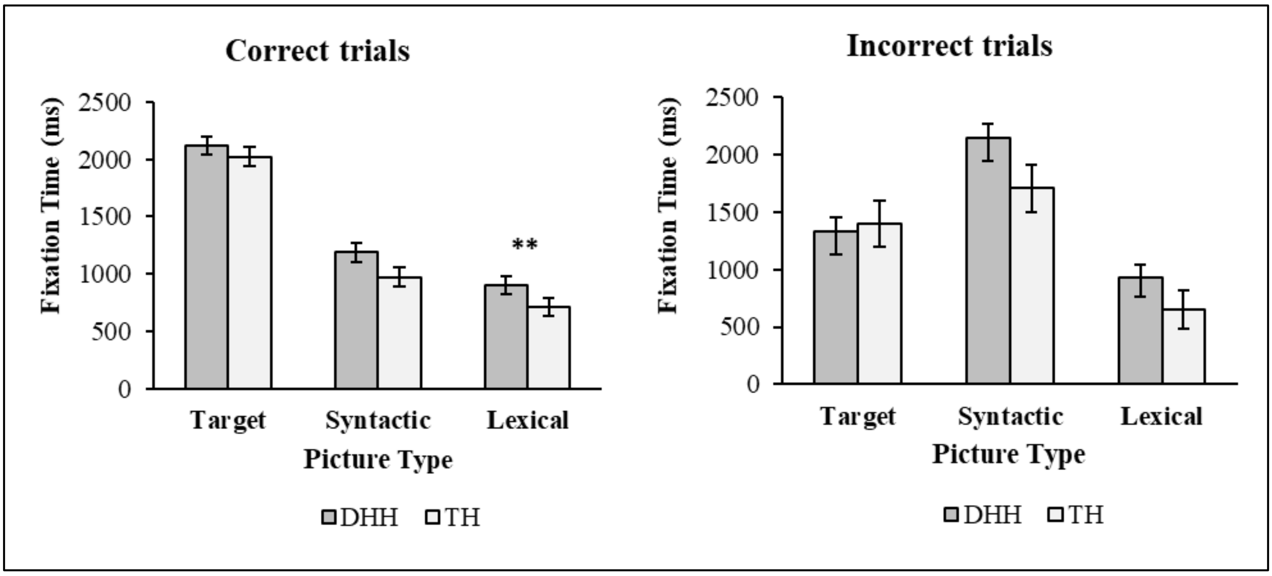

Figure 11. Total Fixation Time on Correct Responses by Picture Type in correct and incorrect trials.
Note. Errors bars represent standard deviations per group and condition.

Fixation Count in Correct Responses. The analyses based on the number of fixations yielded very similar results when considering only correct responses (see Table 8 and Table 9). The main effects of group ($\chi^2(1) = 5.81$; $p = .016$), picture type ($\chi^2(2) = 1134.2$; $p < .001$) and the interaction group by picture type ($\chi^2(2) = 11.15$; $p = .004$) were significant. The analyses of simple effects showed that the target received significantly more fixations than the syntactic distractor by both DHH ($\chi^2(1) = 182.44$; $p < .001$) and the TH participants ($\chi^2(1) = 289.60$; $p < .001$) and this distractor, in turn, received more fixations than the lexical distractor by both DHH ($\chi^2(1) = 15.66$; $p < .001$) and the TH participants ($\chi^2(1) = 35.55$; $p < .001$). Again, as in the case of total fixation time, students with DHH made more fixations on the lexical distractor ($\chi^2(1) = 12.69$; $p = .001$), than students with TH. Yet, no differences between-groups emerged for the syntactic distractor ($\chi^2(1) = 4.78$; $p = .086$, and target ($\chi^2(1) = 0.94$; $p = .999$).

Table 8. *Model Parameters for Total Fixation Time and Fixation Count on correct responses.*

	Total Fixation Time (ms)					**Fixation Count**				
	b	*SE*	*t* value	Pr(>|*t*)		*b*	*SE*	*z* value	Pr(>|*z*)	
(Intercept: TH target)	1319.41	59.51	328.56	< .001	***	1.38	0.04	33.64	< .001	***
DHH	83.22	44.41	2.09	.043	*	0.07	0.03	2.58	.001	**
Syntactic Distractor	-238.52	20.26	-8.44	< .001	***	-0.14	0.02	-7.82	< .001	***
Lexical Distractor	-512.04	17.33	-31.36	< .001	***	-0.35	0.02	-22.18	< .001	***
DHH: Syntactic Distractor	24.78	20.26	0.85	.394		0.00	0.02	0.18	.861	
DHH: Lexical Distractor	9.95	17.32	2.11	.035	*	0.04	0.02	2.59	.010	**

Note. *b* and Standard Error (*SE*) of Total Fixation Time for untransformed data. *T* or *z* and *p* values calculated with transformed data for Fixation Time. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.Random structure for fitted model on Total Fixation Time and Fixation Count (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (Contrast [1] for group: DHH=1/TH: -1; Contrast [1] for picture type: Syntactic Distractor-Target; Contrast [2] for picture type: Lexical Distractor-Target).

Table 9. *Means and Standard Errors for Total Fixation Time and Fixation Count on Correct Responses and incorrect responses by Group and Picture Type.*

	Total Fixation Time (ms)				**Fixation Count (n)**			
	DHH		TH		DHH		TH	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Correct Responses								
Target	2118.45	81.62	2021.48	79.23	6.67	0.05	6.27	0.05
Syntactic Distractor	1189.90	81.52	972.89	79.51	3.73	0.06	3.19	0.06
Lexical Distractor	900.54	76.92	714.21	75.69	3.14	0.05	2.49	0.05
Errors								
Target	1328.81	120.43	1398.36	202.50	4.16	0.09	3.92	0.13
Syntactic Distractor	2141.85	122.51	1706.66	204.49	6.36	0.08	4.73	0.13
Lexical Distractor	927.68	108.18	650.32	168.88	3.21	0.08	2.50	0.13

Note. *M* y *SE* for Total Fixation Time from the non-transformed measure.

Total Fixation Time and Fixation Count for Errors. We repeated the analyses of both total fixation time and fixation count only for errors, in order to check if the eye-movement pattern varied between accurate trials and inaccurate ones (See Table 10). We found that only the main effect of type of picture was significant for both, fixation time ($\chi^2(2)$ =139.72, p < .001) and fixation count ($\chi^2(2)$=153.73, p < .001) so that, in inaccurate trials, the syntactic distractor received more and longer fixations than the target (fixation time, $\chi^2(1)$= 16.44, p < .001; fixation count, $\chi^2(1)$= 14.83, p < .001) and the lexical distractor (fixation time, $\chi^2(1)$= 96.04, p < .001; fixation count, $\chi^2(1)$= 74.54, p < .001) (see Table 9 for means and Table 10 for *b* and t values). The difference between the target and the lexical distractor was also significant for both fixation time ($\chi^2(1)$ = 27.49, p < .001) and fixation count $\chi^2(1)$ = 20.04; p < .001). However, no between-group differences were observed in this case (fixation time, $\chi^2(1)$ = 2.75, p = .097; fixation count, $\chi^2(1)$ = 3.42, p = .065). The interaction group by type of picture did not reach significance (fixation time, $\chi^2(2)$ = 2.36, p = .308; fixation count, $\chi^2(2)$ = 2.39, p = .302). That is, the eye-movements pattern varied in errors in comparison to items with a correct response. For error trials, participants invested fewer time and fixations in the target (as it would had been logically expected for errors) and were mainly distracted by syntactical cues. There were no differences between groups but, as based on their performance on the task (accuracy data), a higher proportion of errors comes from DHH, so this confirms that DHH participants (like TH participants) needed to invest more attention in syntactic cues than in lexical cues. In sum, the analyses of the eye-movements on the error trials seem to support again H3b, (i.e. DHH students' preference for syntactic cues), and to reject again H3c; (i.e., TH students did not show a more homogeneous distribution of fixation time and count between distractors).

Table 10. *Model Parameters for Total Fixation Time and Fixation Count on errors.*

	Total Fixation Time (ms)					Fixation Count				
	b	*SE*	*t* value	Pr(>|*t*)		*b*	*SE*	*z* value	Pr(>|z)	
(Intercept: TH target)	1358.95	95.36	82.06	< .001	***	1.379	0.07	19.65	< .001	***
DHH	107.17	78.92	1.517	.138		0.10	0.06	1.80	.072	
Syntactic Distractor	565.31	74.29	7.61	< .001	***	0.32	0.04	7.20	< .001	***
Lexical Distractor	-569.95	64.60	-9.14	< .001	***	-0.34	0.05	-7.60	< .001	***
DHH: Syntactic Distractor	110.43	74.29	0.876	.381		0.046	0.05	1.05	.295	
DHH: Lexical Distractor	31.51	64.60	0.741	.459		0.02	0.05	0.55	.584	

Note. *b* and Standard Error (*SE*) of Total Fixation Time for untransformed data. *t* or *z* and *p* values calculated with transformed data. Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Random structure for fitted model on Total Fixation Time and Fixation Count (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (Contrast [1] for group: DHH=1/TH: -1; Contrast [1] for picture type: Syntactic Distractor-Target; Contrast [2] for picture type: Lexical Distractor-Target).

Additional Analyses

We conducted a set of correlational analyses in order to explore the relationships between the linguistic and cognitive individual factors and the eye-movement results on the correct responses on the experimental task for each group of participants. Note that all these measures were taken to describe their linguistic/reading functioning, but we did not have previous hypotheses about their relationship with the experimental task. However, exploratory analyses can be useful for future hypothesis formulation.

Therefore, we performed spearman correlation analyses between averaged total fixation time and averaged fixation count in each type of picture (target, syntactic distractor and lexical distractor) with the following background measures: word reading speed (milliseconds needed to complete the task), receptive vocabulary (raw scores), written syntax (raw scores), expressive language (raw scores) and reading span. These set of correlations were performed independently for each group (TH- DHH). As it can be observed in Table 6, we selected mainly the individual measures that differed significantly between groups. The only exceptions were: 1) Written syntax that was included due to the close relationship between this factor and the experimental task and 2) Chronological age because the range was quite large within each group. A summary of the correlations is displayed in Table 11.

With regard to chronological age, a different pattern emerged for TH and DHH students. Chronological age correlated negatively with fixation time and fixation count for students with TH in all picture types (except fixation time on the target, see Table 11). In this sense, as students with TH got older the time and number of fixations invested to process each alternative decreased. In the case of students with DHH, age did not significantly correlate with any measure.

Linguistic skills appeared to correlate significantly with fixation time and fixation count for both groups at the distractors. Regarding the target, receptive vocabulary appeared to correlate highly with fixation time and fixation count only in the TH group, the correlation was negative (as receptive vocabulary increased, fixation time and fixation count on the target decreased). In the case of the DHH students none of the linguistic measurements correlated with the online data related to the target. As for the syntactic distractor, receptive vocabulary, expressive language and written syntactic skills correlated highly with fixation time in the DHH group (i.e., the larger the vocabulary or the higher the syntactic abilities, the lower the time of fixation on the syntactic distractor), yet none of these variables correlated significantly with fixation count. By contrast, students with TH did not show a clear pattern of relationships for the syntactic distractor (see Table 11) as only receptive vocabulary showed a negative correlation with fixation time and expressive language also correlated negatively with the number of fixations. With regard to the lexical distractor, receptive vocabulary, expressive language and written syntax showed a negative correlation with fixation time and fixation count in both groups (DHH and TH) (except for expressive language that did not correlate with fixation count in TH). All in all, although a clear pattern of how online data relate to linguistic abilities cannot be observed, it seems that linguistic abilities were clearly related to the processing of the distractors in the DHH group.

Regarding the remaining measurements, we could hypothesize that the reading span could have had an effect on the results (as the task itself required the reader to hold the sentence meaning until making the choice), yet only in the case of TH online time data related to the target or the lexical distractor correlated with this skill, again in a negative direction (i.e., the larger the reading span, the lower the time and frequency of fixation on the target). Finally, no correlations between eye movement data and word reading speed showed up for any group.

Table 11. *Spearman's rho Correlations between Individual Variables and Eye Movement Data per Type of Picture by Group on Correct Responses*

	Target		**Syntactic Distractor**		**Lexical Distractor**	
	DHH	TH	DHH	TH	DHH	TH
Fixation Time						
Chronological Age (Months)	.22	-.37	.14	**-.53***	-.03	**-.75****
Word Reading Speed (RS)	.14	.22	.11	.30	.14	.22
Receptive Vocabulary (RS)	-.29	**-.47***	**-.51***	**-.50***	**-.46***	**-.64****
Written Syntax (RS)	-.30	-.37	**-.45***	-.36	**-.52***	**-.62****
Expressive Language (RS)	-.39	-.12	**-.45***	-.30	**-.58****	**-.49***
Reading Span (RS)	.00	**-.55***	-.37	-.36	-.25	**-.53***
Number of Fixations						
Chronological Age (Months)	.08	**-.49***	.25	**-55***	.05	**-.65****
Word Reading Speed (RS)	.19	.11	.21	-.11	.09	.05
Receptive Vocabulary (RS)	-.24	**-.60****	-.31	-.43	**-.46***	**-.56***
Written Syntax (RS)	-.32	-.35	-.32	-.29	**-.51***	**-.49***
Expressive Language (RS)	-.33	-.07	-.32	**-.48***	**-.49***	-.38
Reading Span (RS)	-.13	**-.72****	-.23	-.39	-.36	-.41

Note. *$p < 0.05$, **$p < 0.01$. RS= Raw Score

Discussion and Conclusions

The goal of this study was to examine the processing of semantic and syntactic cues during a sentence picture matching task in students with deafness and typically hearing matched at chronological age by monitoring their eye movements.

Our first predictions relate to the accuracy on the sentence picture matching task (grammatical structures task). Regarding accuracy on the overall task, as expected, students with DHH performed more poorly than students with TH, confirming their well-documented grammatical comprehension difficulties in both, reading and oral tasks (Barajas et al., 2016; Figueroa et al., 2020; Friedmann & Szterman, 2006; Pooresmaeil et al., 2019). It should be noted that there was a high variability in the results. While some of the participants with DHH attained the maximum score on the task, half of the participants obtained scores lower than 70%, demonstrating once again, the high intra-group variance of this population (Traxler, 2017). Students with TH by contrast, obtained close to ceiling results (94%).

When sentence type was considered, differences between students with DHH and students with TH disappeared for active sentences and remained for the rest of the sentences. These results are in accordance with studies such as Lee et al. (2018) or Szterman and Friedman (2014), who indicated that students with DHH performed more poorly than their TH peers on complex sentences (passives and object relatives, respectively) but not on simpler sentences (actives). Therefore (H1) was confirmed.

With regard to the type of response, students with DHH chose the target picture in more occasions than the syntactic distractor. Sentences included in the task were reversible in nature, that is, even after reversing main noun phrases the sentence still makes sense. This means that participants needed to access the syntactic structure in order to prevent sentences' misinterpretation (especially in those items that conveyed a more implausible meaning [e.g., *The three little porks frightened the wolf* [note that this example has been invented and was not part of the assessment], see Miller et al., 2012 for a discussion of the plausibility effect). In addition, most of the sentences of the task (62.5%) did not follow a canonical order so they could be misread if participants assigned thematic roles following a word order rule and disregarding syntax. Therefore, as students selected the target (correct alternative) in a higher proportion than the syntactic distractor (which included same elements with thematic roles exchanged), they appeared to be sensitive to syntactic cues during their reading. Consequently, in line with **Study 1**, H2a was not confirmed.

On the other hand, the lexical distractor, appeared as the less chosen alternative by participants for both groups, this pattern was expected for DHH (Confirming H2b), as this option could be easily discarded by considering the lexical cues included in the sentence. If the proportion of errors made by choosing the lexical distractor would have been higher or equal than that obtained by selecting a syntactic distractor, other factors but not grammatical comprehension could have explained the low performance that DHH students demonstrated on the task. In this sense, choosing the lexical distractor a similar number of times than the syntactic one would suggest that the performance of the students would had been motivated by an erratic strategy (Gallego et al., 2016), that they were solving the task by guessing, or that cognitive factors such as attention or memory (as students would not have retained the elements that took part in the scenario/sentence) had had a high influence on task achievement (hindering even syntactic processing to take place). Besides, we found no differences regarding the proportion at which DHH chose the lexical distractors in comparison to TH students. In this case, our results would be in agreement with López-Higes et al. (2015), who found no differences between TH students and students with DHH (regardless of their moment of cochlear implantation) in identifying lexical distractors as the wrong response. Yet, our results yielded significant differences between groups concerning the syntactic distractor. In this sense, students with DHH made a higher number of errors than TH participants by selecting the syntactic distractor. These results agreed partially with López-Higes et al. who indicated a similar performance between DHH students with early-CI and students with TH when detecting the syntactic distractors, but a lower performance in those students with DHH and late-CI. However, it should be noted that in our study only half of the participants (*n*=10) received their CI at an early age whereas the others received their first CI later in time (*n*=6) or were not even CI users (*n*=4). This means that our group of participants with DHH ranged considerably in the moment their received their implants (e.g., it was composed by students that were implanted as soon as they reached their first year of life but also by students that received them at the age of ten). By contrast, López-Higes et al. was able to separate their sample in such a way that he could analyze separately the results from those students that receive their CI before the age of two. Therefore, it might be possible that if we had had the opportunity to separate the sample according to their type of prosthesis and moment of implantation different patterns would have emerged, however the size and characteristics of our sample did not allowed for this comparison.

Finally, regarding students with TH we predicted that as opposed to DHH participants, they would show a homogeneous distribution of the errors between distractors. We expected that they would fail to discard both types of distractors similarly (as they did not have difficulties with syntax, the syntactic distractor was not expected to produce higher confusion than the lexical one). Nonetheless they failed significantly more with the syntactic than the lexical distractor, proving that even for them, the former was more confusing than the latter (H2c was not therefore confirmed).

So far, our results show that students with DHH appear sensitive to syntactic cues. However, they perform more poorly than students with TH when it comes to complex sentence comprehension; this, in turn, could be explained by a lower ability in dealing with syntax.

Whether they required more time to syntactically process the sentences or not will be further explained by online processing data (eye movements).

The rest of the predictions focused on the results derived from eye-movement data. Regarding the alternatives of response (target, syntactic and lexical distractor) when considering only correct responses in the analyses, the target picture was the alternative in which students (with DHH or TH) invested more fixation time and made more fixations. This was a rather expected result (H3a), as answering correctly prompted students to fixate longer at the target picture at least to check for the number of the picture to give a response. With respect to the distractors, students with DHH made longer and more fixations on the syntactic distractor than on the lexical one. These results confirm our predictions regarding students with DHH (H3b), suggesting that due to their grammatical difficulties the syntactic distractor constitutes a higher competitor than the lexical one, and as a consequence requires higher processing demands to discard it as being the correct alternative. However, we need to be cautious when considering that the preference for the syntactic distractor appeared just as a consequence of a weak syntactic ability, as contrary to our expectations (H3c), the TH students did show the same pattern, and despite not having grammatical difficulties they were also more confounded by the syntactic than the lexical distractor (as shown by an increased time and number of fixations in the former). Perhaps, this behaviour was artificially induced by our experimental manipulation since the lexical inaccurate cues provided by the lexical distractors were too easy or evident which would be a methodological shortcoming of our task. In that sense, it is maybe too obvious that the "*sheeps*" of the lexical distractors in the example of Figure 8 was not in the original sentence, so the "witty" strategy in this "experimental situation" is to discard those choices with obvious lexical/semantic inaccurateness and then analyze the syntax. In the same line of results, our previous study (**Study 1**) showed that, both DHH and TH students demonstrated early detection of grammar errors of written sentences (increased fixation time or fixation count as soon as the error occurs in the sentence). Anyhow, we did not analyze the temporal frame/sequence of fixation (see for example Schumacher et al., 2015) on picture choices but the fixation counts and durations per picture, so the interpretation of similarities between our results and the ones of Breadmore et al. (2014) or from our previous study (**Study 1**) has to be taken with caution.

Despite similarities, there were also between-group differences that should be mentioned at this point. In correct trials, students with DHH spent more time and more fixations than students with TH but the difference between groups was only significant in the case of lexical distractors. In this sense, the processing of semantic cues could differ between students with DHH and students with TH. On the one hand, this result would be the only one slightly supporting the KWS hypothesis as DHH students seem to invest more processing resources in the lexical distractor than TH students. On the other hand, our results would not agree with those reported by Breadmore et al. (2014), who suggested that DHH and TH students differed in the time course processing of syntactic but not on semantic cues. Nevertheless, it should be noted that although no differences between fixation time and fixation count related to the syntactic distractor reached significance, in the case of fixation time they were close to it ($p = .079$). Consequently, this could be a Type II error that maybe would have reached significance with a larger sample. However, as far as our sample is concerned, our results indicate that students processed the syntactic cues in a similar way as TH did.

As already stated, concerning correct responses, processing differences between TH and DHH students emerged on the lexical rather than the syntactic distractor or the target. Yet, both groups distributed similarly their processing resources through the alternatives either when answering correctly (they invested more time on the target than on the distractors, and on the syntactic distractor than on the lexical) or when committing errors (the syntactic distractor was the alternative that received more and longer fixations, followed in order by the target and the lexical distractor), in the case of errors, no between groups differences were observed.

Nevertheless, whereas this eye movement pattern resulted in a successful task-solving strategy for students with TH it did not always work for students with DHH. One tentative explanation could be that a lack of proficiency or automaticity of the syntactic process underlies their comprehension failure (Kelly, 2003b). In this sense, students with DHH followed initially the same strategy as students with TH. However, as they were not as proficient with syntax as TH students, when coming to an interpretation they attributed the final meaning to those pictures that were more congruent with their previous-knowledge or with those cues that they feel more confident with in most occasions, that is, content words (which would explain Domínguez et al. [2016]'s results). In this sense, students with DHH did not succeeded in sentence interpretation, but not because they did not specifically consider syntactic cues in their reading (they did so, as shown by the higher rate of target choices), but because their syntactic knowledge was not good enough to provide both an accurate and an efficient (fast and effortful-less) response, as TH students did. As a consequence, students with DHH could felt insecure during their performance and when the syntactic processing failed, they led their interpretation to the information conveyed in those cues that they succeeded more, mainly content words or word order (which in fact, they also struggled with). Therefore, concerning syntactic cues our results did not support the Key Word Strategy in their strict proposal (see Domínguez et al., 2016), instead they call for a redefinition of it, which in other words would state that students with DHH do not ignore but misuse syntactic cues (as already noted in **Study 1**).

Our study is in line with other offline (Gallego et al., 2016; López-Higes et al. 2015) and online studies (Breadmore et al., 2014; **Study 1**) with children and adolescents that state that DHH do use syntactic cues during reading. Yet, aspects regarding the relationship of our eye movement data with some cognitive and linguistic variables deserve further explanation.

First, chronological age was highly and significantly correlated with fixation time and fixation count in the group of TH students but not in the group of students with DHH. It seems that as TH grow up, they increase their competence in some skills (probably vocabulary, syntax and memory span), that help them improve their sentence reading strategies. However, this increment of competence in sentence processing with age is not guaranteed for DHH students.

Second, linguistic abilities influenced the ability of DHH to discard efficiently those items that did not fit with the sentence meaning (distractors). Our results are in line with other studies which claim that receptive vocabulary (Gallego et al., 2016; Lee et al., 2018; Moreno-Pérez et al., 2015) and grammatical comprehension abilities (both, spoken [Barajas et al., 2016] or written [**Study 1**]) play a role in the reading comprehension of students with DHH. However, we found no links between these linguistic variables and the eye movement data when the students with DHH process the correct alternative (target).

On the other hand, word reading speed was not correlated with fixation time or fixation count across the groups, our results are in line with other studies such as Moreno-Pérez et al. (2015) who did not find relationships between word reading speed and sentence reading (measured with a timed sentence reading-completion task).

Finally, reading span abilities correlated with the fixation time and fixation count only in the TH group. These correlations reached significance at the target (where both eye movement measures showed to correlate with it) and lexical distractor (only fixation time was correlated) but they did not at the syntactic distractor. The fact that reading span related to TH participants' sentence processing instead of DHH fails to replicate previous findings such as those reported by Gallego et al. (2016) or Lee et al. (2018), who found that working memory (measured with digit span tasks) related to DHH's but not to TH's performance on sentence comprehension.

Our study has educational implications. As other authors have already claimed (e.g., Barajas et al., 2016; López-Higes et al., 2015), further grammatical comprehension training for students with DHH is needed. In particular, improving the comprehension of complex sentences (and not only simple sentences) should be at the focus of the reading comprehension intervention. We agreed with López Higes et al. (2015) that using tasks similar to the sentence-picture matching task included in this study could aid students with DHH to foster their grammatical competence, as they require the student to make a proper use and interpretation of both grammatical and lexical cues to construct the sentence meaning, however the type of feedback that the student receives could make a difference in this case.

As stated, students with DHH seem to consider syntactic cues during reading, yet these cues do not always lead them to make the correct decision, probably because they do not interpretate them correctly. We therefore consider that providing the student with information beyond their accuracy on each exercise, providing elaborated rather than only corrective feedback (Shute, 2008) (e.g., explaining the student which aspects of the sentence need to be revised when they fail to select the appropriate alternative) could led the student to improve their grammatical skills. However, the use and appropriateness of different types of feedback is far beyond the scope of this study.

Some methodological improvements could have enhanced the quality of our study. In this sense, including more trials per sentence type would have allowed comparing the performance between sentence types. Yet, as mentioned, participants conducted more experimental tasks within the same session, so we decided not to add more items to the task in order to avoid fatigue. In addition, the use of more difficult lexical distractors or, at least, as difficult as syntactical distractors, for example, could help explore more properly the preference for lexical cues. In such a case, lexical distractors would have appeared as higher competitors and it would not have been so easy to discard them. As a consequence, the task would have been more demanding and the differences between skilled and less skill students would be more evident. Finally, the application of additional tasks could have been helpful to better describe the strategy that DHH students followed to complete the task. The use of confidence ratings (ask the participants how confident they are with their answer) as a measure of error awareness in conjunction with eye movements has recently proved to be a useful approach, allowing to understand the nature of sentence processing (Arantzeta, Webster, Laka, Martínez-Zabaleta, & Howard, 2018). Considering this information along with online data could help future studies to disentangle whether sentence processing difficulties in students with DHH stem from a conscious difficulty to apply syntactic knowledge or rather derive from an unconscious ability to deal with it.

Overall, what our data suggest is that students with DHH do consider syntactic cues in their interpretation.

In this Study we have covered some limitations that we already indicated in **Study 1**. That is, we have included complex sentences and semantic cues in the assessment. However, these findings do not necessarily extend to text processing. As noted in the General Introduction there are some aspects that differenciate the online reading pattern on sentences versus texts. In this latter case, integrative processes cooperate more actively to elaborate a mental representation of the material and therefore differences may appear in some other eye-movement measures (e.g., in the form of rereadings or saccade amplitude, see Hyöna & Kaakinen, 2019). We will examine the online processing at the whole text level in the next study (**Study 3**).

"Take Home Messages" from Study 2

- Students with DHH are leveled to students with TH when reading active sentences but underperform them on complex sentences (i.e., passive voice, focalized complement, and relative clause sentences).
- Students with DHH appear sensitive to syntactic cues as they choose the target picture more occasions than the syntactic distractors.
- Eye movements revealed a similar distribution of processing resources between both groups (students with DHH and students with TH).
    - Either in correct responses (they invested more time on the target than on the distractors, and on the syntactic distractor than on the lexical one)
    - Or errors (the syntactic distractor was the alternative that received more and longer fixations, followed in order by the target and the lexical distractor).
- Concerning correct responses, processing differences between TH and DHH students emerged on the lexical rather than in the syntactic distractor or the target. DHH students made longer fixations in the lexical distractors than TH students.

Study 3 *| Text comprehension: Effects of Text Genre and Grammatical Word Class. **

* The content of this section is a manuscript submitted for publication to a peer review journal by the following authors (Nadina Gómez-Merino, Inmaculada Fajardo, Antonio Ferrer, and Holly Joseph)

Abstract

The present study was aimed at analysing eye movement patterns during the comprehension of short texts of deaf and hard of hearing (DHH) students (age range: 9-15 years) in relation to a hearing chronological age matched control group (TH). The effects of two variables were examined: 1) Text genre (narrative vs. expository) and 2) grammatical word class (content vs. function). There was a significant difference in comprehension accuracy between groups only for the narrative texts where TH obtained higher scores. Both groups made more fixations and invested more fixation time in the expository than in the narrative text. However, DHH participants showed longer saccade amplitude in the expository text than in the narrative one whereas participants with TH showed similar saccade amplitudes across text genres. Regarding grammatical word class, both groups skipped less frequently and fixated longer content than function words. With regard to fixation time, the difference between groups was bigger for content than function words. Additional exploratory analyses revealed that receptive vocabulary, grammar and reading span might contribute differentially to DHH and TH students' accuracy and eye-movement patterns during text comprehension. Theoretical and applied implications of these findings for assessment and training of DHH students are discussed.

Introduction

As we have already seen in the previous studies (**Study 1** and **Study 2**), monitoring the eye movements of participants during reading enables to obtain valuable information about their moment-to-moment cognitive processing as they encounter words and process written information of sentences in real time (Rayner, 1998). However, research into the reading patterns of students with DHH by means of eye-tracking is scarce and, with a few notable exceptions that include children as participants (e.g., Bélanger, Lee, & Schotter, 2018; **Study 1** and **2** from this **Thesis**), most of it has been done with adults (e.g., Bélanger, Mayberry, & Rayner, 2013; Bélanger & Rayner, 2013; Bélanger, Slattery, Mayberry, & Rayner, 2012; Piñar et al., 2017; Tomasuolo, Roccaforte, & Di Fabio, 2019) or adolescents (Blythe, Dickins, Kennedy, & Liversedge, 2018).

In addition, to our knowledge, no studies have explored online reading comprehension in children with DHH using whole text as the unit of analysis. In fact, most previous research on population with DHH has used eye-tracking (or similar on-line techniques such as the moving-window paradigm) to explore smaller processing units like sentences (see for example Bélanger et al., 2018; **Study 1** from this **Thesis**). According to Hyönä and Kaakinen (2019), the integrative processes required to build a coherent mental representation of the text would drive to increase rereading rate or saccade amplitude (see Camblin, Gordon, & Swaab, 2007; Hyönä & Kaakinen, 2019, for review and discussion). Although the aim of the present study was not to compare sentence versus passage or text reading, we mention this issue to highlight a research gap in the reading and deafness literature that made us to focus on the whole text as unit of analysis (as highlighted in the overview of studies' designs offered in Table 2). Consequently, focusing on previous eye-tracking studies conducted with texts or passages as unit of analyses and TH students, we learnt that reading proficiency (Kraal, van den Broek, Koornneef, Ganushchak, & Saab, 2019; de Leeuw, Segers, & Verhoeven, 2016a; 2016b), text genre (narrative versus expository, Kraal et al., 2019) and grammatical word class (function versus content words) (de Leeuw et al., 2016b) are among the most relevant factors that influence the eye-movement patterns of students. In addition, grammatical word class effect may be modulated by text difficulty (de Leeuw et al., 2016b), so that more difficult texts (for example, expository texts) would increase the difference between functions and content words.

In order to gain a better understanding of reading proficiency in DHH students, the present study focused on comparing eye-movement patterns during text processing of DHH students and TH and how were these patterns modulated by text genre (narrative text vs. expository text) and grammatical word class (content vs. function words). The relevance of these two factors for the DHH and TH population and what eye-movements tell us about them is introduced in next paragraph.

Rationale

Text Genre

In early grades of elementary school, children are mainly exposed to narrative texts. However, in later grades expository texts become the main way of acquiring academic knowledge (Kraal et al., 2019). Empirical findings in TH children suggest that expository texts are more difficult than narrative texts for several reasons. First, the structure and the reading goals of expository texts are not as clear and familiar as the ones of narrative texts for young readers (Lorch, 2017; McNamara, Ozuru, & Floyd, 2017). Second, comprehension of expository texts is more influenced by readers' prior knowledge than comprehension of narrative texts (Best, Floyd, & McNamara, 2008). In addition, expository texts tend to introduce novel concepts or ideas so the vocabulary might be less familiar for the reader than in narrative texts (McNamara et al., 2017). Finally, these factors make it more difficult for the reader to draw inferences automatically (Lorch, 2017), especially for secondary students with learning disabilities (Sáenz & Fuchs, 2002).

Concerning DHH readers, a recent study by Figueroa et al. (2020) showed that adolescents with CIs ($N = 36$, $M_{age} = 14.03$) obtained significantly lower reading comprehension scores than a TH group of adolescents for both an expository and a narrative text. When the DHH group was splitted by age of implantation of the CI, the differences in both types of text compared to the TH group remained only for the late implanted group. This finding seems to suggest that hearing age might be an important contributor to text comprehension regardless of text genre.

The difficulty that the text poses in typical readers seems to be reflected not only in comprehension scores but also in several eye-movement measures. For example, in the case of TH adults and children, measures such as *Average fixation duration* (sum of duration of all fixations divided by number of fixations in the text); *Number of fixations*; *Total fixation time* *for the text* (sum of the duration from all fixations in the text, known as *Dwell time* if saccades are included on the computation) correlated with subjective ratings of the difficulty of the passages (Rayner et al., 2006). That is, the duration and number of fixations increased in difficult texts (e.g., Average Fixation Duration for adults: M_{easy}= 267 ms; $M_{difficult}$ = 270 ms; [Rayner et al., 2006]; for children: M_{easy} = 268 ms; $M_{difficult\ [disappearing]}$ = 300 ms [Blythe, Liversedge, Joseph, White, & Rayner, 2009]). The *Amplitude of the saccade* (defined as the sum of all saccade amplitude divided by the number of saccades in the text where the amplitude is the distance from start to end point of the saccade) lands between 7-9 letter spaces for typical adult readers (Rayner, 2009) and can also vary with text difficulty. In this way, as text difficulty increases, Saccade Amplitude decreases (for a review, see Rayner, 1998). Finally, *Regressive fixations* (fixations preceded by regressive saccades) in comparison to *Progressive fixations* (fixations preceded by progressive saccades) can also appear as an indicator of effortful reading. As text difficulty increases the number of regressive fixations tends to increase, in many cases as an attempt to recover from comprehension failure (for a review, see Rayner, 1998 and Rayner, Schotter, Masson, Potter, & Treiman, 2016).

Interestingly, text-related characteristics like text genre and student-related characteristics might have an interaction effect on the time-course of text processing (de Leeuw et al., 2016a, 2016b). As text difficulty increases, readers need to invest more resources in terms of background knowledge, vocabulary, inferencing abilities, or metacognitive skills (that help the reader to detect, regulate and restore comprehension breaks). Indeed, in TH readers, reading proficiency has been shown to influence the processing of texts of different genres. For instance, based on the analysis of think-aloud verbal protocols from students in grades 7, 9, and 11, Denton et al. (2015) explored the differences between good and poor comprehenders in monitoring while reading narrative or expository texts. Monitoring behaviour was operationalized with different measures such as “confirmation or disconfirmation of the continuity of current text with prior text information", "Rhetorical queries or statements, or recognition that critical text information is insufficient or missing" or "Revision in interpretation in response to an erroneous on-line interpretation". They found that poor comprehenders showed significantly lower monitoring, regardless of text genre, compared with adequate comprehenders reading expository text. In other words, good comprehenders were able to detect inconsistencies and adapt their reading pattern to genre type more than poor comprehenders. Similarly, Kraal et al. (2019) studied the online processing of text, but they used eye movements instead of verbal protocols. They registered the eye movements of 53 good comprehenders (GC) and 27 poor comprehenders (PC) (M_{age} = 7:8) while they read two expository and two narrative texts. Their comprehension accuracy of each text was assessed by three different types of questions: literal questions, text-based questions, and knowledge-based questions. As expository texts require higher processing demands, the authors expected a) lower comprehension scores in expository than in narrative texts; and b) an interaction between reading proficiency and text genre such that students with high- comprehending skills, in contrast to PCs, were expected to have sufficient resources to modulate their reading pattern as a function of text difficulty, and consequently they were expected to spend longer reading the difficult (expository) texts. The results of Kraal et al.'s study showed that, as expected, comprehension scores were higher for narrative texts than for expository texts in both groups, and that GCs surpassed PCs in all types of questions. In the case of eye movements, PCs made longer first-fixations, longer first-passes and skipped fewer words than GCs in both types of text. However, a different pattern emerged in late-processing measures: while GC spent (numerically but no statistically) more time (Full text time) and made more fixations (Full text fixation count) on the expository text, PCs did so in the narrative text (although the authors highlighted that the reported simple effects should be interpreted cautiously as for full text fixation count only the interaction effect was reliable). Concerning total fixation duration at the level of words, GC students invested more time on expository texts than on narrative texts, while PC students showed similar total times on both types of text. Regarding other late-processing measures, PC students spent more time than GC students rereading narrative texts (*second-pass fixation duration* [milliseconds invested rereading an AOI after it has been read once]) and whereas PC students decreased this rereading time for expository text, GC students did not. With regard to saccade amplitude, PC students made smaller saccades in the narrative and expository texts than GC students (suggesting a more careful or effortful processing). When comparing both texts, PC students increased saccade amplitude in the expository texts (note that this latter effect was not statistically significative). In sum, the differences in the eye movement pattern between comprehension groups were more evident in the case of narrative texts, where PC students made longer fixation times and more fixations. In contrast, such differences were less apparent in the expository texts. As authors suggest, these results indicate that PC students adopt a less efficient processing strategy when facing texts of different difficulty (genre in this case) than GC students.

In the particular case of students with DHH, the literature has documented weaknesses in several domains related to literacy and reading proficiency such as background knowledge (Convertino, Borgna, Marschark, & Durkin, 2014), vocabulary (Harris et al., 2017; Herman, Kyle, & Roy, 2019; Moreno-Pérez et al., 2015), syntactic skills (Barajas et al., 2016), inference generation (Sullivan, Oakhill, Arfé & Gómez-Merino, 2020) and usage of metacognitive strategies such as rereading or looking back (Marschark & Wauters, 2008). All of these findings suggest that the online reading pattern of DHH readers might differ from that of TH readers as a function of their reading proficiency and the type of text they are reading (Kraal et al., 2019), however, studies that have analysed online text comprehension taking into account text-difficulty in students with DHH are rather scarce. In fact, we can only report the Banner and Wang's study (2011) who explored the reading strategies employed by participants with deafness by using thinking-aloud procedures. Although they did not go deeper into the analyses of text genre, adult participants (*n*=5) showed more reading strategies in a narrative text than in an expository text.

In sum, DHH readers have been found to present a profile of poor reading comprehension. Therefore, if their performance is similar to that of TH poor comprehenders, we could expect that their eye-movements reading pattern during text reading would differ from those of TH good comprehenders. In particular, they will show less monitoring behaviour differences in terms of word skipping or saccade amplitude between text genres than TH adequate comprehenders who would adapt their online processing strategies to the more demanding expository texts.

Grammatical Word Class

Considering grammatical class, words can be broadly classified as content words or function words. The group of function words includes words that "are not involved in productive compounding and derivation" (Sweet, 1891 cited at Schmauder, Morris, & Poynor, 2000, p. 1098). They mainly disclose information about structure and new function words are rarely added to the lexicon, thus, they form a closed-class (e.g., prepositions) (Schmauder et al., 2000). In contrast, as content words take part in compounding and derivation, they constitute an open-class (as new words can be added) (Schmauder et al., 2000) and inform meaning. According to Domínguez et al. (2016) words such as nouns, adjectives and verbs would be classified as content words.

Among other text-related variables, such as frequency or word-length (e.g., Hyönä & Kaakinen, 2019; Joseph et al., 2009; Joseph, Nation, & Liversedge, 2013), according to the empirical benchmark effects in eye movement literature with adults, function words are more frequently skipped and receive shorter fixations than content words (Carpenter & Just, 1983;

Rayner and Duffy, 1988, Roy-Charland, Saint-Aubin, Klein, & Lawrence, 2007). Regarding children, de Leeuw et al. (2016b) examined differences in the eye movement patterns on content words versus function words (regressions probability, skipping, and gaze duration) in primary school students. A group of TH students from 3rd grade (*n*=24) and a group of TH students from 5th grade (*n*=20) were asked to read two texts, an easy text (below each grade level) and a difficult text (at each grade level). The authors found that the effect of word class was not significant for gaze duration but there were more regressions from content words than from function words, and that the difference was larger for difficult texts than for easy texts. Regarding skipping probability, 5th grade students skipped more words in general than 3rd grade students. As expected, taking into account the mentioned empirical benchmark effect in eye movement literature with adults (Carpenter & Just, 1983; Rayner & Duffy, 1988; Roy-Charland et al., 2007), students from both groups tended to skip fewer content than function words, except in the case of 3rd grade students in the easy text condition who skipped function and contet words similarly.

Regarding readers with DHH, there are no previous empirical studies that have examined the effect of grammatical word class by means of online measures in children and adolescents and, to our knowledge, only Krejtz, Szarkowska and Łogińska (2016) and Coulter and Goodluck (2015) have done it with adults. Krejtz et al. (2016) monitored the eye-movements of three groups of adult participants (TH and Deaf) while watching videos with audio in Polish (mother tongue), or in English with subtitles (in Polish). However, since the paradigm they used differs from ours (reading task versus subtitle reading task) and they did not follow an audiological criterion to classify their participants as deaf or hard of hearing (participants self-reported whether they identified themselves as deaf or hard-of-hearing), we avoid to draw hypotheses based on the results from this paper. Coulter and Goodluck (2015) used self-paced reading to compare the reading strategies of adults with hearing loss and adults with typical hearing during sentence reading (simple sentences and complex sentences [wh-dependencies]). When reading simple declarative sentences, participants with hearing loss showed longer response times in content words than in function words. This pattern was also observed during complex sentence reading, where, while participants with typical hearing increased their response times along the sentence (either on function or on content words) once they encountered a difficulty in the processing, participants with hearing loss slowed down mainly at content words. Despite the relevance of such results, the absence of information regarding degree of hearing loss of the DHH participants involved in Coulter and Goodluck's makes difficult to derive solid hypotheses and conclusions from it.

With regard to off-line measures' literature, we bring into focus again the aforementioned "*Key-Word Strategy (KWS)*" preference's hypothesis by Soriano et al. (2006), according to which DHH readers construct meaning from text by relying exclusively on the information provided by content words (Domínguez et al., 2016, 2012; González & Domínguez, 2018; Soriano et al., 2006). However, Gallego et al. (2016) have recently questioned it. After improving some methodological limitations of the Dominguez et al.'s studies, they did not find evidence that DHH children show a preference for using semantic cues during sentence reading, on the contrary, they seemed to use both syntactic and semantic cues as TH children do, especially DHH children with early CIs. It is important to note that in any of these previous studies, the processing of function and content words was directly examined but inferred from their offline measures (accuracy completing a sentence with a word among several alternatives that included semantic distractors [e.g., Domínguez et al., 2016] or semantic and syntactic distractors [Gallego et al., 2016]).

Having highlighted the main findings and limitations of the previous and scarce research on online processing of text in DHH children and adolescents and its relation to text genre and grammatical word class effects, we set out the aims of the present study in the next section.

Study 3

The present study examined comprehension accuracy and patterns of eye movements during reading of short texts in two groups: 1) children and adolescents with DHH; and 2) a TH chronological age-matched control group (TH). Participants' eye movements were monitored while they read short texts. Afterwards, they were asked to answer comprehension questions about what they had read. The effects of text genre (narrative versus expository) and grammatical word class (content versus function) on comprehension accuracy and eye-movement patterns were analysed (total reading time, saccade amplitude, number of fixations [regressive and progressive] and skipping probability).

Hypotheses

1. Global comprehension accuracy ("accuracy" in advance):
    a. We expected that DHH participants would perform, in general, more poorly in the text comprehension task than TH participants (e.g. Barajas et al., 2016).
    b. We also expected higher comprehension accuracy for narrative than for expository text for both groups (Best et al., 2008).
2. Eye-movement' measures:
    a. Based on prior findings, we expected that reading times and number of fixations (regressive and progressive) would be higher and saccade amplitude shorter in the expository text than in the narrative text (Best et al., 2008; Rayner, 1998).
    b. We also expected an interaction between hearing status and text genre such that, although DHH group will be slower overall, differences between groups would be lower in expository text than in narrative text (Kraal et al., 2019). That is,

TH readers would show longer fixation time, shorter saccades and more fixations in expository text to adjust to higher processing demands (Best et al., 2008; Rayner, 1998), while for DHH participants eye-movements patterns would be alike across text genres, as they would not adapt their reading behavior appropriately (Denton et al., 2015).

c. For the grammatical word class effect, we expected for both groups: (i) shorter fixation durations on function words than on content words (e.g., Carpenter & Just, 1983), and (ii) a higher probability of skipping behaviour on function words than on content words (e.g., de Leeuw et al., 2016b).

d. If the KWS preference's hypothesis was right, we would expect that the difference in fixation time between groups were higher in content than in function words because DHH participants would invest longer time in content words according to their preference (see Figure 12 for a graphic representation of this hypothesis).

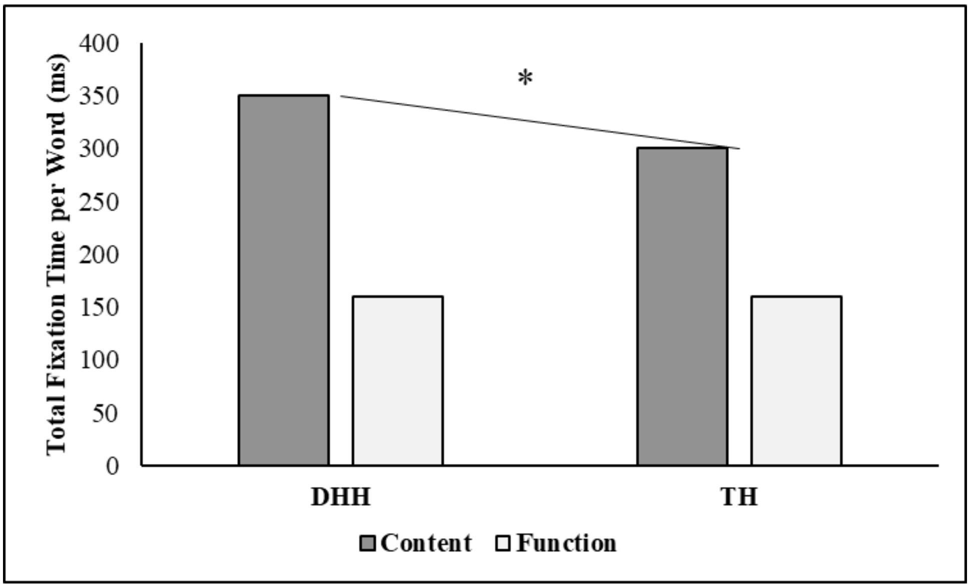

Figure 12. Hypothesis 2d based on the KWS Preference's Postulation.

Note. Fixation times values are not real; they are guessed based on previous research in standards of word fixation time in children.

Method

Participants

Group of Students with Deafness (DHH). The final sample was composed of 19 students (11 girls; mean age 12.4 years, range 9.6- 15.2) with DHH. The type of hearing stimulation and degree of hearing loss of the participants of the DHH group are summarized in the General Methodology section.

Group of students with Typical Hearing (TH). A group of 19 TH students from primary and secondary schools (11 girls; mean age 11.8 years, range 8.8 -14.8) were recruited to take part in the study. As can be seen in Table 12, the distribution by grade level was similar for the DHH and TH participants although it was not a matching criterion.

Table 12. *Means, Standard Deviations (SDs) and Significance Tests for comparisons between DHH and TH Students in Demographic Variables and Background Measures.*

Group	*DHH Group (n=19, 11 girls)*		*TH Group (n=19, 11 girls)*		*Comparisons between groups*			
Background measures	***M (SD)***	***range***	***M (SD)***	***range***	***t***	***U***	***p***	***r***
CA (years; months)	12.4 (1.73)	9.6–15.2	11.8 (1.77)	8.8-14.8	1.00		.322	.17
Non Verbal IQ_ (RS)	32.37 (3.47)	26-37	33.74 (4.95)	26-43	-0.99		.330	.16
Non Verbal IQ (SS)	103.16 (9.38)	87-118	107.84 (10.56)	86-125	-1.45		.157	-.23
Word Reading Accuracy (RS)	39.47 (0.90)	37-40	39.58 (0.61)	38-40		179.00	.958	-.01
Word Reading Accuracy (SS)	106.60 (8.38)	86-115	105.22 (10.93)	76-115		174.00	.849	-.03
Non Word Reading Accuracy (RS)	38.63 (1.61)	34-40	38.37 (1.64)	34-40		160.50	.546	-.10
Non Word Reading Accuracy (SS)	109.40 (9.66)	82-121	107.78 (7.56)	91-121		147.50	.334	-.16
Word Reading Speed (s)	34.11 (7.52)	26-53	28.68 (5.93)	19-41	2.47		.018	.38
Word Reading Speed (SS)	107.09 (10.99)	80 -123	116.69 (6.58)	104-130		82.00	.004	-.47
Non Word Reading Speed (s)	47.74 (8.59)	31-62	50.95 (11.36)	33-75	-.98		.332	-.16
Non Word Reading Speed (SS)	111.47 (10.37)	82-127	112.54 (9.09)	93-127	-.34		.737	-.06
Text Reading Comprehension (SS)	89.47 (17.50)	60-124	104.83 (6.59)	90-115		69.00	.001	-.53
Syntactic Ability Test [a]	43.21 (13.77)	15-59	52.00 (10.42)	29-64		116.50	**.062**	-.30
Expressive Language (RS)[b]	35.84 (8.28)	19-48	43.42 (5.54)	31-50		79.00	.003	-.48
Receptive Vocabulary (RS)	111.37 (25.05)	75-148	139.16 (14.27)	113-162		66.50	.001	-.54
Receptive Vocabulary (SS)	78.00 (20.82)	55-117	106.53 (8.55)	85-116		50.00	<.001	-.62
Reading Span (RS)	2.47 (1.01)	0-4.5	3.03 (0.63)	2-4		116.00	.054	-.31
School level (participants' frequency)								
3º-6º	9		11					
7º-8º	5		5					
9º-10º	5		3					

*Note.*CA= Chronological age; RS=Raw scores (number of correct answers); SS= standard score; s = seconds; *t*= t values; *U* = Man-Whitney *U* test value, *p*= *p* values.
The values from this table differs slightly from the previous ones (Study 1 – Study 2) we consider repeating as two participants (a participant with DHH and the corresponding TH age-matched peer) were removed from this analysis due to an interruption during the experimental task. Both groups differ on the same variables as those reported in Study 2. In contrast to Study 1, groups did not differ in terms of correct responses on the Syntactic Ability Test (*p* value in bold).
[a] Scores from this test are computed in terms of correct answers with respect to the total test (Composed by 64 sentences)[b] Raw scores are also presented for the expressive language sub-test (the maximum score could be 52)

Background and Exclusion Criteria Assessment

Participants in the TH group outperformed participants of the DHH group in word reading speed, text comprehension, expressive language, and vocabulary level but groups were similar for the other background variables (see Table 12 for details).

Target Reading Task

In order to measure global text comprehension, we selected two of the four short texts which made up the reading comprehension subtest of the PROLEC-R Battery (Cuetos et al., 2007). The original subtest consists of four short texts in Spanish, two expository texts (short and long) and two narrative texts (short and long). As this experiment was part of a larger study, we selected the shortest version of each type of text to avoid fatigue effects affecting the results. The expository text contained 75 words (Content words=37 [49.3%]; Function words=38 [50.7%]) while the narrative text contained 94 words (Content words=42 ([44.7%]; Function words=52 [55.3%]). According to the EsPal database (Duchon et al., 2013), there were no significant differences between texts regarding average frequency (U = 3344; z = - .57; p = .567; r = - .81), average number of characters per word (U = 3331; z = -.62; p = .533; r = - .44), average number of syllables per word (U = 3382; z = - .49; p = .625; r = - .35) nor rate of function versus content words that composed each text ($\chi^2(1) = 169) = .60$; p = .439).

To ensure that participants started to read the text from the beginning, a fixation cross located above the left upper corner of the texts preceded each text. The text was automatically presented when the participant fixated the cross for 1 second. After reading each text, participants were asked to answer orally four open questions about them. The order of presentation of the two texts was not counterbalanced in our study, the narrative was always presented before expository text as indicated in the instructions of the original standard test. The maximum score per text was four points, that is, participants could acquire a maximum of

8 points. All of the questions were inferential in nature, that is to say, concerning matters not explicitly described in the text and requiring the reader to draw inferences in order to understand them. In this way, the test attempts to avoid students answering by repeating parts of the text verbatim, without truly understanding the question (Cuetos et al., 2007).

Although these texts were constructed to be appropriate for 1st to 6th graders, we considered the material would be appropriate for our sample given the expected low reading comprehension levels among deaf students.

Procedure

For the experimental task, the procedure was arranged in line with the PROLEC-R manual instructions. Participants were asked to read the two texts silently and indicate orally when they had finished reading. Their eye movements were monitored throughout passage reading but not during question answering. Once they finished each text, the four questions were presented in written form and the participants gave an oral answer to them. Texts were presented centered in black, 28 pt, Courier New font, on a light grey background. The lines were double spaced to prevent overlaps between fixations in the vertical axis.

Results

The results of this section must be treated with caution due to small sample size.

Text Comprehension: Accuracy

As a measure of text comprehension accuracy, we used the percentage of correct answers. As this measure did not follow a normal distribution, non-parametric tests (U-Mann-Whitney test for between group comparisons and Wilcoxon signed-rank test for repeated measurements) were conducted in order to detect significant differences between the DHH and TH group and between types of texts (Narrative- Expository). Means and standard deviations for each group and condition are shown in Table 13.

H1. We expected (a) that DHH participants would perform, in general, more poorly in the text comprehension task than TH participants (Barajas et al., 2016) (b) a general higher comprehension accuracy for narrative than for expository text for both groups (Best et al., 2008).

Confirming H1a, the effect of hearing status was significant (U = 92.00, z = - 2.63, p = .009, r = - .42) with the DHH group obtaining a lower percentage of correct answers (*Mdn* = 62.5) than the TH group (*Mdn* =75). For H1b (see Figure 13), the percentage of correct answers in the narrative text was significantly higher than in the expository text for the TH group, (z = - 2.13, p = .033, r = - .49) but similar for the DHH group (z = - 0.41, p = .685, r = - .09) so this hypothesis was only confirmed for the TH group. On the other hand, when analysing group differences in each type of text, we found that DHH and TH participants differed significantly in the narrative text (U = 89.50, z = - 2.83, p = .007, r = - .46) but not in the expository text (U =140.00; z = - 1.23, p = .246, r = - .20).

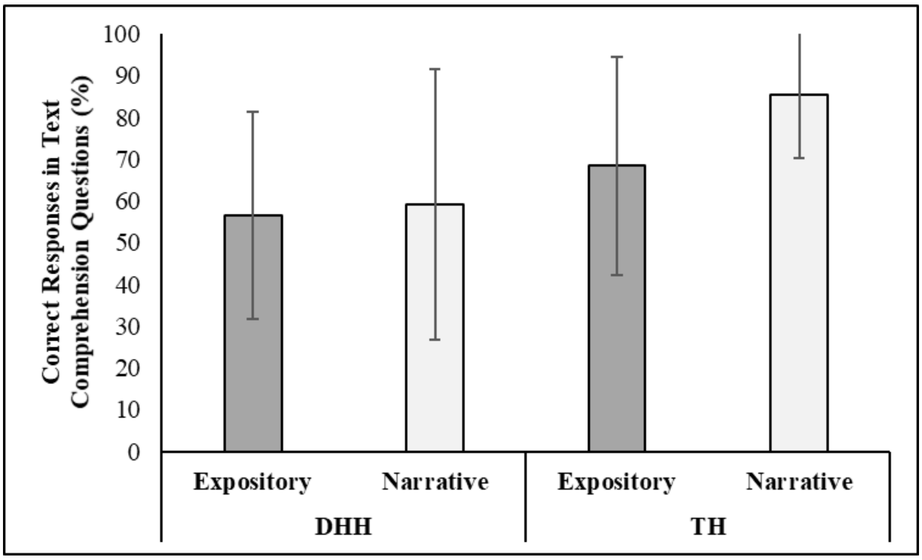

Figure 13. Comprehension Accuracy (Percentage of Correct Answers) for each Text Genre (Expository and Narrative) and Participants' Hearing Status.

Note. Errors bars correspond to standard deviations per group and text genre condition.

Eye movements

Regarding eye-movements, depending on the area of interest, the effect of text genre and grammatical word class were analysed separately or together. When the “whole text” was used as area of interest, only the effect of text genre was analysed. When each individual word of the text was used as area of interest, the effects of text genre and grammatical word class were analysed together.

Eye-movements: Whole text as area of interest

Fixations shorter than 80 ms and longer than 1200 ms were excluded from the data set (following Joseph, Bremmer, Liversedge, & Nation, 2015). For the analysis of text genre effect, the whole text was considered as a single area of interest. Based on previous literature on discourse processing (Rayner, 2009; Rayner et al., 2006), the following measures were considered for this area (already described in the “Introduction” section): dwell time, average fixation duration, number of regressive fixations, number of progressive fixations and saccade amplitude average (expressed in degrees of visual angle and characters).

In order to test for between group or between texts differences, a mixed ANOVA was performed for each eye-movement measure with hearing status (DHH vs. hearing) as a between participants’ factor and type of text (expository vs. narrative) as repeated measure. Bonferroni correction was used for multiple comparisons. As the narrative and expository texts differed in total number of characters (Narrative= 375; Expository= 325), except for saccade amplitude, measures were averaged across number of characters (Folk, & Morris, 2003; Rayner, Carlson & Frazier, 1983). When reading time data were not normally distributed, they were log transformed which corrected for high skewness and kurtosis. However, for ease of interpretation, Table 13 shows untransformed and non-averaged means and standard deviations (*SDs*) on the global text. The descriptive data showed that, on average, the dwell fixation time (sum of the duration of fixations and saccades) was around 34 seconds, that is, around half a minute per text. Participants made around 100 fixations per text, 80% of them were progressive fixations and 20% of them were regressive fixations which shows that reading was mainly linear.

H2a. Based on prior findings we expected that reading times and number of fixations (regressive and progressive) would be higher and saccade amplitude shorter in the expository text than in the narrative text (Best et al., 2008; Rayner, 1998).

As can be seen in Table 13, the effect of text genre was significant for dwell time, average fixation duration, regressive fixations and progressive fixations. On average, participants invested more time and made more fixations in the expository than the narrative texts (see Table 13 for *F* and *p* values), which confirms our predictions particially (H2a). The main effect of text genre was not significant for saccade amplitude so H2a is not confirmed for this measure.

H2b. We expected an interaction between hearing status and text genre such that, although DHH group will be slower overall, differences between groups would be lower in expository text than in narrative text (Kraal et al., 2019). That is, TH readers would slow (longer fixation time, shorter saccades and more fixations) in expository text to adjust to it higher processing demands as good comprehenders do (Best et al., 2008; Rayner, 1998), while for DHH participants eye-movements patterns would be alike across text genres (Denton et al., 2015).

The effect of hearing status was not significant for any eye-movement measure. The interaction between hearing status and text genre was only significant for saccade amplitude. The analysis of simple effects of this interaction showed that the effect of text genre was significantly larger for DHH participants than for TH participants (F (1,36) = 4.71; MSE = .008; p = .037) such that DHH participants showed longer saccade amplitude in the expository than the narrative texts (see Figure 14) which contrasts with H2b that predicted similar eye-movements patterns across text genres for DHH participants. The results could also be interpreted as a crossover interaction because the opposite pattern appeared for TH participants, that is, they showed a slightly longer saccade amplitude (but not statistically significant) in the narrative than in the expository text (that is, a crossover interaction) which is congruent with H2b (shorter saccades to adjust to more difficult texts in TH readers).

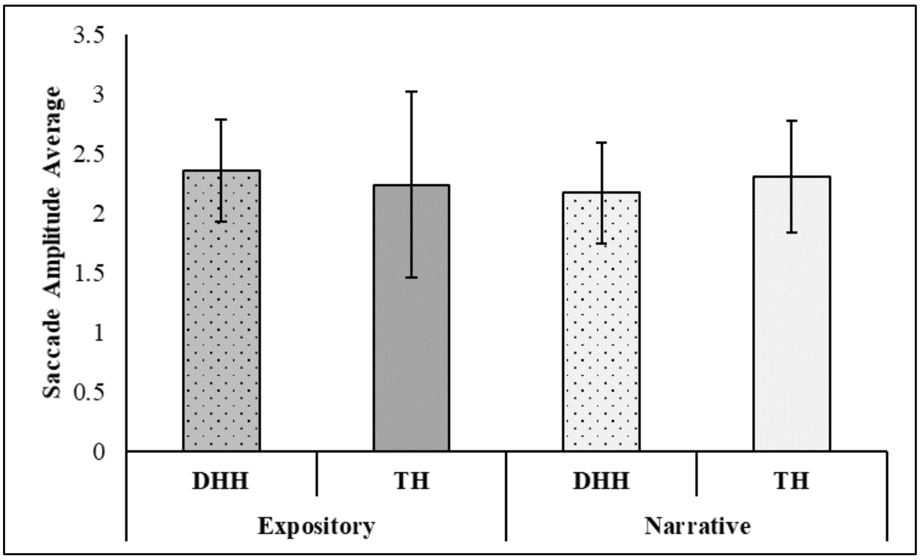

Figure 14. Saccade Amplitude Average per Text Genre and Hearing Status.

Note. Saccade amplitude average expressed in degrees of visual angle.

Table 13. *Descriptive Statistics for each of the Eye-Movement Measures that were Obtained per the Whole Text and Effects of Group, Text Genre and Interactions.*

	N	**Expository**		**Narrative**		**Group**		
		DHH ***M (SD)***	**TH** ***M (SD)***	**DHH** ***M (SD)***	**TH** ***M (SD)***	***U*** [a]		
Percentage of correct answers	19/19	56.58 (24)	68.42 (25)	59.21 (32)	85.53 (15)	92*		
Eye-Movement measure	***N***	**DHH** ***M (SD)***	**TH** ***M (SD)***	**DHH** ***M (SD)***	**TH** ***M (SD)***	**Group** ***F*** [b]	**Genre** ***F***	**Interaction** ***F***
Dwell Time (ms)	19/19	36,083.47 (15,476.57)	32,606.70 (12,559.51)	36,095.82 (16,064.25)	30,542.58 (9,157.86)	0.47	24.25**	0.16
Average Fixation Duration (ms)	19/19	278.57 (3.86)	286.66 (3.83)	271.14 (3.45)	275.16 (3.43)	1.376	9.218**	0.260
Regressive Fixations (n)	18/19	23.47 (12.60)	20.16 (13.31)	21.58 (12.40)	17.84 (9.20)	1.84	6.59*	0.007
Progressive Fixations (n)	19/19	82.37 (28.04)	76.79 (24.64)	92.31 (31.90)	80.11 (19.99)	0.74	4.8*	0.54
Saccade Amplitude Average (Visual angle [characters])	19/19	2.36 (0.43[6.1])	2.24 (0.78[5.85])	2.17 (0.42[5.61])	2.31 (0.47[5.85])	0.02	0.26	4.70*

Note. ** $p < .001$; * $p < .05$.

[a] As this measure did not follow a normal distribution, non-parametric tests were used. Therefore, the value in the *F* column refers to the *U* of the "U-Mann-Whitney test" for between groups

Eye-movements: Words as Area of Interest

Following Domínguez et al. (2016), all words which composed the two texts were classified into content words (substantives, adjectives, verbs, and proper names) or function words (articles, prepositions, adverbs, and connectives). This classification resulted in 90 function words (38 for the expository text and 52 for the narrative text) and 79 content words (37 for the expository text and 42 for the narrative text). Therefore, the analyses of eye movements were performed at the word level with two measures: total fixation time and skipping. We only used one reading time measure to keep the analyses simple. We calculated the total fixation time per word as continuous variable and word skipping as a categorical variable (each word was marked as “1” if it was totally skipped and a “0” if it was fixated at least once).

Regarding total fixation time, we used the lmer program of the lme4 package (Bates et al., 2015) in the R environment (R Core Team, 2019) to perform a linear mixed effects analysis for the time eye-movement measure as dependent variable, and grammatical word class (function vs. content), text genre (narrative vs. expository) and hearing status as fixed factors. As function and content words varied in the number of characters ($M_{\text{CONTENT}} = 6.4$; $M_{\text{FUNCTION}} = 3.2$; $z = 41.58$, $p < .001$), word length was introduced as a continuous fixed factor (covariate) in order to prevent a confounding effect between length and grammatical word class. We used mixed models to account for random variance associated with items (words) and participants. For random effects in the linear mixed models, we had intercepts for participants and items (words), as well as by-item and by-participants random slopes for all fixed effects (see Barr et al., 2013) when they were logical according to the experimental design which resulted in the following syntax:

```
lmer(depvar~group*wordclass*genre+wordlenght+(genre*wordclass|participant) +
(group|item), data = data.
```

Genre and word class were introduced as slopes by participant because they were manipulated within subject so they could affect each participant in a different way. Items (words) appeared exclusively in one type of text and were either function or content words. That is, only the factor group was a within item factor which could affect each one differently, so that it was the only factor included as slope. When the full random structure did not converge, random effects were excluded in the following order until the model converged: random slope by-items, interactions between random slopes by participants, random slopes by-participants one by one, according to how much variance they accounted for. Only converged models are reported (see further details about the fitted models in Appendix). We log transformed reading time data, which resulted in more normal distributions. Effect coding was used to contrast categorical fixed effects (coded in R as follows: DHH=1/TH: -1; Expository = 1/Narrative = -1; Content Words = 1/Funtion Words = - 1). Consequently, the intercept (*b*0) (first raw in Table 14) is the sample mean (285.76) and the regression coefficient of group1 (*b*1) represents the difference between the DHH group (14.38) and the sample mean so that the mean of the DHH group would be 285.76 plus 14.38, that is, 300.14. The regression coefficient of group-1 (*b*-1) is -14.38 so the mean of the TH group would be 285.76 plus -14.38, that is, 271.38. The interpretation logic is similar for the rest of effects showed in Table 14.

Following the standard in the field, effects were considered as significant at the .05 alpha level if the reported (absolute) *t*-values equal to or greater than 1.96 (e.g. Bélanger et al., 2018). Note that in the Results section, we provide *b* and *SE* values in milliseconds (ms) that were computed for fixed effects on raw data to facilitate interpretation (Breadmore & Carroll, 2018 or following Joseph et al., 2015), however, the *t* and *p* values correspond to the effects computed on log-transformed measures. The *b*, *SE*, *t* and *p* values of the fixed effects computed with transformed variables are provided in the Appendix (Table A10).

For the non-continuous dependent variable (word skipping), generalized mixed models were computed with the glmer function ('lme4' R package). Fixed and random structures and model fitting protocol were similar to those of the time variable (including word length as a covariate). Effects for the non-continuous variable was considered as significant when $z \geq 1.96$.

H2. c. (i) For the grammatical word class effect, we expected for both groups: shorter fixation durations on function words than on content words (Carpenter & Just, 1983).

For total time, the main effect of grammatical word class was significant with shorter fixations for function *(M* = 366; *SE* = 24.3) than for content words (*M*= 436; *SE* = 23.6) which supports our prediction (H2c.i) (see Table 14 and 15 for details). The effect of word length was also significant so that the longer the word, the longer they were fixated. The fact that the effect of grammatical word class remained significant after controlling for word length means that there was not a confounding effect between both variables.

Table 14. *Model Parameters for Total Fixation Time at the Word Level*

Fixed effects:	***b***	**Std. Error**	***t* value**	**Pr(>|*t*|)**
(Intercept)	285.76	19.14	208.47	< .001
group1	14.38	15.37	0.69	.496
genre1	22.39	3.08	6.23	< .001
word class1	35.21	5.35	6.57	< .001
word lenght	23.54	2.30	10.35	< .001
group1: genre1	-0.39	2.96	-0.47	.641
group1: word class1	17.85	2.98	5.07	< .001
genre1: word class1	18.09	3.89	4.23	< .001
group1: genre: word class1	-0.50	2.96	-0.34	.731

Note. b and *SE* of total fixation time for untransformed data. T and p values calculated with transformed data. Random structure for fitted model (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (DHH=1/TH: -1; Expository=1/Narrative=-1; Content words=1/Function words=-1).

Table 15. *Means and Standard Errors for Total Fixation Time and Word Skipping (Probability) as a Function of Text Genre, Word Class and Participant's Hearing Status.*

Text genre	**Word class**	**Total fixation time (ms)**				**Word skipping probability**			
		DHH		**TH**		**DHH**		**TH**	
		M	***SE***	***M***	***SE***	***M***	***SE***	***M***	***SE***
Expository	Content	508.12	23.88	445.45	23.74	.15	.23	.12	.24
	Function	366.81	24.81	373.55	24.73	.17	.20	.16	.20
Narrative	Content	428.93	23.39	362.71	23.31	.12	.22	.11	.23
	Function	358.00	23.80	365.16	23.78	.16	.19	.16	.19

Note. In order to facilitate interpretation, for total fixation time we report the untransformed means and standard deviations (SDs) although linear mixed models were computed with transformed time data.

H2. c. (ii) For the grammatical word class effect, we expected for both groups: a higher probability of skipping behaviour on function words than on content words (e.g., de Leeuw et al., 2016b)

Regarding skipping behavior (see Table 16), the main effect of grammatical word class was significant with more skipping rate in function (*M* =.16; *SD* =.19) than in content words (*M* =.12; *SD* =.23) which supports H2c (ii). Again, the effect of word length was also significant so that the shorter the word, the higher was the probability of being skipped.

Table 16. *Model Parameters for Word Skipping at the Word Level.*

Fixed effects:	***b***	**Std. Error**	***z* value**	**Pr(>|*z*|)**
(Intercept)	1.42	0.20	7.16	< .001
group1	0.07	0.11	0.64	.523
genre1	0.05	0.05	0.99	.318
word class1	-0.16	0.08	-2.15	.031
Word length	-0.75	0.04	-17.85	< .001
group1: genre1	0.03	0.04	0.70	.484
group1: word class1	0.04	0.04	0.99	.324
genre: word class1	0.02	0.06	0.33	.739
group1: genre: word class1	0.004	0.04	-0.10	.923

Note. Random structure for fitted model (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (DHH=1/TH: -1; Expository=1/Narrative=-1; Content words=1/Funtion words=-1).

H2. d. Finally, if the KWS preference hypothesis was right, we would expect that the difference in fixation time between groups were higher in content than in function words because DHH participants would invest longer time in content words according to their preference (see Figure 12 for a graphic representation of the expected results according this hypothesis).

The main effect of hearing status was not significant neither for fixation time nor for skipping probability but the interaction between hearing status and grammatical word class was significant for fixation time per word (See Table 14). The analyses of simple effects showed that, both, DHH and TH participants invested more time on content than function words (see Figure 15), in fact, the difference between grammatical word classes was significant for both, TH participants ($\chi^2 = 11.3$; $p < .001$) and DHH participants ($\chi^2 = 66.1$; $p < .001$). In line with H2d, the difference between groups was bigger for content than function words ($\chi^2 = 25.7$; $p < .001$) (see Figure 15). That means that the KWS preference's hypothesis was supported since DHH participants invested more time in content words than TH participants.

The main effect of text genre was analyzed again resulting significant for fixation time. In this case, results showed longer total fixation time on words for the expository text than for the narrative text which was consistent with the effect on dwell time for the whole text area. The interaction between text genre and word class was also reliable for fixation time so that, content words were fixated longer in expository text than in narrative text ($\chi^2 = 57.7$; $p < .001$) but function words were fixated similarly across text genres ($\chi^2 = .23$; $p = 1$). No second order interactions were significant for skipping probability.

Finally, the third order interaction Group x Grammatical Word class x Genre was not significant neither for fixation time nor for skipping probability.

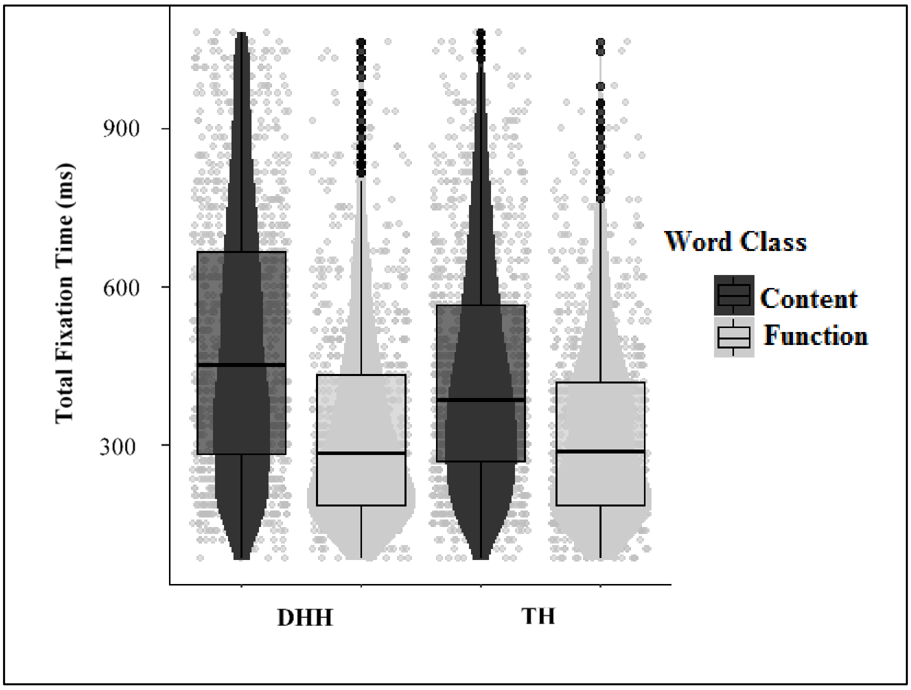

Figure 15. Effect of Word Class on total fixation time for DHH and TH participants

Additional Analyses

Additional exploratory analyses were conducted in order to analyse the association between background variables (mainly language related), on the one hand, and accuracy and word fixation time during text comprehension, on the other, for both TH and DHH participants.

Associations between Language Related Factors and Comprehension Accuracy. For each text genre condition (narrative and expository) and hearing status group, we conducted a set of correlation analyses between the percentage of correct answers, on the one hand, and word and non-word reading speed (raw score in ms so that the more ms, the less speed), written syntax (raw score), receptive vocabulary (raw score) and expressive language skill (raw score) and reading span (raw score), on the other. As the range of chronological age (months) was large, this variable was also included in the correlation analyses. Because some of the individual factors did not follow normal distributions or were ordinal variables, we performed spearman correlations.

As can be seen in Table 17, for the DHH participants, vocabulary, written syntax, expressive language and reading span correlated positive and significantly with comprehension accuracy in the expository text condition. So that, the higher the vocabulary, the written syntax, the expressive language skills, and the reading span, the higher the comprehension accuracy.

For TH participants, there were no significant correlations between individual factors and comprehension accuracy in any text genre condition.

With regard to the narrative text condition there were no significant correlations neither for DHH students nor for TH students.

Table 17. *Spearman's rho Correlations between Individual Variables and Accuracy and Fixation Time per Character by Group.*

	Accuracy				**Fixation Time (ms/cha)**			
	Expository text		**Narrative text**		**Content Words'**		**Function Words'**	
	DHH	**TH**	**DHH**	**TH**	**DHH**	**TH**	**DHH**	**TH**
Chronological Age (Months)	.36	.10	.17	-.23	-.05	-.12	-.16	-.19
Word reading speed (s)	-.40	.01	-.03	.18	.33	.39	.41	.36
Nonword reading speed (s)	-.25	.17	.09	-.01	**.66****	**.55***	**.69****	**.48***
Receptive Vocabulary (RS)	**.63****	.33	.15	.06	**-.63****	-.08	**-.48***	-.04
Written syntax (RS)	**.71****	.14	.09	-.31	**-.55***	-.21	**-.51***	-.37
Expressive Language (RS)	**.66****	.07	-.07	-.14	-.29	-.05	-.25	-.21
Reading Span (RS)	**.55***	-.20	.17	.26	**-.50***	-.19	**-.49***	-.16

Note. *$p < 0.05$, **$p < 0.01$. ms= milliseconds; cha= character; s= seconds; RS= Raw Score

Associations between language related factors and Word Fixation Time. For each group of hearing status and word class (function vs. content), we conducted a set of correlation analyses between the total fixation time (averaged by character), on the one hand, and the same set of individual factors than in the case of comprehension accuracy. We only used total fixation time at the word level because it was the only of the analysed eye-movement measures that showed interaction with hearing status. In order to control for word length in this correlation analysis, we averaged total fixation time by the number of characters of each word and their fixation was again averaged per word class.

As Table 17 shows, for the DHH group, vocabulary, written syntax and reading span were strongly correlated with total fixation time for both content and function words so that, the higher the non-word reading speed (note that the rho value is positive because this variable is inverted, that is, the higher the reading time, the lower the speed), the vocabulary, written grammar skills and reading span, the lower the fixation time on content and function words. Although the correlation between vocabulary and fixation time was higher for content than for function words, the difference was not significant (z = - .62; p = .540).

For the TH group, only non-word reading speed correlated significantly with fixation time in both word class conditions. The difference between the correlation coefficients for DHH and TH was not significant neither for the content words (z = .49; p = .630) nor for the function words (z = .95; p = .340).

As results of this study are complex and extensive, we summarize the main findings as follows:

- Overall, participants with DHH performed more poorly on text comprehension than participants with TH. TH outperformed DHH in the narrative text (but not in the expository one)
- Participants with TH obtained higher comprehension scores in the narrative than in the expository text, whereas participants with DHH performed similarly in both texts.
- The global reading pattern was similar for both groups (both invested around half a minute to read each text and for both reading was mainly linear [progressive fixations predominated over regressive fixations]).
- Participants from both groups invested more time and produced more fixations in the expository text than in the narrative one.

- Participants with DHH demonstrated longer saccade amplitude in the expository than in the narrative text. By contrast, TH participants' saccade amplitude was slightly larger for narrative than for expository texts (although this latter difference was not statistically significant).
- Content words received longer fixations and were fewer skipped than function words in both groups (TH and DHH). However, the difference between participants was bigger for content than for function words with DHH participants investing longer time in content words than TH participants, which resulted coherent with the KWS preference's hypothesis.
- Several linguistic measures correlated with comprehension accuracy of the expository texts, only in the group of DHH readers.

Discussion and Conclusions

In order to gain a better understanding of reading proficiency in DHH children and adolescents in whole texts, the present study aimed to explore the effect of text genre (narrative vs. expository) and grammatical word class (function vs. content) on the accuracy and eye-movement' patterns of DHH and TH students as they read texts for comprehension.

Regarding comprehension accuracy, we expected that DHH participants would show poorer performance than TH participants (H1a) and that both groups would obtain higher comprehension accuracy in narrative than in expository texts (H1b). Our results only confirmed partially these predictions as comprehension accuracy differed for TH participants, who obtained a lower percentage of correct answers in the expository text condition than in the narrative one (Best et al., 2008), but remained similar across text genres for DHH participants. There was a significant difference in performance between groups only for the narrative texts (TH performed better). This interaction between hearing status and text genre does not seem to be consistent with the recent findings of Figueroa et al. (2020) who showed that adolescents with TH outperformed adolescents with deafness and CIs not only in expository but also in narrative texts. Between-study differences in participants' age range could explain such a discrepancy, since we included children and adolescents while Figueroa et al. (2020) only included adolescents However, this explanation does not seem to be supported by our additional exploratory analyses which showed that chronological age was not correlated with accuracy across text genre conditions for any group. Consequently, and in contrast with our accuracy predictions, our results seem to be more consistent with the findings of Kraal et al. (2019), who observed that low comprehending participants (as our DHH participants were) differed less in answering comprehension questions (specifically the knowledge-based ones) from high-comprehending participants in expository texts than in narrative texts. Differences in material could also explain this difference between our study and Figueroa et al's., as while they used texts that were appropriate for students' chronological age, we selected materials that were originally addressed to younger readers.

Regarding eye-movements measures, and, before discussing the results regarding our predictions, it is important to highlight some important global measures' results that seem to converge with previous research in children and adult readers with TH. The descriptive data showed that, on average, the dwell fixation time (sum of the duration of fixations and saccades) was around 34 seconds, that is, around half a minute per text. Participants made around 100 fixations per text, 80% of them were progressive fixations and 20% of them were regressive fixations which shows that reading was mainly linear. These proportions were similar to those seen in previous studies (e.g., Joseph et al., 2009; Kraal et al., 2019). The average fixation duration per word was 280 ms, and the average saccade amplitude, around six letters (in line with previous literature; e.g., Blythe & Joseph, 2011 [for a review]; Blythe et al., 2009; Rayner, 2009; Rayner et al., 2006).

In relation to our particular hypothesis about the effect of text genre on the eye-movement patterns in our two groups, we expected that reading time (global text dwell and average fixation duration), and number of fixations (regressive and progressive) would be higher and saccade amplitude would be smaller in the expository text than in the narrative text (H2a). Confirming partially this prediction, both DHH and TH participants showed longer dwell times, average fixation times and made more fixations in the expository text than in the narrative text. However, for saccade amplitudes, we found an interaction between hearing status and text genre that was against our predictions (H2a and H2b). Indeed, H2b predicted an interaction between hearing status and text genre such that differences between groups would be lower in expository text than in narrative text (Kraal et al., 2019) as TH readers were expected to slow down in expository texts to adjust to their higher processing demands (Best et al., 2008; Denton et al., 2015), while for DHH participants both expository and narrative texts would be equally demanding. Instead, we found that DHH participants showed longer saccade amplitude in the expository than in the narrative texts in comparison with TH participants, who showed the opposite pattern (longer saccade amplitude in the narrative than in the expository) although the difference across text genres was smaller than for DHH.The longer saccade amplitude in expository texts could be interpreted as evidence that DHH readers adopt a more careless reading strategy because they did not detect the difficulty of the expository text, so it could be an index of lack of reading monitoring strategies (see Kraal et al., 2019). Actually, this result is somewhat consistent with the results of Banner and Wang (2011) who found that deaf adults were able to report the usage of more reading strategies in narrative than in expository texts which means that they seemed to self-regulate better in the easiest and more familiar narrative text structure. Also, this result seems to agree with Kraal et al. (2019) who found that students with poor comprehension made smaller saccades in the narrative texts than GC students (suggesting a more careful or effortful processing) and increased saccade amplitude in the expository text in comparison to the narrative one. We did not use this result of Kraal et al. (2019) to make our predictions because as they admit it (and we informed in the Introduction section of **Study 3**), this effect was not statistically reliable. It is also possible that being DHH's reading difficulties associated with poor linguistic (vocabulary) knowledge they may have not known the meaning of many words in the expository text and being the task too difficulty they did not try to adapt their reading according to the text demands.

A final remark about saccade length, and in particular, forward saccade length is that it would also serve as a useful measure of how much information is included within one fixation as it is related to the extrafoveal distribution of visual attention (Rayner, 1998). So that, longer saccade lengths would mean that readers are extracting more information per fixation or in other words, that they have a higher perceptual span. If we accepted this premise, it would mean that our DHH participants are extracting more information from the expository texts than from the narrative. However, their comprehension scores in the expository text are similar to those in the narrative text so this "enhanced" perceptual span is not improving global comprehension.

Another interesting finding is that in our study, the average saccade amplitude was around six letters which is in line with some previous literature in regular readers (e.g., Blythe & Joseph, 2011 [for a review]; Blythe et al., 2009; Rayner, 2009; Rayner et al., 2006) but differ from the enhanced perceptual span found by Bélanger et al., 2018) in participants with DHH (10 characters to the right of fixation). Of course there are many methodological differences between our study and the one of Bélanger et al. that should be taken into account to interpret correctly this lack of consistency but a hypothesis is that, as most of Bélanger et al. participants with DHH were experienced users of sign language (while our participants with DHH were mostly users of oral language), their perceptual span was enhanced due to the experience with a visuo-spatial language such as sign language.

With regard to the effect of grammatical word class in eye-movement measures, we found that, for both groups, function words were more frequently skipped and fixated shorter than content words. We consider that our results regarding skipping behaviour confirm our prediction about grammatical word class (H2c [ii]) and previous findings in TH children (de Leeuw et al., 2016b).

Regarding group comparisons, prediction H2d stated that DHH participants would fixate content words longer than TH participants as an indication of the KWS preference's hypothesis and previous empirical results with a self-paced reading task (Coulter and Goodluck, 2015). In line with H2d, the two groups differed in total fixation time in content words which was interpreted as a support to the Key word strategy (KWS) although not in the original form that this hypothesis was formulated: "the key word strategy (KWS), … consists of identifying some frequent content words and ignoring function words" (Domínguez et al., 2016, p.439). In particular, our results of **Study 3** would support a bigger preference for content words in participants with DHH than in readers with TH but not an absence of attention to function words (also supported by results of **Study 1** and **2**). In fact, **Study 1** and **Study 2** showed that DHH readers are not ignoring grammatical cues signaled by function words as part of their grammatical analysis of sentences but perhaps only misusing them.

Additional exploratory analyses revealed that receptive vocabulary, grammatical knowledge and reading span might contribute differentially to DHH and TH students' comprehension and eye movement patterns when reading narrative and expository texts. In particular, for DHH participants the higher their vocabulary, written syntax, expressive language skills and the reading span, the higher the comprehension accuracy of the expository (but not narrative) texts. For TH participants, there were no significant correlations between individual factors and comprehension accuracy in any text genre condition. These results might suggest that those DHH with higher oral and written language skills invested more time/resources on the expository text and this could be due to the fact that they found the expository text more difficult than the narrative one. That is, they were trying to regulate their comprehension although maybe they lack the skills needed. In particular, the results regarding vocabulary and written syntax seem consistent with previous studies which identified different contributions of these factors in DHH and TH readers (Barajas et al., 2016; Harris et al., 2017; Herman et al., 2019; Moreno-Pérez et al., 2015).

With regard to eye-movement measures, we found that the same set of individual variables of DHH readers correlated significantly with fixation times on both content and function words. In particular, the higher the non-word reading speed, vocabulary, written grammar skills and reading span, the lower their fixation times on content and function words. In contrast, for the TH group, only non-word reading speed correlated significantly with fixation time in both word class conditions.

It is important to highlight that DHH participants presented significantly lower scores than TH participants in all these individual factors (except non-word reading speed). In addition, the small sample size and the fact that TH participants showed lower variability in those factors may explain the lack of correlations in this group. Nevertheless, decoding seems to be the factor most strongly related to word fixation time, but in order to verify which variable would be more important for each text genre and word class, a regression analysis is needed. Unfortunately, we do not have sufficient sample size to perform valid multiple regression analyses, but these preliminary results might serve to guide the formulation of future hypotheses to be tested with more refined regression analyses.

In addition, we cautiously interpret the results of our correlation analyses as consistent with the study of de Leeuw et al. (2016b) who found that in children from Grade 3 and 5 decoding skills predicted word gaze duration during text comprehension (the higher the decoding skills, the shorter the gaze durations). However, for working memory (similar to our measure of reading span) they found a differential effect among grades, so that working memory was positively associated with gaze duration in Grade 3 but negatively related in Grade 5. We did not find an effect of chronological age (which coincides with education level in our study) regarding reading span, but an effect of hearing status such that the significant correlation between reading span and fixation time (the higher the reading span, the lower the total word fixation time) appeared in the DHH group but not in the TH group. The absence of significant correlation in the TH group might be due to the low variability of this group on the reading span measure. In addition, our results would also agree with the main findings of the longitudinal study of Harris et al. (2017) who found that vocabulary was more closely related to reading comprehension for DHH children than to TH children of similar age.

Finally, it is necessary to remark that our study presented some methodological limitations, some of them already noted, that might compromise the generalization of our results and should be considered in future research. As in the previous studies (**Study 1** and **Study 2**) we will only mention those limitations that are specifically related to this study, those limitations that appear common to the whole **Thesis** will be developed in the next chapter (General Discussion and Conclusions). With regard to the present study, the order of presentation of the two texts was not counterbalanced in our study (narrative was always presented before expository text). A possible consequence of this fixed order is that the text genre effects on comprehension accuracy and eye-movement' patterns might be the result of fatigue or familiarity with the procedure as Kraal et al. (2019) highlighted for their own research where a fixed text genre order was used too. However, the advantage of the fixed order was to be consistent with the procedure recommended by the original standardized test from which the texts were extracted (PROLEC-R reading battery, Cuetos et al., 2007). Moreover, fixed order is also recommended with small sample size, as counterbalancing order effects add another manipulation/variable to the study. In addition, as the narrative text was actually expected to be easier than the expository text, we expected this might motivate readers to keep engaged in the task. The other limitation we would like to mention is that there was just one text by genre condition so the effects could be due to particularities of the texts used and not to the genre itself. Future research should include a higher number of texts per condition.

In terms of implications, we can suggest educators be aware that the similar levels of performance obtained by DHH students in comparison to TH students with the easiest type of text (narrative) does not necessarily mean DHH students have completely acquired the competency to deal with them. In fact, they might be investing more resources than TH students to obtain the same level of comprehension.

In addition, as DHH students seem to invest more resources in both, function and content words, more attention needs to be devoted to increasing both their grammar and lexical competencies (in particular vocabulary breadth and depth) by primary and secondary teachers, especially if they have to cope with expository texts where the mobilization of online reading strategies (e.g. less skipping behaviour, longer fixations and more regressions) seem to be critical.

“Take Home Messages” from Study 3

- Students with DHH differ from students with TH in terms of comprehension accuracy and eye-movements at the text level.
- Students with DHH do not benefit from the “text genre advantage”. That is, narrative texts do not seem to be easier for them to comprehend than expository texts.
- However, whereas students with DHH seem to adjust their reading to the demands of the narrative texts, they do not appear to regulate their reading in the expository texts as TH readers do.
- Function words receive shorter fixations and are more frequently skipped than content words either by students with DHH or students with TH.
- Both groups invest similar fixation time on function words. With regard to content words, students with DHH invest longer fixation time than students with TH.

Chapter 3

General Discussion and Conclusions

- Summary of Results
- General Discussion and Conclusions
- Limitations and Future Research
- Practical Implications

In this final chapter, we will first summarize the main results from the three studies. Then, we shall integrate them in a conjoined discussion. Finally, we shall expose the limitations, future research lines and practical implications drawn upon this work. Conclusions are reported at the end of this section.

3 | 1 Summary of Results

This **Thesis** focused on describing the online reading pattern of students with DHH and the factors that affected it. Previous studies have widely reported and described the difficulties that students with DHH demonstrate during reading. Despite authors' efforts to address this issue there are still some questions in which results do not coverge (e.g., Do students with DHH ignore grammatical cues during sentence reading? [Domínguez et al., 2016; Gallego et al., 2016]) or that have been barely explored (e.g., Do previous claims [preference for top-down processing or the Key Word Strategy] extend to text reading? Do students with DHH adapt their reading according to text demands?). Therefore, these questions remain open to new procedures that can disentangle or at least contribute to the understanding of DHH students' reading problems. So far, most of the studies has approached to this issue by measuring students' performance (accuracy) on several linguistic or reading-related tasks. Our general goal, is to fill in this gap in the literature by exploring DHH students' reading problems with a focus on the reading process and to reveal qualitative patterns in reading that are typical for DHH and atypical when compared to TH students. With that aim, twenty students with prelingual deafness and a chronological age-matched control group participated in a series of experimental tasks in which their written grammatical comprehension abilities at the single sentence level (**Study 1** and **Study 2**) and their general reading comprehension skills at the text level (**Study 3**) were assessed. In the meanwhile, students' reading process was monitored with eye movements.

Additionally, offline measurements assessing background linguistic, cognitive, and reading skills were collected with the aim of better describing the sample and relating the online results and exploring the links between individual variables and eye-movement measurements of reading. The use of a combination of online (eye movements) and offline measures (accuracy on tasks and background measurements) to explore the reading pattern in a non-adult population (children and adolescents) with DHH constitutes one of the novelties provided by this work. As systematically noted alongside this **Thesis** (see for example, General Introduction and **Study 3**), studies exploring the reading comprehension skills with online measurements (eye movements in this case) in young population with DHH are very scarce, in fact, even studies on eye-tracking with non-adult TH population were quite unfrequent 5 years ago (Schroeder, Hyönä, & Liversedge, 2015).

Due to this paucity of previous research, it was challenging to draw specific hypotheses from studies conducted with online measurements and much of our predictions were based on theoretical models and previous studies conducted with offline or behavioral data (e.g., **Study 2**). Anyhow, the empirical set presented here was confirmatory in nature, that is, we tried to test specific hypotheses about the relationship between eye-movements measures and reading in DHH and TH students derived from theory or previous empirical research. Theoretically, our predictions were generally grounded on the "top-down preference" hypothesis of Miller (2000), re-visited later by Domínguez and Alegría (2010) in what they called "Key Word Strategy" preference's hypothesis. This hypothesis basically states that DHH individuals present a syntactic skill deficit that they compensated by ignoring grammatical cues such as function words and showing a preference for a top-down processing of content words during sentence or text comprehension. This top-down strategy would drive them to commit meaning interpretation errors when grammar cues are essential to make sense of the passages or when lexical or previous topic knowledge is incomplete. Regarding individual differences, the approach was exploratory though, because sufficient knowledge of (i.e., prior research on) DHH online reading processes is lacking, therefore, we just uncover possible relationships between variables and generate hypothesis for future research.

The central findings from this **Thesis** appear summarized in Table 18.

In **Study 1**, we aimed to investigate the time-course of grammatical processing during sentence reading of DHH children and adolescents.

As predicted, students with DHH were less accurate than students with TH when detecting the incongruences in the sentences. Differently from what one would expect, eye-movement analyses showed that students with DHH were sensitive to grammatical incongruences. In addition, like TH they realized about the inconsistencies very soon.

Regarding differences between-groups, DHH made more and shorter fixations than their TH peers in the target area (where the manipulation was made). As opposed to previous evidence (Breadmore et al., 2014), TH students also showed delayed effects in the detection of the incongruences at the post-target area. Finally, written syntactic skills were systematically related to the time-course processing throughout the experiment. We consider syntax limitations could potentially explain the differences in the time course processing of sentences between groups.

In **Study 2**, the goal was to explore the processing of syntactic and semantic cues during sentence reading.

As expected, students with DHH showed lower grammatical comprehension skills than students with TH for all sentence types (passive, object relatives and focalized complement sentences) except for the active ones. Accuracy results suggest that students with DHH did not ignore syntactic cues, as they selected the target (correct alternative) in a higher proportion than the syntactic distractor (which included same elements with thematic roles exchanged), however, they missused syntax as when commiting errors they selected the syntactic distractor in more occasions than students with TH.

Eye movements supported accuracy results, as in correct answered trials, both DHH and TH participants fixated longer and made more fixations in the target than in the syntactic distractor and in the later than in the lexical distractor. Students with DHH only differed from students with TH in the lexical distractor (where students with DHH invested more time and more fixations than TH readers). In errors, both groups invested more time and made more fixations in the syntactic distractor than in the lexical one. Finally, only in the group of TH students, chronological age was negatively correlated with the number and duration of fixations in both distractors.

Finally, **Study 3** aimed to examine the eye-movement pattern of students with deafness at the whole text level.

As predicted, students with DHH showed lower reading comprehension skills than chronological-age matched TH students. However, once genre of text was considered, differences between-groups were limited to the narrative text, contradicting previous findings (see Figueroa et al., 2020). As expected, (e.g., Best et al., 2008) students with TH obtained better comprehension scores in the narrative than expository text, however, participants with DHH performed similarly in both text genres. The global reading pattern of both groups (i.e., dwell fixation time, proportion of progressive and regressive fixations, average fixation duration and saccade amplitude) was quite similar and reflected results very much alike to those already found by previous studies involving typically hearing students. Moreover, for both groups the reading pattern was mainly linear.

With regard to text genre, either students with TH or students with DHH spent more time and made more fixations in the expository text than in the narrative one. DHH students, showed larger saccade amplitude in the expository than in the narrative text. However, the opposite happened for students with TH (the amplitude of the saccade was slightly larger for narrative text than for the expository one).

With respect to grammatical word class, participants from both groups invested more time fixating content than function words. An interesting finding was that the difference between groups was significant only in the case of content words with DHH students fixating longer content words than TH students. Finally, regarding word skipping, as predicted, function words were more frequently skipped than content words, this was true for both groups, with no differences between students with DHH and TH readers.

Table 18. *Main Results from the Empirical Research Set: Similarities and Differences between Hearing Status Groups (DHH and TH students) and both Offline and Online (Eye-movements' Measures) of Reading Comprehension.*

Similarities	Differences
Background measures	
Non-verbal IQ Non-Word Reading Speed Word Decoding (word and non-word accuracy) Written Syntax (Study 2 and Study 3) Reading Span (Study 3)	Receptive Vocabulary (lower for DHH) Reading Comprehension (lower for DHH) Word reading speed (DHH are slower than TH) Written Syntax (Study 1); (lower for DHH) Expressive Language (lower for DHH) Reading Span (lower for DHH, Study 2)
Study 1	
Participants of both groups were sensitive to grammatical incongruences (more time and more fixations at the target in incongruent than congruent sentences).	DHH were less accurate TH students when detecting the incongruences in the sentences.
Participants of both groups showed inversed delayed effects, investing more time in congruent than incongruent sentence at the post-target region.	DHH made more and shorter fixations than their TH peers in the area were the manipulation was made (target).
Study 2	
Similar accuracy scores in active sentences.	TH outperformed DHH students in more complex sentences: passive, object relatives and focalized complement sentences.
In correct answered trials, they fixated longer and made more fixations in the target than in the syntactic distractor and in the later than in the lexical distractor.	In correct trials, students with DHH made longer and more fixations in the lexical distractor than students with TH.
In errors, they selected more and made more and longer fixations in the syntactic distractor than in the lexical one	In errors, students with DHH chose the syntactic distractor in a higher percentage than students with TH although both groups were more confused by this distractor and not by the lexical one.
	Only in the group of TH students, chronological age was negatively correlated with the number and duration of fixations in both distractors.
Study 3	
Similar percentage of correct asnwers in the expository text	TH outperformed DHH in the narrative text
Global reading patern of texts: the dwell fixation time (around half a minute per text), progressive (80%) and regressive fixations (20%). More time and more fixations in the expository text than in the narrative one	For DHH the amplitude of the saccade was larger in the expository than in the narrative text. For TH, it happened the opposite (longer saccade amplitudes for the narrative text than the expository one)
Function words were more frequently skipped than content words. Function words were fixated shorter than content words.	Students with DHH fixated longer content words than students with TH but there were no group differences for function words. For DHH readers, vocabulary, written syntax, expressive language skills and the reading span positively correlated with comprehension accuracy of the expository text and negatively with the time of fixation in content and function words (except expressive language). Only non-word reading speed correlated with fixation time in content and function words for TH readers (it also did for readers with DHH).

3 | 2 General Discussion and Conclusions

The well-documented gap shown between DHH and TH children and adolescents in reading comprehension performance (Geers et al., 2008; Harris & Terlektsi, 2011; Traxler, 2000) may be attenuating recently thanks to early educative and medical interventions (e.g. Figueroa et al., 2020) and refined assessment instruments (Easterbrooks & Beal-Alvarez, 2012). Our results do not point to this trend, instead they suggested that either when assessing students at the sentence level (**Study 1** and **Study 2**) or when examining their performance at the whole text level (**Study 3**), students with DHH still differed from TH students of the same chronological age. However, this conclusion may not hold for many students because as we have reflected throughout the discussions of each study (**Study 1**, **2** and **3**), the range of scores in this group was large, and whereas some participants succeeded in the tasks other obtained results far below the mean (**Study 1** [Table 5], **Study 2** [Figure 9], and **Study 3** [Figure 13]). Therefore, we can conclude that our studies replicate both the low reading comprehension achievement and the high intra-group variance already reported by previous studies (Harris et al., 2017; Mathews & O'Donnell, 2020; Mayer & Trezek, 2018).

3|2.1 Which aspects characterize the online reading pattern of students with deafness?

Students with DHH and students with TH showed a similar pattern of online processing at the sentence level. For example, both groups were more disturbed by grammatical than lexical distractors (**Study 2**) and both detected grammatical inconsistencies early in their reading and at the same time (**Study 1**), proving to be sensitive to grammatical cues (Breadmore et al., 2014; Piñar et al., 2017). Although scarce, between-group differences should also be mentioned. In this regard, the reading pattern of students with DHH was characterized by the presence of more, but shorter, fixations in comparison to students with TH (**Study 1**).

At the text level (**Study 3**), most of the eye-movement related values were similar to those reported in previous studies with typical hearing readers (e.g., saccade amplitude [Bélanger et al., 2018]; average fixation duration [Blythe et al., 2009]; percentage of regressive and progressive fixations [Joseph et al., 2009; Kraal et al., 2019]). They also showed a similar processing between grammatical word classes, investing more time on content than on function words.

The presence of such differences in reading comprehension accuracy together with the absence of clear differences in the online reading pattern of students with DHH lead us to question whether students with DHH were actually regulating or not their own reading process.

Several results suggested that participants with DHH were trying to regulate their reading according to the demands of the task. First, in **Study 3**, both groups invested more time and more fixations in the expository text than in the narrative one, suggesting that they both invested more resources when processing the expository (apparently more difficult at least for TH readers [as accuracy scores suggest]) than the narrative text. This statement, however, does not stand for saccade amplitude. In this last case, students with DHH responded differently than students with TH. For students with DHH, the amplitude of the saccade was larger in the expository than in the narrative text. By contrast, students with TH showed slightly longer saccade amplitudes for the narrative than the expository text. A potential interpretation of this result is that DHH students are not being able to monitor their behavior completely to adapt to the difficulty of the expository text as TH students do. That is, longer saccade length could be interpreted as evidence that DHH readers adopt a more careless reading strategy because they did not detect the difficulty of the expository text, so it could be an index of lack of reading monitoring strategies. This lack of monitoring behaviour could be caused indirectly by the lack of syntactic awarenss of DHH readers that may interfer with their ability to assess whether they understand what they are reading (See discussion in Cain, 2010, Chapter 5).

3|2.2 Do students with deafness follow a semantic-based strategy when constructing sentence/text meaning?

The *top-down preference hypothesis* (Miller, 2000) or *structural knowledge deficit hypothesis* (Miller et al., 2012) and the *Key Word Strategy* (e.g., Domínguez et al., 2016) constitute the starting point of this question. It is important to recall what both proposals suggest.

According to Miller et al. (2012), the structural knowledge deficit hypothesis associates the sentence reading comprehension failure "with insufficiently developed syntactic knowledge and, consequently, a tendency to ignore structural information (particularly word order) as a vital source for elaborating the final meaning of a sentence" (Miller et al., 2012; p. 441). In the same vein, Domínguez and colleagues state the following: "Previous studies have shown that deaf persons read sentences using the key word strategy (KWS), which consists of identifying some frequent content words and ignoring function words." (Domínguez et al., 2016, p.439).

Both hypotheses converge at some point by assuming that students with deafness overlook or ignore grammatical cues during sentence reading. Our results do not seem to support these hypotheses; or better to say, they do not sustain them in the way that they have been described above by the authors. The fact that DHH students slowed down when sentences contained a grammatical inconsistency in **Study 1** or chose the target option in a higher proportion than the syntactic distractor in **Study 2** corroborate that they were sensitive to grammatical cues during sentence reading, as also did other studies (Breadmore et al., 2014; Gallego et al., 2016; Piñar et al., 2017). We can also confirm this at text level, where DHH students invested the same total fixation time and skipped the same percentage of function words than TH participants (**Study 3**). However, the fact that they invested more time on content words compared to TH students leaves the door open to different interpretations (See discussion **Study 3** for a detailed description on the topic). One of the possibilities is that differences in lexical access accounted for this variation in the reading pattern. Indeed, this is compatible with the result that we observed in **Study 1**, where students with DHH made more, but shorter, fixations in the manipulated area (target). At the same time, our results could be in accordance with the “bottle-neck effect” suggested by Kelly (1996), who considered that grammatical difficulties could hinder the reading process in such a way that they could “block” it, preventing the reader to access to the lexical dimension (meaning) of the written material. However, as already discussed (See **Study 1**), the access to meaning would not be blocked, but would be flawed, being more appropriate to define the effect as a chain of events or as we already noted a “cascade effect/hyphotesis”.

We therefore suggest that students with DHH do not ignore but that they do not process grammatical cues properly or at least in the way that their grammatical skills require. This was indeed suggested by Miller et al. (2012):

> semantic readers did not wrongly answer all semantically implausible sentences (2.43 [standard deviation 1.13] correct answers out of 8). This raises the possibility that—rather than skipping syntactic processing entirely—they may have relied on a limited set of simplistic syntactic rules (e.g., choosing the noun nearest the verb as the verb’s subject) that failed to produce proper sentence comprehension most of the time (p.455)

It may also be the case that those lower results were a reflection of the insecurety that produces to students with deafness to derive the meaning from a set of cues that they fail to dominate. This was indeed anticipated in the discussion of **Study 1** and **Study 2**. As students are not profient with grammatical cues, they rely on the information they know better, that is, their prior knowledge and content words (as the longer time spent on content words in comparison with TH participants in **Study 3** seems to corroborate). This may be one of the reasons why they fail to comprehend the text/sentences when the role of grammatical skills is vital for get to the meaning (i.e., semantically implausible sentences [Miller, 2000] or reversible complex sentences [**Study 2**]).

Overall, our results would call for a redifinition of the Key Word Strategy in such a way that emphasizes that grammatical cues may not be ignored but rather that students with DHH may missuse of them.

3 | 3 Limitations and Future Research

Future research should examine the online reading pattern at a higher level (long texts), this would allow to identify different reading profiles or strategies in a more ecological context (See for example Hyönä, Lorch, & Kaakinen, 2002; also see Hyönä & Nurminen, 2006). However, to do so a larger sample would be needed. It would be also interesting to conduct studies including individuals with DHH who attend to university courses, as the reading achievement of Spanish students in these levels of education have been barely explored (see as exceptions Domínguez, Carrillo, Pérez, & Alegría, 2014; Villalba, Ferrer, & Asensi, 1999), and up to our knowledge in Spain no study has yet examined their reading process with online measurements.

Regarding study limitations, there are three that stand out. We will develop them as follows.

3|3.1 The sample size

Students with DHH

Twenty students with DHH (nineteen for **Study 3**) was the largest number of participants with homogeneous characteristics in terms of degree of hearing loss, moment of acquisition, communication mode, age range and non-verbal IQ who were available in our educational context. Overall, participants' availability (school exams, homework, etc) and the presence of comorbidities were some of the main factors that hindered the recruitment process. In some cases, it was students' willingness to take part in the investigation what impede their inclusion in the studies. This latter point is somewhat understandable considering that many students with DHH struggle with reading, and in our research we were exactly asking them to voluntarily do it; also their chronological age (many of them were adolescents) influenced on this aspect.

Based on previous experiences (e.g., Villalba et al., 1999) and studies (See Mastrantuono, 2018) with population with deafness, we expected that finding eligible participants could be a hazardous process and therefore, could take a long time. Indeed, it took us close to two years to recruit the whole sample. As noted in the preface section, we anticipated this issue in the design of the **Thesis**, choosing and designing the experimental and background tasks so they could ensure a complete assessment and be carried out by the same participant in the less amount of time possible. This is the reason why we had to leave out from the design of the tasks some methodological aspects that would have improved the quality of our studies. For example, including filler items in **Study 1** or including more than one text genre per condition in **Study 3**.

The sample size of our study limits the generalization of our results for three main reasons. First, it did not allow us to make more in depth comparisons dividing the sample according to the type of prosthesis or the moment that they received their CI. If we had been able to control for these variables, maybe several profiles would have shown up as it has happened in other studies where audiological characteristics of this kind, were considered in their experimental design (see Gallego et al., 2016; López-Higes et al., 2015 [developed in **Study 2**]). Nonetheless, neither these latter studies were able to control for these factors, as if we look at their sample, a higher percentage of students (47%) from the early-CI group were bilateral implanted, whereas the late-CI group were not (21% implanted bilaterally). So, it is hard to predict how different our results would have been if we had controlled for it.

In addition, it would have been interesting to divide the sample according to their reading level (i.e., poor DHH readers – skilled DHH readers), this categorization has proved to be successful to explore the online sentence reading on participants with deafness in other studies (e.g., Kelly, 2003b), leaving the possibility to analyze different reading profiles within this population.

Second, this is a small sample size in terms of statistical power so type II errors might have occurred (the research fails to identify a significant difference or effect that exists). Anyhow, our results might serve as a basis for future meta-analyses that combine similar individual studies on the topic of time-course of grammatical processing in deaf readers.

Finally, given the difficulties of finding a homogeneous sample we included participants from a wide age range (9-15 years old), although, a shorter age range would have been recommendable, this is frequent in studies involving non-adult population with deafness (See Bélanger et al., 2018, who included participants from 7 to 15 years old)

Given the limitations that a small and sample with a high intra-group variability imply, we tried to reduce as much as possible the impact that these factors could have had on our results by analyzing the eye-movement data with generalized lineal mixed models (See Chapter 2, General Methodology section for further details).

Students with Typical Hearing

A chronological age TH control group participated in the study but not a reading age control one. A reading age control is necessary to verify if time-course differences are typical of younger and immature readers or qualitatively different and a by-product of the particular hearing and language experience of prelingual DHH children and adolescents. As noted in the General Methodology Section (Chapter 2) the reading comprehension scores of some students with deafness were too low to match them with typically hearing students of the same reading level (even when trying to match them with third grade students). It could have been possible though, to include only a subset of the students with DHH to allow for this comparison, however, we considered that the number of participants with DHH was not big enough to conduct that analyses. Similar difficulties have been reported by other studies studying the reading pattern of young population with deafness with online measures (see Bélanger et al., 2018, who from a total of 24 participants with deafness had to select only 13 students to conduct the corresponding comparison).

Finally, as already noted in the General Methodology section the experimental tasks (those recorded with eye-tracking), were piloted with several volunteers. However, all of them were typically hearing participants, most of them college students (only one volunteer was an adolescent). It would have been better to pilot the experiments with children (as we did with the material from **Study 1**) and moreover, it would have been good practice to test them with students with DHH. Yet, due to the difficulties in recruiting the sample this option was not possible.

3|3.2 The Sample Frequency of Eye-movements

As it happened in de Leeuw's et al. (2016a; 2016b) our sample rate of registering (60Hz) might limit the quality of the data. Yet, other reading studies with children with and without developmental disabilities [e.g. Davidson & Weismer, 2017; Khelifi, Sparrow, & Casalis, 2019) have used this sample rate as well. Besides, according to Andersson, Nyström and Holmqvist (2010) we had enough data points to reduce the possibility of a temporal sampling error.

3|3.3 The experimental materials

With regard to the *experimental tasks* of **Study 1**, the inclusion of fillers with different types of manipulations (not only grammatical) would have eliminated the possibility to adopt a strategic reading pattern. Besides, including different types of grammatical violations would have allowed to describe how participants with deafness responded to different types of grammatical manipulations. One example of this would be the study conducted by Dias et al. (2018) who assessed the time-course of grammatical processing on individuals with deafness by registering their EEG responses to a series of grammatical violations presented during a grammatical acceptability judgment task. In particular, they included 3 types of grammatical violations: number (e.g., *Mi casa era grandes y bonita* [*My house was big and nice*]), transparent gender (e.g., *Su mesa estaba sucio de tomate* [*Her table was dirty of tomate*]), opaque gender (e.g., *Mi serpiente está enfermo* [*My snake is sick*]) and a semantic one (e.g., *Su silla estaba triste esta mañana* [*Your chair was sad this morning*]).

Regarding **Study 2**, we avoided presenting both, sentences and pictures together (as the original PROLEC-R task recommends), this was done to adapt the task to the constrains of the eye-tracking methodology (See methods section from **Study 2**). As a consequence, the performance of the students in this task could be highly mediated by students' working memory capacity. Although no relationship was observed in **Study 2** between the eye-movement data and the reading span (working memory) scores of students with DHH, it would be interesting to repeat (and afterwards compare) the assessment presenting the sentence and the pictures at the same time and separately. Yet, as the literature anticipates us (see Kelly, 2003b, developed in the General Introduction) this aspect may not be the principal aspect accounting for their reading comprehension failure. Further analyses could have contributed to a better description of participants' online reading behavior. In this sense, we could have analyzed the eye-movements produced at the sentences (not only at the pictures as we did), however, we decided to focus only at pictures in order to keep the study as simple as possible, otherwise the results and discussion section of this Study would have been too large.

We will not insist on the limitations of **Study 3** (order of presentation of texts and more texts per genre condition) as they have been well developed in the empirical part of the corresponding study.

With respect to the background measurements (i.e., the offline tasks), it would have been useful to include some tasks in the protocol, particularly, a speech perception measurement and a task assessing the vocabulary depth of the students would have allowed for a better description of the effects. Regarding the first, as noted in the General Introduction of this **Thesis** (Chapter 1), some studies attribute part of the delays that students with DHH demonstrate in grammar to the difficulty to perceive some of the words that mostly contain the grammatical information (i.e., function words or suffixes). In this regard, it would have been good practice to control for this variable in the assessment. As to the vocabulary, we measured the amplitude dimension, which is a domain where many students with DHH still struggle to succeed in (see Moreno-Pérez et al., 2015). Yet, as mentioned in the General Introduction of this **Thesis** vocabulary depth can also be related to the acquisition of function words. Thus, applying a task of that kind (e.g., the vocabulary task included in the PEALE battery, Domínguez et al., 2013) would have provided an added value to our work.

Our last comments relate to the correction procedure of the syntactic ability task (SAT). Although when applying this task to the students we followed exactly the same procedure recommended by the authors, we did not correct it in the same way. If we remember the task, it comprised of 64 incomplete sentences (a function word was missing). Students were asked to complete each item (sentence) by choosing between four options (function words) in a limited set of time (5 minutes). The final scores that we used in our experiments corresponded to the total number of items correctly answered by each participant. The authors instead obtained the final score by subtracting the errors (divided by three) to the number of correct responses, this allowed them to control for responses given by guessing. This fact should be considered when comparing the results with the results of Domínguez et al. (2016) in this specific task.

3 | 4 Practical Implications

Our study gives rise to several practical implications. First, fostering grammatical skills should be one of the focus of the reading intervention when working with students with DHH. Throughout this **Thesis** we have corroborated that despite current advances there are still children who fall behind their typical chronological-aged matched typically hearing peers when they are asked to complete tasks that involve the use of grammatical skills (**Study 1** and **Study 2**). By improving their grammatical skills, this ability would have a lower impact in reading, and specifically in the other processess (e.g., inference making, prior knowledge) that need to cooperate efficiently and effortfuless to construct the meaning. Indeed, Kelly (2003a) emphasizes the importance of accomplishing automaticity on such bottom-up processes in order to allow for reading comprehension. This author compares the reading process with the act of juggling, where the individual has to manage with multiple operations (balls) at the same time in order to succeed in the task (See Figure 16).

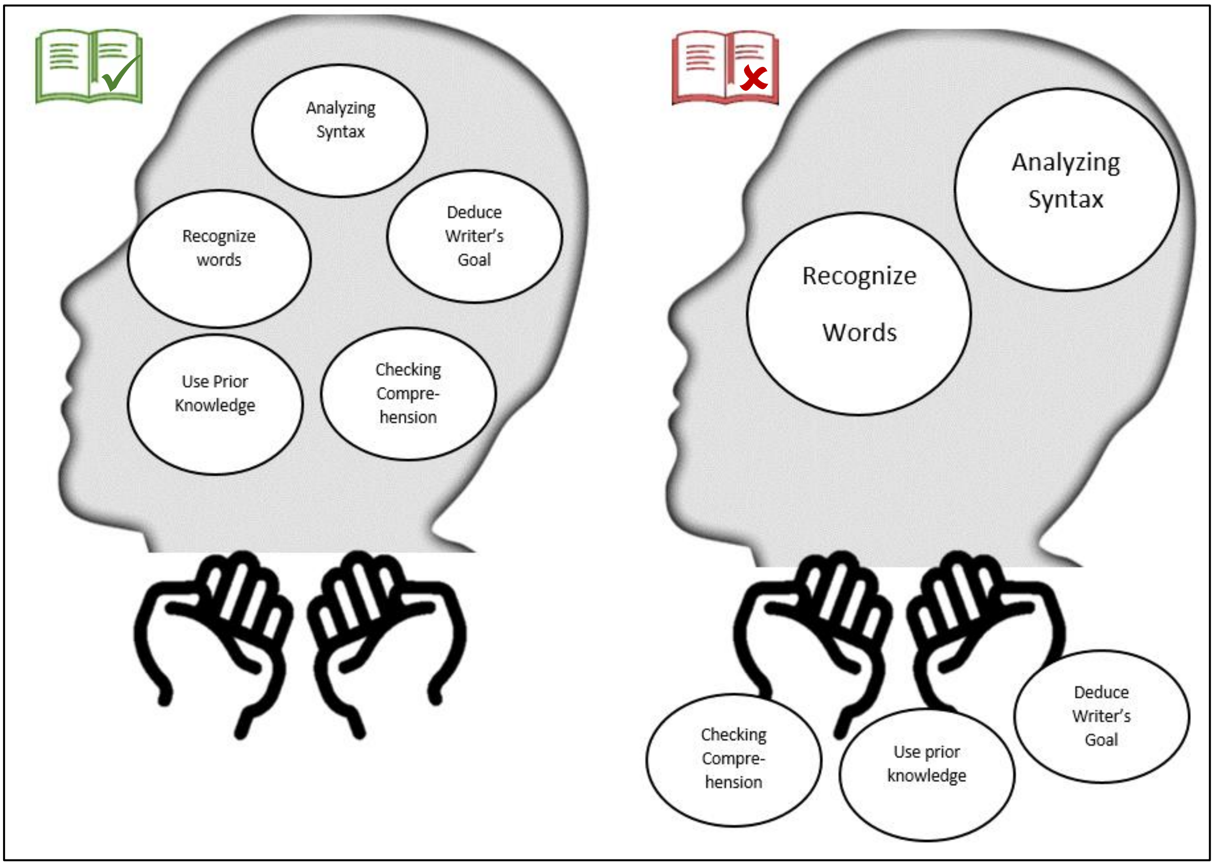

Figure 16. Comparing reading as juggling. Left side: The reader shares' cognitive resources with several operations. Right side: When the reader has lower grammatical skills, cognitive resources are mostly invested in the grammatical domain leaving behind the rest actions. (Figure adapted from Johnson, 2001 as cited in Kelly, 2003a).

Thefore, if syntactic abilities are at the heart of DHH students' problems with reading comprehension, helping students gain more efficient syntactic parsing skills would have positive cascading effects on reading processes at text level, as well as freeing up memory and attention resources required for local text processing (Arfé, Rossi, & Sicoli, 2015; Kelly, 1996; 1998; 2003a).

These recommendations will be in line with other studies, who already concluded that improving grammatical skills should be one of the main goals when working with students with DHH (e.g., Cannon et al., 2020). However, more studies are needed in order to test the effectivity of this kind of interventions. Recently, Cannon et al. (2020) assessed the effectiveness of an interactive software for teaching syntax to a group of 37 canadian students with DHH from 7 to 12 years old. In this case, no change was observed between the control group and the group that received the treatment, which suggests that more research is needed in order to know which specific aspects and in which way professionals should train these students in order to obtain positive results. In Spain, Domínguez and colleagues have recently developed an open-source intervention program "Ana y Coco: en busca del Cromo perdido", consisting of a set of activities aimed at fostering student's abilities to manage with function words. However, up to our knowledge the effectiveness of this latter program has not been tested empirically. We agree with Domínguez and colleagues (2019) in that an explicit grammar instruction could be useful for improving DHH students' grammatical competence, in this regard, asking them to judge sentences with grammatical inconsistencies (**Study 1**), or including tasks such as the one used in our **Study 2** could be of interest to improve their skills. Based on our findings, we also recommend that it is important to train students in comprehending complex sentences (e.g., semantically reversible sentences and sentences that do not follow a canonical word order), given that students with DHH appear to be as efficient as students with typical hearing when comprehending (but not when judging the correctness) of sentences with a simpler syntactical structure.

Another practical implication of these findings is the need of a greater focus on reading processes and strategies in instructional intervention and not only on DHH students' grammatical knowledge. For example, in school settings, the incongruence detection and correction tasks could be used for both individual assessment and explicit grammar training of students with DHH. Training in grammar correction tasks would increase not only grammar knowledge but also students' self-regulation, skills that both deaf and hearing students appear to lack (Breadmore et al., 2014).

Teachers might apply these practical recommendations in order to provide inclusive support for DHH students, especially if they present a similar profile than the sample of our study, that is, users of CI or HAs and spoken language as their preferred means of communication who are usually attending mainstream schools and receiving oral education (Archbold & Mayer, 2012).

Intervention with students with DHH should focus on improving vocabulary skills as well. In the present research, DHH participants demonstrated a marked delay in comparison to their TH peers in this domain. Instruction should focus on both dimensions, amplitude and vocabulary depth. It is obvious that if the reader does not know most of the words of the text it will be difficult to understand it, however there are other reasons why fostering their vocabulary skills can benefit their reading. In this sense, vocabulary can help the reader to compensate for their grammatical difficulties when trying to elaborate the meaning of a text or sentence. Although, as we have learnt, this practice would not work in some contexts (e.g., semantically implausible sentences), it will work better than when both domains appear to be deficient.

Finally, text structure knowledge (test genre) could be also improved in students with DHH as we have seen that it has an impact in students' comprehension, in both groups (readers with TH and with DHH). For example, Paris and Paris (2007) provided 5 weeks of direct strategy instruction about narrative elements and relations in 4 first-grade classrooms. They found that understanding and recall of main narrative elements improved, as did inference-making skills and understanding of the psychological aspects of stories. This kind of training could be tested in DHH of Primary and Secondary school and also applying other type of structures, not only to narrative as the use of it in school decrease throughout the schooling years. Adding eye-movement measures (pre and post) to the text structure intervention could inform about effects on monitoring and reading efficiency.

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Appendix

Additional Content from Study 1

Table A1. *Model for the First-pass time on the TAR. The model was based on 700 observations from 40 participants and 24 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	7.234e-06	0.002
Ítem (Intercept)	3.250e-05	0.005
Residual	3.771e-04	0.019

Fixed effects:

	Estimate	Std. Error	df	*t* value	Pr(>|*t*|)
(Intercept)	1.201e+00	1.824e-03	4.223e+01	658.216	<2e-16 ***
group	-3.614e-03	1.404e-03	3.460e+01	-2.574	.014 *
congruency	-3.227e-03	1.237e-03	6.791e+02	-2.608	.009 **
age	7.626e-04	1.011e-03	3.758e+01	0.754	.455
wordspeed	-1.253e-04	1.296e-04	3.547e+01	-0.967	.340
vocabulary	-3.131e-05	9.088e-05	3.663e+01	-0.344	.732
syntax	-2.720e-04	1.034e-04	3.705e+01	-2.631	.012 *
group:congruency	-3.850e-04	1.215e-03	6.596e+02	-0.317	.751
group:age	-7.006e-04	1.011e-03	3.757e+01	-0.693	.492
group:wordspeed	1.316e-05	1.296e-04	3.545e+01	0.102	.919
group:vocabulary	1.555e-04	9.086e-05	3.655e+01	1.711	.095
group:syntax	2.966e-05	1.033e-04	3.694e+01	0.287	.775
congruency:age	-5.813e-04	8.924e-04	6.665e+02	-0.651	.515
congruency:wordspeed	-1.505e-04	1.133e-04	6.635e+02	-1.329	.184
congruency:vocabulary	4.938e-05	7.858e-05	6.496e+02	0.628	.530
congruency:syntax	8.172e-06	9.099e-05	6.647e+02	0.090	.928
group:congruency:age	1.039e-04	8.971e-04	6.680e+02	0.116	.907
group:congruency_wordspeed	4.849e-06	1.165e-04	6.751e+02	0.042	.966
group:congruency:vocabulary	-1.657e-05	7.866e-05	6.518e+02	-0.211	.833
group:congruency:syntax	-5.750e-05	9.301e-05	6.723e+02	-0.618	.536

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transform ed data. Formula: firstpasslog ~ group: congruency: age + group: congruency: wordspeed+ group: congruency: vocabulary + group: congruency: syntax + groupf: congruency + group: age + group: wordspeed + group: vocabulary + group: syntax + congruency: age + congruency: wordspeed + congruency: vocabulary + congruency: syntax + group + congruency + age + wordspeed + vocabulary + syntax + (1 | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent=-1) as was participant gro up (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

Table A2. *Model for the Second-pass time on the TAR. The model was based on 484 observations from 40 participants and 24 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	8.262e-04	0.028
Congruency	5.015e-05	0.007
Ítem (Intercept)	2.388e-04	0.015
Residual	1.712e-02	0.130

Fixed effects:

	Estimate	Std. Error	df	*t* value	Pr(>|*t*|)
(Intercept)	1.891	0.013	41.511	139.269	< 2e-16 ***
group	-0.013	0.013	44.654	-1.033	.307
congruency	-0.035	0.010	37.941	-3.264	.002 **
age	-0.009	0.008	35.449	-1.041	.304
wordspeed	-0.002	0.001	34.878	-2.086	.044*
vocabulary	-0.0008	0.0008	43.581	-0.991	.327
syntax	-0.0002	0.0009	38.745	-0.284	.777
group:congruency	-0.004	0.010	37.206	-0.371	.712
group:age	0.005	0.008	35.528	0.592	.557
group:wordspeed	0.0003	0.001	34.834	0.312	.756
group:vocabulary	-0.0001	0.0008	43.477	-0.194	.847
group:syntax	-0.0003	0.0009	38.737	-0.362	.719
congruency:age	-0.009	0.007	25.979	-1.399	.173
congruency:wordspeed	-0.0003	0.0009	25.787	-0.389	.700
congruency:vocabulary	-0.000001	0.0006	36.650	-0.003	.997
congruency:syntax	0.001	0.0007	29.532	1.707	.098
group:congruency:age	-0.011	0.007	26.188	-1.614	.118
group:congruency_wordspeed	-0.0009	0.0009	26.623	-1.064	.296
group:congruency:vocabulary	-0.0008	0.0006	36.392	-1.302	.200
group:congruency:syntax	0.001	0.0007	30.096	1.426	.164

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transform ed data. Formula: secondpasslog ~ group: congruency: age + group: congruency: wordspeed + group: congruency: vocabulary + group: congruency: syntax + group: congruency + groupf: age + group: words peed + group: vocabulary + groupf: syntax + congruency: age + congruency: wordspeed + congruency: vocabulary + congruency: syntax + group + congruency + age + wordspeed + vocabulary + syntax + (congruency | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent=-1) as was part icipant group (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test

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

Table A3. *Fixation Count in the TAR region. The model was based on 700 observations from 40 participants and 24 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	0.024	0.157
Ítem (Intercept)	0.014	0.121

Fixed effects:

	Estimate	Std. Error	*z* value	Pr(>|*z*|)
(Intercept)	0.917	0.043	21.177	< 2e-16 ***
group	0.078	0.034	2.239	.025 *
congruency	-0.065	0.024	-2.664	.007 **
age	0.002	0.018	0.147	.883
group:congruency	0.013	0.024	0.542	.588
group:age	0.015	0.018	0.842	.399
congruency:age	-0.012	0.012	-0.964	.335
group:congruency:age	-0.010	0.012	-0.798	.424

Note. Formula: fixationcount ~ group: congruency: age + group: congruency + group: age + congruency: age + group + congruency + age + (1 | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent =-1) as was participant group (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test.

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

Table A4. *Model for the First-pass time on the POST.* *The model was based on 725 observations from 40 participants and 24 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	7.806e-06	0.002
Ítem (Intercept)	4.528e-06	0.002
Residual	3.777e-05	0.006

Fixed effects:

	Estimate	Std. Error	df	*t* value	Pr(>|*t*|)
(Intercept)	9.239e-01	9.386e-04	4.042e+01	984.356	< 2e-16 ***
group	1.137e-03	8.312e-04	2.933e+01	1.368	.181
congruency	-1.769e-03	3.883e-04	6.770e+02	-4.557	6.16e-06 ***
age	-7.734e-04	5.940e-04	3.084e+01	-1.302	.202
wordspeed	-1.415e-05	7.670e-05	2.973e+01	-0.184	.854
vocabulary	-1.101e-05	5.340e-05	2.996e+01	-0.206	.838
syntax	1.428e-04	6.059e-05	3.039e+01	2.358	.025 *
group:congruency	3.888e-04	3.818e-04	6.636e+02	1.018	.308
group:age	1.029e-04	5.939e-04	3.081e+01	0.173	.863
group:wordspeed	-8.062e-05	7.669e-05	2.972e+01	-1.051	.301
group:vocabulary	-1.066e-05	5.339e-05	2.994e+01	-0.200	.843
group:syntax	-4.770e-05	6.056e-05	3.034e+01	-0.788	.437
congruency:age	2.616e-05	2.867e-04	6.696e+02	0.091	.927
congruency:wordspeed	5.168e-05	3.572e-05	6.661e+02	1.447	.148
congruency:vocabulary	3.876e-06	2.478e-05	6.579e+02	0.156	.875
congruency:syntax	-6.696e-06	2.873e-05	6.648e+02	-0.233	.815
group:congruency:age	8.121e-05	2.883e-04	6.732e+02	0.282	.778
group:congruency:wordspeed	-1.927e-05	3.670e-05	6.785e+02	-0.525	.599
group:congruency:vocabulary	-1.563e-06	2.485e-05	6.602e+02	-0.063	.949
group:congruency:syntax	-4.997e-05	2.949e-05	6.778e+02	-1.694	.090

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transform ed data. Formula: firstpasslog ~ group: congruency: age + group: congruency: wordspeed + group: congruency: vocabulary + group: congruency: syntax + group: congruency + group: age + group: wordspeed + group: vocabu lary + group: syntax + congruency: age + congruency: wordspeed + congruency: vocabulary + congruency: syntax + group + congruency + age + wordspeed + vocabulary + syntax + (1 | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent=-1) as was participant group (DHH=1, TH=-1)

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the Syntactic Ability Test.

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

Table A5. *Model for the Second-pass time on the POST. The model was based on 336 observations from 39 participants and 24 items.*

Random effects:

Groups Name	*Variance*	*Std.Dev.*
Participant (Intercept)	1.166e-06	0.001
Ítem (Intercept)	6.894e-06	0.002
Residual	3.936e-05	0.006

Fixed effects:

	Estimate	Std. Error	df	*t* value	Pr(>|*t*|)
(Intercept)	9.402e-01	8.764e-04	3.474e+01	1072.737	<2e-16 ***
group	4.932e-06	6.941e-04	2.661e+01	0.007	.994
congruency	-1.439e-04	6.558e-04	3.106e+02	-0.219	.826
age	-4.705e-04	4.688e-04	2.454e+01	-1.004	.325
wordspeed	-4.494e-06	5.781e-05	2.095e+01	-0.078	.938
vocabulary	2.291e-06	4.410e-05	3.003e+01	0.052	.958
syntax	5.142e-05	5.016e-05	2.482e+01	1.025	.315
group:congruency	2.554e-04	6.242e-04	2.893e+02	0.409	.682
group:age	-8.367e-04	4.648e-04	2.393e+01	-1.800	.084
group:wordspeed	-1.076e-04	5.756e-05	2.061e+01	-1.869	.075
group:vocabulary	-3.520e-05	4.396e-05	2.962e+01	-0.801	.429
group:syntax	4.663e-05	4.986e-05	2.429e+01	0.935	.358
congruency:age	6.300e-04	4.222e-04	2.992e+02	1.492	.136
congruency:wordspeed	3.663e-06	5.119e-05	2.898e+02	0.072	.943
congruency:vocabulary	3.491e-05	4.019e-05	2.970e+02	0.869	.385
congruency:syntax	-5.934e-05	4.573e-05	3.061e+02	-1.298	.195
group:congruency:age	3.865e-04	4.390e-04	3.131e+02	0.880	.379
group:congruency:wordspeed	7.544e-05	5.432e-05	3.101e+02	1.389	.165
group:congruency:vocabulary	1.227e-05	4.035e-05	3.015e+02	0.304	.761
group:congruency:syntax	-5.738e-05	4.808e-05	3.134e+02	-1.194	.233

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transformed data. Formula: secondpasslog ~ groupf: congruencyf: cca + groupf: congruencyf: cptd_wspeed + groupf: congruencyf: ciqvoc + groupf: congruencyf: cpersnt + groupf: congruencyf + groupf: cca + groupf: cptd_wspeed + groupf: ciqvoc + groupf: cpersnt + congruencyf: cca + congruencyf: cptd_wspeed + congruencyf: ciqvoc + congruencyf: cpersnt + groupf + congruencyf + cca + cptd_wspeed + ciqvoc + cpersnt + (1 | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent=-1) as was participant group (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test.

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

Table A6. *Fixation Count in the POST region. The model was based on 725 from 40 participants and 24 items.*

Random effects:

Groups Name	*Variance*	*Std.Dev.*
Participant (Intercept)	0.02304	0.1518
Ítem (Intercept)	0.02586	0.1608

Fixed effects:

	Estimate	Std. Error	*z* value	*Pr(>|z|)*
(Intercept)	0.652	0.049	13.185	<2e-16 ***
group	0.033	0.036	0.922	.356
congruency	0.056	0.027	2.058	.039 *
age	0.008	0.019	0.413	.679
group:congruency	-0.016	0.027	-0.607	.543
group:age	0.013	0.019	0.676	.499
congruency:age	0.002	0.014	0.143	.886
group:congruency:age	-0.001	0.014	-0.088	.929

Note. Formula: fixationcount ~ group: congruency: age + group: congruency + group: age + congruency: age + group + congruency + age + (1 | participant) + (1 | item). Congruity was effect coded (congruent= 1, incongruent =-1) as was participant group (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test.

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

Table A7. *Model for the Second-pass time on the PRE.* *The model was based on 625 observations from 40 participants and 24 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	0.013	0.114
Ítem (Intercept)	0.035	0.188
Residual	0.055	0.236

Fixed effects:

	Estimate	Std. Error	df	*t* value	Pr(>|*t*|)
(Intercept)	2.198e+00	5.156e-02	4.647e+01	42.628	< 2e-16 ***
group	4.531e-02	3.467e-02	3.162e+01	1.307	.200
congruency	3.236e-03	1.634e-02	5.602e+02	0.198	.843
age	1.065e-02	2.432e-02	3.100e+01	0.438	.664
wordspeed	2.641e-04	3.155e-03	3.045e+01	0.084	.933
vocabulary	-1.508e-04	2.194e-03	3.058e+01	-0.069	.945
syntax	-2.697e-03	2.485e-03	3.076e+01	-1.086	.286
group:congruency	9.389e-03	1.610e-02	5.527e+02	0.583	.560
group:age	2.504e-02	2.433e-02	3.107e+01	1.029	.311
group:wordspeed	9.065e-04	3.155e-03	3.044e+01	0.287	.775
group:vocabulary	1.235e-03	2.194e-03	3.058e+01	0.563	.577
group:syntax	-4.759e-03	2.485e-03	3.080e+01	-1.915	.064
congruency:age	-2.158e-02	1.170e-02	5.547e+02	-1.844	.065
congruency:wordspeed	8.871e-04	1.481e-03	5.215e+02	0.599	.549
congruency:vocabulary	7.664e-04	1.020e-03	5.525e+02	0.751	.452
congruency:syntax	3.170e-03	1.182e-03	5.296e+02	2.682	.007 **
group:congruency:age	-6.066e-03	1.170e-02	5.531e+02	-0.519	.604
group:congruency:wordspeed	-7.141e-04	1.520e-03	5.596e+02	-0.470	.638
group:congruency:vocabulary	-2.472e-03	1.024e-03	5.497e+02	-2.413	.016 *
group:congruency:syntax	-2.252e-04	1.206e-03	5.573e+02	-0.187	.851

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transformed data. Formula: secondpasslog ~ group: congruency: age + group: congruency: wordspeed + group:congruency:vocabulary + group:congruency:syntax + group:congruency + group:age + group:wordspeed + group:vocabulary + group:syntax + congruency:age + congruency:wordspeed + congruency:vocabulary + congruency:syntax + group + congruency+ age+ wordspeed + vocabulary + syntax + (1 | participant) + (group | item). Congruity was effect coded (congruent= 1, incongruent=-1) as was participant group (DHH=1, TH=-1).

Age= Chronological Age; wordspeed= Standard Score on word speed; vocabulary= Standard Score on receptive vocabulary; syntax= Raw Score on the syntactic ability test.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

Additional content from Study 2

Table A8. *Model Parameters for Total Fixation Time on correct responses.* *The model was based on 2032 observations from 40 participants and 16 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	0.000426	0.02065
Word_code (Intercept)	0.000160	0.01268
Residual	0.002078	0.04559

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept: TH target)	1.539e+00	4.683e-03	3.911e+01	328.556	< 2e-16	***
group1 (DHH)	7.1993-03	3.444e-03	3.830e+01	2.090	0.0433	*
picture_type1 (syntactic)	-1.341e-02	1.589e-03	1.972e+03	-8.442	<.2e-16	***
picture_type2 (lexical)	-4.262e-02	1.359e-03	1.973e+03	-31.362	<.2e-16	***
group1(DHH):picture_type1(syntactic)	1.352e-03	1.589e-03	1.972e+03	0.851	0.3947	
group1(DHH):picture_type2(lexical)	2.870e-03	1.359e-03	1.972e+03	2.113	.0348	*

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transformed data. Formula: fixationtime_log~group*picture_type+ (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (Contrast [1] for group: DHH=1/TH: -1; Contrast [1] for picture type: Syntactic Distractor-Target; Contrast [2] for picture type: Lexical Distractor-Target).

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

Table A9. *Model Parameters for Total Fixation Time on errors. The model was based on 400 observations from 32 participants and 16 items.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	0.013611	0.11667
Word_code (Intercept)	0.007486	0.08652
Residual	0.081311	0.28515

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept: TH target)	3.20880	0.03910	25.41349	82.064	< 2e-16	***
group1 (DHH)	0.04670	0.03079	37.20213	1.517	0.138	
picture_type1 (syntactic)	0.22291	0.02929	352.77651	7.614	2.46e-13	***
picture_type2 (lexical)	-0.23261	0.02545	350.39172	-9.140	<.2e-16	***
group1(DHH):picture_type1(syntactic)	0.02566	0.02928	352.75194	0.876	0.381	
group1(DHH):picture_type2(lexical)	0.01886	0.02545	350.39795	0.741	.0459	

Note. *b* and *SE* of the fixed effects computed with transformed variables. *t* and *p* values calculated with transformed data. Formula: fixationtime_log~group*picture_type+ (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (Contrast [1] for group: DHH=1/TH: -1; Contrast [1] for picture type: Syntactic Distractor-Target; Contrast [2] for picture type: Lexical Distractor-Target).

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

Additional content from Study 3

Table A10. *Model Parameters for Total Fixation Time at the Word Level. The model was based on 4151 observations from 38 participants.*

Random effects:

Groups Name	Variance	Std.Dev.
Participant (Intercept)	0.0015	0.03908
Word_code (Intercept)	0.0038	0.01969
Residual	0.0062	0.07902

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	1.703e+00	8.168e-03	8.851e+01	208.567	< 2e-16	***
group1	4.443e-03	6.466e-03	3.590e+01	0.687	0.496	
genre1	8.202e-03	1.316e-03	3.993e+03	6.233	<.001	***
word class1	1.522e-02	2.315e-03	1.138e+03	6.572	<.001	***
word length	1.032e-02	9.968e-04	9.094e+02	10.349	< 2e-16	
group1:genre1	-5.869e-04	1.260e-03	4.038e+03	-0.466	0.641	
group1:word class1	6.430e-03	1.268e-03	4.040e+03	5.069	<.001	***
genre1:word class1	7.121e-03	1.685e-03	9.647e+02	4.225	<.001	***
group:genre:word class	-4.339e-04	1.261e-03	4.039e+03	-0.344	0.731	

Note. *b* and *SE* of the fixed effects computed with transformed variables. T and p values calculated with transformed data. Formula that converged: fixation_time_log~group*genre*wordclass*n_characters+ (1|participant) + (1|item). Effect coding was used to contrast categorical fixed effects (DHH=1/TH: -1; Expository=1/Narrative=-1; Content Words=1/Function Words=-1).

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