TESIS DOCTORAL

Cognitive Precursors to Reading Skill Acquisition in Spanish

Precursores Cognitivos de la Adquisición de la Habilidad Lectora en Español

Eduardo Onochie-Quintanilla

Directores:

Silvia A. Defior Citoler e Ian C. Simpson

Departamento de Psicología Evolutiva y de la Educación

Facultad de Ciencias de la Educación

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(Cognitive Precursors to Reading Skill Acquisition in Spanish)

El doctorando: **Eduardo Onochie Quintanilla** y los directores de la tesis: **Silvia Defior Citoler** e **Ian C. Simpson** garantizamos, al firmar esta tesis doctoral, que el trabajo ha sido realizado por el doctorando bajo la dirección de los directores de la tesis y hasta donde nuestro conocimiento alcanza, en la realización del trabajo, se han respetado los derechos de otros autores a ser citados, cuando se han utilizado sus resultados o publicaciones. Asimismo, avalamos tanto la calidad de la misma como la formación del doctorando para aspirar al grado de doctor en *Ciencias de la Educación*, de la Universidad de Granada.

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Doctorando

Eduardo Onochie Quintanilla

Fdo.:

Director/es de la Tesis

Silvia Defior Citoler

Fdo.:

Ian C. Simpson

Fdo.:

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Resumen en Español

Un nivel básico de habilidad lectora es una condición necesaria para poder desenvolverse adecuadamente en nuestra sociedad actual. Además de su utilidad para la vida en el día a día, la lectura es el principal método a través del cual el aprendiz de cualquier materia se enriquece del conocimiento adquirido por los expertos que le preceden. Por lo tanto, para poder sacar provecho de la inmensa cantidad de conocimiento acumulado que se encuentra en los escritos creados por el ser humano, es previamente necesario aprender a leer. La lectura es una de las principales habilidades que los niños han de adquirir durante la fase inicial de educación escolar obligatoria precisamente por el hecho de ser una herramienta fundamental para el aprendizaje de cualquier asignatura. Los profesionales de la educación dedican una gran cantidad de trabajo y mucha dedicación a la enseñanza de la lectura. Sin embargo, aún no tenemos un conocimiento completo de cuáles son los factores subyacentes que permiten a algunos niños adquirir la habilidad lectora con relativa facilidad mientras que otros muestran grandes dificultades. A pesar de que la literatura científica indica que ciertos factores de carácter cognitivo son centrales para el aprendizaje lector, su función específica en la adquisición de la lectura aún está por determinar. La finalidad última de este trabajo es ayudar a esclarecer cuál es el papel que juegan estas habilidades cognitivas en el desarrollo de la habilidad lectora.

De entre los múltiples factores asociados a la adquisición y dominio de una habilidad tan compleja como la lectura, la investigación de las últimas décadas atribuye un papel crucial a un pequeño número de habilidades cognitivas. Gran parte del interés en esta área de investigación se ha focalizado sobre una habilidad denominada como conciencia fonológica (CF), cuya influencia sobre el aprendizaje de la lectura está bien documentada (Byrne & Fielding-Barnsley, 1989; Defior & Tudela, 1994; Vellutino et al., 2004; Wagner & Torgesen, 1987). Otra habilidad de importancia es la velocidad de nombramiento (Kirby et al., 2003; Bowers & Wolf, 1993), cuya influencia sobre la lectura es menos comprendida, a pesar de haber sido detalladamente estudiada. En los últimos años han surgido nuevas evidencias sugiriendo la trascendencia de una tercera habilidad cognitiva, el procesamiento visual, en el aprendizaje de la lectura (Bosse & Valdois, 2009; Rayner, 2009; Vidyasagar & Pammer, 2010). A pesar del gran progreso realizado en el estudio de estas habilidades cognitivas, aún prevalecen numerosas dudas acerca de cuál es el rol preciso que juegan cada una de ellas dentro de los mecanismos subyacentes al aprendizaje de la lectura y acerca del periodo durante el cual son principalmente influyentes (Lervåg et al., 2009; Shapiro et al., 2013; van den Boer et al., 2013).

Varios modelos de lectura han sido propuestos con la intención de sintetizar el conocimiento sobre la adquisición de la habilidad lectora y los diferentes procedimientos lectores. Los modelos evolutivos de aprendizaje lector ofrecen una visión global del proceso a través del cual un individuo progresa a lo largo de diferentes periodos en su camino desde lector novato a lector experto. Varios modelos evolutivos 'por fases' (ej., Ehri, 2005; Frith, 1986; Seymour & Duncan, 2001) coinciden en su entendimiento de la existencia de una fase inicial durante la cual transcurre la asimilación del código alfabético (el aprendizaje de la relación entre los grafemas y sus sonidos asociados). A esta fase le sigue la fase ortográfica, durante la cual el lector aprende a procesar agrupaciones comunes de letras como unidades individuales y así mejorar la velocidad lectora. Por otro lado, Share (1995) propone un modelo de desarrollo continuo y 'por ítem', en vez de 'por fases', que describe como cada vez que una palabra es decodificada el lector se beneficia de una oportunidad de autoaprendizaje para almacenar su representación ortográfica. Una vez registrada la ortografía de la palabra, esta será reconocida instantáneamente la próxima vez que el lector se tope con ella, sin necesidad de ser decodificada. De igual manera, numerosos modelos de lectura experta consideran que la familiaridad de una palabra es el principal factor que determina si una palabra será decodificada sublexicamente o reconocida instantáneamente (ej. Ans et al., 1998; Coltheart et al., 2001).

Independientemente del modelo específico, todos proponen que diferentes procedimientos lectores se implementan durante diferentes periodos, dependiendo de la fase de desarrollo o de la experiencia del lector. Por lo tanto, la estrategia o procedimiento lector variará en función de la fase de desarrollo o de la familiaridad de la palabra leída. Consecuentemente, las diferencias individuales en una habilidad cognitiva que sea importante para una fase evolutiva o un procedimiento lector especifico, correlacionará o no, con el rendimiento lector dependiendo del tipo de palabra o el periodo de desarrollo durante el cual se mida la lectura. La variabilidad en los resultados obtenidos dependiendo del tipo de palabra o el periodo de desarrollo podría dar lugar a una confusión considerable a la hora de interpretar los resultados si no se presta especial atención a estos factores. Por otro lado, manipular factores psicolingüísticos, como el tipo de palabra (ej., conocida o desconocida) y prestar atención a cómo cambia el rendimiento lector dependiendo del periodo de desarrollo, pueden ser herramientas extremadamente útiles para investigar el papel desempeñado por las habilidades cognitivas relacionadas con la lectura.

La habilidad cognitiva que ha sido más asociada con el desarrollo de la habilidad lectora es la CF (Defior, 2004; Vellutino et al., 2004). A pesar de que la relación entre la conciencia fonológica y la lectura ha sido meticulosamente estudiada a lo largo de las últimas décadas, todavía subsisten varias inconsistencias en la literatura científica que merecen especial atención. Específicamente, la explicación establecida sobre el rol de la CF en el aprendizaje de la lectura es que (1) es necesaria para aprender el código alfabético, y (2) que asiste en las conversiones grafema-fonema. No obstante, numerosos estudios han obtenido resultados en los cuales la relación entre la lectura y la conciencia fonológica se debilita significativamente según el niño progresa en la educación primaria (e.g., Badian, 2001; Kirby et al., 2003). Los datos son aún más contundentes cuando se trata de lenguajes con sistemas ortográficos transparentes (e.g., español: Defior, 2008; holandés: Vaessen & Blomert, 2010; finlandés: Leppänen et al., 2006). Esta disminución en la correlación entre la lectura y la CF, según el lector obtiene experiencia, parece contradecir el entendimiento de que la CF está involucrada en las conversiones grafema-fonema, ya que estas son cruciales para la decodificación. Por lo tanto, uno de los objetivos de esta tesis es clarificar si el rol principal de la CF es asistir con las conversiones grafema-fonema o meramente favorecer el aprendizaje de las correspondencias grafema-fonema.

Otra habilidad cognitiva que está muy vinculada con el nivel lector es la velocidad de nombramiento o velocidad de denominación. La velocidad de nombramiento suele evaluarse por medio del test RAN (*Rapid Automatized Naming*), que mide la velocidad con la cual un individuo puede nombrar una serie de estímulos (dibujos, colores, letras o números). Los resultados de múltiples estudios llevados a cabo durante las últimas tres décadas han demostrado repetidas veces que la velocidad de nombramiento es un importante predictor de la velocidad de lectura, tanto en inglés como en sistemas escritos transparentes (inglés: Kirby et al., 2003; holandés: de Jong & van der Leij, 1999; noruego: Lervag & Hulme, 2009; español: Aguilar et al., 2010). Sin embargo, a pesar de que se han propuesto numerosas teorías a lo largo de los años con la intención de explicar la estrecha relación entre RAN y la lectura, aún no se ha alcanzado un consenso sobre qué papel juega la velocidad de nombramiento en la lectura. Una de las teorías más debatidas propone que RAN es una medida de procesamiento ortográfico, entendido como la habilidad de procesar amalgamas familiares de letras como unidades individuales. En esta tesis, la familiaridad ortográfica de palabras será manipulada con el fin de clarificar si la velocidad de nombramiento realmente está relacionada con el procesamiento ortográfico.

A pesar de que en la literatura científica la postura más establecida considera que los problemas asociados a la lectura se encuentran en el ámbito fonológico, recientemente nuevas evidencias sugieren que factores puramente visuales quizás también jueguen un papel central en su adquisición (inglés: Bosse et al., 2007; español: Lallier et al., 2014; holandés: van den Boer et al., 2013). Sin embargo, los estudios realizados hasta la fecha han generado resultados no concluyentes. Un aspecto metodológico a la base de estas inconsistencias, al igual que ocurre con la conciencia fonémica, es que la propia experiencia lectora altera los niveles de habilidad visual (HV) (Dehaene et al., 2010). Por lo tanto, al contemplar una correlación entre la HV y el rendimiento lector es difícil discernir cual es la dirección de causalidad. Además, mientras varios estudios han presentado evidencias de que la HV contribuye a la lectura durante ciertos periodos del desarrollo lector (ej., Bosse et al., 2007), otros estudios que evalúan el rendimiento lector durante diferentes periodos han obtenido resultados opuestos (ej. Shapiro et al., 2013). Esto indica la posibilidad de que la HV ejerza una influencia sobre el nivel lector durante ciertos periodos pero no otros. Finalmente, en el supuesto caso de que la HV ciertamente juegue un papel significativo en la lectura, no está claro aún si esta está principalmente involucrada en el reconocimiento automático de palabras conocidas o en la decodificación de palabras desconocidas. Uno de los objetivos de esta tesis es aclarar si la HV contribuye a la lectura significativamente, durante qué periodos y ejerciendo qué función.

Otro motivo de debate en el estudio de la adquisición de la lectura concierne la validez de los resultados obtenidos en una lengua, con el fin de comprender la adquisición de la lectura en otras con diferentes características. Por ejemplo, los modelos de desarrollo de la lectura han sido elaborados mayoritariamente en el contexto del aprendizaje en inglés, cuyo sistema escrito tiene unas características particulares. De igual manera, la gran mayoría de los estudios que han establecido la importancia de la conciencia fonológica como una habilidad determinante del éxito en la adquisición de la lectura también han sido llevados a cabo en inglés. Se ha argumentado que, debido a su ortografía opaca y a los diferentes métodos de enseñanza de la lectura utilizados en países de habla inglesa, el inglés probablemente no sea el modelo más apropiado para comprender el desarrollo lector en otras lenguas con sistemas escritos más transparentes (Share, 2008; Wesseling & Reitsma, 2000). Dada esta circunstancia, esta tesis pretende proporcionar una interesante contribución a la investigación al complementar el trabajo ya realizado en inglés con datos obtenidos al estudiar la adquisición de la lectura en español. En primer lugar, hay un interés por determinar si los modelos de desarrollo lector elaborados en el contexto inglés son aplicables al español. En segundo lugar, y con mayor importancia, hay un interés en dilucidar si las habilidades cognitivas que han sido identificadas como importantes para la adquisición de la lectura en inglés lo son también en español.

Objetivos y Diseño

La investigación llevada a cabo es de carácter longitudinal; tiene como finalidad estudiar el desarrollo lector en español e investigar la relativa importancia de la conciencia fonémica, la velocidad de nombramiento y la habilidad visual en el aprendizaje de la lectura durante los primeros 5 años de escolarización. El objetivo principal es determinar si estas tres habilidades cognitivas, medidas durante la etapa pre-escolar, contribuyen independiente y significativamente a los niveles futuros de lectura, durante qué periodos y entender mejor la función que ejercen. Basándonos en los modelos de desarrollo lector elaborados para el inglés, el primer estudio investiga cuáles son los periodos de desarrollo durante los cuales cada una de las tres habilidades cognitivas de interés (CF, RAN, HV) ejerce mayor influencia sobre la lectura. El segundo estudio se centra en evaluar el papel que juega el procesamiento visual en la lectura a través de la manipulación de factores psicolingüísticos como la frecuencia léxica y la longitud de las palabras. Más concretamente, este estudio investiga si la habilidad visual está predominantemente relacionada con la decodificación de palabras desconocidas o con el reconocimiento de palabras conocidas. En el tercer estudio se manipula la familiaridad de las palabras (frecuencia léxica, frecuencia silábica y lexicalidad) con el objetivo de evaluar la relación entre la velocidad de nombramiento y la familiaridad ortográfica.

De este modo, se diseñó un estudio longitudinal compuesto de tres sub-estudios. Comenzó cuando los niños cursaban el último año de pre-escolar y tenían una edad media de 5 años, 6 meses (*DT* = 3.6 meses, rango: 5 años, 1 mes – 6 años, 1 mes). 188 niños españoles (85 niñas, 103 niños) participaron en el inicio de la recolección de datos. Al comienzo se les administró una amplia batería de pruebas para medir sus habilidades cognitivas (coeficiente intelectual, CF, RAN y HV). Los datos de esta evaluación inicial fueron utilizados como variables predictoras para los tres sub-estudios. También se evaluaron la inteligencia verbal y no verbal. Dado que la primera evaluación se efectuó en el año previo al inicio de la enseñanza obligatoria, las habilidades en el área de la lecto-escritura eran aún limitadas. Esto permitió excluir de los análisis a todos los niños que ya sabían leer en pre-escolar, reduciendo la muestra a 120 niños. A través de estas medidas se garantizó el control de la influencia que la experiencia lectora ejerce sobre las habilidades cognitivas (CF: Hogan et al., 2005; HV: Dehaene et al., 2010; RAN: Wolff, 2014). Se llevó a cabo un seguimiento de estos niños durante los siguientes 64 meses, durante los cuales se administraron diferentes pruebas de rendimiento lecto-escritor.

Estudio 1

Además de las pruebas de carácter cognitivo administradas en pre-escolar y comunes a los tres estudios de la tesis, en el estudio 1 se administraron dos pruebas de lectura (lectura de palabras y pseudopalabras). Estas dos pruebas se administraron en cinco momentos diferentes con intervalos de 12 meses entre cada evaluación. Además, durante los primeros dos años del estudio se aplicó una prueba que evaluaba el conocimiento de las correspondencias entre grafemas y fonemas. Haciendo uso de estas pruebas de lecto-escritura fue posible constatar, en primer lugar, si los modelos de desarrollo elaborados para describir el proceso de adquisición de la lectura son aplicables al español. En segundo lugar, hizo posible investigar durante qué periodos de adquisición de la lecto-escritura son más influyentes los predictores cognitivos de interés (CF, RAN y HV).

Los resultados revelaron que, en cierta medida, las descripciones del proceso de adquisición lectora presentadas por los modelos de desarrollo elaborados en el contexto de la lengua inglesa son también aplicables al español. Así, indican que el periodo durante el cual el lector novato aprende las correspondencias grafema-fonema (Fase Alfabética: Frith, 1986; Fase Alfabética-Fonológica: Høien & Lundberg, 2000; Fase de Cimientos de la Lecto-escritura: Seymour & Duncan, 2001; Fases Parcial Alfabética y Completa Alfabética: Ehri, 2005) y desarrolla la precisión lectora (figura 1) tiene lugar desde el comienzo de la adquisición de la lectura hasta finales de Primer curso. No obstante, una vez alcanzada la precisión lectora, la velocidad de decodificación (representada por la velocidad de lectura de pseudopalabras) sigue aumentando anualmente de manera significativa. Este resultado indica que los niños desarrollan un método para leer palabras no-familiares que es más eficiente que la decodificación letra a letra, lo cual apoya la noción de una transición a la fase ortográfica (Fase Ortográfica: Frith, 1986; Seymour & Duncan; 2001; Fase Consolidada: Ehri, 2005). Este periodo, durante el cual el lector comienza a desarrollar el procesamiento ortográfico, entendido como la habilidad de leer grupos de letras con los cuales el lector ya está familiarizado como unidades individuales, tiene lugar a partir de finales de Primero.

Por otro lado, la diferencia de velocidad lectora entre palabras y pseudopalabras (figura 2), no solo es significativa en todas las evaluaciones, sino que la aceleración en esta diferencia también es significativa para cada evaluación. Por lo tanto, mientras la transición de la fase alfabética a la fase ortográfica parece tener lugar a finales de primero, el desarrollo de la lectura léxica parece desarrollarse desde los inicios de la adquisición de la lecto-escritura. Este resultado concuerda con la descripción presentada por el modelo por ítems de Share (1995, 2008), que explica como las palabras de frecuencia alta se aprenderán y leerán de manera léxica desde las fases iniciales, mientras que las palabras de baja frecuencia serán procesadas a través de una estrategia de decodificación analítica hasta que sean aprendidas. De esta manera, los resultados de este estudio longitudinal apoyan el modelo de desarrollo por ítems de Share (1995) en lo que se refiere al desarrollo de la lectura léxica. Sin embargo, en lo que se refiere al aprendizaje del código alfabético y al desarrollo de la habilidad decodificadora, los modelos por fases (e.g., Ehri, 2005; Frith, 1986) son más acertados. Además, dado el carácter transparente que caracteriza al español (Defior & Serrano, 2014), esta transición de la etapa alfabética a la etapa ortográfica se realiza tempranamente.

En cuanto a las habilidades cognitivas relacionadas con el desarrollo lector, los resultados del estudio 1 indican que la conciencia fonológica, la habilidad visual y la velocidad de nombramiento son todos predictores pre-lectores significativos e independientes de la lectura. Los análisis de regresión múltiple (*path analyses*) revelaron que estas tres habilidades cognitivas contribuyen a la lectura diferentemente en función del periodo en el cual se evalúa la lectura (tabla 3). De esta manera, la conciencia fonológica demostró una gran influencia sobre la lectura de palabras a finales del último año de pre-escolar. Sin embargo, esta habilidad resultó ser irrelevante de ahí en adelante, sin contribuir de manera significativa a la lectura de palabras o pseudopalabras desde final de Primero hasta final de Cuarto. La habilidad visual predijo el nivel lector a partir de Primero, pero no durante pre-escolar, lo cual confirma que esta habilidad predice la lectura cuando los niños adquieren cierto nivel de experiencia lectora, pero no antes (Shapiro et al., 2013). La habilidad visual tuvo una mayor capacidad explicativa sobre la lectura de pseudopalabras (Primero, Segundo y Cuarto) que sobre la lectura de palabras (Primero). La velocidad de nombramiento demostró ser un poderoso predictor de la habilidad lectora, ya que contribuyó a la varianza en lectura de palabras y pseudopalabras en todos los cursos. Por lo tanto, el papel de cada uno de los predictores parece ser distinto dependiendo de la fase de aprendizaje en la cual se encuentre el lector.

La no contribución de la conciencia fonológica a la lectura al final de Primero es un resultado sorprendente, dada la gran cantidad de estudios que han encontrado que la conciencia fonológica es un predictor clave de la lectura (ej. Muter et al., 2004; Vellutino et al., 2004; Wagner & Torgesen, 1987). No obstante, es cierto que a medida que se han realizado estudios en sistemas escritos más transparentes que el inglés, se ha visto que el periodo durante el cual la conciencia fonológica ejerce una influencia sobre la lectura es muy limitado en lenguas con una ortografía regular (e.g., holandés: de Jong & van der Leij, 1999; español: Defior, 2008; finlandés: Leppänen et al., 2006; noruego: Lervåg et al., 2009). Este resultado, según el cual la conciencia fonológica no contribuye significativamente a la lectura de palabras ni de pseudopalabras después de Primero, definitivamente contradice la noción de que la CF esté permanentemente involucrada en las conversiones grafema-fonema, ya que estas son cruciales para la decodificación.

Nuestros resultados apoyan más bien la idea de que la conciencia fonológica juega un papel crítico en el aprendizaje del código alfabético (ej. Byrne & Fielding-Barnsley, 1989; de Jong & Olson, 2004). Los resultados también son consistentes con la hipótesis de la ‘opacidad operativa’ propuesta por Share (2008), la cual explica que el periodo de máxima influencia de la conciencia fonológica sobre la lectura corresponde a la etapa durante la cual el código alfabético aun le resulta opaco al lector novato. Dado el carácter transparente del código ortográfico del español, esta etapa solo se extiende hasta finales de Primero. Por lo tanto, los resultados del estudio 1 señalan que finales de Primero es un momento clave en la evolución de la lecto-escritura. Este es el periodo durante el cual los niños terminan de asimilar el código alfabético, la precisión lectora se aproxima al techo y la conciencia fonológica deja de ser un predictor significativo de la lectura. Más aún, finales de Primero es también el momento en el cual la velocidad lectora se convierte en el principal barómetro del nivel lector, la habilidad visual comienza a predecir la varianza en la lectura y la velocidad de nombramiento se convierte en el más importante predictor del rendimiento lector.

Estudio 2

Mientras que el primer estudio sirvió para aclarar los periodos durante los cuales las habilidades cognitivas asociadas con el desarrollo lector son significativamente influyentes, el segundo estudio se orientó a investigar en mayor detalle el rol específico desempeñado por la habilidad visual. Había un interés particular por esclarecer si la habilidad visual está principalmente involucrada en la lectura de palabras familiares o en la decodificación analítica de palabras no familiares. Por lo tanto, se examinó la contribución de la habilidad visual a la lectura en función de la familiaridad y la longitud de las palabras a leer. El estudio 2 solo tuvo dos evaluaciones: la primera en pre-escolar (común a los tres estudios) en la cual se administraron las pruebas cognitivas y la segunda en 3º de Primaria. Se administraron 4 listas de lectura, que se diferenciaron en dos factores (longitud y frecuencia léxica de las palabras). De esta manera, fue posible evaluar si la HV contribuía de manera diferente a la lectura de palabras largas de frecuencia alta, largas de frecuencia baja, cortas de frecuencia alta y cortas de frecuencia baja.

Los resultados indicaron que la habilidad visual, medida en la etapa pre-lectora, predice la velocidad lectora de palabras largas y no-familiares, pero no la velocidad lectora de palabras familiares (largas o cortas), ni de palabras cortas no-familiares (figura 4). La primera conclusión que se puede sacar de estos resultados es que la habilidad visual no parece estar involucrada en la lectura léxica de palabras familiares, lo cual contradice los resultados de muchos de los estudios que han encontrado una asociación significativa entre la lectura y la habilidad visual (francés: Bosse et al., 2007; inglés: Bosse & Valdois, 2009; español: Lallier et al., 2014; holandés: van den Boer et al., 2013). Posibles razones explicativas sobre estas diferencias en los resultados pueden ser el tipo de ítems utilizados y el momento en el cual se evaluó la habilidad visual. La mayoría de los estudios que han descrito una relación significativa entre la habilidad visual y la lectura léxica midieron la habilidad visual haciendo uso de letras, mientras que en este estudio se utilizaron símbolos no-verbales. Dado que el conocimiento de letras es un importante predictor de la lectura (Bowey, 2005), quizás este factor haya influido en los resultados de estos estudios.

Por otro lado, los estudios que han encontrado una asociación significativa entre la habilidad visual y la lectura léxica de palabras familiares (ej. francés e inglés: Bosse et al., 2007) midieron la habilidad visual cuando los participantes tenían varios años de experiencia lectora. Dado que la experiencia lectora ejerce una influencia transformadora sobre la habilidad visual (Dehaene et al., 2010; Duñabeitia et al., 2014; Perfetti et al., 2013), si se mide cuando ya ha comenzado la adquisición de la lectura, es posible que la experiencia lectora altere los niveles de habilidad visual. En tal supuesto, se observaría una relación significativa entre la habilidad visual y la lectura, pero causada por la influencia ejercida por la práctica lectora sobre el desarrollo de la habilidad visual y no al contrario. Por lo tanto, es importante prestar atención al periodo durante el cual se mide la habilidad visual. De igual manera, a la hora de entender la relación entre la lectura y la habilidad visual, es importante el periodo durante el cual se mide la lectura. De acuerdo con los resultados del estudio 1, se observó que la habilidad visual no contribuyó a la lectura durante pre-escolar, cuando los niños aun leían realizando lentas conversiones grafema-fonema de manera individual, lo cual sugiere que la habilidad visual tiene mayor importancia una vez que incrementa la velocidad lectora.

Asimismo, los resultados del estudio 2 señalan que la habilidad visual juega un rol en la decodificación de palabras no familiares. Varios estudios han alcanzado conclusiones similares (Auclair & Siéroff, 2002; Collis et al., 2013; Facoetti et al., 2006; Jones et al., 2008; Kinsey et al., 2004). Esto explicaría también porque en el estudio 1 la habilidad visual predijo la lectura de palabras de alta frecuencia en Primero, un periodo durante el cual todo tipo de palabras serían no familiares ortográficamente y, por lo tanto, seían decodificadas. Sin embargo, hay diferentes explicaciones sobre la función desempeñada por la habilidad visual en la decodificación. De acuerdo con Jones et al. (2008), la eficiencia de la orientación serial de la atención a lo largo de la secuencia de grafemas determina el rendimiento de la lectura analítica de palabras no conocidas. Otra perspectiva explica que el procesamiento visual de elementos múltiples determina el número de letras que pueden ser procesadas de manera simultánea durante la decodificación (Prado et al., 2007). Esta segunda explicación coincide más con los resultados del estudio, ya que la habilidad visual resultó estar significativamente relacionada con la lectura de palabras de baja frecuencia largas, pero no las cortas. Este resultado sugiere que el procesamiento visual de elementos múltiples es necesario para la decodificación únicamente cuando ésta requiere procesar un amplio número de letras (Hawelka & Wimmer, 2005), lo cual determina la velocidad lectora (Häikiö et al., 2009; Kwon et al., 2007; Lobier et al., 2013; Rayner et al., 2010).

Estudio 3

Este estudio consideró en detalle la relación entre la velocidad de nombramiento y la familiaridad ortográfica. Varias teorías han sido propuestas para explicar la fuerte y longitudinal relación que existe entre la velocidad de nombramiento, medida a través del RAN, y la lectura. Posiblemente, la teoría más discutida es aquella que entiende la velocidad de nombramiento como una medida de procesamiento ortográfico, definido como la habilidad de procesar grupos de grafemas de manera simultánea como unidades individuales. La familiaridad ortográfica determina el procedimiento lector a nivel léxico y subléxico. A nivel léxico, la representación ortográfica entera de una palabra familiar será reconocida de forma automática mientras que una palabra no familiar deberá ser decodificada (Share, 2008). Asimismo, la familiaridad ortográfica también determina el procedimiento lector a nivel subléxico. Cuando el lector encuentra una palabra desconocida pero ortográficamente familiar, los grupos de letras familiares de esa palabra serán procesados como unidades individuales (decodificación avanzada) (Ehri, 1998). Sin embargo, una palabra desconocida y además ortográficamente no familiar será procesada letra por letra (decodificación simple) (Ehri, 1998). Esta diferencia se manifiesta a través del efecto de la frecuencia silábica, el cual revela como pseudopalabras familiares (frecuencia silábica alta) son leídas con mayor rapidez que pseudopalabras no-familiares (frecuencia silábica baja) (ej. Carreiras & Perea, 2004).

Por lo tanto, para este estudio se manipuló la frecuencia léxica y la frecuencia silábica de los ítems con el objetivo de examinar la contribución del RAN tanto a la lectura de palabras familiares y no familiares, como a la lectura de pseudopalabras familiares y no familiares. Al igual que en los primeros dos estudios, la primera evaluación en la cual se administraron las pruebas cognitivas tuvo lugar en pre-escolar. En 5º de Educación Primaria se administraron 4 listas de lectura (palabras de frecuencia léxica alta y baja; pseudopalabras de frecuencia silábica alta y baja). También se hizo uso de los datos del estudio 1 de lectura de palabras y pseudopalabras desde 1º hasta 4º como medida de la experiencia lectora previa. Además, se incluyó una prueba de elección múltiple de conocimiento ortográfico en la cual la ortografía correcta de las palabras solo podía ser identificada por medio de conocimiento léxico.

Los resultados indicaron que RAN contribuyó de igual manera a la lectura, independientemente de la familiaridad ortográfica de las palabras. El RAN contribuyó también de manera significativa al rendimiento en la prueba de conocimiento ortográfico, pero en menor medida que a la lectura de pseudopalabras de frecuencia silábica baja (tabla 8). Estos resultados se interpretan como evidencia de que la velocidad de nombramiento no está específicamente involucrada en la lectura a través del procesamiento ortográfico, ya que contribuyó de manera comparable a la lectura de palabras de alta frecuencia (altamente familiares) como a la lectura de pseudopalabras de frecuencia silábica baja (altamente no familiares). Por el contrario, este patrón de resultados cambia cuando se controla en el análisis la experiencia lectora previa, donde se observa que RAN tiene una mayor capacidad explicativa de la varianza en la lectura de pseudopalabras que en los demás tipos de palabras. Más específicamente, los resultados indican que la contribución de RAN a la velocidad en la lectura de palabras parece depender en cierto grado de la experiencia previa, pero en menor medida en el caso de la lectura de pseudopalabras. Por lo tanto, si RAN contribuye principalmente a la decodificación, y dado que la decodificación facilita que el lector adquiera conocimiento ortográfico léxico (Share, 1995), la contribución de RAN a la lectura de palabras familiares podría ser indirecta y mediada a través de la decodificación.

A pesar de que los resultados de este estudio son evidencia firme de que la velocidad de nombramiento no juega un rol específico en el procesamiento ortográfico, no termina de aclarar qué tipo de habilidad cognitiva relacionada con la lectura es la que realmente mide RAN. Cuatro habilidades son necesarias tanto para completar el test RAN como para la lectura de palabras a lo largo del espectro de familiaridad ortográfica: (1) el procesamiento visual (Logan & Schatschneider, 2014), (2) la recuperación fonológica (Torgesen et al., 1994), (3) la formación de conexiones entre estímulos visuales y verbales (Manis et al., 1999) y (4) la recuperación fluida de información verbal a través de un estímulo visual (Moll et al., 2009).

Las dos primeras posibilidades pueden ser descartadas, ya que hay numerosas evidencias de que ni el procesamiento visual (ej. Landerl, 2001), ni la recuperación fonológica (ej. Jones et al., 2009) son responsables de la totalidad de la varianza en la lectura explicada por RAN. Asimismo, RAN contribuye de manera directa a la lectura de pseudopalabras de frecuencia baja, aun cuando se controla la experiencia previa. Este resultado indica que la velocidad de nombramiento está involucrada de manera directa en la decodificación, pero no a través de la formación de conexiones grafema-fonema. Si midiese la formación de conexiones entre estímulos visuales y verbales (Manis et al., 1999), no contribuiría a la lectura de pseudopalabras una vez controlada la experiencia lectora previa, ya que las conexiones grafema-fonema fueron establecidas años atrás. Por lo tanto, investigaciones futuras deberían examinar la posibilidad de que el RAN mida la recuperación fluida de información verbal a través de un estímulo visual (Moll et al., 2009).

Conclusiones Generales

Este trabajo tuvo como finalidad principal dilucidar de forma empírica la influencia de las principales habilidades cognitivas de interés sobre el proceso de adquisición de la lectura en español. Los hallazgos de esta tesis son de gran interés por las implicaciones para la comprensión de las estructuras responsables de la habilidad lectora en lenguas con ortografías transparentes. Contrariamente a los resultados obtenidos en otros estudios sobre los factores predictores de la lectura en inglés, la conciencia fonológica no parece tener una influencia tan prolongada en español. La explicación que más concuerda con los resultados obtenidos es que la conciencia fonémica ejerce una labor crítica y directa en el momento de aprendizaje de las correspondencias grafema-fonema. Este estudio también presenta evidencia de que la habilidad visual juega un papel crucial en el desarrollo de la habilidad lecto-escritora. Su importancia podría venir dada de la necesidad de procesar con rapidez y precisión grupos de grafemas durante la decodificación de palabras no familiares. En lo que se refiere a la velocidad de nombramiento, el principal hallazgo de esta tesis es la evidencia obtenida señalando que RAN no mide la capacidad de procesamiento ortográfico, sino probablemente la fluidez de las conversiones visual-verbales.

Desde un punto de vista aplicado, la actividad de los profesionales de la educación puede beneficiarse de varias de las conclusiones de esta tesis. En primer lugar, hemos visto que es posible predecir el nivel de lectura futuro, al igual que posibles problemas en su desarrollo, desde la etapa pre-lectora del niño a través de la aplicación de test de las habilidades cognitivas asociadas, antes del inicio del aprendizaje lector. Este conocimiento puede ayudar a maestros y profesionales de la educación a evaluar y diagnosticar, e igualmente prevenir, futuros déficits en el proceso de adquisición de la lectura. Si un niño en riesgo de problemas lecto-escritores puede ser diagnosticado durante un periodo temprano, de alta plasticidad cerebral, podría evitarse el fracaso en tareas ligadas a la lectura. Asimismo, la velocidad de nombramiento se ha manifestado como un importante predictor longitudinal de la lectura, independientemente del periodo de desarrollo y del tipo de palabra a leer. Este resultado permite identificar el test RAN como una herramienta altamente valiosa a la hora de evaluar la predisposición del alumno para desarrollar una lectura fluida (Georgiou et al., 2006; Lervåg & Hulme, 2009). En cualquier caso, son necesarios más trabajos de investigación en esta área para dilucidar con mayor precisión cuál es el papel que juegan las habilidades fonológicas, visuales y de velocidad de nombramiento en el aprendizaje lector.

Introduction

Most children are able to adequately develop the skills which are necessary to learn how to read in an accurate, fluid and proficient manner. Nevertheless, some children struggle to acquire these competencies. These include the skill to effectively learn the correspondences between graphemes and phonemes, the skill to accurately and rapidly decode the letter strings that form unfamiliar words, the skill to register and recognize the orthographic pattern of previously known words, as well as the comprehension to understand sentences and text. Among many other factors (e.g., quality of instruction, home literacy environment or emotional stability), whether or not children succeed in developing these skills depends on the proficiency of certain reading-related cognitive abilities. While much effort has already been dedicated to identifying the abilities which need to operate efficiently in order for the whole system to function correctly, there are still several crucial, yet unresolved, issues regarding the understanding of these cognitive abilities.

During several decades of research in the field of literacy acquisition many cognitive abilities have been reported as being important in the acquisition of reading. This thesis will focus on three of the most relevant ones. Despite the fact that a robust link to reading skill acquisition has been extensively documented (Bowey, 2005, for a review), for two of these cognitive abilities, phonological awareness and naming speed, many questions remain regarding their role in reading skill acquisition. The relevance of another cognitive ability, visual processing skill, has been intensely contested in recent years. However, at present its role is even less understood than that of naming speed or phonological awareness. Determining where these cognitive abilities fit within the underlying mechanisms of learning to read still remains a rather elusive question at the core of an ongoing debate (Lervåg, Bråten, & Hulme, 2009; Moll, Ramus, Bartling, Bruder, Kunze, Neuhoff,... & Landerl, 2014; van den Boer, de Jong, & Haentjens-van Meeteren, 2013; Vidyasagar & Pammer, 2010). One unresolved issue is whether the influence of these abilities varies depending on the language in which the child learns to read. Other unanswered questions pertain to the precise role performed by each of these abilities and the period in reading development during which these cognitive abilities come into play. Additional longitudinal studies are needed which can examine the periods of reading development during which these cognitive abilities are most influential and the specific reading strategies to which they predominantly contribute.

Throughout the last 40 years several reading models have been proposed in attempts to synthesize our knowledge about how reading skill is learnt and applied. Developmental reading models offer us an overview of how children evolve through the different periods in their path from novel to proficient readers. Many stage-based models (e.g., Ehri, 2005; Frith, 1986) agree that an initial phase towards learning to read is assimilating the code by which letters will be translated into sounds. These models also converge in that, in order to increase reading speed, during the subsequent phase the reader learns to process commonly occurring groups of letters as individual units. Other developmental models (Share, 1995; Wolf, 2008) conceive the process of learning to read as a continuum rather than stage-based. Share's (1995) item-based model describes how, while all words are initially unfamiliar, every time a word is decoded the reader profits from a self-teaching opportunity to encode the whole orthographic representation of that word. Once the orthographic representation of that word has been fully encoded it will be rapidly recognized as a whole the next time it is encountered. Likewise, numerous models of skilled reading also envisage that word familiarity is the main factor which will determine whether a word is decoded through grapheme-to-phoneme (GtP) conversions or is recognized as a whole through direct-retrieval mechanisms.

Regardless of the specific reading model, they all propose that different reading strategies or procedures are implemented depending on the reader's knowledge and expertise. Therefore, the reading procedure being implemented will vary depending on the familiarity of the word being read and the developmental period in which the reader finds him or herself. Consequently, a cognitive ability which is particularly important during a specific moment of development will correlate with reading, or not, depending on the learning phase in which reading is assessed. Furthermore, a cognitive ability which is crucial for a specific reading procedure (e.g., decoding vs. sight-word reading) will correlate, or not, with reading depending on the type of word with which reading is being assessed. This variability could lead to confusion when attempting to interpret results if little attention is being paid to the type of word used in the reading tests or the period of development in which reading is being assessed. On the other hand, manipulating psycholinguistic factors such as word type (e.g., known vs. novel words) and observing how reading performance varies depending on the school grade can be extremely useful tools to investigate the specific role played by reading-related cognitive skills.

Developmental reading models shed light on what learning episode takes place at each age period or school grade and the specific reading procedures which are invoked.

The cognitive ability which is most commonly associated with reading skill development is phonological awareness, defined as the conceptual understanding and explicit awareness that spoken words consist of individual speech sounds (phonemes) and combinations of these speech sounds (syllables, onset-rime units) (Defior, 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004). An individual's phonological awareness tends to significantly correlate with his or her reading performance. While the reading-phonological awareness relationship has been thoroughly studied in the past few decades, there are still some inconsistencies within the literature which deserve closer examination. More specifically, phonological awareness is regularly argued (1) to be necessary to learn the alphabetic code, and (2) to assist with GtP conversions. However, many studies have found that the reading-phonological awareness relationship weakens as the reader advances through primary school (e.g., Badian, 2001; Kirby, Parrila, & Pfeiffer, 2003). This is particularly true for languages with regular orthographic systems (e.g., Dutch: Vaessen & Blomert, 2010; Finnish: Leppänen, Niemi, Aunola, & Nurmi, 2006). The weakening correlation between phonological awareness and reading, as the child gains experience, appears to contradict the understanding that phonological awareness is involved in performing the GtP conversions which are necessary for decoding. Therefore, one goal of this thesis is to clarify whether the predominant role of phonological awareness is to assist with performing GtP conversions in an ongoing basis or merely to support the learning of the GtP correspondences early on in reading acquisition.

A second cognitive ability known as naming speed, referring to the speed at which an individual can name a number of familiar objects, pictures, letters or digits, is often measured by means of a task called Rapid Automatized Naming (RAN). Scores obtained in the RAN task have been repeatedly reported to correlate with different measures of literacy performance, most especially reading speed. This relationship has been observed not only in English but in many other alphabetic scripts. There is little doubt within the literacy research field that naming speed, as measured by the RAN task, is important for fluent reading performance. However, while numerous theories have been proposed over the years to explain the nature of the RAN-reading relationship, the precise role played by naming speed in reading has yet to be resolved. One of the most accepted theories explaining why RAN correlates with reading submits that RAN measures orthographic processing, understood as an individual's ability to process a familiar letter-string as an individual unit. In this thesis, word familiarity and sublexical orthographic familiarity will be manipulated in order to clarify whether RAN truly relates to orthographic processing defined in this way.

Visual processing skill is a third cognitive variable that has been linked to reading development. While the most established perspective is that reading skill deficits are phonological in nature, in recent years an increasing amount of attention has been granted to alternative evidence which suggests that visual factors might also play a significant role in reading skill acquisition and reading performance. However, studies assessing the relevance of visual processing skills to reading have produced mixed and inconclusive results. One of the methodological issues at the source of the uncertainty regarding this topic is that visual skills are known to improve with reading experience. Therefore, when observing a reading-visual skills relationship it is difficult to determine whether it is visual skills which are influencing reading or vice versa. Furthermore, some studies have found visual skills to contribute to reading during certain periods of development while other studies examining reading during different timeframes have found contradicting results. It is possible, therefore, that visual skills are involved in reading acquisition only during specific stages of reading skill development. Moreover, even if visual skills are involved in reading it remains largely unclear whether they predominantly assist with decoding or with sight-word reading. Therefore, another goal of this thesis is attempting to answer what type of reading procedure are visual skills involved in and during what periods.

A further source of debate within the field of literacy acquisition concerns the validity of results obtained in one language to the understanding of literacy acquisition in other languages. For instance, developmental reading models have for the most part been elaborated to understand the process of reading skill acquisition in English. The English language has an orthographic system which, due to its exceptional letter-sound associations, has been argued not to be representative of other languages with more regular orthographic systems (Share, 2008). Therefore, it is not clear to what extent these models apply to other alphabetic scripts. Consequently, as the majority of research regarding the importance of reading-related cognitive abilities has been carried out using English as the language of study, this raises questions about the relevance to other orthographies of results obtained with English-speaking samples. To this end, this thesis will provide a valuable addition to the work already carried out in English and will help establish whether or not the models elaborated for English and the results obtained in English are applicable to transparent orthographies.

The coming section will provide the overall theoretical framework which supports the three studies which constitute the core of the thesis. These studies have been conducted in order to achieve the main goal of the thesis: to further understand the role played by visual processing skill, naming speed and phonological awareness within the process of reading skill acquisition in a transparent orthography. The first study will focus on verifying to what extent English-based models of reading development apply to the Spanish orthography and, more importantly, observing during which developmental periods the cognitive abilities of interest are most influential. The second study aims to shed light on the role played by visual processing skills, measured through a multi-element processing task, on reading performance. By manipulating word-familiarity and word-length we will assess the contribution by visual skills to decoding and sight-word reading. The focus of the third study will be the role of naming speed, as measured by the RAN task, to orthographic processing. Orthographic syllable frequency will be manipulated in order to assess the contribution made by naming speed skill to reading of words which vary in orthographic familiarity. One section will be dedicated to each of these studies and the theoretical implications of the results as a whole will be reflected upon in the final discussion section.

Theoretical Framework

Reading Development

Many theoretical reading models have been elaborated with the aim of clarifying the developmental learning processes through which children evolve until they can proficiently extract meaning from text. Several models of reading development in the English orthography describe how novice and more skilled readers use different procedures to read (e.g., Chall, 1983; Ehri, 2005; Frith, 1986; Seymour & Duncan, 2001; Share, 1995; Stuart & Coltheart, 1988; Wolf, 2008). Stage-based models such as those provided by Ehri (2002; 2005) or Frith (1986), converge in their understanding that a transition occurs from a slow letter-by-letter reading phase to a phase where larger orthographic forms are processed together in a faster manner. Continuous models, like Share's self-teaching hypothesis (1995), argue that word recognition will depend primarily on the frequency of any particular word to which a child has been exposed. Unknown words will be sublexically decoded, while known words will be recognized from memory and directly read by sight. They are referred to as continuous because they are based on the progressive transition through which individual words turn from unfamiliar to familiar. Regardless of the specifics of each model, they all converge in their understanding that, as the child gains experience, a transition occurs from an initial period where letters are being learned and processed individually, through a period where larger orthographic forms are processed in a faster manner, culminating when the reader becomes proficient and lexical reading predominates.

Stage-Based Developmental Reading Models

According to Ehri's phase theory (Ehri, 2002; 2005), the learning process initially evolves through the partial and full alphabetic phases, an early period during which beginner readers learn the GtP correspondences. As soon as the children understand the GtP correspondences for the vowels and a few common consonants, they can begin to read words through basic decoding, i.e., translating individual written symbols into a sound based representation (Frith, Wimmer & Landerl, 1998; Wesseling & Reitsma, 2002). Frith's (1986) alphabetic phase, Høien and Lundberg's (2000) alphabetic-phonological phase, as well as Seymour and Duncan's (2001) foundational literacy phase, all share many similarities with Ehri's (2005) partial and full alphabetic phases. It is during this period that the novice reader understands the relationship between letters and sounds and begins to engage in sequential and individual GtP conversions. From the very beginning of this period the children can start to read words by applying this slow sequential decoding strategy, albeit making numerous errors (Ehri, 2005). At this point in development, the number of errors that the child makes while reading will be directly related to the number of GtP correspondences which he or she has assimilated. This is the probable reason why letter knowledge of school entrants strongly predicts early reading performance (e.g., Caravolas, Lervåg, Mousikou, Efrim, Litavský, Onochie-Quintanilla... & Hulme, 2012; Lervåg et al., 2009; Muter et al., 2004).

The GtP correspondences known by a child before being introduced to the alphabet in school is probably determined by the extent to which s/he has been taught/exposed to those letters away from the school (e.g., at home). Since learning the letters is a precondition to reading (Ehri, 2005) the early correlation between letter knowledge and reading skill should not come as a surprise. Obviously, children who know plenty of letters can read more words correctly than children who know fewer letters. However, once the children master most GtP correspondences they become able to proficiently use their newly-acquired understanding of the decoding rules to accurately decode all regularly spelled words (Ehri, 2005). Moreover, learning to write strengthens the understanding of the alphabetic code and becomes a substantial aid toward attaining decoding-accuracy, and vice versa (Conrad, 2008; Frith, 1985). Nevertheless, while reading accuracy is indeed necessary, it is not sufficient to acquire reading proficiency. Once accuracy approaches ceiling, reading speed becomes the main discriminating measure of developmental differences, and this is especially true for transparent orthographies.

Once decoding accuracy has been mastered, during Ehri's so-called consolidated alphabetic phase (Ehri, 2005), which is roughly equivalent to the orthographic phase described by other authors (Frith, 1986; Seymour & Duncan, 2001; Stuart & Coltheart, 1988), decoding speed continues to increase through the implementation of orthographic processing. Orthographic processing occurs when the reader unitizes familiar letter-clusters consisting of frequent spelling patterns (e.g., syllables or morphemes) or whole words, and mapping them onto their phonological counterparts. Therefore, rather than relying on effortful letter-by-letter processing, children turn from simple decoding (grapho-phonemic) to advanced decoding (grapho-syllabic), the latter being faster and less demanding (Ehri, 1998). Indeed, it has been argued that one-to-one GtP correspondences are theoretically important only for a limited span of time during the acquisition of reading skills (Wesseling & Reitsma, 2000). However, the encompassing process by which the reader processes familiar multi-letter orthographic patterns as individual units, commonly referred to as unitization (Ehri, 2005; LaBerge & Samuels, 1974), not only serves to develop advance decoding, but also whole-word reading. Lastly, the progressive development of automaticity characterizes mature readers who recognize most words automatically by sight and apply advanced decoding when reading unfamiliar words (Ehri & McCormick, 1998).

Share's Self-Teaching Hypothesis

Continuous reading models propose that reading development is a progressive process with no distinct phases. According to Share's developmental model (Share, 1995; 1999; 2008) unknown words are sublexically decoded, while known words are read lexically. The act of decoding (which Share refers to as 'phonological recoding') performs a self-teaching function which enables the learner to acquire the detailed orthographic representations necessary for fast, efficient visual word recognition in subsequent encounters. Numerous studies support the idea that being able to decode the entire orthographic representation of a word leads to visual orthographic learning of that word (Bhattacharya & Ehri, 2004; Bosse, Chaves, Largy & Valdois, 2013; Cunningham, Perry, Stanovich & Share, 2002; Share, 1999). This self-teaching device allows a child to independently develop the word-specific orthographic entries essential for spelling and lexical reading. The more words the child decodes, the more words which are added to the orthographic lexicon. Therefore, word recognition will depend primarily on the frequency with which a child has been exposed to a particular word. There is ample evidence that exposure to print (a measure of reading experience) is reliably linked to differences in orthographic processing ability not explained by phonological abilities (e.g., Cunningham & Stanovich, 1993; Griffiths & Snowling, 2002; McBride-Chang, Manis, Seidenberg, Custodio, & Doi, 1993; Shapiro, Carroll, & Solity, 2013). Furthermore, the enrichment of the orthographic lexicon initiates as soon as kindergarten (Ehri & Wilce, 1987, Ehri & Sweet, 1991; Share; 1995). Therefore, decoding and sight-word learning develop in parallel.

Despite the differences inherent in the described models, they also share some commonalities. Firstly, many developmental reading models (e.g. Backman, Bruck, Hebert, & Seidenberg, 1984; Ehri, 2005; LaBerge & Samuels, 1974; Share, 1999, 2008) converge in their understanding that orthographic familiarity determines how print will be processed. Focusing on Ehri's (2005) and Share's (1995) models, they both agree that there is a period when most words are unknown and therefore decoding predominates, as well as a later period when the reader is proficient and words are predominantly processed as a whole. Furthermore, Share (1995) concedes that, while initially unknown words are processed through individual letter-by-letter reading, once the reader is more experienced, unknown words are processed by decoding familiar groups of letters. Likewise, according to both models sight-word reading for some words commences from early on in the process of reading skill acquisition. Therefore, both continuous and stage-based models agree that different reading procedures are being applied at different periods in development. Throughout the rest of this thesis we will refer to these periods as follows: the alphabetic phase as the initial literacy acquisition period during which the GtP correspondences are being learned; the orthographic phase as the period when groups of letters begin to be decoded as individual units; and lexical reading as the period during which automatic recognition of sight words develops.

Models of Skilled Reading

Models of skilled single-word reading can be primarily divided into two categories. On the one hand, there are dual route models (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) which posit that the reader will use a serial decoding strategy when encountering novel or unfamiliar words and a lexical reading strategy when encountering known or familiar words. In order to apply the former, the word's sub-lexical orthographic units are sequentially converted into their phonological counterparts. Conversely, a known word is holistically recognized as a whole unit and its whole-phonological representation is retrieved from memory instantly. Although these two processes have been assigned many labels, we will mostly use the terms decoding (also referred to as phonological recoding or analytic reading procedure) and sight-word reading (also referred to as lexical reading, whole-word orthographic processing or global reading procedure). On the other hand, connectionist models (e.g., Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) try to simulate reading skill learning through the neuronal networks on which it is based. These models submit that the strength of the connections between orthography, phonology and semantics depends on, and increases through practice and repetition. Alternatively, connectionist dual process models which build on the strengths of two of the previous types of models have also been proposed (Perry, Ziegler, & Zorzi, 2007; Zorzi, Houghton, & Butterworth, 1998).

Regardless of their contrasting perspectives, models of skilled single-word reading share one crucial characteristic with developmental reading models. The majority of these models emphasize the critical importance of word familiarity. According to dual route skilled-reading models (e.g., Coltheart et al., 2001), connectionist skilled-reading models (e.g., Ans, Carbonnel, & Valdois, 1998), stage-based developmental models (e.g., Ehri, 2005) or continuous developmental models (e.g., Share, 2008), whether a written word is sublexically decoded or holistically recognized as a unit will depend upon how familiar that word's orthographic representation is to the reader. Therefore, reading strategy/procedure is determined by orthographic familiarity. In agreement with the notion that familiarity determines reading procedure, familiarity-related psycholinguistic factors have been reported to exert the strongest effects on reading speed. Age-of-Acquisition, for instance, has been reported to be the strongest correlate to word naming (e.g., English: Brown & Watson, 1987; Japanese Kanji: Yamazaki, Ellis, Morrison, & Ralph, 1997; Spanish: Cuetos & Barbón, 2006).

The frequency effect, whereby high frequency words are processed faster than matched low frequency words, is another familiarity-related psycholinguistic factor which has been extensively described (e.g. English: Balota & Chumbley, 1984; Connine, Mullennix, Shernoff, & Yelen, 1990; Rayner & Duffy, 1986; Italian: Barca, Burani, & Arduino, 2002; Dutch: Grainger, 1990; German: Kliegl, Grabner, Rolfs, & Engbert, 2004; Spanish: Carreiras, Alvarez & De Vega; Defior, Justicia & Martos, 1996; Jiménez, González & Hernández-Valle, 2000). This evidence concurs with the understanding that familiar words are read by sight, while unfamiliar words are decoded. The length effect, by which shorter words are processed faster than longer words (English: Weekes, 1997; Dutch: Marinus & de Jong, 2010; Spanish: Defior et al., 1996; Cuetos & Barbón, 2006), tends to be larger for unfamiliar words, which must be linearly decoded, than for familiar words, which are automatically recognized and processed in a parallel manner. Thus, the size of the length effect between short and long words can indicate the type of reading taking place – sight word reading in the case of a small length effect and decoding in the case of a large length effect.

Although developing adequate accuracy and speed are critical aspects of proficient reading, being able to extract meaning from text is the ultimate goal of acquiring the skill of reading. While other skills like prosodic- (Calet, Gutiérrez-Palma, Simpson, González-Trujillo, & Defior, 2015), syntactic- (Cain, 2007) or morphological- awareness (Tong, Deacon, Kirby, Cain, & Parrila, 2011) have been reported to play a role in reading comprehension, the simple view of reading (Hoover & Gough, 1990) submits that reading comprehension is primarily dependent upon two skills, decoding ability (when referred to as reading accuracy and fluency) and listening comprehension. Crucially, it appears that different reading skills share attentional resources. When reading text, unknown words encountered by the novice reader will require slow and effortful decoding. This will in turn disrupt ongoing comprehension processes by demanding the available cognitive resources (Perfetti, 1985; Share 1995). In contrast, the automaticity achieved by the proficient reader will free up limited attentional resources which can be allocated to reading comprehension (LaBerge & Samuels, 1974). Therefore, if one particular skill (e.g., decoding) siphons additional resources, this could impact negatively on the adequate functioning of another skill (e.g., comprehension). However, while the main purpose of reading is being able to comprehend the content of the text which is being read, this thesis will focus on observing the underlying cognitive mechanisms which are relevant to the acquisition of reading skill.

Development Depends on Orthographic Transparency

A specific doubt regarding reading development is whether the developmental reading models which have been proposed for English are relevant to other orthographies. Due to its exceptional spelling-sound correspondence when compared to more transparent orthographies (Ellis & Hooper, 2001; Frith et al., 1998; Seymour, Aro, & Erskine, 2003), English has been argued to be an outlier orthography (Share, 2008). While the main principle of all alphabetic orthographies is that graphemes represent specific phonemes in speech, the consistency of GtP mappings differs from one script to another. English is considered the least consistent of all alphabetic scripts (Ziegler, Stone, & Jacobs, 1997), which is the likely explanation why development of decoding skills takes longer in English than in other more consistent orthographies (Katz & Frost, 1992; Seymour et al., 2003; Share, 2008; Ziegler & Goswami, 2005). Similarly to other transparent alphabetic scripts (e.g., Italian: Angelelli, Notarnicola, Judica, Zoccolotti, & Luzzatti, 2010; German: Moll, Fussenegger, Willburger, & Landerl, 2009; Wimmer & Mayringer, 2002), Spanish is an asymmetric orthography (Defior, Jimenez Fernandez, & Serrano, 2009), meaning that it is characterized by forward regularity (grapheme–phoneme conversion) more than by backward regularity (phoneme–grapheme conversion) (Desimoni, Scalisi, & Orsolini, 2012). Therefore, in the Spanish orthography there are no inconsistencies in reading and it has an almost perfect consistency in GtP correspondence (Goikoetxea, 2006; Katz & Frost, 1992; Thonis, 1983).

The English orthographic system consists of 26 alphabetic letters (21 consonants and 5 vowels) which can be orthographically combined to generate up to 250 graphemes (Caravolas, 2006), representing at least 44 phonemes (Fashola, Drum, Mayer, & Kang, 1996; Stockwell, Bowen, & Martin, 1965). In contrast, the 27 letters of the Spanish alphabet combine to form no more than 30 graphemes (Cressey, 1978; Fashola, Drum, Mayer, & Kang, 1996), which represent no more than 25 phonemes (Defior & Serrano, 2014; Goikoetxea, 2006). Spanish is a phonetic language which has a very consistent set of phonics rules, with the 5 vowel-letters representing only 5 vowel-phonemes in a consistent one-to-one correspondence. Of the Spanish graphemes, the 5 vowels plus 19 consonants each represent a unique sound (Goikoetxea, 2006). The only exceptions are three context-dependent consonants (c, g, and r) for which the correct pronunciation is strictly governed by simple orthographic rules (Goikoetxea, 2006). Bearing in mind the substantial differences in terms of orthographic consistency, it is conceivable that the models of reading development which have been proposed for the opaque English orthography might not fully apply to transparent orthographies like Spanish.

Firstly, the simple alphabetic code of transparent orthographic systems should result in most children learning the GtP correspondences with relative ease and decoding becoming a reasonably straightforward task. In accordance with this view, in transparent orthographies such as Spanish, Finnish or German, accuracy levels for both words and non-words approach ceiling by the end of Grade 1 (Aro & Wimmer, 2003; Defior, Martos, & Cary, 2002; Genard, Alegria, Leybaert, Mousty, & Defior, 2005; Serrano, Genard, Sucena, Defior, Alegria, Mousty,… & Seymour, 2011; Seymour et al., 2003). Since high-levels of accuracy are characteristic of transparent orthographies after this point, reading speed becomes the main indicator of reading performance (e.g., Spanish: Serrano & Defior, 2008; German: Wimmer, 1993; Finnish: Müller & Brady, 2001).

There are other aspects of reading development which appear to be common to most alphabetic scripts. Despite the evidence that orthographic transparency modulates the grain size of orthographic processing (Lallier, Carreiras, Tainturier, Savill, & Thierry, 2013), sublexical multi-letter processing is known to occur both in highly transparent orthographies (Spanish: Perea & Carreiras, 1998; Italian: Burani, Marcolini & Stella, 2002) as in more opaque scripts (English: Goswami, Gombert & De Barrera, 1998; Treiman, Goswami, & Bruck, 1990; French: Ecalle & Magnan, 2007; Sprenger-Charolles & Siegel, 1997). Likewise, similarly to English, in transparent orthographies the transition to lexical reading is a continued process which already begins in early stages of reading acquisition (Italian: Orsolini, Fanari, Tosi, De Nigris & Carrieri, 2006; Zoccolotti, de Luca, Di Filippo, Judica, & Martelli, 2009; Turkish: Öney, Peter, & Katz, 1997).

Specifically regarding reading development in the Spanish orthography, several studies have found indications of a progressive transition from sublexical to lexical reading (Avdyli, Castejón, & Cuetos, 2014; Castejón, Rodríguez-Ferreiro, & Cuetos, 2013; Castejón, González-Pumariega & Cuetos, 2015; Cuetos & Suárez-Coalla, 2009; Davies, Seijas, & Cuetos, 2007; Valle-Arroyo, 1996), but no evidence of a distinct transition between the alphabetic to the orthographic phase (Castejón et al., 2015; Cuetos & Suárez-Coalla, 2009). Furthermore, the simple one-to-one correspondence between graphemes and phonemes allows children to rapidly master the skill of decoding (Cuetos & Suárez-Coalla, 2009; Defior et al., 2002; Genard et al., 2005). One idiosyncrasy of the Spanish language is its marked syllabic structure, with the syllable being the functional unit of the reading process. Therefore, decoding of novel polysyllabic words is accomplished by parsing syllabic structures into their corresponding orthographic units, which makes syllable-frequency instrumental for decoding speed (Alvarez, Carreiras, & Taft, 2001; Conrad, Carreiras, & Jacobs, 2008; Luque, López-Zamora, Álvarez, & Bordoy, 2013; Perea & Carreiras, 1998). Clarifying to what extend the developmental reading procedures described by reading models apply to learning to read in Spanish can be of great assistance to further understand the role played by reading-related cognitive abilities.

The theoretical context presented by the reviewed reading models offers suitable templates which are helpful for the purpose of gaining insight into the underlying cognitive systems that enable reading skill acquisition. For instance, during the alphabetic phase, progress will be dependent on cognitive abilities which assist in learning the GtP correspondences. A cognitive variable which correlates with reading during this developmental period but not thereafter may play a role in establishing letter-sound mappings. Cognitive abilities which are not important during this early period but become relevant later on will likely be involved in orthographic processing, lexical reading or general reading speed/fluency. Furthermore, given that unfamiliar words are decoded while familiar words are read by sight, cognitive abilities which play a role in serial analytical processing (decoding) will correlate further with unfamiliar-word reading (e.g., non-word or low-frequency word reading). Likewise, cognitive abilities which are more involved in sight-word reading will correlate more strongly with familiar-word reading (i.e., reading of high-frequency words). Therefore, by manipulating psycholinguistic factors which determine reading procedure and by paying attention to the processes which take place during different developmental periods, we can better understand the relevance of reading-related cognitive abilities to reading skill acquisition.

Phonological Awareness Skills

Out of the all the primary skills which have been shown to be involved in the process of reading acquisition phonological awareness is the most acknowledged one. Phonological awareness refers to the ability to identify and manipulate units of oral language (Wagner & Torgesen, 1987). It is a general term which comprises a broad set of skills. Some of these skills are the so-called phonemic awareness, syllabic awareness, intra-syllabic awareness, or rhyme awareness, referring to the ability to identify and manipulate phonemes, syllables, onset-rimes and rhymes, respectively. Phonemes are the smallest units comprising spoken language. A child with adequate phonemic awareness should be able to segment and blend phonemes into syllables and words or identify the beginning and ending sounds in a word. Similarly, a child with adequate syllabic awareness should be able, for instance, to break spoken words into syllables. Likewise, a child with adequate intra-syllabic awareness should be able to identify and match the beginnings and endings of words. Finally, a child with adequate rhyme awareness should be able to detect rhymes. Given that phonological awareness applies to several different skills which are highly interrelated, it is often used as an umbrella term when alluding to any of them. Furthermore, phonological awareness provides the basis for the teaching of phonics, which can be defined as the understanding of the specific relationship between graphemes and their corresponding phonemes (Rose, 2006).

Within the research field of literacy acquisition, it is widely accepted that phonological awareness is intricately linked with learning to read. Especially in the English orthographic system there is ample evidence of the foundational importance of phonological awareness to reading skill acquisition (Byrne & Fielding-Barnsley, 1989; Muter, Hulme, Snowling, & Stevenson, 2004; Vellutino et al., 2004; Wagner & Torgesen, 1987). In fact, phonological skill deficiencies associated with phonological coding deficits are thought to be the main probable cause of the dyslexic disorder (Vellutino et al., 2004). More specifically, an extensive amount of research on the field of reading skill development has established importance of phonemic awareness (PA) as a foundation of reading in English (Muter et al., 2004; Wagner & Torgesen, 1987) as well as in many of other writing systems (e.g., Norwegian: Lervåg et al., 2009; Czech: Caravolas, Volín, & Hulme, 2005; German: Landerl & Wimmer, 2008; Turkish: Öney & Durgunoglu, 1997), including Spanish (Defior & Tudela, 1994; Carrillo, 1994; Suárez-Coalla, García-De-Castro, & Cuetos, 2013).

It is thought that the reason phonemic awareness is a crucial factor in the acquisition of reading skill is because it assists with learning how to convert graphemes into phonemes. A wealth of evidence indicates that grapheme-phoneme knowledge and phonemic awareness are the basis to begin acquiring the skill of reading (e.g., Bradley & Bryant, 1983; Juel, Griffith, & Gough, 1986; Share, 1995). Byrne and Fielding-Barnsley (1989) argued that the combination of phonemic awareness and grapheme-phoneme knowledge is needed for acquisition of the alphabetic principle. Furthermore, it has been proposed that an awareness of phonemes is a prerequisite of the ability to segment letter strings into phoneme-based units and to blend the resulting phonemes into words (Wagner & Torgesen, 1987). Decoding requires the skill of blending phonemes together in order to transform graphemes into recognizable words (Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh, & Shanahan, 2001). In line with the notion that phonemic awareness is crucial for accurate decoding, phoneme sensitivity tasks have been consistently reported to correlate with decoding skills (e.g., Manis, Seidenberg, & Doi, 1999; Sunseth & Bowers, 2002; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997).

The Reciprocal Relationship between PA and reading requires a Longitudinal Approach

An important characteristic of the bond between PA and decoding is that it is marked by a strong reciprocal connection (Bentin & Leshem, 1993; Hogan, Catts & Little, 2005; Hulme, Caravolas, Malkova, & Brigstocke, 2005; Perfetti, Beck, Bell, & Hughes, 1987). This means that while PA assists the child in learning to read, learning to read in turn provides explicit knowledge of the phonological structure of language. This newly-acquired awareness granted by reading experience complements the largely tacit knowledge acquired from experience at listening and speaking (Wagner & Torgesen, 1987). We know reading experience influences phonological skill because several studies have shown that phoneme awareness does not arise naturally outside the context of learning to read an alphabetic script (de Santos Loureiro, Braga, do Nascimento Souza, Filho, Queiroz, & Dellatolas, 2004; Morais, Cary, Alegria, & Bertelson, 1979). Evidence gathered from an extensive amount of research reveals that adult illiterates (people who have not learned to read and write) have great trouble performing phonemic awareness tasks (Bertelson, de Gelder, Tfouni, & Morais, 1989; Morais, Bertelson, Cary, & Alegria, 1987; Morais & Kolinsky, 2005). Furthermore, it must be pointed out that both literates and illiterates exhibit similar levels of syllabic awareness, as measured through syllabic vowel deletion and rhyme judgment tasks (Bertelson et al., 1989), which indicates that it is the awareness of individual phonemes which is most notably transformed by reading experience.

Furthermore, children learning to read by rote in a non-grapho-phonemic script, such as Chinese, have been shown to have difficulty segmenting speech into phonemes (Mann, 1987; Read, Zhang, Nie, & Ding, 1987) and have been reported not to develop phoneme awareness to the same level as children learning to read in an alphabetic script (Huang & Hanley, 1995). These findings suggest that phonemic awareness does not arise spontaneously in the normal course of cognitive and linguistic development but only in the specific context of learning to read in an alphabetic script (Share, 1995). Moreover, the influence that literacy acquisition in a grapho-phonemic script has on children's phonological ability has also been documented in opaque and transparent orthographies (e.g., English: Ehri & Wilce, 1980; Hogan et al., 2005; Spanish: Aguilar-Villagrán, Marchena-Consejero, Navarro-Guzmán, Menacho-Jiménez, & Alcale-Cuevas, 2011). Studies investigating the reciprocal influence of reading acquisition and phonemic awareness have found that learning to read is the most important factor accounting for the improvement of phonemic awareness (Bentin & Leshem, 1993). For instance, Hogan et al. (2005) found a reciprocal relationship between phonemic awareness and word reading, with kindergarten phonemic awareness predicting 2nd-grade word reading and, conversely, 2nd-grade word reading predicting 4th-grade phonemic awareness.

While numerous studies have documented the concurrent correlation between phonemic awareness and reading performance (e.g., English: Hulme, Goetz, Gooch, Adams, & Snowling, 2007; Manis, Doi, & Bhadha, 2000; Windfuhr & Snowling, 2001; Spanish: Rodríguez, van den Boer, Jiménez, & de Jong, 2015; Dutch: Vaessen & Blomert, 2010), given the fact that PA is modified by reading experience, it is difficult to discern whether the observed correlation reflects the influence that PA exerts on reading or vice versa. Some authors have even questioned whether PA has any influence on reading or if PA is merely a consequence of reading (Castles & Coltheart, 2004). Therefore, it is critical to make the distinction between results obtained in studies which test concurrent predictors of reading from results obtained in longitudinal studies of reading. A concurrent PA-reading correlation merely reflects a significant relationship in either direction. However, a longitudinal correlation between PA levels measured at, or before, the onset of reading instruction and future reading suggests that the former (unaffected by reading experience) influences the latter. Several English-language longitudinal studies measuring PA during kindergarten, before the exposure to the alphabet has triggered drastic changes in phonemic awareness, have found PA to be a powerful predictor of future reading (e.g., Kirby et al., 2003; Muter et al., 2004; Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess,… & Garon, 1997), thus, lending support to the idea that PA exerts a causal influence on reading.

The Interaction between Phonology and Orthographic Transparency

Studies conducted in languages with more transparent orthographies have also consistently found a highly significant contribution by PA to reading (e.g., Duncan, Castro, Defior, Seymour, Baillie, Leybaert… & Serrano 2013; Spanish: Suárez-Coalla, García-De-Castro, & Cuetos, 2013; Defior & Tudela, 1994; German: Landerl & Wimmer, 2000, 2008; Turkish: Öney & Durgunoglu, 1997; Finnish: Leppänen et al., 2006; Czech: Caravolas et al., 2005). However, many such studies have found that the predictive power of pre-reading PA has a very limited timeframe of influence on future reading (e.g., Dutch: de Jong & van der Leij, 1999; Spanish: Defior, 2008; Finnish: Leppänen et al., 2006; Norwegian: Lervåg et al., 2009). More specifically, longitudinal studies conducted in transparent orthographies have repeatedly found that the contribution by early-PA to reading is only important during the first one or two years of schooling, but not beyond that period (e.g., Norwegian: Lervåg et al., 2009; Dutch: de Jong & van der Leij, 1999; German: Landerl & Wimmer, 2000, 2008; Turkish: Öney & Durgunoglu, 1997; Finnish: Leppänen et al., 2006; Spanish: Defior, 2008). This finding appears to contradict the view that PA is involved in GtP conversion, a skill which is needed to decode unfamiliar words regardless of the developmental period.

Given the substantial differences in terms of spelling regularity between the English orthography and other orthographies, it is conceivable that the relevance of a cognitive skill which is involved in GtP conversion or GtP correspondence learning, such as PA, might be language-dependent. Such differences could possibly be due to differences in the orthographic consistency of each language. These cross-linguistic differences have led to debate regarding the relative importance of PA and other cognitive abilities, found to be important in English reading development, as predictors of reading development in other alphabetic orthographies (e.g., de Jong & van der Leij, 1999; Wimmer, Mayringer, & Landerl, 2000). Several large-scale cross-linguistic studies have been carried out with the aim to clarify whether the cognitive predictors of reading have the same relative importance in different languages or are language/orthography-specific. Studies which have addressed this question by assessing the concurrent contributions by certain cognitive predictors to reading have found that they are relatively universal across these alphabetic languages, although their precise weight varies systematically as a function of script transparency (Moll et al., 2014; Vaessen, Bertrand, Tóth, Csépe, Faísca, Reis, & Blomert, 2010; Ziegler, Bertrand, Tóth, Csépe, Reis, Faísca,... & Blomert, 2010a).

Two longitudinal cross-linguistic studies conducted to directly compare the longitudinal contribution by early predictors on future reading skills found contradicting results. Caravolas et al., (2012) found that phoneme awareness, letter-sound knowledge, and RAN were all reliable predictors of reading in Grade 1 in English (opaque), Spanish (transparent), Slovak (transparent), and Czech (transparent). In contrast, Georgiou, Torppa, Manolitsis, Lyytinen and Parrila (2012) found that pre-reading PA was a significant predictor of Grade 2 decoding in English, but not in Finnish and Greek (the latter two being transparent). In the only longitudinal cross-linguistic study to date which has assessed the contribution made by kindergarten predictors to future reading at more than one point in development, Caravolas, Lervåg, Defior, Seidlová Málková and Hulme (2013) found that phoneme awareness, letter-sound knowledge, and RAN did not differ in importance as predictors of variations in reading development among English, Spanish and Czech. Interestingly, Caravolas et al. (2013) found that PA was only associated with the very early growth in reading skills. Once again, this finding does not align well with the understanding that PA is permanently involved in GtP conversion and suggests that PA's role in reading skill acquisition is limited to the earliest stages.

Several Spanish-language studies have also examined the PA-reading relationship. For instance, Rodríguez et al. (2015) examined the relations of PA and RAN with reading in a cross-sectional study from Grades 2 to 6. Results revealed that the concurrent correlations between PA and reading increased in the higher grades. However, as pointed out earlier, due to the reciprocal nature of the PA-reading relationship it is hard to determine the direction of causality. Apart from the cross-linguistic studies reviewed in the previous paragraph, a number of longitudinal studies have been carried out which have examined the PA-reading relationship in Spanish-speaking samples. Aguilar-Villagrán, Navarro-Guzmán, Menacho-Jiménez, Alcale-Cuevas, Marchena-Consejero and Ramiro-Olivier (2010), Defior, Serrano and Marín-Cano (2008) and Suarez-Coalla, García-de-Castro and Cuetos (2013) administered PA tasks to pre-reading children in kindergarten.

Suarez-Coalla et al. (2013) found that pre-reading PA significantly predicted reading accuracy and speed during the last year of kindergarten, at a very early period of reading acquisition. Defior et al. (2008) measured PA and reading at 10 time-points between the ages of 4 and 9. They found the correlation between pre-reading PA and reading after April of Grade 1 to be predominantly non-significant. Aguilar-Villagrán et al. (2010) also found PA not to make a significant contribution to reading in June of Grade 1, a period when pre-reading PA might not be relevant any more in highly transparent orthographies (e.g., Finnish: Leppänen et al., 2006; Norwegian: Lervåg et al., 2009).

The finding that PA ceases to make a significant contribution to reading during the initial grades of primary school also does not reconcile well with the notion that PA plays a role in converting graphemes into phonemes. GtP conversion is a reading procedure which is applied to unfamiliar words throughout development. The PA-reading pattern observed in transparent orthographies aligns better with the view that PA assists the novice reader with the initial and crucial task of learning the alphabetic code (e.g. Byrne & Fielding-Barnsley, 1989; de Jong & Olson, 2004). In line with this view, when proposing the 'functional opacity hypothesis', Share (2008) points out that PA is maximally influential when children's GtP correspondence knowledge is still incomplete (Hebrew: Bentin & Leshem, 1993; Dutch: Wesseling & Reitsma; 2000). If that were the case, being phonemically aware would only be necessary while the GtP correspondences are being learned during the early period of reading development (Stanovich, 1986a), namely the alphabetic phase (Ehri, 2005). Furthermore, seen as learning the GtP correspondences is easier in transparent than in opaque orthographies, the functional opacity hypothesis argues that PA is likely to be equally important in consistent and inconsistent orthographies but during different timeframes in development (Share, 2008). In order to determine the role played by PA in reading in Spanish it would be advantageous to clarify whether the developmental timescale of PA's influence coincides with Ehri's alphabetic phase.

In summary, PA is generally thought to be crucial to conduct the GtP conversions which are necessary during phonological decoding (Manis et al., 1999; Vellutino et al., 2004). However, the significant decline of PA's contribution to reading in transparent orthographies as the reader gathers experience seems to contradict the notion that PA plays a permanent role in decoding. Otherwise, much emphasis has been placed on how phonemic awareness acts as a specific tool for learning the alphabetic principle (Byrne & Fielding-Barnsley, 1989; Goswami, 2002; de Jong & Olson, 2004). The latter explanation seems to be more consistent with the PA-reading relationship observed in transparent writing systems. In order to clarify the function carried out by PA in reading it is convenient to determine the period of development during which it is most relevant to reading. Furthermore, PA must be measured before the onset of literacy instruction, given that otherwise the strong reciprocal influence that PA and reading have on each other (Hogan et al., 2005; Perfetti et al., 1987) complicates any attempts to interpret correlational results. Therefore, the current thesis will examine whether pre-reading PA contributes to future reading permanently or only during the period when the children are learning the alphabetic code.

Visual Processing Skills

While much of the research in the field of literacy acquisition has been aimed at understanding the relationship between phonological awareness and learning to read, the potential importance of visual processing skill has been much less explored. Although a link between visual processing skills (VPS) and reading has been suggested for several decades (e.g., Cairns & Steward, 1970; Lovegrove, Martin, & Slaghuis, 1986; Mason & Katz, 1976), this possibility has gathered more attention in more recent years. In the past decade ample evidence in different languages has been presented claiming that VPS play an independent role in reading skill acquisition (English: Pammer, Lavis, Hansen & Cornelissen, 2004; Rayner, 2009; Vidyasagar & Pammer, 2010; Italian: Facoetti, Zorzi, Cestnick, Lorusso, Molteni, Paganoni,… & Mascetti 2006; French: Bosse, Tainturier, & Valdois, 2007; Spanish: Lallier, Valdois, Lassus-Sangosse, Prado, & Kandel, 2014). Similarly, many other studies failed to find a significant relationship between VPS and reading (e.g., English: Shapiro et al., 2013; Vellutino, Scanlon, Small, & Tanzman, 1991; Japanese Kanji: Kobayashi, Haynes, Macaruso, Hook, & Kato, 2005). Even if VPS and reading do correlate, a causal role for visual skills in reading skill development is far from being established. An abundance of contradicting results characterizes the VPS-reading research literature.

Different Aspects of Visual Processing Skills

One source of the inconsistencies reported in studies which examine the association between VPS and reading skill could very well be due to the high variability in the type of task used in each study, and, therefore, the amount of potentially different visual skills being tested. Visual processing skills comprise several abilities which have been claimed to be associated with reading development and dyslexia (for reviews on the topic see Gori & Facoetti, 2014; Rayner, 2009; Vidyasagar & Pammer, 2010). Many different tasks have been used in order to measure VPS performance. Using spatial attention tasks, which assess the participants visuo-spatial skills, many studies have provided evidence of a link between VPS and reading (e.g., Facoetti et al. 2006, Facoetti, Trussardi, Ruffino, Lorusso, Cattaneo, Galli,... & Zorzi, 2010; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Reynolds & Besner, 2006; Sieroff & Posner, 1988). A large number of studies have investigated the role of VPS in reading by using coherent motion tasks (Cornelissen, Richardson, Mason, Fowler, & Stein, 1995; Hood & Conlon, 2004; Witton, Talcott, Hansen, Richardson, Griffiths, Rees, Stein, & Green, 1998), which test the participant's visual sensitivity to movement. Visual search tasks, which assess the speed and/or accuracy with which the participant can visually scan and locate stimuli, are yet another type of VPS test which has provided numerous positive (e.g., Franceschini et al., 2012; Jones, Branigan & Kelly, 2008; Rayner, 2009) and negative results (e.g., Kobayashi et al, 2005; Shapiro et al., 2013).

Another field of research has investigated the association between reading and visual multi-element processing. In general MEP tasks assess the accuracy with which the participant can recognize or recall the identity and/or sequence of word-like symbol strings previously presented (e.g., Hawelka & Wimmer, 2005; Jones et al., 2008; Pammer et al., 2004). For instance, visual attention span – defined as the number of distinct visual elements which can be simultaneously processed at a glance – has been shown to contribute to reading performance, beyond other established predictors such as IQ, vocabulary, and PA in normally developing children (Bosse & Valdois, 2009; van den Boer et al., 2013). Moreover, when required to process arrays of digits, letters or other symbols, children with dyslexia have been documented to suffer from a visual multi-element processing deficit (Bednarek, Saldana, Quintero-Gallego, Garcia, Grabowska & Gomez, 2004; Collis, Kohnen & Kinoshita; 2013; Hawelka & Wimmer, 2005; Pammer et al., 2004; Reilhac, Jucla, Iannuzzi, Valdois & Démonet, 2012;). Hawelka and Wimmer (2005) found that although children with dyslexia did not show a deficit on 2-digit arrays compared with control subjects, they did exhibit poorer recognition performance on 4- and 6-digit arrays. This result indicates a deficit when processing long symbol-strings, but not short symbol strings. Similarly, a visual attention span deficit has been documented when children with dyslexia perform letter-reporting tasks (e.g., Bosse et al., 2007, Bosse & Valdois, 2009; Lallier et al., 2014).

What is the Role Played by Visual Processing Skills in Reading?

In order to determine whether VPS are related to reading it is essential to clarify which type of VPS (e.g., sensitivity to coherent motion, visual search speed or multi-element processing), if any, are the most relevant. However, equally as important is to discern the specific role played by these visual processing skills in the development of reading. Various alternatives have been proposed to explain the nature of this relationship. Several studies have reported a significant relationship between VPS tasks and unfamiliar word reading (Auclair & Siéroff, 2002; Facoetti et al., 2006; Jones, et al., 2008; Kinsey, Rose, Hansen, Richardson, & Stein; 2004). For instance, Jones et al. (2008) found that performance on visual-search and letter-position encoding tasks significantly correlated with non-word reading, leading them to suggest that serial allocation of attention across the letter string may be specifically relevant to decoding. In line with this view, Kinsey et al. (2004) found a stronger relationship between visuo-spatial attention and non-word reading than between visuo-spatial attention and irregular word reading. The claim that visual attention plays a specific role in decoding is perhaps most clearly shown in the work by Facoetti (e.g., Facoetti et al., 2006; Facoetti, Ruffino, Peru, Paganoni, & Chelazzi, 2008; Facoetti, Corradi, Ruffino, Gori, & Zorzi, 2010). According to Facoetti et al. (2006), a spatial selection mechanism which operates on graphemes appears to be a basic component of the phonological assembly process. They therefore suggest that a visual deficit impairs graphemic parsing, which could affect all subsequent spelling-to-sound conversion processes.

Another possible account of the role visual ability plays in reading is suggested by the Multiple-Trace Memory (MTM) model (Ans et al., 1998). This connectionist model posits that reading is accomplished via two processes: a global (sight-word reading) approach which is generally applied to familiar words, and an analytic (decoding) form which is more useful for unfamiliar words. Importantly, this model proposes that visual attention span, defined as the amount of visual elements (e.g., letters or symbols) that can be processed in parallel, is crucial for both the sight-word reading and the analytical processes. These global and analytical reading procedures differ in the type of visual attention required. The global processing requires a larger visual attention span which extends over the whole letter string. The analytic procedure, on the other hand, requires visual attention to be focused successively on smaller orthographic units, such as syllables or letters, resulting in length effects (van den Boer et al., 2013). Consistent with this view, visual attention span deficits have been found to be responsible for impaired word trace creation of the entire orthographic sequence of known words (Bosse et al., 2007). Likewise, visual attention span deficits have been reported to be related with poor analytical decoding of novel words (Bosse et al., 2007; Valdois, Carbonnel, Juphard, Baciu, Ans, Peyrin, & Segebarth, 2006), as well as to the length effect and therefore to a serial processing strategy (e.g., van den Boer et al., 2013).

The word familiarity and word length factors can be useful tools in order to determine whether VPS is involved in decoding, sight-word reading or both. As described by the reading models presented in the previous sections of this chapter (Ans, et al., 1998; Coltheart et al., 2001; Ehri, 2005; LaBerge & Samuels, 1974; Share, 1999, 2008), familiar words (e.g., high-frequency words for proficient readers) will be automatically read by sight, whereas unfamiliar words (e.g., low-frequency words or non-words) will be analytically decoded. Therefore, by manipulating the lexicality and frequency factors, it is possible to determine whether a list of words will be predominantly decoded or read by sight. With regards to word length, an increased length effect is an indication that a particular group of words is being decoded (Weekes, 1997). Therefore, a correlation between VPS and reading performance on a group of words which exhibit a length effect suggests a relationship between VPS and decoding. Furthermore, if global and analytic reading procedures are dependent on an adequate visual attention span (Ans et al., 1998, Bosse et al., 2007) long-word reading should be more strongly related to visual attention span than short-word reading.

The Reciprocal Relationship between VPS and Reading, Transparency and the need for Longitudinal Studies

One further psycholinguistic factor which is a candidate source of inconsistencies in reported results is the specific language in which the VPS-reading relationship is being assessed. Even though studies in several orthographies with different degrees of transparency have found significant correlations between VPS and reading (e.g., French: Bosse & Valdois, 2009; Spanish: Lallier et al., 2014; English: Bosse et al., 2007; Dutch: van den Boer et al., 2013), differences in orthographic transparency may also influence the reliance by reading skill on VPS. As described in preceding sections, English has been argued to be an outlier orthography (Share, 2008) because of its irregular spelling-sound correspondence (e.g., Frith et al., 1998; Seymour et al., 2003). Due to its opaque orthographic transparency, there are a large proportion of words in the English orthographic lexicon which can be defined as irregular or exceptional. Given that these words do not comply with conventional decoding rules, their orthographic representation must be learnt as a whole and recognized by sight. Therefore, these sorts of words cannot be decoded through the implementation of regular GtP conversion rules and will need to be learnt as a whole and subsequently read by sight. It follows that if sight-word reading requires a higher VPS demand than decoding, VPS may be more related to reading in opaque orthographies like English than in more transparent orthographies.

Furthermore, when attempting to clarify the influence that VPS has within the process of reading there is an additional methodological issue which is also worthy of consideration. As previously discussed with regards to PA, cognitive abilities often maintain a reciprocal developmental relationship with reading proficiency which can potentially lead to a misinterpretation of the relationship between the two. In the same way as the child's phonological awareness, naming speed or visual processing skills appear to influence reading performance, reading experience may also alter these cognitive abilities. As with PA (Hogan et al., 2005), learning to read has also been shown to account for a significant improvement in the levels VPS (McBride-Chang, Zhou, Cho, Aram, Levin, & Tolchinsky, 2011). Regarding visual ability in particular, neural and behavioral evidence presented by several studies indicate a probable transformative influence of reading experience on visual processing (e.g., Dehaene, Pegado, Braga, Ventura, Nunes Filho, Jobert… & Cohen, 2010; Perfetti, Cao, & Booth, 2013). This implies that inferring the direction of causality can be problematic when a significant concurrent correlation is found between a cognitive ability and reading in a sample of individuals who already have several years of reading experience.

However, the few studies conducted in alphabetic orthographies which have examined the contribution made by VPS measured in kindergarten to future word reading have reported contradicting results. In a study of Italian speaking children, Franceschini et al. (2012) found kindergarten individual differences in visual search and spatial cue facilitation tasks predicted both word and non-word reading measured in Grades 1 and 2 (approximately 7 and 8 years old, respectively). In contrast, Shapiro et al. (2013) conducted a longitudinal study with an English speaking sample but failed to find a significant contribution by pre-reading visual search skills to reading of words or non-words when the children were approximately 5 years old. However, to our knowledge, the extent to which the pre-reading visual attention span or visual multi-element processing skill (as opposed to visual search and spatial attention) contributes to future reading has never been assessed. For these reasons there is a need for longitudinal studies, as they allow us to observe the particular dynamics which take place at each period of development, given that VPS might be related to reading during a specific developmental phase but not at another. Furthermore, no longitudinal study in Spanish has measured VPS before the onset of reading instruction.

Moreover, many of the VPS studies which have assessed whether visual processing skills significantly influence reading performance have relied on tasks which either use items comprised of alphabet letters or for which the answer is provided verbally (e.g., Bosse et al., 2007; Kwon, Legge & Dubbels, 2007; Valdois, Bosse & Tainturier, 2004). However, other authors have failed to find a visual link to reading skill when the visual task required no verbal response (Hawelka & Wimmer, 2008) or included no verbal material (Collis et al., 2013; Shovman & Ahissar, 2006). The possibility that visual skill tasks which involve verbal material actually measure symbol-sound mapping (Ziegler, Pech-Georgel, Dufau & Grainger, 2010b) and the fact that letter knowledge itself is a known predictor of reading (Bowey, 2005) warn against using these type of stimuli when attempting to assess whether pure visual skills play an independent role in reading. Therefore, when aiming to assess the relevance of VPS to reading it is imperative to pay close attention to the type of items being used (e.g., nameable or non-nameable). Furthermore, other factors like orthographic transparency of the testing language, period when VPS and reading are measured or psycholinguistic characteristics of the reading material (e.g., word frequency or word length) must be carefully considered.

In summary, there are many questions in need of answers with regards to the potential role which VPS might hold within the development of reading skills. One goal of this thesis is to determine whether visual skills casually influence reading performance. In order not to confound the effect that visual skills may have on reading with the effect that reading experience may have on visual skills, visual skills ought to be tested before the onset of literacy instruction. This procedure will guarantee that visual skills are uninfluenced by reading experience at the time of testing. Furthermore, the second aim is to clarify the precise role which visual processing skill play in reading performance and reading development. While there are many different visual skills which have been tested with regards to reading skill, the potential link between multi-element processing and reading skill acquisition is of particular interest to this thesis. The main research question of this thesis regarding VPS is whether multi-element processing is crucially related to global (sight-word reading) or analytical (decoding) word processing. Manipulating word-length and word-familiarity factors, such as word frequency and lexicality, will be of great assistance in meeting this objective.

Naming Speed Skills

Another of the most prominent reading-related cognitive abilities is naming speed (Kirby, Georgiou, Martinussen, & Parrila, 2010, for a review). Naming speed refers to the ability to rapidly recognize and name a number of visually presented, highly familiar linguistic stimuli (Wolf & Bowers, 1999). An extensive amount of evidence indicates that naming speed ability is closely correlated with reading in typically developing children (e.g., Cutting & Denckla, 2001; de Jong & van der Leij, 1999; Kirby et al., 2003; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007). Furthermore, a large percentage of poor readers have been reported to exhibit naming-speed deficits (e.g., Denckla & Rudel, 1976; Heikkilä, Närhi, Aro, & Ahonen, 2009; McBride-Chang & Manis, 1996; Wimmer, 1993; Wolf & Bowers, 1999). The best known measure naming speed is the rapid automatized naming test, designed and developed by Denckla and Rudel (1974, 1976). The RAN task assesses the speed with which the participant is able to name a series of serial or continuous (as opposed to individually-displayed) visually presented familiar items, such as common colors, objects, numbers or letters (Kirby et al., 2010).

Several findings regarding the association between RAN and reading are virtually undisputed. In order to demonstrate that the naming speed cognitive ability has a direct and independent influence on reading skill it is imperative to determine whether naming speed has a unique effect on reading performance beyond the effects of other predictors. Providing evidence of naming speed's independent influence of reading skill, RAN has been reported to be a significant predictor of reading after the statistical control of broad background measures such as verbal and nonverbal IQ (e.g., Babayigit & Stainthorp, 2010; Manis et al., 1999; Vaessen & Blomert, 2010) and socioeconomic status (e.g., Felton, Naylor, & Wood, 1990; Swanson, Trainin, Necoechea, & Hammill, 2003). Furthermore, there is ample evidence of RAN's independent contribution to reading skill beyond the effects of visual ability (e.g., Shapiro et al., 2013; van den Boer et al., 2013), paired-associate learning (e.g., Litt, de Jong, van Bergen, & Nation, 2013; Warmington & Hulme; 2012) and phonological skill (e.g., Kirby et al., 2003; Parrila, Kirby, & McQuarrie, 2004; Manis et al., 2000; Powell et al., 2007). Unsurprisingly, yet very importantly, naming speed has been widely observed to be more closely related to word reading speed than with word reading accuracy (e.g., Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Vaessen, Gerretsen, & Blomert, 2009; Warmington & Hulme; 2012). This finding suggests that RAN performance should be more strongly related to reading after the child has reached high accuracy levels and his reading level is better reflected in terms of speed.

Furthermore, early levels of naming speed have been repeatedly documented to predict future reading (e.g., Babayigit & Stainthorp, 2010; Caravolas et al., 2012; Kirby et al., 2003; Lervåg et al., 2009; Shapiro et al., 2013) as far as Grade 10 (Georgiou, Papadopoulos, & Kaizer, 2014). RAN's effect on reading also remains significant after statistically controlling for prior reading ability (e.g., Badian, 1993; Parrila et al., 2004). The significant and independent contribution by pre-reading RAN to future reading crucially supports the notion that naming speed is causally related to reading performance. A methodological aspect which deserves close attention is the potential effect that reading experience may or may not exert on naming speed ability itself. As reviewed in previous sections, phonological ability (e.g., Hogan et al, 2005) and visual skill (e.g., Perfetti et al., 2013) both maintain a reciprocal relationship with reading. Several studies have examined whether the same is true for naming speed. Whereas Lervåg and Hulme (2009) as well as Wei Wei, Georgiou and Deng (2015) found no evidence of a reciprocal relationship between RAN and reading in their longitudinal studies, Compton (2003) and Wolff (2014) reported a bidirectional relationship between RAN and word reading. While the evidence is non-conclusive it cautions against the over-interpretation of results obtained with samples of readers which have ample reading experience.

RAN and Orthographic Transparency

Numerous studies have documented naming speed's effect, as measured through the RAN tasks, on reading skill when working with English-speaking samples (e.g., Caravolas et al., 2012; Compton, 2003; Kirby et al., 2003; McBride-Chang & Manis, 1996; Shapiro et al., 2013). RAN's robust predictive power of reading performance has also been corroborated in languages with more transparent orthographic systems (e.g., Dutch: de Jong & van der Leij, 1999; Italian: Di Filippo, Brizzolara, Chilosi, De Luca, Judica, & Pecini, 2006; Greek: Georgiou, Parrila, & Papadopoulos, 2008; Finnish: Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Norwegian: Lervåg et al., 2009; German: Moll et al., 2009; Spanish: Escribano, 2007; Suárez-Coalla, García-De-Castro, & Cuetos, 2013). Moreover, it has even been argued that naming speed may be a stronger predictor of reading in transparent orthographies than in more opaque orthographies (e.g., de Jong & van der Leij, 1999; Landerl & Wimmer, 2000; Wimmer, Landerl, & Frith, 1999).

However, results gathered from cross-linguistic studies do not support these claims (Caravolas et al., 2012; Moll et al., 2014). This unsubstantiated perception might originate from the relatively stronger effect that naming speed has on reading compared to phonemic awareness (de Jong & van der Leij, 1999; Landerl & Wimmer, 2000). RAN's robust predictive power across languages suggests it is the best, perhaps universal (Tan, Spinks, Eden, Perfetti, & Siok, 2005), proxy reading task devised so far which can be administered to pre-literate children.

Similarly to the results obtained in other languages with transparent orthographic systems, Spanish studies which have measured the effect of naming speed on reading have found significant relationships (e.g., Aguilar-Villagrán et al., 2010; Caravolas et al., 2012; Rodríguez et al., 2015; Suarez-Coalla et al., 2013). Aguilar-Villagrán et al. (2010) and Suarez-Coalla et al. (2013) both reported how RAN, measured at the onset of reading instruction, made a significant contribution to Grade 1 reading speed beyond the effect of phonological awareness. Rodríguez et al. (2015) measured both RAN and PA in several consecutive grades (from Grades 2 to 6) in order to examine the differential effect that these cognitive abilities exerted on reading during different developmental periods. They found that the RAN–reading relationship decreased for words, whereas the relationship remained stable for pseudowords. In two cross-linguistic studies Caravolas et al. (2012, 2013) reported that kindergarten-RAN was a reliable independent predictor of reading at comparable levels to other languages. With regards to dyslexia research in Spanish, Escribano and Katzir (2008) found RAN scores to significantly correlate with reading speed, orthographic knowledge and reading comprehension measures. Jiménez, Hernández-Valle, Rodríguez, Guzmán, Díaz and Ortiz (2008) found that children with dyslexia who had a naming speed deficit, but average phonological awareness, to exhibit significantly lower reading speed than controls.

Theories of RAN's Relationship to Reading

Despite RAN's intimate correlation with reading and the test's pre-reading robust longitudinal predictive power, the underlying mechanisms which drive the RAN-reading relationship are not yet fully clear. RAN task performance and reading performance tap on several common cognitive demands. Precisely because both RAN and reading require the cross-modal ability of rapidly transforming the visual into the phonological, RAN has been described as a microcosm of the processes involved in reading (Norton & Wolf, 2012).

While this makes RAN an ideal pre-reading test for predicting future reading performance, we have yet to clarify which is the predominant cognitive ability at the core of the RAN-reading relationship. Perhaps the most intuitive explanation of this relationship is that picture naming speed and word naming speed both primarily rely on general cognitive processing speed (Kail & Hall, 1994; Kail, Hall, & Caskey, 1999). However, this theory is inconsistent with the wealth of evidence indicating that RAN scores are still significantly related to reading after statistically controlling for speed of processing (e.g., Bowey, McGuigan, & Ruschena 2005; Liao et al., 2015; Powell et al., 2007; Stainthorp, Stuart, Powell, Quinlan, & Garwood, 2010).

Wolf and Bowers (1999), who consider naming speed deficits to be a second core deficit in dyslexia, argued that the RAN tasks tap into a timing mechanism that is important for the development of multi-letter orthographic patterns. Disruption of this ability would require additional viewings in order to learn the specific spelling patterns. Similarly, Manis et al. (1999) proposed that the RAN task assesses the ability to establish the link between visual and verbal stimuli. Interestingly, it has also been proposed that the ability to establish the link between visual and verbal stimuli is the common correlate between reading and another reading-related cognitive ability: Paired Associate Learning (PAL). The relationship between PAL and reading has been increasingly investigated over the past decade (Hulme et al., 2007; Lervåg et al., 2009; Liao et al., 2015; Litt et al., 2013). PAL tasks require the participant to learn the association between a visual and a verbal stimulus (e.g., a face and a name).

It has been argued that the PAL tasks correlate with reading because PAL taps the crossmodal stimulus–response associative learning mechanism that forms the link between letter-sounds and orthography-phonology mappings (e.g., Hulme et al., 2007). Despite the similarity between this explanation and the reasoning which has been advanced to explain the RAN-reading relationship (Manis et al., 1999), PAL and RAN have been shown to be distinctly independent from each other (Lervåg et al., 2009; Liao et al., 2015; Litt et al., 2013). In two recent studies, Litt et al. managed to disassociate the role of modality and verbal demand driving the PAL–reading relationship by comparing performance across four PAL mapping conditions (visual–verbal, verbal–verbal, visual–visual and verbal–visual). Firstly, they found that only the tasks requiring verbal output (visual–verbal PAL and verbal–verbal PAL) accounted for the PAL–reading relationship (Litt et al., 2013). Secondly, they found that children with dyslexia only exhibited deficits in these two PAL formats (Litt & Nation, 2014). These findings led them to conclude that PAL deficits in dyslexia are not a consequence of difficulties with associative learning, but due to deficits in phonological form learning.

However, the RAN task could potentially assess the ability to process the whole orthographic representation of a word as a single unit, just like the individual symbols in the RAN task (Manis et al., 1999). In this sense, a RAN task and a familiar-word reading task can both be considered as whole-unit lexical access measures (Georgiou, Parrila, & Kirby, 2009). Data from irregular word reading, which is generally thought to rely upon orthographic processing, supports this view. In an irregular word the one-to-one relationships between the letters and the sounds are not fully reliable. Therefore, the spelling of the whole word must be learned as a single unit. In line with the hypothesis that RAN predicts reading because it assesses the ability to establish accurate orthographic representations of words, RAN has been found to account for independent variance in irregular word reading accuracy (Clarke, Hulme & Snowling, 2005; Kruk, Mayer & Funk, 2014) and irregular word spelling (Stainthorp, Powell, & Stuart, 2013), when phonological skills were controlled.

Detailed orthographic representations enable rapid and effortless recognition of familiar words (i.e. sight-word reading or lexical reading) through direct-retrieval mechanisms (Ans, et al., 1998) increasing word reading fluency. It follows that, if the cognitive ability measured by RAN does play a role in processing the orthographic representations of words, then fast-RAN individuals will be fast word readers. In agreement with this perspective, RAN has repeatedly been shown to be the strongest predictor of word reading speed after the initial period of reading acquisition is over (Babayigit & Stainthorp, 2011; Lervåg et al., 2009; Moll et al., 2009; Papadopoulos, Georgiou, & Kendeou, 2009; Vaessen & Blomert, 2010). The knowledge that RAN is the best predictor of familiar word reading is in line with the notion that RAN is involved in whole-word orthographic processing (sight-word reading). Nonetheless, researchers have increasingly noted that RAN not only contributes to familiar word reading speed (high-frequency words), but also to unfamiliar word reading speed (non-words) just as strongly (Moll et al., 2009; Poulsen & Elbro, 2013; van den Boer et al., 2013). This evidence firmly indicates that RAN is not exclusively involved in whole-word orthographic processing.

However, RAN's contribution to non-word reading does not necessarily oppose the understanding of RAN as a measure of orthographic processing, given that orthographic processing is not only involved in sight-word recognition, but is also an integral part of fluent sublexical processing. In fact, the critical importance of grapho-syllabic connections to the development of skilled word reading is recognized in orthographic systems across the whole range of the transparency spectrum (e.g., Italian: Burani et al., 2002; French: Sprenger-Charolles & Siegel, 1997; English: Bhattacharya & Ehri, 2004; Treiman et al., 1990). In Spanish, a transparent orthography with a marked syllabic structure, orthographic syllable frequency significantly influences the manner and speed in which words are decoded and recognized (Alvarez et al., 2001; Conrad et al., 2008; Luque et al., 2013; Perea & Carreiras, 1998). More specifically, non-words composed of high-frequency syllables are read significantly faster than non-words composed of low-frequency syllables (e.g., Carreiras et al., 1993; Carreiras & Perea, 2004). In accordance with the view that RAN taps on orthographic processing skills, numerous studies have reported significant associations between scores on naming speed and sublexical orthographic processing tasks (Conrad & Levy, 2007; Georgiou et al., 2009; Levy, Bourassa & Horn, 1999; Loveall, Channell, Phillips & Conners, 2013; Powell, Stainthorp & Stuart, 2014).

Visual and Verbal Components of RAN

It is also possible that the common cognitive ability that drives the RAN-reading association operates, not only at a whole-word and multi-letter processing level, but also at an individual letter level. However, a contribution by RAN to individual processing of letters would be strong evidence that orthographic processing, when defined as the ability to acquire and process familiar multi-letter spelling patterns as individual units, is not at the core of the RAN-reading relationship. After finding no major differences in the concurrent contribution made by RAN to reading of two types of non-words with different syllable structure, Moll et al. (2009) concluded that RAN is not a measure of orthographic processing. If the predominant cognitive skill shared by RAN and reading does in effect operate at a whole-word, grapho-syllabic and grapho-phonemic level, it follows that the RAN-reading relationship is driven by a more general cognitive skill. Some candidates would be the ability to establish a link between a visual symbol and a verbal label (Manis et al., 1999), the ability to efficiently and fluently convert visually presented stimuli into its corresponding phonological counterpart (Moll et al., 2009), phonological retrieval fluency

(Torgesen, Wagner, & Rashotte, 1994) or visual serial processing (Logan & Schatschneider, 2014).

It is indeed conceivable that the visual processing component of RAN is a basic constituent to the RAN-reading relationship. Many studies have focused on examining the relevance of RAN's visual component to reading (e.g., de Jong, 2011; Jones, Branigan & Kelly, 2009; Logan & Schatschneider, 2014; Rodríguez et al., 2015; Torgesen et al., 1994; Wagner et al., 1997). RAN's visual component can be isolated by comparing discrete and serial formats of the RAN task. Discrete naming speed tests, in which the stimuli are presented individually, generally yield weaker correlations with reading than the serial or continuous versions (e.g., Logan & Schatschneider, 2014; Torgesen et al., 1994; Wagner et al., 1997). This differentiation implies that visual serial processing partly accounts for the RAN-reading relationship. Jones et al. (2009) found readers with dyslexia to exhibit a significant impairment on continuous RAN, whereas unimpaired readers showed marginal facilitation for this format. Recently, several studies by de Jong et al. have reported how the strength of the RAN–reading fluency relationship is dependent on the visual format of both RAN and the reading task (de Jong, 2011; Rodríguez et al., 2015). While this line of research is very promising in clarifying the nature of RAN's association with reading, this topic is beyond the scope of the current thesis.

In this section dedicated to naming speed and the RAN test we have reviewed the intimate association that naming speed ability holds with reading, and reading speed in particular. It has been documented how this relationship extends beyond orthographic transparency (including Spanish). However, despite the vast amount of research conducted on the topic of naming speed and reading, the nature of this relationship is far from being completely understood. Although there is ample evidence supporting naming speed's causal influence on reading, Wolff's (2014) finding that naming speed skill itself may be modified by reading practice increases the experimental value of longitudinal studies which measure naming speed before the onset of reading instruction. While it seems relatively clear that the relationship between RAN and reading is not merely due to general processing speed, the validity of the RAN-orthographic processing theory is yet to be determined. Regarding the exploration of the RAN-reading connection, the third study of this thesis will aim to examine to what extend RAN is related to reading through the ability to process multi-letter orthographic patterns as individual units.

Aims & Design

Aims of the Thesis

Understanding the role that phonemic awareness, visual processing skills and naming speed play in reading acquisition and reading performance is of paramount importance given their evidenced involvement in reading skill acquisition. In terms of advancing our knowledge, discerning the contribution that these cognitive abilities make to reading is essential to develop the theoretical map of literacy skills' acquisition. The theoretical framework which is laid out by developmental and skilled single-word reading models reveals how different reading procedures are implemented depending on the experience of the reader and the type of word being read. Therefore, in order to comprehend better the relationship between the core reading-related cognitive abilities and reading itself, the overall goal of this project is to examine the period of development during which these skills are most influential and the reading strategies to which they predominantly contribute. Our approach to meet this goal will be to carry out a longitudinal study composed of three sub-studies, each of which will focus on the different topics of interest. This will be a useful means, not only to determine which cognitive abilities are precursors to future reading performance, but to uncover for what purpose these cognitive abilities come into play and the periods of development when they are most influential.

The reviewed stage-based developmental reading models describe a progression from an alphabetic phase, during which the grapheme-to-phoneme correspondences are learned, towards an orthographic phase, where groups of letters are processed together as single units. Meanwhile, according to Share's item-based developmental model, a constant expansion of the orthographic lexicon, which enables sight-word reading, takes place in parallel. While these developmental models have been elaborated to explain reading skill acquisition in the opaque English orthography, study 1 will examine to what extent they apply to the highly transparent Spanish orthography. More importantly, by observing the co-occurrence between the reading development periods described by these models and the periods of influence of reading-related cognitive abilities, study 1 will also allow us to further understand the role played by these cognitive skills within the underlying mechanism of reading skill acquisition. For instance, while phonemic awareness is well known to play a crucial part within the learning process described above, it is not clear whether it is permanently involved in reading or whether its timeframe of influence is limited to the earlier stages. Observing how phonemic awareness ability relates to reading depending on the period of development will be a useful method of shedding light on this issue. The prediction is that PA will only be related during the initial period of reading skill acquisition.

This thesis will also attempt to tackle some of the unanswered questions regarding the nature of the relationship between reading and visual processing skills. Firstly, there is an interest to examine the differences in the contribution made by visual processing skills to reading skill at different periods of development. The longitudinal aspect of study 1 will help us understand during which period visual ability is most influential to reading. In turn, this will allow us to further comprehend its potential role in the development of reading skill acquisition. Moreover, while some theories claim that visual processing skills are crucial for sight-word reading, others claim that they are predominantly involved in decoding. Given that unfamiliar words are decoded while familiar words are read by sight, and given that longer words require additional decoding demand than shorter words, in study 2 word features such as word frequency and length will be manipulated in order to help us adjudicate between these competing viewpoints. As reviewed in the previous chapter, reading experience exerts a transformative effect on visual ability and phonemic awareness. Therefore, in order to help discern the direction of causality, all cognitive abilities will be measured before the onset of reading instruction.

Finally, within the main goals of this thesis is to further understand what cognitive ability drives the relationship between RAN and reading speed. As with the other cognitive abilities of interest, one important question which this thesis attempts to explore is the period of development at which naming speed is most influential. Given RAN's established relationship with reading speed, we anticipate that naming speed will make larger contributions to reading at later grades – that is, once children have learned all of the GtP correspondences and the main distinguishing factor between good and poor readers becomes reading speed, rather than reading accuracy. Moreover, of particular interest is naming speed's potential influence on orthographic processing. A higher contribution by RAN to familiar-word reading speed would be evidence of this. In study 3 we will undertake the goal to investigate this topic by manipulating the orthographic familiarity of the words to be read, as regulated by word frequency, syllabic frequency and lexicality. If naming speed were involved in orthographic processing, RAN should correlate more with orthographically familiar- than unfamiliar- words. If the pattern of contribution was the opposite or equal, other explanations would gain more credence. In summary, this thesis aims to further understand the role played by naming speed, visual and phonological skills by investigating what reading procedures and what developmental periods they are predominantly related to.

The longitudinal study which comprises this thesis lasted 64 months. It commenced when the children were in mid-kindergarten, 9 months before the onset of formal literacy instruction, and expanded throughout the first 5 years of schooling. Word and non-word reading accuracy and fluency, as well as GtP correspondence knowledge, were monitored with the partial aim to distinguish the developmental periods which the children evolve through. If we can discriminate what development periods take place at each grade we will be better positioned to understand the roles played by the reading-related cognitive abilities of interest. Phonemic awareness, visual processing skills and naming speed were measured at the onset of the study. In order to investigate the relevance of PA, VPS and RAN at different time-points in reading development, we will examine which are the grades during which these cognitive abilities contribute most to reading performance. In order to investigate the nature of the relationship that PA, VPS and RAN share with decoding and sight-word reading, word-frequency, lexicality, syllable-frequency and word-length will be manipulated. Other cognitive abilities and literacy-related skills like verbal IQ, non-verbal IQ and orthographic knowledge will also be controlled for.

General Design

All the studies of the current thesis are based on longitudinal data from the same children. The Spanish children who participated in this study were in mid-kindergarten (February/March) at the inception of the data-collection. In the Spanish schooling system, children enter the kindergarten grade in September of the year in which they turn 5 years old. These children were followed for 64 months starting in mid-kindergarten. However, although the three sub-studies which comprise this thesis share the same starting point (February of kindergarten), they all have a different number of time-points, as well as finishing points, and therefore different overall lengths. All three studies of this thesis are primarily based on a sub-sample of children who were at a pre-reading stage at the onset of the study. This condition was assured by excluding all early readers from the main sample. The reason for this is that, as it has already been discussed on the 'theoretical framework' section, the three cognitive abilities of interest have been reported to hold a reciprocal relationship with reading skill (VPS: Perfetti et al., 2013; PA: Hogan et al., 2005; RAN: Wolff, 2014). Therefore, it is necessary to measure these cognitive abilities prior to the onset of reading skill acquisition in order to guarantee that any significant relationship reflects an influence of the cognitive abilities on reading, and not the contrary.

The cognitive abilities of interest were measured at the onset of the study and the children's performance on reading and other literacy skills was monitored at different time-points throughout the length of the 64 month-long data collection. While the scores obtained by the children on the cognitive ability tests were included in all the analyses of all three studies, each study used different literacy tasks and assessed different literacy skills. Tasks corresponding to two control variables (verbal and non-verbal IQ) and the three cognitive abilities of interest (PA; VPS; RAN) were administered in February of kindergarten, along with the 'initial reading level' test needed to identify and exclude early readers. A word and a non-word reading test were administered once a year (month of June) over the next four years in order to monitor the children's reading skill progress (Study 1). A different reading test which manipulated word-frequency and word-length factors was administered exclusively at Grade 3 (Study 2). Finally, a further reading test which manipulated word-frequency and syllable-frequency factors was administered at Grade 5, along with an orthographic knowledge test (Study 3). The cognitive variables (verbal and non-verbal IQ, PA, RAN and VPS) assessed in kindergarten were used to predict later literacy skills in each of the three studies. Detailed descriptions of all cognitive and literacy measures are provided in the methods section of each study.

Study 1:

Predictors of Reading Development in Spanish:

A 5-year Longitudinal Study

Introduction

As mentioned in chapter 2, many questions remain unanswered regarding the nature of the relationship between the three cognitive abilities of interest (phonemic awareness, visual processing skills and naming speed) and reading skill acquisition. This first study will be directed at elucidating whether pre-reading levels of these three cognitive abilities are significant predictors of future reading, and most importantly, what are the specific periods of development during which these abilities are most influential. In order to understand the significance of these cognitive abilities to the process of reading acquisition it is essential to uncover when these cognitive abilities come into play and for what purpose. Models of reading development provide a useful representation of how reading acquisition evolves and how different reading procedures are predominantly used depending on the experience of the reader. In light of the timeline laid out by these models we will be able to further understand the relevance of the contribution by each cognitive skill to specific periods of reading development.

Do Developmental Models of Reading apply to the Spanish Orthography?

The alphabetic and orthographic phases described by the most recognized stage-based developmental models (e.g. Ehri, 2005, Frith, 1986) have been conceived within the context of the opaque English orthography. Whether they apply to the Spanish orthography must be established before focusing on the timeframe of influence of the cognitive abilities of interest. The period commonly referred to as the alphabetic phase, where the beginning reader is introduced to the alphabetic code and learns the GtP correspondences, is of crucial importance. One indication which marks the transition from the alphabetic to the orthographic phase is children mastering most of the GtP correspondences. A further marker of this transition is decoding accuracy approaching ceiling for regularly spelled words. In transparent orthographies decoding accuracy generally approaches ceiling by the end of Grade 1 (Seymour et al., 2003), suggesting that the alphabetic phase in Spanish should be shorter than in English. During the subsequent orthographic phase, advanced decoding increases decoding speed through the process where common multi-grapheme orthographic patterns and their phonological counterparts are processed as a single element. A continued increase in decoding speed after complete decoding accuracy has been achieved is an indication that children are applying this sort of orthographic processing.

The transition from decoding to lexical reading seems to be more clearly defined by the item-based model referred to as the self-teaching hypothesis (Share, 1999, 2008), where each successfully decoded word provides a self-teaching opportunity for the reader to register the unitized orthographic representation of a word. Therefore, as the reader is increasingly exposed to print, the volume of visually memorized sight words increases. Consequently, sight words stored in the orthographic lexicon will be instrumental to invoke the fastest, most direct route from print to speech, namely lexical reading (Orsolini et al., 2006; Share, 1999). Thus, an initial reliance on sublexical phonological recoding (decoding) is gradually replaced by sight-word reading. However, in transparent orthographies the transition to lexical reading, evidenced by the emergence of lexical effects, has been reported to begin early within the process of reading acquisition (Cuetos & Súarez-Coalla, 2009; Orsolini et al., 2006) as it appears to be a continual process based on items rather than on stages (Share, 1999). A confirmed lexical effect, where words are read faster than non-words is evidence that lexical reading is taking place.

Does the Relevance of Cognitive Abilities depend on the Developmental Period?

A prominent view within the field of literacy acquisition regards PA as a central component in the mechanism responsible for phonological decoding, as suggested by its reported association with reading tasks like non-word reading (Badian, 1993; Manis et al., 1999; Sunseth & Bowers, 2002; Torgesen et al., 1997). However, the contribution by PA to reading appears to wane after the initial period of reading acquisition (English: Badian, 2001; Kirby et al., 2003) which does not reconcile well with the notion that PA is permanently involved in converting graphemes into phonemes. In transparent orthographies the contribution made by early-PA diminishes as early as Grade 1 (Dutch: de Jong & van der Leij, 1999; Spanish: Defior, 2008; Finnish: Leppänen et al., 2006; Norwegian: Lervåg et al., 2009). Even in studies assessing the concurrent relationship between PA and non-word reading, the correlation between these two skills tends to decreases in strength as the reader becomes proficient (e.g. Dutch: Vaessen & Blomert, 2010; Finnish: Müller & Brady, 2001). However, if PA's predominant role in reading was assisting during phonological decoding the significant correlation between PA and non-word reading would remain strong, not only up until Grade 1, but at all periods in the process of reading development.

Therefore, if PA is not permanently involved in phonological decoding, an alternative explanation is required for the significant PA-reading relationship observed at the onset of literacy acquisition. Share's functional opacity hypothesis (2008) emphasizes that PA is maximally influential when a child has learned some, but not all, GtP correspondences; that is, while the knowledge of spelling-sound mappings is still incomplete. In fact, it has long been proposed that PA is crucial for the acquisition of the alphabetic principle (e.g. Byrne & Fielding-Barnsley, 1989; Goswami, 2002; Vellutino et al., 2004) and that being phonemically aware is a requirement only during the early stages of reading development (Stanovich, 1986a). If PA were not so crucial for converting graphemes into phonemes, but rather it was crucial for the initial learning of those GtP correspondences, a PA-reading relationship would be predominantly observed during the period when the alphabetic code is being learned, but would thereafter diminish. While the PA-reading relationship in transparent orthographies seems primarily constrained to early reading development, it has not yet been examined whether PA's period of maximal influence matches the phase during which the children acquire the letter-sound knowledge, namely Ehri's alphabetic phase (2002, 2005).

Regarding visual processing skills, the few studies which have examined the contribution of pre-reading visual ability to later reading have found contradicting results. In a study carried out by Franceschini et al. (2012), a significant longitudinal relationship was found between pre-reading visual search ability and reading when the latter was measured while their sample of Italian-speaking children was approximately 7 years of age. In contrast, Shapiro et al. (2013) measured reading when their sample of English-speaking children were on average 5 years and 2 months of age, and found pre-reading visual search not to make a significant contribution to reading. Therefore, whether pre-reading levels of this entirely non-linguistic skill are causally related to subsequent reading performance in alphabetic orthographies has not been fully established. However, the observed inconsistency between these results could be reconciled under the following assumption.

As previously reviewed, the development of unitization begins after the alphabetic phase is over and allows the novice reader to process the multi-letter orthographic patterns of novel words through advanced decoding (Ehri, 2005; LaBerge & Samuels, 1974). In order to accurately and rapidly recognize and process these unitized letter-clusters, the reader may require efficient serial visual-attentional orientation (Facoetti et al., 2006) or a sufficiently large visual-attentional span to encompass the whole orthographic pattern (Ans, et al., 1998). In this scenario, pre-reading VPS would predict reading during the orthographic phase, but not during the alphabetic phase, a period during which slow letter-by-letter decoding predominates. Whether the noted difference between the results obtained in different studies examining the importance of pre-reading VPS is due to the period in which reading was measured is hard to determine, since no studies to-date have assessed the contribution of pre-reading VPS to reading at multiple points using the same sample of children. With regards to Spanish, no longitudinal study has assessed VPS, even with just two time points. Furthermore, no study to-date has examined the longitudinal contribution of pre-reading visual multi-element processing ability (using either letters or using symbols) to future reading.

RAN is typically associated with reading speed, rather than with reading accuracy (Schatschneider et al., 2002; Vaessen et al., 2009). Given that in transparent orthographies reading accuracy approaches ceiling early in the process of reading skill acquisition, the expectation for this study is that RAN will be more related to reading once reading speed becomes the discriminating factor of reading performance. However, numerous studies have shown that after the initial phases of reading acquisition, RAN performance strongly contributes to reading speed (e.g., Caravolas et al., 2013; Kirby et al., 2003; Vaessen & Blomert, 2010) as far as Grade 10 (e.g., Georgiou et al., 2014). Hence, the focus of this first study was merely in assessing whether RAN's longitudinal contribution to reading commenced early on within the alphabetic phase or after the alphabetic phase is over. Naming speed's role in reading is a topic which will be examined in study 3.

The intelligence quotient (IQ) is also known to have an effect on reading (e.g., Bowey, 2005; de Jong & van der Leij, 1999). In fact, among the various definitions of dyslexia which have been considered over the years, a condition *sine qua non* for diagnosis is that the subject must have IQ levels within the normal range (e.g., Stanovich, 1986b; Shaywitz, 2003). Individual variation in Verbal IQ, often measured by means of vocabulary or semantic skill tests, has been known to contribute to the acquisition of reading (Caravolas, Hulme, & Snowling, 2001; Nation & Snowling, 1998; Plaut et al., 1996). Several studies have confirmed a substantial role for semantic knowledge in word recognition (see Nation, 2008, for a review), which itself will increase with reading experience. Therefore, verbal and non-verbal IQ should always be taken into account when attempting to examine the relationship between reading and reading-related cognitive abilities.

Link between Cognitive Abilities and Specific Reading Developmental Periods

The models of reading development described above provide us with a theoretical background which defines the progression a child makes in the acquisition of reading, commencing with the process of predominantly decoding unfamiliar words to ultimately recognizing known words automatically. In order to help clarify the relevance of PA, VPS and RAN to reading skill acquisition, it would be beneficial to witness how the contribution made by these abilities varies depending on the period of reading development. Assuming that the acquisition of reading fluency involves a shift between the processes mentioned earlier, it is reasonable to expect that the contribution of the cognitive abilities which the child relies on might follow a concomitant shift. Coupling our understanding about these developmental learning periods with our knowledge of reading-related cognitive abilities will allow us to obtain further insight into the underlying mechanisms that enable appropriate reading skill acquisition.

When assessing whether cognitive abilities are causally related to future reading skill it is important to remember that these abilities are themselves influenced by reading skill. For example, as reviewed in previous chapters, it has been shown that PA is modified by reading experience (Bentin & Leshem, 1993; Hogan et al., 2005). Likewise, neural (Dehaene et al., 2010) and behavioral data (Duñabeitia, Orihuela & Carreiras, 2014; Perfetti et al., 2013) suggest that reading experience also modifies visual processing skill. This evidence indicates that the relationships that VPS and PA maintain with reading are bi-directional. Therefore, in order to rule out the possibility that individual differences in the predictors are a consequence of individual differences in reading experience, cognitive abilities should be measured before the onset of reading skill acquisition.

The Present Study

This 52-month longitudinal study in Spanish, a highly transparent orthography, is aimed at observing the pattern of reading skill development from its onset, along with the cognitive abilities which support this learning process at each time point. Developmental reading models describe a progression based on overlapping stages, where an earlier alphabetic phase is replaced by an orthographic phase; all the while lexical reading develops in parallel. One goal of this study is to examine whether these theoretical representations are compatible with the pattern of development displayed by a large unselected sample of Spanish children. The second goal is to observe to what extent pre-reading levels of literacy-related cognitive abilities match the developmental timeline, with the intention to further understand the relevance of these reading precursors within the underlying mechanism of the learning process. Of note is that this is the first study to examine the differences in the contribution of pre-reading VPS to multiple time-points in future reading.

Reading ability was assessed initially at the end of kindergarten and followed up until Grade 4. Given that words eventually become familiar, and are thus read lexically, non-word reading was assessed from Grade 1 onwards to track decoding skill. GtP correspondence knowledge was also measured from the onset of the study until end of Grade 1, when it approached ceiling. We assessed whether improvement on reading fluency and accuracy occurred in unison to the acquisition of GtP correspondence knowledge. Reading-related cognitive abilities (PA, RAN and VPS) were measured at mid-kindergarten, 9 months prior to the start of formal literacy instruction, with the aim of evaluating to what degree each predictor was related to future reading performance in different grades. We expected PA ability to predict reading skills early on, while children are still learning the alphabetic code, and to cease to be a predictor after the alphabetic code had been mastered. Once children became proficient with letter-to-sound mapping and reading speed, rather than reading accuracy, becomes the main marker of reading performance, we anticipated naming speed and visual processing skills to be responsible for higher rates of contribution to reading.

Methodology

Participants

188 Spanish children (85 girls, 103 boys) were initially tested at the onset of the study. All participants were monolingual Spanish speakers. All children who were unable to complete the tasks due to speech, cognitive, and/or hearing disability were excluded from the study. All children were recruited from five schools, which reduced the likelihood of biases due to school idiosyncrasies and/or socio-economic status factors. All participants had parental and school consent to take part in the study (see Consent Form in Appendices 1 - 3).

In the Spanish schooling curricula, formal literacy instruction officially begins at the onset of Grade 1 of primary school. All schools included in this study employed a phonics-based method of literacy instruction. Although formal literacy instruction does not commence until Grade 1, all schools did provide some instruction of letter-sound knowledge during kindergarten. The level of kindergarten instruction of letter-sound knowledge varied from school to school. Therefore, even though the study started 9 months prior to formal reading instruction, some children had already been introduced, at least partially, to the alphabet, either at school or at home. As reviewed in the chapter corresponding to the theoretical framework, reading practice has been shown to influence cognitive skills (VPS: Dehaene et al., 2010; Perfetti et al., 2013; PA: Bentin & Leshem, 1993; Hogan et al., 2005). Although at the onset of the current study 50% of the children in the sample were not able to read any words correctly and only 20% of the children could read more than 10 high-frequency three-letter words in less than 60 seconds, there was still a concern that the cognitive abilities of these early readers in the sample could already have been altered by initial reading experience. It is plausible therefore, that an observed relationship between a cognitive variable and reading may have been partly driven by the transformation that reading practice had exerted on the cognitive abilities of the early readers in the sample.

To guard against the possibility that the scores by children with early reading experience influenced the results of the analyses, early readers were excluded from the sample at the beginning of the study, thus ensuring that the retained sample consisted entirely of pre-literate children. This procedure ensured that the cognitive skills were unmodified by reading practice at that time when they were assessed. For this end, the single-word reading list used in study 1 at each time point was also administered to the children at the onset of the study, at mid-kindergarten (see Appendix 16). A child was considered an early reader if s/he could accurately read any item which contained more than two letters. This resulted in the exclusion of 68 children from the sample. Therefore, only children who could not read any of these words correctly were included in the study. After exclusion of the early readers, 120 children remained in kindergarten (53 girls, 67 boys). The mean age of these children at the outset of testing was 5 years, 6 months (*SD* = 3.6 months, range 5 years, 1 month – 6 years, 1 month). Due to drop-outs 100 children remained in the study during the last assessment and their mean age was 9 years, 10 months (*SD* = 3.7 months, range 9 years, 5 months – 10 years, 5 months).

Design and Procedure

All cognitive abilities of interest were first assessed in mid-kindergarten (February-March), along with the control variables, 9 months prior to the commencement of formal reading instruction. Reading skill was assessed on five occasions in June of every grade. A word reading test was administered once a year from kindergarten to Grade 4, while a non-word reading test was administered from Grade 1 to Grade 4. GtP correspondence knowledge was measured once during kindergarten, and again in Grade 1, at which time it approached ceiling. Except for the reading fluency tests, in all tasks children first saw a number of demonstration items and/or completed a number of practice items to ensure that they understood what was required of them. All testing was done in school by trained experimenters and all the tests were individually administered in a fixed order.

Tests and Materials

- **General Intelligence**

Verbal and non-verbal skills were evaluated as control variables for all the studies. They were respectively assessed with the Vocabulary and Block Design subtests taken from the Spanish version of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) for children (Wechsler, 2001).

Verbal IQ - For the Vocabulary test, children were asked to provide the definition of spoken words. 22 items were administered with increasing difficulty. One point was awarded for every correct answer. The manual supplied by the WPPSI test provided the criteria to discern correct from incorrect answers. Items for which no definition was given were awarded zero points. The test was discontinued after five consecutive wrong answers.

Non-verbal IQ - With regards to the Block Design test, the child was asked to reproduce the pattern showed to him/her, by spinning a number of colored cubes and arranging them correctly. After some demonstrations, 20 items were administered. The child had two opportunities at each item and there was a different time limit for each item. The test was discontinued after two failed attempts at the same item.

- **Phonemic Awareness**

Phonemic awareness was assessed using a phoneme isolation task and a phoneme blending task.

Phoneme Isolation - This task consisted of four blocks of eight non-word items of increasing difficulty comprised of simple (CVC) and complex (CCVC) structures (see Appendices 4 and 5). On the first two blocks, children were required to isolate and pronounce the initial phoneme, and on the last two blocks the final phoneme of each item. Children listened to two demonstration items before attempting two practice items. Administration in each block was discontinued after four consecutive errors.

Phoneme Blending - This task required children to blend spoken phonemic segments into real, high frequency words. Following two demonstrations and two practice items, 10 mono-syllabic test items with increasingly complex syllable structures were administered (see Appendices 6 and 7). Partial points were awarded for correct phoneme recognition, with a further point awarded for correctly pronouncing the target word. The test was discontinued after six consecutive responses that showed no overlap with any of the sounds in the target word.

- **Visual Processing Skills**

A multi-element processing task was designed to measure the children's ability to encode the position of letter-like symbols within a string. Participants had to memorize the position of each item in the string and then select the correct string from a two-alternative forced-choice (2AFC). To guarantee that this task required no phonological processing, the stimuli consisted of a selection Greek and Cyrillic characters which were chosen to minimize their visual similarity to the Latin letters which make up the Spanish alphabet. These symbols were not familiar to Spanish children within this study's age range, and thus can be considered non-nameable pseudo-letter symbols. Hence, the task used functionally non-linguistic symbols and required no verbal response, thus measuring pure visual processing ability.

All stimuli consisted of horizontal sequences of adjacent symbols, forming word-like symbol strings. Stimuli were displayed in black on white background and were presented in upper-case 72-point Times New Roman font. The distance between the centers of each symbol was larger than 1cm to avoid a crowding effect (Spinelli, De Luca, Judica, & Zoccolotti, 2002). Each trial consisted of a target string depicted on a memory card which was shown for 4 seconds and was immediately followed by a test card displaying two symbol-strings one above the other in a 2AFC paradigm. Decoy strings consisted of the same symbols as the target string, but presented in a different order. Participants were instructed to decide which one of these two strings of symbols was presented in the preceding card by pointing to their chosen string. The number of symbols per string present in each trial progressively increased. The task was discontinued if children made three consecutive errors. Children were shown three blocks of items: four two-symbol, four three-symbol and four four-symbol strings (see Appendices 8 and 9).

- **Naming Speed**

Alphanumeric RAN (letters and digits) has been found to yield stronger correlations with literacy measures than non-alphanumeric RAN (objects and colors) in most studies which have compared the two (e.g., Lervåg et al., 2009; van den Bos, Zijlstra, & Lutje Spelberg, 2002). However, there are doubts about the methodological suitability of using a form of RAN which is partly based on letter knowledge, as letter knowledge itself has been widely recognized as a powerful predictor of early reading (see Bowey, 2005 for a review). Because of the potential confound between letter knowledge and naming speed, non-alphanumeric forms of RAN (objects and colors) were chosen for the present study, for which Spanish versions were developed (adapted from Denckla & Rudel, 1974). The RAN composite score was computed by averaging the *z*-scores of RAN Objects and RAN Colors (r = .71)

RAN Objects - Five pictures were repeated eight times, giving a total of forty items, and these were displayed over five lines of a single A-4 card. Children were asked to name the items sequentially as fast as possible, starting in the upper left corner of the sheet and ending in the lower right. Two trials were administered, with items arranged in a different, quasi-random order on each trial. The items consisted of drawings of a key [llave], a dog [perro], a table [mesa], an eye [ojo] and a lion [león]. The average time taken to complete the two trials was used as the final score (see Appendices 10 and 11).

RAN Colors - The procedure and calculation for the RAN Colors task was identical to that of the RAN Objects task. The items consisted of filled circles of the colors red [rojo], brown [marrón], green [verde], blue [azul] and black [negro] (see Appendix 12).

- **Grapheme-to-Phoneme Correspondence Knowledge**

This task was designed to assess the child's knowledge of the correspondence between letters and their associated sounds. 23 out of the 27 letters in the Spanish alphabet, as well as two extensively used digraphs (*ch* and *ll*), were presented individually on separate cards. The graphemes *k* and *w*, which are only contained in words with foreign origins, together with *h* and *q,* which by themselves have no sound, were excluded from the analysis. The children were asked to provide the sound for each letter or digraph. The sequence of presentation was based on the order in which letters are taught in most children's alphabet books in Spanish (e.g. Martínez-Belinchón, Sahuquillo & García, 2006), from most common to least common, starting with the vowels. This task was discontinued if the child gave four consecutive incorrect responses. The whole procedure was carried out twice: first with upper- and then lower-case versions of the letters. Accuracy scores were aggregated across case to produce estimates of GtP correspondence knowledge (see Appendices 13 and 14).

- **Reading Speed and Accuracy**

As reading accuracy has been shown to approach ceiling at an early age in transparent languages (Seymour et al., 2003), and due to the length of our study, a test which exclusively assessed reading accuracy would not have provided sufficient variability amongst the children at later time points. Thus, reading tasks which provided both speed and accuracy data were applied.

One-Minute Word Reading - A single-word reading list was created comprising words of frequency >10 in 1 million, which were selected from child and adult word-frequency corpora (Martínez & García, 2004). Words were arranged into three columns on each side of an A-4 sheet in 18-point Arial Bold font. The list included all forms of words but was composed mainly of nouns, adjectives, and adverbs. The items were ordered by increasing phono-graphic complexity, ranging from single-letter words up to four-syllable words, although it was not expected that all children would reach the most complex words, especially in the earlier assessments, given the time limit imposed. Children were instructed to read the words aloud as quickly and as accurately as possible until asked to stop (see Appendices 15 and 16).

One-Minute Non-Word Reading - An analogous single non-word reading task was also applied to measure decoding skill. Each item in the non-word reading task was derived from its corresponding item in the word reading task by changing one, two or three letters, depending on the length of the item (see Appendices 17). For both the word and the non-word task, reading speed was defined as the number of correctly read items in 60 seconds. Reading accuracy was defined as the proportion of correctly read items out of all items attempted by each child. Skipped items were counted as incorrect. The accuracy measure was not primarily used to study individual differences. Therefore, even if the accuracy proportion was calculated out of a different amount of items for every child, it is still a representative average of the proportion of reading errors made by the whole sample. The word and non-word reading tasks were administered in different testing sessions and the session containing the non-word task was always administered first.

Results

Table 1

Means, Standard Deviations (SD) and Reliability for Cognitive and Literacy Measures

• ***Kindergarten Cognitive Measures***	Mean (*SD*)	Range	Reliability
Non-Verbal IQ (20)	10.97 (3.53)	3 - 17	std
Verbal IQ (22)	8.47 (3.26)	1 - 16	std
RAN Pictures	57.72 (12.32)	38 - 87	r = .73 (**) [a]
RAN Colors	66.49 (21.05)	36 - 128	r = .80 (**) [a]
Phoneme Isolation (64)	11.04 (14.16)	0 - 54	α = .97
Phoneme Blending (10)	2.75 (2.44)	0 - 10	α = .87
Visual Processing Skills (24)	14.72 (6.69)	0 - 24	α = .82
• ***Grapheme-to-Phoneme Correspondence***			
Kindergarten GtP correspondence (25)	6.68 (5.32)	0 - 24	α = .99
Grade 1 GtP correspondence (25)	19.16 (5.14)	11 - 25	
• ***Word Reading Accuracy (% correct)***			
Kindergarten Reading	44.88 (35.32)	0 - 100	r = 0.64 (**) [a]
Grade 1 Reading	94.35 (6.22)	61 - 100	
Grade 2 Reading	97.97 (4.14)	64 - 100	
Grade 3 Reading	98.99 (1.54)	92 - 100	
Grade 4 Reading	99.52 (0.86)	96 - 100	
• ***Word Reading Speed (words/minute)***			
Kindergarten Reading	5.29 (7.81)	0 - 39	r = 0.88 (**) [a]
Grade 1 Reading	49.91 (14.50)	7 - 91	
Grade 2 Reading	71.74 (15.91)	18 - 109	
Grade 3 Reading	84.07 (16.07)	35 - 117	
Grade 4 Reading	93.66 (13.83)	41 - 129	
• ***Non-Word Reading Accuracy (% correct)***			
Grade 1 Reading	87.19 (10.19)	43 - 100	r = 0.44 (**) [a]
Grade 2 Reading	94.09 (7.06)	68 - 100	
Grade 3 Reading	94.82 (4.76)	71 - 100	
Grade 4 Reading	97.08 (2.62)	86 - 100	
• ***Non-Word Reading Speed (words/minute)***			
Grade 1 Reading	35.24 (9.19)	5 - 64	r = 0.79 (**) [a]
Grade 2 Reading	46.80 (10.36)	13 - 79	
Grade 3 Reading	53.53 (10.62)	25 - 86	
Grade 4 Reading	59.88 (10.14)	31 - 92	

Note. The maximum score for each test is presented in parentheses next to its name, except for reading speed and accuracy, which are measured in time and percentage correct, respectively. std = standardized test.

[a] These values are the correlations between the same variable one time point later. All remaining reliabilities are Cronbach's Alpha.

**p* < .05; ***p* < .001.

The descriptive statistics and the reliability indices for all the variables measured in this study are presented in Table 1. Word and non-word reading accuracy scores approached ceiling from Grade 1 onwards (95% and 87%, respectively), displaying negative skews. This skewness was expected, given that in highly transparent orthographic systems children tend to reduce their reading error rate to near zero by end of Grade 1 (Seymour et al., 2003). Regarding reading speed, all measures were normally distributed, with the exception of word reading when measured in kindergarten, which was positively skewed given that many children could not read at that stage. Excluding word (r = .64) and non-word reading accuracy (r = .44), all reliability indices for all non-standardized measures were above .73 (Table 1).

The group of early readers which was excluded from the study had higher levels of PA and VPS than the sample of pre-readers in kindergarten ($F_{PA}[1, 187] = 9.69$, $p = .002$; $F_{VPS}[1, 188] = 15.62$, $p < .001$). There are two potential explanations for this. The first possibility is that, as the early readers had been exposed to the alphabetic code more than the pre-readers, this exposure had resulted in higher levels of VPS and PA in the early readers, compared to the pre-readers. The second possibility is that the early readers possessed higher levels of PA and VPS compared to the pre-readers (for reasons unrelated to exposure to print), and this superior knowledge allowed the pre-readers to develop superior early reading performance, compared to the pre-readers. In this latter case, we would expect the pre-readers to maintain their advantage over the pre-readers in terms of reading skill, at least for the following few time points. However, once all children had assimilated the alphabetic code in Grade 1, there were no significant differences between the two groups in terms of reading level ($F[1, 179] = 0.99$, $p = .321$), and this was also true at all subsequent time points.

This result suggests that the early readers had higher levels of PA and VPS at the onset of the study because of having been introduced to the alphabetic code earlier than their peers. For this reason their differences in reading level disappeared as soon as all children had been introduced to the alphabetic code (end of Grade 1). Were the reading performance differences due to pre-reading differences in PA and VPS levels, kindergarten differences in reading levels would have still been present one year later, even after the pre-reading group had learnt the alphabetic code. Nevertheless, the analyses showed that the difference in reading performance became non-significant. Therefore, the current result supports the notion that the PA and VPS scores obtained by the group of early readers were influenced by literacy instruction. Consequently, had early readers been included in the study, these elevated levels would have distorted the results.

Figure 1 shows the yearly development in reading accuracy (June of every grade) by presenting the percentage of word and non-word reading errors superimposed over the percentage of GtP correspondence errors. Percentage of word reading errors is presented across all grades. GtP correspondence percentage scores are only presented from kindergarten until Grade 1 and non-word scores are only presented from Grade 1 onwards, as they were only measured at those time-points of the study. For word reading accuracy it can be observed that there is a rapid decrease towards zero errors from kindergarten to Grade 1. Non-word reading errors are also low from Grade 1 onwards. Of note is the concomitant pattern revealed between GtP correspondence knowledge and word/non-word reading accuracy. Despite the fact that children were reading longer and more structurally complex words in later grades, the word and non-word error rate remained at near zero after Grade 1.

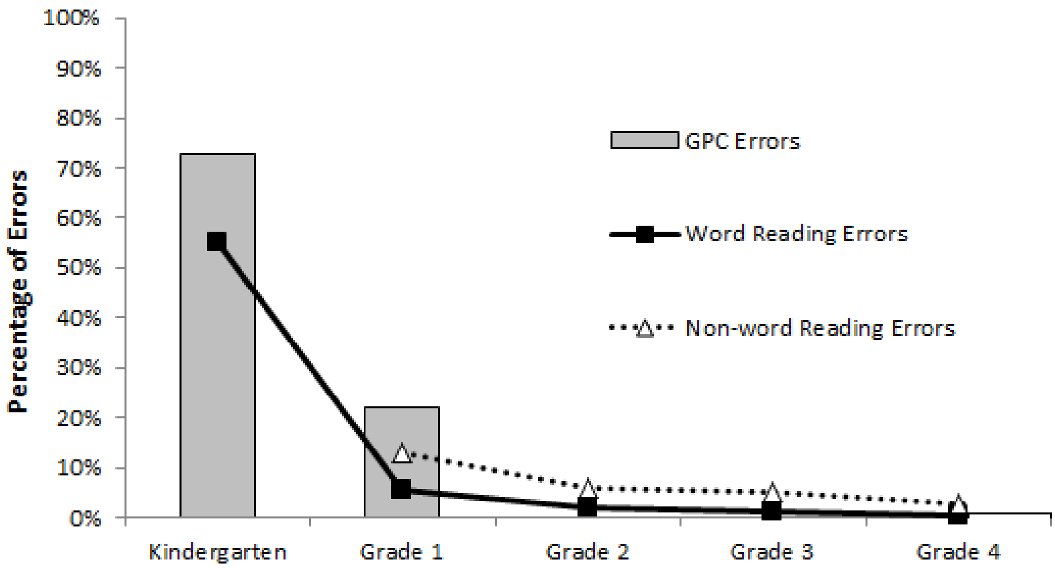

Figure 1. Percentage of errors in grapheme-to-phoneme correspondence (GPC) knowledge, word and non-word reading accuracy by grade.

The yearly growth in word and non-word reading speed (June of every grade) can be seen in Figure 2. Given that words increase in length along the reading list, at later time points the children were reading longer words than at earlier time points. Therefore, a conversion from words into syllables was calculated to offer a more consistent assessment of the incremental development. Figure 2 shows how decoding speed (non-word reading) continues to increase from Grade 2 onwards, even after decoding accuracy has reached ceiling. This was substantiated by simple planned ANOVA contrasts which confirmed the increase in non-word reading speed between Grade 1 and Grade 2 ($F[1, 96] = 329.00$, $p < .001$), Grade 2 and Grade 3 ($F[1, 96] = 50.62$, $p < .001$), and between Grade 3 and Grade 4 ($F[1, 96] = 65.62$, $p < .001$). Furthermore, the faster acceleration in word reading speed compared to non-word reading speed appears to signal a gradual transition into lexical reading.

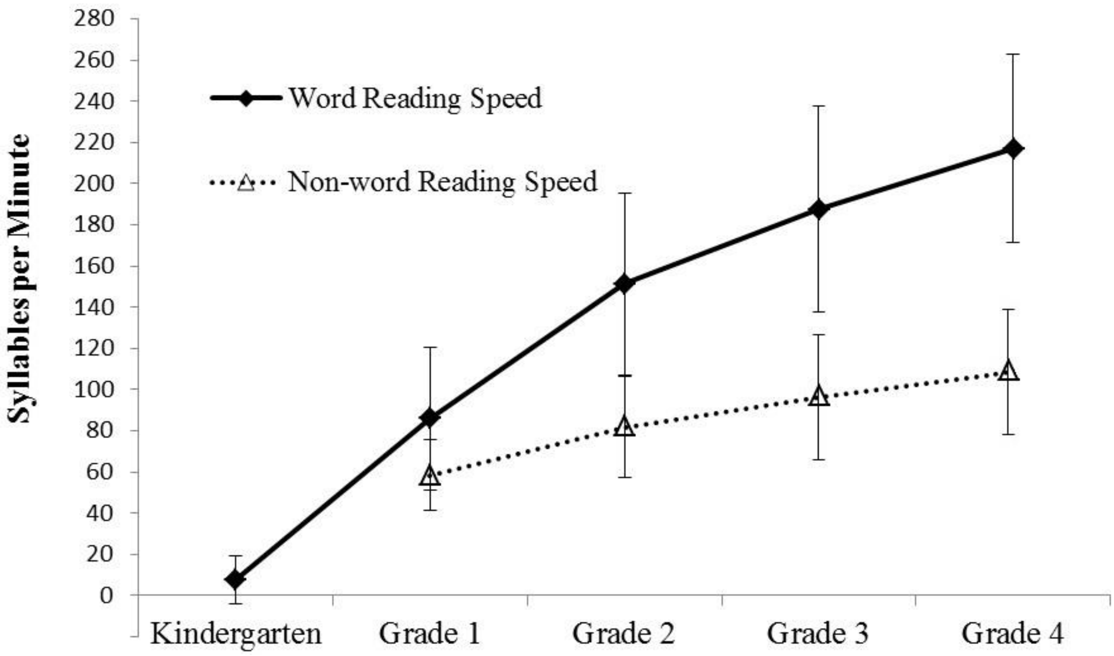

Figure 2. Mean word and non-word reading speed (syllables/minute) by grade. Error bars represent 1 standard deviation.

Before exploring the longitudinal predictors of reading skills, and in order to reduce the possibility of collinearity, composite scores for the PA (phoneme isolation and phoneme blending) and RAN tasks (RAN pictures and RAN colors) were computed by averaging their z-scores, thus providing a single variable for each. The subsequent data analyses are based on these composite scores. Table 2 provides results of the longitudinal correlation analyses between the three cognitive abilities plus the two controls, measured in kindergarten, against GtP correspondence knowledge at kindergarten and Grade 1 and all reading speed and accuracy variables from kindergarten to Grade 4. Chronological age was partialed out. Of note is the correlation between PA and kindergarten GtP correspondence knowledge (r = .49) and Grade 1 GtP correspondence knowledge (r = .38). Also noteworthy, is that the significant correlation that PA exhibits with reading speed (r = .51) and reading accuracy (r = .25) is only present prior to reading accuracy and GtP correspondence knowledge approaching ceiling. It is also interesting that PA does not significantly correlate with any word or non-word measure (speed or accuracy) from Grade 1 onwards. Interestingly, the correlations that VPS and RAN hold with reading speed exhibit a pattern which is diametrically opposed to that of the PA-reading speed correlation. VPS and RAN start to correlate significantly with reading speed only from Grade 1 onwards.

Given the rapidness with which Spanish children achieve near-perfect reading accuracy, (as observed in Figure 1), individual differences in reading performance after Grade 1 are not reflected in the reading accuracy scores. For this reason, the subsequent analyses will focus on word and non-word reading speed.

Table 2

Correlations between reading-related cognitive abilities measured in kindergarten and reading speed and accuracy measured from kindergarten to Grade 4

	Kindergarten Cognitive Abilities				
	PA	VPS	RAN	NV-IQ	Verbal IQ
Kinder GtP correspondence	0.49***	-0.05	-0.11	0.01	0.16
Grade 1 GtP correspondence	0.38***	0.11	-0.18	0.23*	0.05
Kinder W. Reading Acc.	0.37***	0.25*	-0.13	0.19	0.13
Grade 1 W. Reading Acc.	0.17	0.09	-0.31**	0.09	0.14
Grade 2 W. Reading Acc.	0.15	0.27**	-0.12	0.21	0.13
Grade 3 W. Reading Acc.	0.07	0.07	0.10	0.03	0.20
Grade 4 W. Reading Acc.	0.27	0.03	0.08	0.08	0.08
Kinder W. Reading Speed	0.51***	0.18	-0.15	0.12	0.19
Grade 1 W. Reading Speed	0.18	0.23*	-0.31**	0.14	0.16
Grade 2 W. Reading Speed	0.13	0.20	-0.31**	0.14	0.12
Grade 3 W. Reading Speed	0.07	0.15	-0.24*	0.06	0.09
Grade 4 W. Reading Speed	-0.09	0.08	-0.31**	-0.05	-0.01
Grade 1 NW. Reading Acc.	0.25**	0.19*	-0.15	0.15	0.30**
Grade 2 NW. Reading Acc.	0.07	0.18	0.17	0.07	0.15
Grade 3 NW. Reading Acc.	-0.03	0.24*	-0.25*	0.15	0.12
Grade 4 NW. Reading Acc.	0.02	0.11	-0.11	0.18	0.06
Grade 1 NW. Reading Speed	0.18	0.27**	-0.26**	0.16	0.25**
Grade 2 NW. Reading Speed	0.13	0.24*	-0.26**	0.11	0.14
Grade 3 NW. Reading Speed	-0.01	0.21*	-0.38***	0.17	0.11
Grade 4 NW. Reading Speed	-0.01	0.19	-0.28**	-0.10	-0.03

Note. All values represent partial correlations with age partialed out; PA = Phonemic Awareness Composite; VPS = Visual Processing Skills; RAN = RAN Composite Scores; NV-IQ = Non-Verbal IQ; Kinder = Kindergarten; GtP = Grapheme-to-Phoneme; W = Word; NW = Non-word; Reading Acc. = Reading Accuracy.

**p* < .05; ***p* < .01; ****p* < .001

To assess the longitudinal contribution of pre-reading RAN, VPS and PA to word and non-word reading in different grades we conducted a series of path analyses – 5 models in all; one for each grade from kindergarten to Grade 4. These analyses were conducted as structural equation models in Mplus (Version 6.1; Muthén & Muthén, 2010). The small amount of missing data was handled by full-information maximum-likelihood estimators with robust standard errors (estimator MLR in Mplus). Separately for each grade, we first estimated the saturated model shown in Figure 3. This model contains all possible co-variances between the predictor variables (RAN, VPS and PA) and the control variables (age, verbal IQ, non-verbal IQ) along with all possible paths from these variables to word reading and non-word reading.

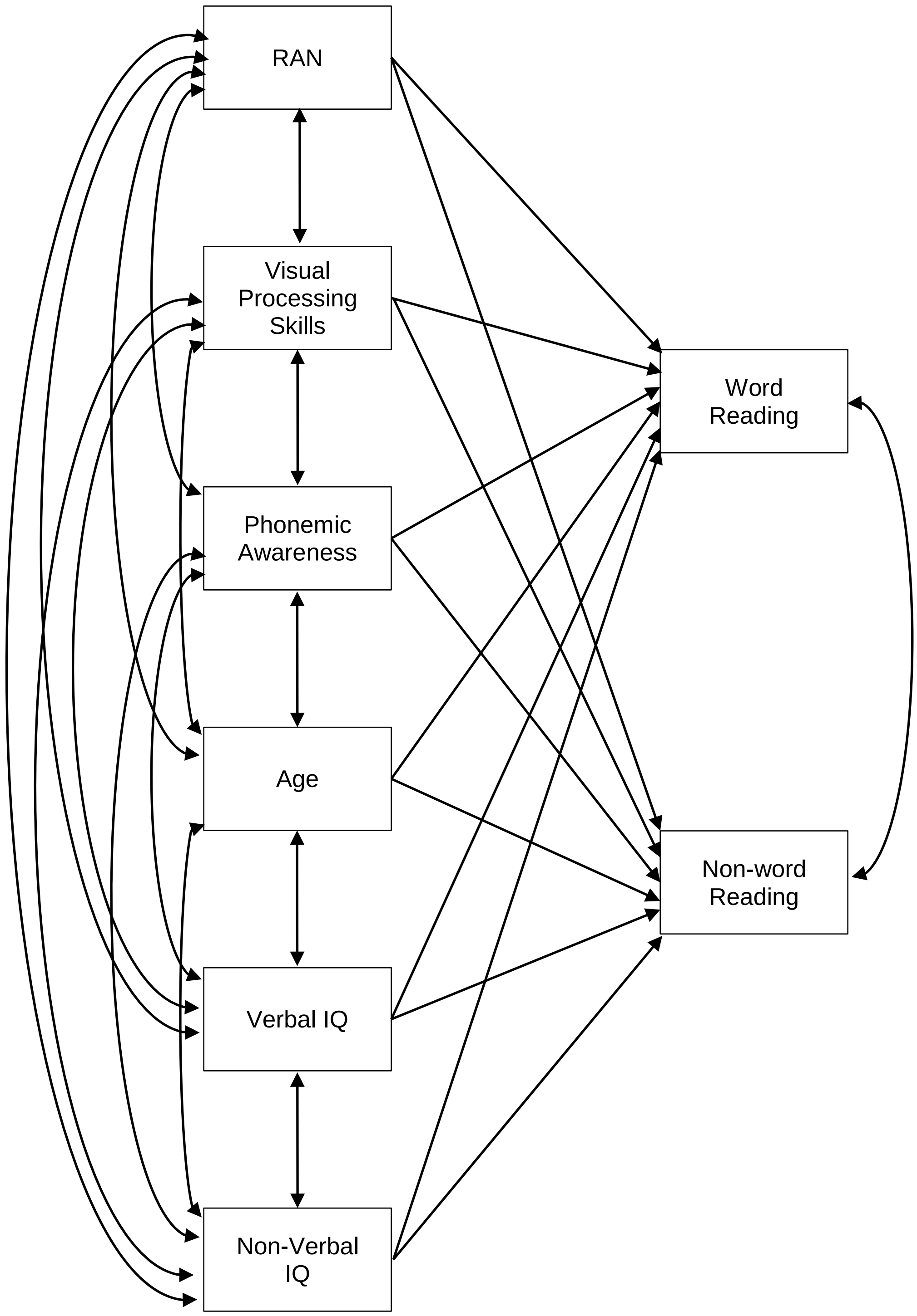

Figure 3. The path model used to assess the ability of RAN, Visual Processing Skills and Phonemic Awareness, measured prior to the commencement of formal reading instruction, to predict word and non-word reading at the end of all grades from kindergarten to Grade 4, except kindergarten, in which only word reading was assessed.

We were interested to know if the contribution made by each cognitive variable (RAN, VPS and PA) differed between word and non-word reading. To assess this, separately for each cognitive variable in each model, we constrained the two path weights originating from the cognitive variable leading word and non-word reading to be the same. We then used the Yuan-Bentler scaled χ^2 difference test to assess the difference between the base models and the constrained models. A significant difference between models indicates a significant difference between path weights. Standardized path weights for each model, along with the results of the comparisons are shown in Table 3.

We can observe that during kindergarten, PA was a significant predictor of word reading speed (β = 0.43). However, from the end of Grade 1, PA ceased to explain any variance in word or non-word reading speed (all *p*s > .325). Furthermore, the difference in the contribution made by PA to word and non-word reading was not significant in any grade, although given PA's non-significant contribution from Grade 1 onwards it is probably unsurprising that no differences were found when comparing PA's contribution to word and non-word reading.

In contrast, RAN was found to be a strong longitudinal predictor of both word and non-word reading. Initially, in kindergarten, RAN predicted a small but significant amount of variance in word reading (β = -0.12). However, from Grade 1 the strength of the relationship almost tripled (β = -0.32), and this relationship remained largely unchanged all the way through to Grade 4 (βs between -0.32 and -0.36). RAN was also a significant predictor of non-word reading in all grades.

Although not being a significant predictor of word reading in kindergarten, VPS emerged as a significant independent contributor to word reading speed in grade 1 (β = 0.21), but its impact progressively decreased in strength, just failing to reach significance in Grade 2 (β = 0.15, p = .056), and becoming non-significant from Grade 3. In contrast, for non-word reading VPS made an independent contribution to all grades in which it was assessed, apart from Grade 3, where it just failed to reach significance (p = .060).

As previously stated, these results were calculated using only the subsample of children who at the onset of the study were still at a pre-reading stage. However, when a second set of analyses were performed which included the early readers the same pattern of results was obtained.

Table 3

Path Weights for Five Different Models Predicting Word and Non-word Reading from Pre-Reading RAN, Visual Processing Skills and Phonemic Awareness, along with the Results of Comparisons of the Strength of the Path Weights between Word and Non-word Reading

	Word Reading		Non-word Reading		Word/Non-word Comparison	
	β	*p*	*β*	*p*	$\chi^2(1)^a$	*p*
Kindergarten						
RAN	-0.12	.033				
VPS	0.03	.677				
PA	0.43	< .001				
Model R^2	28.8%					
Grade 1						
RAN	-0.32	< .001	-0.26	.001	9.30	< .01
VPS	0.21	.002	0.20	.020	2.93	< .10
PA	0.05	.645	0.07	.463	0.00	> .05
Model R^2	24.9%		21.9%			
Grade 2						
RAN	-0.36	< .001	-0.25	.007	16.32	< .001
VPS	0.15	.056	0.20	.013	0.27	> .05
PA	0.05	.596	0.05	.636	0.17	> .05
Model R^2	20.6%		15.1%			
Grade 3						
RAN	-0.35	.001	-0.36	.001	2.77	< .10
VPS	0.12	.186	0.15	.060	0.07	> .05
PA	0.02	.863	-0.08	.325	1.01	> .05
Model R^2	16.4%		19.9%			
Grade 4						
RAN	-0.32	.001	-0.31	.002	2.83	< .10
VPS	0.12	.196	0.21	.010	0.23	> .05
PA	-0.08	.437	-0.05	.642	0.55	> .05
R^2	14.6%		16.8%			

RAN = Rapid Automatized Naming; VPS = Visual Processing Skill; PA = Phonemic Awareness.

[a] All tests were performed using the Yuan-Bentler scaled χ^2 difference.

Discussion

In this longitudinal study we observed the developmental profile of early reading skills in Spanish over the first 52 months of literacy instruction and examined the potential causal contribution made by relevant cognitive abilities (VPS, RAN and PA). A shift from the alphabetic to the orthographic phase can be perceived. The former extends from the onset of literacy teaching until most letter-sound correspondences have been attained by the children. This boundary is reached at the end of Grade 1 and is marked by GtP correspondence knowledge and reading accuracy approaching ceiling, while decoding speed continues to increase. Thus, the pattern of results observed here fits the description presented by existing developmental reading models. Pre-reading levels of PA, RAN and VPS all made reliable longitudinal contributions to reading skill during the first four years of literacy acquisition, confirming their status as precursors to reading. However, the longitudinal pattern of the three predictors was heterogeneous. PA correlated with GtP correspondence and exerted a strong influence on word reading speed at the earlier phase of the learning process, while the children were still learning the alphabetic code. VPS and RAN were not significant predictors of reading speed until most GtP correspondences had been learnt.

Reading Development in the Highly Regular Spanish Orthography

According to developmental models (e.g., Ehri, 2005; Frith, 1986), children move from a reliance on basic decoding at the alphabetic phase, while they learn the major GtP correspondences, through to the orthographic phase, enabling faster word processing. The one-letter-one-phoneme mapping principle which characterizes the Spanish orthography allows for a rapid development of basic decoding skills and a quick transition to advanced decoding of unitized letter-clusters. In line with these theories, our results revealed a shift in performance across development. Once formal tuition of letter knowledge commenced, word and non-word reading accuracy quickly followed an asymptotic pattern until it reached ceiling, at which point reading speed became the only discriminating factor of reading performance. Decoding speed of words and non-words continued to increase after reading accuracy had been achieved, suggesting a more efficient decoding procedure is being applied. Furthermore, and in line with the findings by Cuetos and Suarez-Coalla (2009), the progressively widening gap between word and non-word reading speed suggests a gradual transition from advanced decoding into lexical reading.

According to the results of the current study, substantial changes take place towards the end of the first year of primary school. It is during this period that children complete their understanding of GFCs and reading accuracy for words and non-words approaches ceiling. Furthermore, decoding speed continues to increase after Grade 1 despite decoding accuracy having been attained. Considering these observations together, the end of Grade 1 appears to mark a distinct turning point in the course of development. While the item-based transition into lexical reading may be a more progressive process which starts early on in reading development (Share, 1999), the shift from the alphabetic to the orthographic stage appears to be a more narrowly defined episode in development. This study's results denote a clear variation in performance at the end of Grade 1. This interval seems to correspond to the period when the alphabetic code is fully grasped and basic decoding proficiency is achieved, suggesting a transition from the foundational period during which the child learns the GtP correspondences to the period when groups of letters begin to be decoded in groups. In summary, the description of the alphabetic and orthographic phases together with the transition towards lexical reading depicted by developmental models of reading developed for English also seem to apply to Spanish speaking children.

Match between Cognitive Abilities and Developmental Periods

We examined the independent contribution made by VPS, RAN and PA to future reading skills in order to assess whether there is a match between their period of significant influence and the developmental periods described by theoretical models of reading development. Since all early readers were excluded from the sample at the onset of the study, the three cognitive abilities were longitudinal pre-reading predictors of future reading speed, though at different intervals over the 52 month-span of the study. The shift in reading strategies depicted by developmental reading models is also supported by the gradual shift observed in the contribution made by cognitive predictors to future reading.

Pre-reading levels of PA made an independent contribution to reading during the kindergarten period, but its influence decreased abruptly thereafter. At kindergarten, when the children could recode approximately one quarter of the letters and word reading accuracy was below 50%, the correlation between GtP correspondence knowledge and PA was medium-large and PA explained the largest amount of variability in reading speed. In contrast, by the end of Grade 1, once the mean of the children's GtP correspondence knowledge exceeded 75% accuracy, and reading accuracy had approached ceiling, PA's contribution to reading was surpassed by RAN, and was thereafter no longer related to word reading or even to decoding skill (non-word reading). This result firmly contradicts the view that PA is primarily involved in GtP conversions. If this was the case PA would have predicted non-word reading. Therefore, the results of this study indicate that pre-reading levels of PA exert a critical influence on reading in Spanish which is limited to the earliest period of reading acquisition. This finding supports the functional opacity hypothesis (Share, 2008) which states that PA is maximally influential while children's letter-sound mappings are for the most part still incomplete.

Furthermore, this perspective concurs with results reported by studies in other transparent orthographies which reveal that the influence of pre-reading PA undergoes a sharp decline after Grade 1 (Dutch: de Jong & van der Leij, 1999; Finnish: Leppänen et al., 2006; Norwegian: Lervåg et al., 2009). However, the current study extends this result by showing that the period when PA's influence wanes coincides with the moment when children achieve overall spelling-to-sound mapping knowledge and their levels of word and non-word reading accuracy approach ceiling. Thus, for the highly transparent Spanish orthography, the period when PA's contribution to reading ceases to be significant appears to match the interval of transition from the alphabetic to the orthographic phase. This finding converges with the understanding that phonological skill is crucial for acquisition of the alphabetic principle (Byrne & Fielding-Barnsley, 1989; Goswami, 2002; de Jong & Olson, 2004; Vellutino et al., 2004) providing the necessary template to decrypt the alphabetic code (Share, 2008). This would explain why PA's influence in reading development of orthographies with simple and consistent GtP correspondences has a limited time span.

RAN was the most constant longitudinal predictor out of the three, contributing to reading speed at all grades except kindergarten. Its relevance to reading speed increased from Grade 1 onwards, once reading accuracy reached ceiling and speed surpassed 100 syllables-per-minute. The onset of RAN's major influence on reading seems to match the beginning of the orthographic phase, during which unknown words are predominantly read through the process of advanced decoding. Furthermore, RAN was also responsible for a significant amount of unique explained variance in word reading at Grades 3 and 4. Given that by this point in development the words comprising the current reading task (frequency >10 in 1 million) would have been read as sight-words in the transparent Spanish orthography (Spanish: Cuetos & Suárez-Coalla, 2009; Italian: Orsolini et al., 2006), RAN's influence seems to extend to the period where lexical reading for high-frequency words predominates. The relevance of these results to the understanding of the RAN-reading relationship will be further discussed in study 3.

VPS predicted a significant amount of variance in word reading during Grade 1 (almost significant contribution to Grade 2) and in non-word reading during Grades 1, 2 and 4 (almost significant during Grade 3), beyond that explained by all other variables. This positive correlation concurs with previous findings demonstrating that sensitivity to the spatial sequence of word-like symbol strings predicts reading performance (Jones et al., 2008; Pammer et al., 2004) and with studies which have reported correlations between visual skills and reading fluency (Lobier, Dubois & Valdois, 2013; Prado, Dubois & Valdois, 2007). Furthermore, the current evidence suggests that pre-reading VPS may be causally related to reading skill independently of other cognitive abilities. However, interestingly VPS did not account for any variance in reading skill at the end of kindergarten and only started to make a contribution to reading by the end of Grade 1. Therefore, VPS' contribution to reading became significant only after most letter-sound correspondences had been learnt and reading rate had gathered pace, at the end of Grade 1. This result indicates that VPS may play a stronger role after the alphabetic phase is over, when children have become faster and more proficient at word reading.

The results appear to contradict the results obtained by Shapiro et al. (2013). However, upon closer inspection the findings from these two studies appear compatible. Shapiro et al. (2013) found pre-reading VPS not to be a significant predictor of reading speed when the latter was measured when the children were 5 years old. This means that VPS was not a significant contributor to reading at a point when the children could read less than 16 words per minute and their average word reading accuracy score was below 25%. Likewise, in the current study, the results revealed that pre-reading VPS did not make a significant contribution to word reading speed when the children were ending kindergarten (approx. 6 years old), but it did significantly contribute to word and non-word reading speed at the end of Grade 1 (approx. 7 years old). Therefore, VPS was not a significant predictor of reading when the mean reading accuracy was 45% and the reading speed mean was 5 words per minute. VPS only became significant at the end of Grade 1, when reading accuracy was 94% and the mean reading speed was 50 words per minute. Thus, the results obtained in study 1 match the results presented by Shapiro et al. (2013) in that pre-reading VPS do not predict reading while the children's accuracy is very poor and speed is very slow.

This result can be understood if VPS is involved in rapid serial visual-attentional orientation (Facoetti et al., 2006) or if a sufficiently large visual-attentional span is necessary to encompass large orthographic patterns (Ans, et al., 1998). Neither of these two VPS functions would come into play at the initial alphabetic phase, during which the novice reader is still engaging in slow letter-by-letter reading. In line with the current results, many other studies have found a significant contribution by VPS to word and non-word reading when reading was measured in samples of children 7 years old or older (English: Bosse & Valdois, 2009; Spanish: Lallier et al., 2014; Italian: Franceschini et al., 2012; French: Bosse et al., 2007; Dutch: van den Boer et al., 2013). While most of these studies examined the concurrent contribution by VPS to reading in samples of children who already had substantial reading experience, Franceschini et al. (2012) also found pre-reading VPS to make a longitudinal contribution to Grade 1 and Grade 2 word and non-word reading. However, of note is that in the current study the relationship between VPS and word reading was not symmetrical to the relationship between VPS and non-word reading. Although the difference in the contribution made by VPS to word reading and non-word reading was not statistically significant at any grade, the contribution by VPS to non-word reading was more protracted in time than its contribution to word reading. This suggests that VPS is more involved in decoding. This possibility will be further examined in study 2.

Conclusions

This longitudinal study beginning before the onset of formal literacy teaching, clarifies several issues concerning the underlying cognitive and linguistic foundations of early reading skills, within the context of the Spanish orthographic system. The current results show that the speed and accuracy measures, assessing reading performance from kindergarten to Grade 4, exhibit a developmental pattern compatible with the learning procedures described by developmental models elaborated for English. As children approach full understanding of the GtP correspondences, reading errors are critically reduced, which coupled with a continued increase in decoding speed, suggests a shift from the alphabetic to the orthographic reading phase at the end of Grade 1. Furthermore, the progressively increasing gap between word and non-word reading speed is evidence of a slow but constant transition towards lexical reading.

The end of Grade 1 is also the period when early-PA ceases to influence reading speed, while early-VPS and early-RAN start to influence it. PA appears to be essential early on, during the alphabetic phase, whilst the alphabetic system is, for the interim, functionally opaque (Share, 2008). RAN’s contribution to reading speed extends along most grades examined in this study, but its relevance increases after the alphabetic code has been assimilated. On the other hand, VPS seems to become particularly influential to reading during the timeframe in which advanced decoding develops and the focus turns to reading speed, rather than accuracy. These results reflect that different cognitive abilities influence reading proficiency differently depending on the developmental period and caution against generalizing findings obtained when working with one particular age group.

Study 2:

The Role of Visual Processing Skills in Word Decoding

Introduction

The results obtained in study 1, where VPS predicted reading performance, support previous evidence of a relationship between visual ability and reading reported in the VPS research literature (English: Rayner, 2009; Italian: Facoetti et al., 2006; French: Bosse & Valdois, 2009; Spanish: Lallier et al., 2014). The outcome of study 1 extends on previous findings because VPS, measured by assessing visual multi-element processing at a pre-reading period of development, made a significant contribution to future word and non-word reading. This result strongly suggests that VPS are causally related to reading skill. However, the contribution made by VPS to word and non-word reading was not homogeneous. In study 1, VPS was significantly related to non-word reading during grades 1, 2 and 4, but it was only significantly related to word reading in Grade 1. Even though these results appear to indicate that VPS is more associated with non-word reading than with word reading, there was no significant difference between the contributions made by VPS to each type of reading. Therefore, one aspect regarding the VPS-reading relationship that still remains largely unclear is whether visual ability is specifically related to analytical decoding of novel words or whether it is predominantly involved in global recognition of known words, or both. Furthermore, there is an interest to understand what the underlying mechanism which drives these potential relationships is.

Decoding or Sight-Word Reading

As noted in the revision of the literature in the theoretical framework chapter, on the one hand visual ability has been reported to be involved in sight-word reading (Ans et al., 1998; Bosse et al., 2007). On the other hand, a number of studies have concluded that visual skills play a significant role in sublexical decoding (Auclair & Siéroff, 2002; Facoetti et al., 2006; Jones et al., 2008; Kinsey et al., 2004). According to various developmental reading models (e.g., Backman et al., 1984; Ehri, 2005; Share, 2008), as well as several models of skilled reading (e.g., Ans et al., 1998; Coltheart et al., 2001; Forster & Chambers, 1973; LaBerge & Samuels, 1974), orthographic familiarity is the key element which will determine which of these two critical reading procedures (decoding or sight-word reading) readers use to decipher text. In this sense, in order to process novel or unfamiliar words, the reader will use a slow decoding strategy, by which sub-lexical units in the word (letters or letter clusters) will be sequentially converted into their phonological counterparts. In contrast, a known or familiar word will be automatically recognized as a whole unit, via rapid direct-retrieval mechanisms. Studies which have assessed VPS by means of multi-element processing, have reported specific associations with both, decoding of unfamiliar words and sight-word reading of familiar words (e.g., Bosse et al., 2007; van den Boer et al., 2013).

Word familiarity is often assessed using 'word frequency' or 'age of acquisition' measures (Italian: Barca et al., 2002; French: Bonin, Barry, Méot, & Chalard, 2004; Spanish: Cuetos & Barbón, 2006; Japanese Kanji: Yamazaki et al., 1997). The word frequency effect, whereby high frequency words are processed faster than matched low frequency words, has been extensively reported in English language studies (Connine et al., 1990; Rayner & Duffy, 1986), as well as in more regular orthographies (Italian: Barca et al., 2002; German: Kliegl et al., 2004; Dutch: Leij & Daal, 1999), including Spanish (Cuetos & Barbón, 2006; Defior et al., 1996; Valle-Arroyo, 1996). The word frequency effect is evidence supporting the understanding that familiar words are rapidly processed by means of sight-word reading, while unfamiliar words are decoded, the latter being a slower reading procedure.

The Importance of Word-Length

The length effect can also be employed as a marker of the reading procedure. The length effect refers to how reading latencies increase as a function of word length (Italian: Barca et al., 2002; Spanish: Cuetos & Barbón, 2006; Defior et al., 1996; Dutch: Marinus & de Jong, 2010; English: Weekes, 1997; German: Ziegler, Perry, Jacobs, & Braun, 2001). More interestingly, an increased length effect for unfamiliar than for familiar words is a well-established result pattern for naming latencies in reading tasks (Juphard, Carbonnel, & Valdois, 2004; Weekes, 1997; Ziegler et al., 2001; Zoccolotti, De Luca, Di Pace, Gasperini, Judica, & Spinelli, 2005). For instance, an effect of number of syllables has been reported for low-frequency words but not for high-frequency words (Ferrand & New, 2003; Jared & Seidenberg, 1990; Weekes, 1997). Likewise, and increased number of letters increases reading times for low-frequency words or non-words significantly more than it does for high-frequency words (e.g., Weekes, 1997). This word-length by word-familiarity interaction on naming latencies is evidence of sight-word reading for known words and serial decoding processing of novel words. This is simply because unfamiliar words must be read via a length-sensitive sequential decoding mechanism (Weekes, 1997), whereas familiar words are stored in the orthographic lexicon of the reader, enabling instant recognition.

Moreover, the length factor is directly relevant to the potential influence that visual multi-element processing may have on reading. Assuming visual attention span determines the number of letters or symbols that can be processed in parallel (Bosse et al., 2007) it follows that short words will not require much visual attention span demand. On the contrary, it is expected that multi-element processing will be more strongly related to longer than shorter words. In line with this perspective, Hawelka and Wimmer (2005) found readers with dyslexia to exhibit poorer performance than controls for recognition of four- and six-digit strings, but not for two-digit strings, indicating a visual multi-element processing deficit. Furthermore, larger visual attention capacity is associated with a larger number of visual elements (letters, graphemes, or syllables) (Lobier et al., 2013). Kwon, Legge and Dubbels (2007) reported that 34-52% of variability in children's reading speed was accounted for by the size of the visual span. Therefore, the reader's maximum size of the visuo-attentional window will exert limits on reading speed (Ans et al, 1998). Accordingly, several studies have found that fast readers have a larger perceptual span than slow readers (e.g., Häikiö, Bertram, Hyönä, & Neimi, 2009; Rayner, Slattery & Bélanger, 2010). Furthermore, several studies have found that visual attention span predicts reading speed (Kwon et al., 2007; Lobier et al., 2013) independently from IQ, PA (Bosse & Valdois, 2009) and RAN (van den Boer et al. 2013).

According to the MTM model (Ans et al., 1998) both the global (sight-word reading) and the analytical (decoding) reading procedures differ in the type of visual attention required. Whereas the global procedure requires a larger visual attention span to extend over the whole word, in the analytic procedure visual attention is focused successively on parts of the orthographic representation of the word. In support of this view, there is evidence that visual attention span is specifically related to serial processing during unfamiliar word reading (e.g., Bosse & Valdois, 2009; Valdois et al., 2006; van den Boer et al., 2013) and also to sight-word reading of familiar words (e.g., Bosse & Valdois, 2009; van den Boer et al., 2013). Of note, Jones et al. (2008), as well as Pammer et al. (2004), found multi-element processing to be specifically related to sublexical decoding. Moreover, if long-word reading (whether familiar or unfamiliar) relies on multi-element processing to a larger extent than short-word reading, word-length should influence the relationship between multi-element processing and word reading. Results of previous studies support this claim (e.g., Valdois et al., 2006; van den Boer et al., 2013). For instance, van den Boer et al. (2013) found that individual differences in the length effect were predicted by visual attention span.

Methodological Issues Worthy of Consideration

There are two methodological issues which have often been overlooked in studies which have examined the link between visual multi-element processing and reading. Firstly, the task typically used by Valdois and colleagues to capture differences in visual attention span requires the child to visually process a string of letters and subsequently recall the target letters by reporting them verbally. Therefore, given that the child must perform visual-to-verbal conversions in order to provide the answer it is possible that the observed deficits represent, not impaired visual-attentional processing, but impaired symbol-sound mapping (Ziegler et al., 2010b). In fact, some dyslexia studies have found that visual processing deficits are significant only for alphanumeric strings, but not for non-verbal symbol strings (Ziegler et al., 2010b), or only when a verbal response is required (Hawelka & Wimmer, 2008). While these findings are difficult to reconcile with the notion that pure visual skills play an independent role in reading, other studies have found that multi-element processing deficits also extend to tasks involving no phonological component (Jones et al., 2008; Lobier, Zoubrinetzky, & Valdois, 2012). Pammer et al. (2004) along with Jones et al. (2008) found that sensitivity to the spatial sequence of non-nameable symbol strings correlated with reading. This conflicting evidence, together with the fact that letter-knowledge is a well-established correlate of reading (Bowey, 2005), indicates that letters are non-ideal stimuli to assess whether pure VPS predict reading.

Furthermore, another crucial methodological issue which is often disregarded, when investigating the nature of the link between reading and multi-element processing, is the reciprocal relationship which VPS holds with reading skill. As previously reviewed, given that reading practice has been reported in several studies to have a transformative influence on visual ability levels (Dehaene et al., 2010; McBride-Chang et., 2011; Perfetti et al., 2013), the reported link between visual multi-element processing and reading (Jones et al., 2008; Lobier et al., 2012; Pammer et al., 2004) could be due to the influence that reading practice has on VPS. Therefore, part of the uncertainty regarding the role that VPS plays in reading might be due to the fact that most studies on this subject have focused on samples of subjects who have at least two years of reading experience (e.g., Bosse et al., 2007; Facoetti et al., 2006; Lobier et al., 2013; Valdois et al., 2006). Potentially, the observed correlation between VPS and sight-word reading, as opposed to decoding, may arise from early reading practice improving both visual ability and sight-word reading. These findings raise the matter of testing chronology, and suggest that in order to determine whether VPS influences decoding and/or sight-word reading performance, longitudinal studies which assess VPS with pre-reading children are needed (Goswami, 2015; Hawelka & Wimmer, 2005).

Even though this study will focus on examining whether VPS are predominantly related to decoding or sight-word reading, other cognitive abilities which are known to influence reading must also be taken into account. Regarding naming speed, having observed in study 1 the contribution that RAN made to both word and non-word reading, it is certainly a significant predictor and thus should be controlled for. Regarding PA, it is widely accepted that phonological skills are intricately linked with the process of learning to read. However, in accordance with the results obtained in study 1, results from other longitudinal studies conducted in transparent orthographies have consistently found that the contribution by early-PA to reading is only important during the first one or two years of schooling, but not beyond that period.

This Study

In summary, whereas in study 1 VPS made a significant contribution to both word and non-word reading, the specific role played by visual processing skill is yet to be clearly established. Thus, the purpose of this study is to examine the potential causal influence of early levels of visual multi-element processing to each of the two most important reading procedures (decoding and sight-word reading) by manipulating word frequency and word length. Assuming that unfamiliar words will be decoded, whilst highly familiar words will be automatically recognized as a whole (Ans et al., 1998; Ehri, 2005; Share, 2008), manipulation of word frequency will assist in exploring the VPS-reading relationship. This study will be conducted in Grade 3 to guarantee that the children will be at a developmental time-point where the orthographic representations of high-frequency words are likely to be very familiar to the children. Furthermore, as the precise role played by visual processing skills might be mediated by visual attention span, manipulating word length will be a useful tool in order to study this possibility. The approach will be to examine the specific contribution by visual multi-element processing to the reading of long and short, high- and low-frequency words.

Given PA and RAN's contribution to reading development it is imperative to include them in all analyses to ensure that any relationships found between the VPS and reading ability do not result from a spurious association with PA and/or RAN. IQ will also be controlled for. The MTM model (Ans et al., 1998) postulates that visual attention span is crucial for decoding and sight-word reading. If this model applies to the transparent Spanish orthography, visual multi-element processing is expected to contribute to the reading of all types of words, but especially to long words, which exert more visual attention span demand. In contrast, if sublexical decoding is specifically influenced by visual skills, this will be indicated by a stronger contribution by visual skills to low-frequency (LF), than to high-frequency (HF) words. Moreover, given that longer unfamiliar words will be decoded faster by children with a wider visual attention span, a stronger contribution by visual multi-element processing to long- compared to short LF word reading will be evidence of a specific relationship between visual multi-element processing and sublexical decoding.

Methodology

Participants

After the exclusion of the early readers, and due to dropouts/absenteeism during the subsequent years since the commencement of data-collection, 100 children (42 girls, 58 boys) remained in the study. Children which completed all tasks of both time-points at study 2 had a mean age of 5 years, 6 months (SD = 3.6 months, range 5 years, 1 month – 6 years, 1 month) during the first assessment (kindergarten) and 8 years, 10 months (SD = 3.6 months, range: 8 years, 5 months – 9 years, 5 months) during the second assessment (Grade 3) . For more details on the participants of the study see the methods section of study 1 (4.2 methodology).

Design

The predictor cognitive abilities of interest, along with the control variables were assessed in mid-kindergarten, nine months before the commencement of formal literacy instruction. In June of Grade 3, three years and three months after the cognitive abilities were measured, reading performance was assessed by means of four reading lists varying in word familiarity and word length.

Tests and Materials

- **General Intelligence**

Verbal and non-verbal skills were evaluated as control variables. They were respectively assessed with the Vocabulary and Block Design subtests taken from the Spanish version of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) for children (Wechsler, 2001).

- **Phonemic Awareness**

The phonemic awareness variable was based on the scores of the phoneme isolation task and the phoneme blending task. For more details on the phonemic awareness tasks see the methods section of study 1 (4.2 methodology).

Phoneme Blending - This task required children to blend spoken phonemic segments into real, high frequency words (see Appendices 4 and 5).

Phoneme Isolation - The task consisted of four blocks of eight non-word items. In the first two blocks, children were required to isolate and pronounce the initial phoneme whereas in the last two blocks the final phoneme was the focus of the task (see Appendices 6 and 7).

- **Visual Processing Skills**

This multi-element processing task measured the children's visual ability to encode the position of letter-like symbols within a string. For each of 12 items, which progressively increases in number of symbols, a target string consisting of a word-like sequence of Greek and Cyrillic characters was initially presented in a memory card. Subsequently, a second card displaying two strings of symbols was shown, from which the child had to discriminate the target string from a decoy string formed of the same symbols only in different order. For more details on this task see the methods section of study 1 (4.2 methodology, as well as Appendices 8 and 9).

- **Rapid Automatized Naming**

A Spanish version of RAN, adapted from Denckla & Rudel (1974), was created using two different categories of non-alphanumeric symbols, RAN-Objects and RAN-Colors. For both categories, trials of forty stimuli, consisting of five items repeated eight times each, were displayed over five lines of an A-4 card. Children were asked to name the items sequentially as fast as they could. Two trials were administered for each category, with items arranged in a different, quasi-random order on each trial. The RAN score was computed by averaging the z-scores of the two trials of RAN-Objects with the two trials of RAN-Colors. For more details on this task see the methods section of study 1 (4.2 methodology) (see Appendices 10 to 12).

- **Reading Measures**

Familiarity Word Lists (Grade 3) - Reading lists manipulating word familiarity and word length resulted in four main reading conditions: long high-frequency words (LHF), long low-frequency words (LLF), short high-frequency words (SHF), short low-frequency words (SLF). Each of these reading lists contained 25 words each (see Appendix 19). The HF and LF lists contained words of '>100' and '1-5' occurrences per 1 million words, respectively (Martínez & García, 2004). Items across the HF and LF lists were matched on letter length, syllable length, and syllable structure to their counterparts in the other frequency category. The total number of items per list containing diacritics (stress marks) was also matched. Words in the short conditions ranged from three to six letters and one to two syllables, while words in the two long conditions ranged from seven to ten letters and three to four syllables.

Each list was printed on a white sheet of A4 paper, in a lower-case format (Calibri, 14 point) with all items in columns on two separate sheets. The participants were instructed to read aloud the words in each list as quickly and accurately as possible (see Appendix 18). Reading speed was expressed in number of seconds required to read the entire list, irrespective of reading errors, providing a pure speed measure. All Grade 3 reading accuracy measures were at ceiling in terms of accuracy (all means > 95%) and did not correlate significantly with any of the cognitive variables. Indeed, given the highly transparent nature of the Spanish writing system, children's accuracy tends to approach ceiling by end of Grade 1 (Seymour et al., 2003). Furthermore, it is common for literacy acquisition studies in transparent orthographies, particularly after Grade 1, to assess reading by means of speed measures (e.g., Turkish: Babayigit & Stainthorp, 2010; Norwegian: Lervåg et al., 2009). On this basis, the speed scores were used as the measure of reading.

Results

The descriptive statistics and reliabilities for all the variables measured at kindergarten and Grade 3 are presented in Table 4. Generally all cognitive and control variables showed an acceptable range of scores in the distribution suggesting that the measures had adequate sensitivity to capture individual differences. All Grade 3 reading speed variables exhibited a normal distribution. Performance on IQ measures was within the average range. No strong floor or ceiling effects were apparent in any of the tasks. Scores on the RAN tasks, as well as those for the Grade 3 reading lists, are measures of time (in seconds) and therefore lower scores indicate better performance. Therefore, a positive relationship between RAN or reading and any other cognitive variable will be indicated by a negative correlation. The reliability for all non-standardized measures was acceptable ($r > .70$; see Table 4).

A two-way repeated measures ANOVA was carried out to predict reading speed. The two within subject factors were word-frequency (2 levels: HF and LF) and length (2 levels: short and long). Unsurprisingly, there were significant main effects of word-length and word-frequency, with shorter items being read significantly faster than longer items, $F(1, 99) = 251.41$, $p < .001$, partial $\eta^2 = .72$, and HF words being read faster than LF words $F(1, 99) = 351.66$, $p < .001$, partial $\eta^2 = .78$. There was a significant interaction, $F(1, 99) = 97.31$, $p < .001$, partial $\eta^2 = .50$, indicating that the difference between short and long words was significantly larger for LF words than for HF words.

Table 4

Means, Standard Deviations (SD) and Reliability for Cognitive and Reading Measures

• ***Kindergarten Cognitive Measures***	Mean (*SD*)	Range	Reliability
Non-Verbal IQ (20)	10.7 (3.61)	3 - 17	std
Verbal IQ (22)	8.6 (3.21)	1 - 16	std
Phoneme Isolation (64)	11.3 (14.15)	2 - 52	$\alpha = .90$ [a]
Phoneme Blending (10)	2.8 (2.49)	0 - 10	$\alpha = .87$ [a]
RAN Pictures	58.0 (12.25)	40 - 87	$r = .73$ (**) [b]
RAN Colors	66.9 (21.82)	37 - 128	$r = .80$ (**) [b]
Visual Processing Skills (24)	15.4 (6.40)	0 - 24	$\alpha = .82$ [a]
• ***Grade 3 Reading Speed Measures***			
Short High-Frequency Words	14.86 (4.39)	10 - 37	$r = .88$ (**) [c]
Long High-Frequency Words	22.80 (10.35)	10 - 68	$r = .93$ (**) [c]
Short Low-Frequency Words	26.39 (9.49)	13 - 60	$r = .79$ (**) [c]
Long Low-Frequency Words	42.82 (18.13)	17 - 129	$r = .95$ (**) [c]

Note. Except for the time-based tasks, the maximum score for each test is presented in parentheses following its name. std = standardized test.

[a] Cronbach's Alpha. [b] Correlations from test/re-test using the whole sample.

[c] Correlations from test/re-test using a sub-sample ($n = 68$).

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

Correlation Analyses

To gain a first insight into the overall relationship between VPS and the reading of words with different word familiarity and length, correlation analyses were conducted. Table 5 provides results of the longitudinal correlations between all variables measured at kindergarten and the Grade 3 reading scores. Values above the diagonal represent estimated correlations controlling solely for chronological age, while values below the diagonal correspond to correlations controlling for both verbal IQ (Vocabulary) and non-verbal IQ (Block Design) measures, in addition to age. For many relationships the strength of the correlations weakens below the diagonal, thus confirming the need to control for IQ.

Table 5

Correlations between the control and predictor variables measured at kindergarten, and the Grade 3 reading measures

	2	3	4	5	6	7	8	9
1. Kindergarten Verbal IQ	.17	.31**	.10	.06	-.15	-.18	-.06	-.06
2. Kindergarten Non-Verbal IQ	–	.06	-.27**	.27**	-.10	-.12	-.14	-.18
3. Kindergarten Phonemic Awareness		–	.02	.18	-.08	-.07	-.06	-.11
4. Kindergarten Naming Speed (RAN)		-.01	–	-.13	.39***	.39***	.41***	.42***
5. Kindergarten Visual Processing Skill		.17	-.07	–	-.15	-.17	-.16	-.32**
6. Grade 3 Short High Frequency Words		-.03	.41***	-.13	–	.86***	.77***	.75***
7. Grade 3 Long High Frequency Words		-.01	.41***	-.14	.86***	–	.84***	.81***
8. Grade 3 Short Low Frequency Words		-.04	.40***	-.13	.77***	.84***	–	.90***
9. Grade 3 Long Low Frequency Words		-.09	.40***	-.28**	.75***	.82***	.90***	–

Note. Above the diagonal, partial correlations controlling for age. Below the diagonal, partial correlations controlling for age, Verbal and non-Verbal IQ.

*p < .05; **p < .01; ***p < .001

Above the diagonal, it can be seen that both IQ control measures were significantly correlated to most other cognitive variables. It is also notable that the IQ measures were substantially correlated with several reading variables. Below the diagonal, phonemic awareness, RAN and VPS showed no significant correlations between them, suggesting these three cognitive measures are largely independent of each other.

Using the below-the-diagonal correlations as a reference, this analysis revealed the different strength of the relationships between reading and the three cognitive abilities of interest. Firstly, RAN was the most consistent and powerful longitudinal correlate of Grade 3 reading speed ($r_{SHF} = .41$, $r_{LHF} = .41$, $r_{SLF} = .40$, $r_{LLF} = .40$, all ps < .001). Secondly, we note that PA was not significantly correlated with any Grade 3 reading speed measures ($r_{SHF} = -.03$, $r_{LHF} = -.01$, $r_{SLF} = -.04$, $r_{LLF} = -.09$, all ps > .05). Finally, VPS showed significant correlations with Grade 3 long low-frequency words ($r = -.28$, $p < .01$), but not with long high-frequency words ($r = -.14$, $p > .05$), short low-frequency words ($r = -.13$, $p > .05$) or short high-frequency words ($r = -.13$, $p > .05$). From this initial analysis, VPS and RAN appear to be longitudinal predictors of reading in Spanish, over and above the contribution made by age and IQ.

Longitudinal Path Analyses

To assess the contribution of kindergarten RAN, VPS and PA, to individual reading fluency of different types of words in Grade 3, we conducted a series of path analyses. The analyses were conducted as structural equation models in Mplus (Version 6.1; Muthén & Muthén, 2010). The small amount of missing data was handled by full-information maximum-likelihood estimators with robust standard errors (estimator MLR in Mplus). Before conducting the analyses, the four reading scores were standardized. Separately for each reading condition, we first estimated a saturated model with all possible correlations between the predictor variables (RAN, VPS and PA) and the control variables (age, verbal IQ, non-verbal IQ) along with all possible paths from these variables to reading. Subsequently, a model simplification process was undertaken. All relationships involving the three predictor variables were retained, whereas non-significant correlations and paths involving the control variables were dropped iteratively. Changes in model fit were examined until a simplified model was obtained in which all remaining paths and covariances were statistically significant, or involved the three predictor variables.

Figure 4A. Short high frequency (HF) word reading

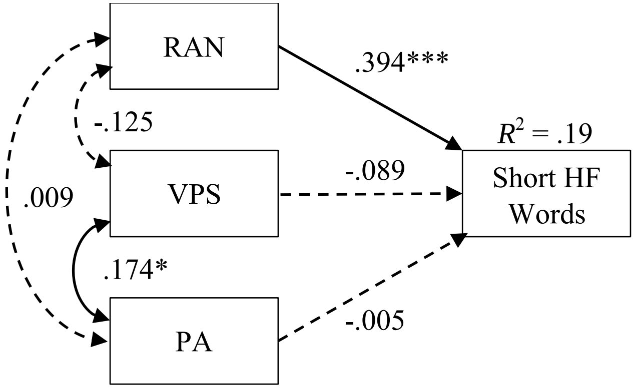

Figure 4B. Long high frequency (HF) word reading

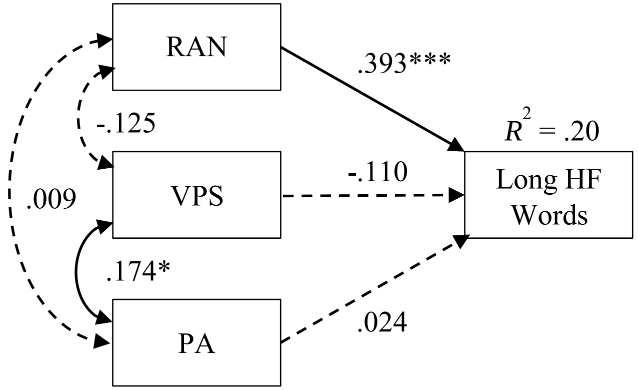

Figure 4C. Short low frequency (LF) word reading

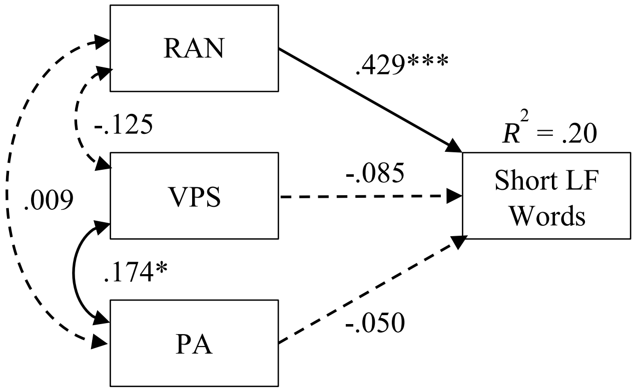

Figure 4D. Long low frequency (LF) word reading

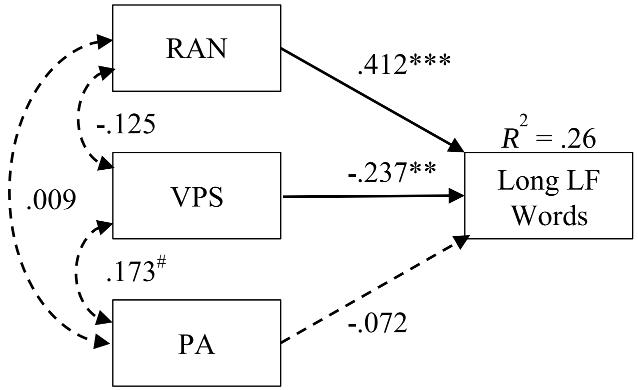

*Figure 4***.** Four path analysis models predicting ***(A)*** short high frequency reading ability, ***(B)*** long high frequency reading ability, ***(C)*** short low frequency reading ability, and ***(D)*** long low frequency reading ability, from cognitive variables. *Note.* Fit indices are: ***(A)*** $\chi^2(4, N = 100) = 3.82$, $p = .43$, TLI = 1.01, SRMR = .037, RMSEA = .000 (90% CI = .000 – .148); ***(B)*** $\chi^2(4, N = 100) = 4.26$, $p = .37$, TLI = 0.981, SRMR = .037, RMSEA = .026 (90% CI = .000 – .155); ***(C)*** $\chi^2(5, N = 100) = 5.59$, $p = .35$, TLI = 0.968, SRMR = .044, RMSEA = .034 (90% CI = .000 – .147); ***(D)*** $\chi^2(5, N = 100) = 4.78$, $p = .44$, TLI = 1.01, SRMR = .041, RMSEA = .000 (90% CI = .000 – .136). Standardized path weights are shown. Solid arrows represent statistically significant relationships. Dashed paths represent non-significant relationships. $^{\#}p < .1$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Non-significant relationships involving control variables were dropped from the simplified models. For clarity, the control variables age, verbal IQ and non-verbal IQ are not shown in these figures. RAN = rapid automatized naming; VPS = visual processing skills; PA = phonemic awareness; TLI = Tucker Lewis index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; CI = confidence interval.

Figure 4 shows the relationships between the three predictor variables and the reading measures taken from these simplified models. All models provide a good fit to the data. For all four types of words, RAN proved to be a significant predictor of variation in reading skill. Additionally, VPS explained significant additional variance on long, low frequency word reading. Unsurprisingly, given that PA has been shown not to explain variation in reading in shallow orthographies beyond Grade 1, PA did not explain variation in any of the four reading conditions.

It is apparent from Figure 4 that the path weights for RAN are all very similar, suggesting that the predictive power of RAN is equal for each type of word. It also appears as though the predictive power of VPS is much stronger for long, low-frequency words compared to other types of words. To formally test these observations, we created an additional path model in which all four word types were included in the one model as separate endogenous variables with separate paths from all predictors to each one. Such a model allows for the direct comparison of path weights leading to each type of word. After first fitting the saturated model, non-significant paths were removed as described above. The resulting simplified model fit the data well, $\chi^2(10, N = 100) = 6.03$, $p = .81$, TLI = 1.03, SRMR = .036, RMSEA = .000 (90% CI = .000 – .068). We then constrained the four path weights originating from RAN to be the same. The Yuan-Bentler scaled χ^2 difference test was not significant ($\Delta\chi^2[3] = 0.14$, $p > .05$), confirming that RAN's predictive power did not differ with word type. In contrast, when we constrained the four path weights originating from VPS to be the same, the Yuan-Bentler scaled χ^2 difference test was significant ($\Delta\chi^2[3] = 20.89$, $p < .001$). Subsequent testing confirmed that the path weight from VPS to long low-frequency words was significantly stronger compared to all other types of words.

Discussion

Children's visual multi-element processing has been previously claimed to be linked to sight-word reading of familiar words (Bosse et al., 2007; Lallier et al., 2014) and to decoding of unfamiliar words (Jones et al., 2008; Pammer et al., 2004). However, such studies have often overlooked two crucial methodological issues: the importance of using non-namable stimuli and the reciprocal nature of the VPS-reading relationship. The present study examined the influence of VPS, assessed at a pre-reading stage by measuring the ability to encode non-namable symbol positions within a string, on reading performance. The aim was to assess if VPS was predominantly related with familiar or unfamiliar word reading. Furthermore, if reading performance is dependent on visual attention span, the expectation was to observe a stronger contribution by multi-element processing to long words than to short words. Path analyses were conducted to test whether VPS, differentially accounted for independent variance in Grade 3 reading lists varying in word familiarity and length. Results revealed that pre-reading visual processing skills significantly predicted word reading in Grade 3 beyond the contributions made by RAN, PA and IQ, provided the words were both unfamiliar and long. This suggests that a reliance by sublexical decoding, but not by sight-word reading, on visual multi-element processing. The theoretical implications of these findings are considered below.

Noting that the present study measured VPS before the onset of formal literacy instruction and at a time when none of the children in the sample could read, the current results, together with those of study 1, suggest that individual differences in visual processing are causally linked to future reading acquisition. These results are in line with the previous findings of Franceschini et al. (2012) in Italian. Moreover, the visual multi-element processing task used in the present study was comprised of non-namable stimuli (as the symbols used were unknown to the children) and the required responses were non-verbal. Thus, these results could not have been driven by phonological or letter knowledge individual differences. Therefore, the present study extends previous findings of a significant link between multi-element visual processing of symbol strings and reading skill (Bosse & Valdois, 2009; Hawelka & Wimmer, 2005; Jones et al., 2008; Pammer et al., 2004) by providing reliable evidence that pre-reading performance on symbol-position encoding influences future reading.

Multi-element Processing Predicts Decoding, Not Sight-Word Reading

The influence of VPS on word reading was moderated by word-length and word-familiarity. VPS contributed only to the reading of long, unfamiliar words. This word-length by word-frequency interaction on reading latencies is important because it is a clear indication of two distinct reading processes: lexical processing of familiar words (i.e., high frequency words) and serial decoding of long, unfamiliar words (i.e., low-frequency words) (Weekes, 1997). VPS' selective prediction of long low-frequency word reading, but not high-frequency word reading, indicates that VPS is not directly involved in the sight-word reading of familiar words, partly refuting the predictions made by the MTM Model (Ans et al., 1998; Bosse & Valdois, 2009), at least for a highly transparent orthography. The current results are in line with other studies which found a link between VPS, measured through, visual spatial attention skill tasks and the accuracy with which readers process unfamiliar letters-strings (Auclair & Siéroff, 2002; Collis et al., 2013; Facoetti et al., 2006; Jones et al., 2008; Kinsey et al., 2004). The combination of these results suggests that VPS plays a part in analytical decoding of novel words. According to Jones et al. (2008), the effectiveness in guiding attention serially over the letter string might be particularly pertinent for decoding of unfamiliar words.

However, the current study found a correlation between VPS and unfamiliar word reading speed, rather than accuracy (which was at ceiling, see methodology). Furthermore, VPS was a significant predictor only when reading long unfamiliar words, but not short unfamiliar words. The idea that VPS might play a role in how rapidly long (but not short) words are decoded, rather than how accurately any word is decoded, can be understood under the assumption that multi-element processing skill measures the amount of letters that can be processed simultaneously during decoding (Prado et al., 2007). This is consistent with the findings of Hawelka and Wimmer (2005), who reported that readers with dyslexia exhibited a digit-position encoding impairment for four- and six-digit strings but not for two-digit strings. Hawelka and Wimmer described impaired readers as having a visual multi-element processing deficit, which might correspond with the impairment known as the visual attention span deficit (Bosse et al., 2007). A wider visual attention span will enable larger multi-element processing which might be crucial to unitize larger letter-clusters as individual units (Ehri, 2005; LaBerge & Samuels, 1974), allowing for greater reading speed (Häikiö et al., 2009; Kwon et al., 2007; Lobier et al., 2013; Rayner et al., 2010).

Possible Explanations for Contradicting Results

The present study found a significant independent contribution by multi-element processing to unfamiliar word reading, but not familiar word reading. This contradicts the results obtained in other studies conducted in transparent and opaque orthographies which found VPS to contribute to both familiar and unfamiliar word reading (French: Bosse et al., 2007; English: Bosse & Valdois, 2009; Spanish: Lallier et al., 2014; Dutch: van den Boer et al., 2013). A common feature of all of these studies is that they all used visual tasks in which the items were composed of letters. In contrast, the current study's use of non-verbal stimuli in the visual task sets it apart. Despite the fact that some of these studies controlled for 'letter identification' skill it is still plausible that the correlation between letter knowledge and reading (Bowey, 2005, for a review) inflated the correlation between familiar word reading and VPS. More importantly, these studies comprised samples of children with at least one or more years of reading experience. Therefore, it cannot be ruled out that reading practice might have already improved visual ability (Dehaene et al., 2010; Perfetti et al., 2013), thus increasing the strength of the correlation between the multi-element processing and sight-word reading. This possibility could lead to an erroneous interpretation of the direction of causality.

Franceschini et al. (2012) did find a significant contribution by pre-reading VPS to reading of familiar words, as well as unfamiliar words in Italian speaking children. Their visual tasks also comprised non-nameable symbols and required no verbal response. The difference in VPS task used by Franceschini et al. (2012) (visual search and visuo-spatial attention tasks, as opposed to multi-element processing) could explain the differences between the current results and theirs. However, Jones et al. (2008) considers that visual-search and multi-element processing share a common mechanism which is applied when rapidly guiding serial attention across the word (see general discussion). Otherwise, as noted in the discussion of study 1, Franceschini et al. (2012) found pre-reading VPS to contribute to reading during Grades 1 and 2 – a period of development during which most words would be unfamiliar to the novice reader and thus would be decoded. Study 1 of this thesis obtained comparable results. Furthermore, in study 1, VPS made a contribution to non-word reading as late as Grade 4. However, VPS did not account for any independent variance in word reading during Grades 3 and 4, a time when most high frequency words in Spanish are probably read lexically (Cuetos & Suárez-Coalla, 2009). Given that most words (regardless of their frequency) will be unfamiliar to the novice reader during the early stages of reading, if VPS are specifically related to sublexical decoding, VPS should be expected to contribute, not only to non-word reading, but also to word reading during those early stages.

Therefore, it seems that one factor which might contribute to the differences in the results obtained by VPS-reading studies might pertain to the period when reading is assessed. Even if VPS predicts decoding speed, it appears that VPS is not relevant until reading accuracy is high and reading speed has picked up some pace. Shapiro et al. (2013) also measured VPS on pre-reading children using visual tasks which comprised no nameable symbols and required no verbal response. In contrast to Franceschini et al. (2012), they found pre-reading visual search ability not to be a significant predictor of either word or non-word reading speed. However, as noted in the discussion of study 1, Shapiro et al. (2013) measured reading when their sample of children had a mean age of 5 years and 2 months, a period during which reading rate is relatively low. Therefore, these results are compatible with the notion that pre-reading VPS predicts decoding speed (whether of non-words, LF-words or HF-words), as long as they are unfamiliar to the reader. However, pre-reading VPS does not predict decoding speed until the novice reader has surpassed the alphabetic phase and reading rate has picked up. In this sense, our results of studies 1 and 2 appear to follow a pattern compatible with those of Franceschini et al. (2012) and Shapiro et al., (2013).

Conclusions

The main purpose of the present study was to manipulate word-frequency and word-length factors with the aim to assess whether pre-reading VPS significantly contributes to word decoding or sight-word reading. Pure visual processing skills were found to make a significant independent contribution to future reading of long, unfamiliar words. There was reliable evidence of a stronger length effect for low-frequency words than for high-frequency words. This result indicates that low-frequency words were unfamiliar to the readers and therefore decoded, rather than read by sight. VPS, measured by means of a multi-element processing task, was a significant predictor of long, but not short, low-frequency word reading. A possible interpretation for this result is that multi-element processing is only relevant for decoding speed of items which require a wide visual attention span. Furthermore, the longitudinal nature of the study and the fact that these cognitive measures were assessed prior to the onset of reading skill acquisition clearly identifies the direction of the relationship. This finding is evidence that, at least in a transparent orthography as Spanish, a child's pre-reading level of visual multi-element processing is predictive of future word decoding speed, but not sight-word reading speed.

Study 3:

RAN as a Measure of Sight-Word Reading and Decoding Fluency

Introduction

Despite a long-standing debate on what is the core common ability that accounts for the RAN-reading relationship, the answer still remains largely unclear. A particularly controversial interpretation proposed to explain the link has been the suggestion that the mechanisms which underpin RAN are involved in processing word-specific orthographic representations (Bowers & Wolf, 1993; Georgiou et al., 2009; Manis et al., 1999). If the RAN task does indeed tap onto the ability to process word-specific orthographic patterns, the hypothesis that follows holds that RAN should contribute more to familiar word reading than to unfamiliar word reading. However, while some studies have found that RAN contributes more strongly to familiar- than unfamiliar-word reading speed (e.g., Vaessen & Blomert, 2010), other evidence shows that RAN contributes similarly to unfamiliar- and familiar-word reading speed (Dutch: van den Boer et al., 2013; Danish: Poulsen & Elbro, 2013; German: Moll et al., 2009). Nevertheless, orthographic processing, defined as the ability to process multi-letter spelling patterns as individual units, occurs both at a whole-word (e.g., *call* or *bird*) and at a sublexical level (e.g., *-ing* or *-tion*). Therefore, if RAN measured orthographic processing it could also contribute to novel words as long as they were comprised of familiar orthographic patterns.

According to Ehri (2005), when decoding unfamiliar words, as the novice reader becomes proficient, simple (grapho-phonemic) decoding is replaced by advanced (grapho-syllabic) decoding. Advanced decoding, where specific connections link amalgamated orthographic representations with their pronunciation (Ehri, 2005), occurs in transparent as much as in opaque orthographies. The children use learned orthographic regularities to map grapheme clusters, rather than single graphemes, into phonological units consisting of onsets, rimes, syllables and morphemes. This advanced phase of decoding is quicker, more effective and less demanding (Orsolini et al. 2006). Thus, the role of the syllable in proficient reading is crucial for fluent decoding of unknown polysyllabic words, as they cannot be recognized as a whole unit and so must be broken down into smaller orthographic units (Ans, et al., 1998). In several alphabetic scripts, polysyllabic-word processing is mediated by syllabic structure, indicating that the syllable is a functional unit of the reading process (Spanish: Carreiras et al., 1993; French: Mathey & Zagar, 2002; German: Conrad, Carreiras, Tamm, & Jacobs, 2009; but see Macizo & van Petten, 2007 for conflicting evidence in English). Nevertheless, while some children seem to encode frequent spelling patterns with ease, others appear to require additional exposures to a word before they can register its orthographic pattern (e.g., Ehri & Saltmarsh, 1995; Share & Shalev, 2004). If the ability tapped on by RAN was crucial for orthographic processing, it would also manifest itself at the sublexical grapho-syllabic level, explaining RAN's contribution to non-word reading fluency.

Does RAN Measure Sublexical Orthographic Processing?

In support of the understanding that RAN is implicated in the establishment of fully specified orthographic representations, Levy, Bourassa and Horn (1999) observed that slow-RAN children experienced more difficulties in learning orthographic patterns compared to fast-RAN children. Furthermore, Conrad and Levy (2007), found slow-RAN children to exhibit relatively poor performance in the formation of memory representations of letter strings. Together with the results of numerous other studies which have also reported RAN to be linked to lexical and sublexical orthographic processing tasks (e.g., Bowers, Sunseth & Golden, 1999; Georgiou et al., 2009; Loveall et al., 2013; Manis et al., 2000; Powell, Stainthorp & Stuart, 2014), this evidence supports the understanding that slow-RAN scores represent some kind of 'insensitivity-to-practice' (Wolf & Bowers, 1999). This insensitivity-to-practice would be due to a deficit in the child's ability to learn and/or automatize recurring orthographic structures, which would in turn result in less fluent reading. However, other studies have found RAN not to be specifically associated with orthographic processing (Bowey & Miller, 2007; Cunningham, Perry, Stanovich & Share, 2002).

Alternatively, if performance on the RAN task were not exclusively involved in whole-word and/or grapho-syllabic, but also in individual grapho-phonemic processing, then the primary reading-related ability tapped on by the RAN task must be different from orthographic processing. Assessing reading skills of German-speaking children in a very large sample composed mainly of third-graders, Moll et al. (2009) examined the concurrent contribution made by RAN to reading speed of words and two types of non-words which differed in 'word-likeness'. While one set of non-words was composed of simple consonant–vowel syllable structure (uncommon in German), the other set had higher orthographic similarity to real German words. Regression analyses revealed no major differences in the unique variance explained by RAN, regardless of syllable structure. This finding suggests that the ability common to RAN and reading might also operate at an individual grapheme level. Additionally, their results revealed that RAN accounted for a very small amount of variance over and above non-word reading fluency, leading Moll et al. (2009) to conclude that RAN does not tap into any cognitive mechanism involved in orthographic processing. If RAN were related to orthographic processing, it was expected that it would account for more unique variance in word than non-word reading, given the higher amount of orthographic processing involved in word compared to non-word reading.

Does RAN Measure Visual-to-Verbal Conversion Ability?

A cognitive skill which is crucial to engage in grapho-phonemic decoding, grapho-syllabic decoding and lexical reading, as well as for naming speed tasks, is visual-verbal processing. For the RAN task to be an index of orthography-to-phonology processing implies that RAN measures one of the following abilities. Firstly, RAN could measure the initial ability to establish mappings between visual symbols and verbal labels (Manis et al., 1999; Wimmer, Mayringer, and Landerl, 2000). However, the link between the orthographic representation of a word and its corresponding phonological representation is not established when that word is being read. On the contrary, that link is established beforehand; when the orthographic representation of that word is phonologically recoded the first few times it is encountered (Cunningham et al., 2002; Share, 1999). Likewise, when a word is phonologically recoded, the link between the orthographic representation of the individual letters or sublexical orthographic units and their phonological counterparts, is established back when those orthographic units were first learnt, during the earliest stages of reading skill acquisition. The reason this is important is because, if RAN measures the ability to establish the links between orthography and phonology, it means the contribution by naming speed to reading is not direct, and therefore should be cancelled when previous reading performance is controlled.

Secondly, apart from the initial establishment of the links between symbols and sounds, adequate performance on the RAN task also requires a rapid, fluent conversion from visual stimuli into their corresponding phonological stimuli. Moll et al. (2009) concluded their study speculating that the association between RAN and reading might reflect the automaticity with which orthography-to-phonology associations can be invoked at the letter and letter cluster level. If RAN does predominantly measure the fluency with which visual-to-verbal conversions can be completed, slow-RAN children would demonstrate a general speed-impairment which would affect their reading at the lexical, grapho-syllabic and grapho-phonemic levels. In fact, reading an orthographically unfamiliar word must require more visual-to-verbal conversion demand than reading an orthographically familiar word, which is read by recognizing the whole orthographic pattern of a word as a single unit (lexical reading). Therefore, if RAN was a measure of visual-to-verbal conversion at all levels, RAN would predict reading more strongly when visual-to-verbal conversion occurred at the grapho-phonemic and grapho-syllabic levels (i.e., when decoding unfamiliar words) in comparison to visual-to-verbal conversion at the lexical level (i.e., when reading familiar words by sight).

Furthermore, it must be noted that RAN performance has recently been reported to be significantly enhanced by a reciprocal relationship with reading experience (Wolff, 2014). Although Lervåg and Hulme (2009) did not find evidence of such reciprocal relationship, Wolff's results question the interpretations of studies which assessed RAN performance on samples of experienced readers. If reading practice does indeed influence RAN performance, when assessing the correlation between RAN and reading in a sample of children with substantial reading experience, the direction of causality in these relationships can easily be misinterpreted. Consequently, in order to avoid a potential confound regarding the direction of the contribution in the RAN-reading relationship, RAN should be measured at, or before, the onset of reading instruction, before reading experience has potentially altered the levels of naming speed.

Finally, given that sight-word reading of familiar words is faster than decoding of unfamiliar words (e.g., Weekes, 1997), reading speed relies on the amount of sight-words known by the reader (sight vocabulary) (Torgesen, 2002). The self-teaching hypothesis (Share 1999, 2008) posits that the lexical orthographic knowledge needed for sight-word reading is acquired incidentally through decoding during reading practice. Therefore, sight vocabulary, also referred to as the orthographic lexicon (Bergmann & Wimmer, 2008), is itself largely reliant on reading practice or reading volume. Indeed, several studies have reported empirical evidence in support of an association between quantity of exposure-to-print (or past reading practice) and reading performance (Griffiths & Snowling, 2002; McBride-Chang et al., 1993; Shapiro et al., 2013). Thus, very importantly, if exposure-to-print (or past reading practice) contributes to future lexical reading (or sight-word reading), then any variables which contribute to past reading practice will have an indirect effect on sight-word reading. For example, if naming speed contributes to decoding skill, which in turn contributes to the expansion of the sight vocabulary, naming speed might appear to have a direct influence on sight-word reading. The implication of this possibility is that controlling for previous reading level must be done in order to distinguish between direct and indirect influences.

This Study

In summary, the notion of orthographic processing as the driver for the RAN-reading relationship has been debated for over two decades. One source of confusion regarding the nature of this relationship pertains to the similar correlations reported between RAN and both word reading fluency and non-word reading fluency. One possible explanation is that RAN might tap into the processing of familiar spelling patterns, both at a lexical and a sublexical level, an ability which would come into play when reading both words and non-words comprised of commonly-occurring letter-clusters. This proposal can be easily tested by manipulating orthographic syllable frequency. If RAN measures the ability to process familiar orthographic patterns it should correlate more with orthographically familiar non-words than with orthographically unfamiliar non-words.

Therefore, the aim of this study is to examine RAN's relation to orthographic familiarity by assessing the potential differential contribution of pre-reading RAN to Grade 5 reading of non-words comprised of high- and low-frequency syllables, as well as real words. IQ, visual and phonological skills must be controlled. Through this procedure it will be possible to assess RAN's influence in reading performance (1) at a whole-word level, (2) at a grapho-syllabic level and (3) at a grapho-phonemic level. To our knowledge, this is the first study to systematically examine the relationship between RAN and syllable frequency. This procedure will allow us to discern whether RAN taps into orthographic processing of familiar spelling patterns or whether the association between RAN and reading may primarily have to do with visual-to-verbal processing. If RAN contributes more strongly to reading of high-frequency syllable (HFS) non-words than it does to low-frequency syllable (LFS) non-words, it would suggest that RAN taps into orthographic processing of familiar spelling patterns contained in HFS non-words, as opposed to the effortful letter-by-letter processing required to decode the unfamiliar letter sequences contained in LFS non-words. Conversely, if RAN made an equal contribution to LFS non-word reading than to HFS non-word reading, it would suggest that the association between RAN and reading is based on the visual-to-verbal processing which is necessary for both. Furthermore, if RAN measures orthographic processing, we would also expect a significant contribution by RAN to orthographic knowledge. Therefore, the contribution by RAN to orthographic knowledge will also be assessed.

In order to further investigate the association between RAN and orthographic familiarity we will assess whether RAN's influence to each reading procedure (grapho-phonemic decoding, grapho-syllabic decoding and sight-word reading) is direct or indirect. This will be done by examining to what extent RAN contributes to Grade 5 reading performance of each type of word beyond the influence of previous reading performance. This study was conducted in Grade 5 in order to be able to assess whether pre-reading RAN would still contribute to future reading beyond the influence of reading level during each of the previous 4 grades. The idea is that if RAN taps into some cognitive mechanism directly involved in orthographic processing, it should still account for unique variance in word reading or orthographic knowledge scores beyond the influence by previous reading level. In contrast, if RAN contributes to reading via a cognitive mechanism which is more relevant to sublexical decoding than to sight-word reading then RAN should still account for unique variance in non-word reading (especially LFS non-words) after controlling for differences in previous reading level. Such a result would suggest that RAN's relation to reading is mediated through visual-to-verbal conversion for which there is a higher demand when decoding than when sight-word reading.

Methodology

Participants

89 children completed all tasks corresponding to study 3. The mean age of the sample during the first assessment (kindergarten) was 5 years, 6 months (SD = 3.6 months, range: 5 years, 1 month – 6 years, 1 month) and 10 years, 10 months (SD = 3.6 months, range: 10 years, 5 months – 11 years, 5 months) during the second assessment (Grade 5). For more details on the participants of the study see the methods section of study 1 (4.2 methodology).

Design and Procedure

RAN, along with the all the cognitive control measures (verbal and non-verbal IQ, PA, and VPS) were assessed in kindergarten, 9 months prior to the commencement of formal reading instruction. Orthographic knowledge and reading fluency were assessed five years later in Grade 5. All the tests were individually administered to all the participants, except for the orthographic knowledge test, which was administered in groups.

Tests and Materials

- **General Intelligence**

Verbal and non-verbal skills were evaluated as control variables. They were respectively assessed with the Vocabulary and Block Design subtests taken from the Spanish version of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) for children (Wechsler, 2001).

- **Phonemic Awareness**

The phonemic awareness variable was based on the scores of the phoneme isolation task and the phoneme blending task. For more details on the phonemic awareness tasks see the methods section of study 1 (4.2 methodology).

Phoneme Blending - This task required children to blend spoken phonemic segments into real, high frequency words (see Appendices 4 and 5).

Phoneme Isolation - The task consisted of four blocks of eight non-word items. In the first two blocks, children were required to isolate and pronounce the initial phoneme whereas in the last two blocks the final phoneme was the focus of the task (see Appendices 6 and 7).

- **Visual Processing Skills**

This multi-element processing task measured the children's visual ability to encode the position of letter-like symbols within a string. For each of 12 items, which progressively increases in number of symbols, a target string consisting of a word-like sequence of Greek and Cyrillic characters was initially presented in a memory card. Subsequently, a second card displaying two strings of symbols was shown, from which the child had to discriminate the target string from a decoy string formed of the same symbols only in different order. For more details on this task see the methods section of study 1 (4.2 methodology) (see Appendices 8 and 9).

- **Rapid Automatized Naming**

A Spanish version of RAN, adapted from Denckla & Rudel (1974), was created using two different categories of non-alphanumeric symbols, RAN-Objects and RAN-Colors. For both categories, trials of forty stimuli, consisting of five items repeated eight times each, were displayed over five lines of an A-4 card. Children were asked to name the items sequentially as fast as they could. Two trials were administered for each category, with items arranged in a different, quasi-random order on each trial. The RAN score was computed by averaging the z-scores of the two trials of RAN-Objects with the two trials of RAN-Colors. For more details on this task see the methods section of study 1 (4.2 methodology) (see Appendices 10 to 12).

- **Orthographic Knowledge**

An orthographic choice task designed to measure word-specific orthographic knowledge was administered by assessing the participants' ability to identify correct spelling patterns of words. For each of twenty-eight experimental items, the children were shown four alternative spellings of the target word, which were comprised of the correctly-spelled target word accompanied by three distractor pseudo-homophones (e.g., salvaje [wild]; salbage; salvage; salbaje). Participants were required to select the correct spelling of the word by ticking the box next to the selected word (see Appendix 20). For each item the position of the target word was counterbalanced (see Appendix 21). The lexical frequency of the target words was 1 to 10 per million for ten items, 10 to 100 per million for another ten items, and > 100 per million for the remaining eight items, according to a Spanish child and adult word-frequency corpora (Martínez & García, 2004).

Due to its high transparency, the Spanish writing system contains few spelling inconsistencies. These inconsistencies pertain to the instances where two graphemes map onto the same phoneme. Thus, despite the Spanish orthography being regular for reading, homophones and pseudohomophones do exist. All the target words selected for this test contained a minimum of two potential inconsistent spellings. This procedure enabled the possibility to create for each item three alternative decoy pseudo-homophones. Therefore, the task could not be completed by resorting to GtP conversion rules, by accessing the underlying phonological representation of the word or by resorting to morphological knowledge cues to disambiguate between alternative spellings. Only word-specific lexical orthographic knowledge could be of assistance in order to select the correct response. The child's score on this task was the total number of correctly completed items.

- **Reading Measures**

Reading Lists Varying in Word- and Syllable- Frequency - Four reading lists of 25 stimuli each were created: high-frequency words, low-frequency words, high-frequency syllable non-words and low-frequency syllable non-words. All 100 stimuli contained 7-10 letters and 3-4 syllables. Items across the four lists were matched on letter length and syllable structure. The high-frequency (HF) word list and low-frequency (LF) word list were composed of a majority of nouns and a small number of adjectives and verbs. The lexical frequency of words in the HF and LF lists were '>100' and '1-5' occurrences per 1 million words, respectively. Both lexical and syllable frequency were defined by the child and adult word-frequency corpora Martínez and García (2004).

The items for the non-word lists were created by selecting the syllables according to their token positional frequency, denoting the number of times that the syllable (weighted by lexical frequency) appears in that syllable position. Non-words in the HFS and LFS lists were matched in letter length, syllable structure, identity of the vowels and their position within the word. None of the non-words had any orthographic neighbors (i.e., real words differing by one letter). The mean syllable frequency for the LFS non-word list was 39.17 per million (pm) (*SD* 62.84) for the first syllable, 29.84 pm (*SD* 33.71) for the second syllable, 14.60 pm (*SD* 13.44) for the third syllable and 266.76 pm (*SD* 252.01) for the final syllable. For the HFS non-word list, the mean syllable frequency was 1972.88 pm (*SD* 1892.34) for the first syllable, 902.52 pm (*SD* 889.51) for the second syllable, 396.60 pm (*SD* 224.19) for the third syllable and 2435.12 pm (*SD* 2013.71) for the final syllable (see Appendix 23).

The task consisted in reading each list aloud (see Appendix 22). The order of the stimuli within each list was the same for all participants. The order of presentation of the lists was also the same for all participants (LFS non-words; HFS non-words; LF words; HF words). Each list was presented as a single column and printed on a white sheet of A4 paper, in a lower-case bold format (Calibri font, 14 point). Children were instructed to read all the items in the list aloud as quickly and as accurately as possible. Number of errors and total reading time for each list were registered. Due to high reading accuracy, list reading speed, expressed in number of seconds (irrespective of reading errors), provided a pure speed measure and was used as the only reading performance variable for the current study.

One-Minute Word Reading - The single-word reading list (word frequency >10 in 1 million) applied in Grades 1, 2, 3 and 4 for study 1 was used in the current study to assess previous word reading performance (see Appendices 15 and 16).

One-Minute Non-Word Reading - The non-word reading list applied in Grades 1, 2, 3 and 4 for study 1 was used in the current study to assess previous decoding performance (see Appendix 17).

Results

Table 6 provides the descriptive statistics and reliability for all the variables measured at kindergarten and Grade 5. All cognitive and literacy variables showed an acceptable range of scores in the distribution. Performance on IQ measures was within the average range. For the RAN tasks, as well as for the Grade 5 reading tests, lower scores indicate better performance, given that they are measures of time (in seconds). Therefore any positive relationship between RAN and reading will be indicated by a positive correlation and any positive relationship between RAN and any of the remaining variables will be indicated by a negative correlation. The reliability for all non-standardized measures was acceptable (r >.70). HF real-words were read faster than LF real-words ($F[1, 142] = 291.21$, $p < .001$), which were read faster than HFS non-words ($F[1, 142] = 614.63$, $p < .001$), revealing a lexical-frequency effect. HFS non-words were in turn read faster than LFS non-words ($F[1, 142] = 360.65$, $p < .001$), revealing a syllable-frequency effect.

Table 6

Means, Standard Deviations (SD) and Reliability for Cognitive and Literacy Measures

• ***Kindergarten Cognitive Measures***	Mean (*SD*)	Range	Reliability
Non-Verbal IQ (20)	12.4 (4.74)	1 - 19	std
Verbal IQ (22)	9.5 (3.52)	2 - 19	std
RAN Pictures	57.95 (12.14)	41 - 87	*r* = .73 (**) [b]
RAN Colors	67.43 (20.74)	40 - 126	*r* = .80 (**) [b]
Visual Processing Skills (24)	14.66 (6.90)	0 - 24	α = .82 [a]
Phonemic Isolation (64)	11.8 (13.97)	2 - 52	α = .97 [a]
Phonemic Blending (10)	2.9 (2.13)	0 - 10	α = .87 [a]
• ***Grade 5 Literacy Measures***			
Grade 5 Orthographic Knowledge (28)	19.0 (4.00)	9 - 26	α = .79 [a]
Grade 5 HF Word Reading	17.3 (5.70)	10 - 48	*r* = .79 (**) [b]
Grade 5 LF Word Reading	30.2 (12.66)	13 - 86	*r* = .92 (**) [b]
Grade 5 HFS Non-Word Reading	47.0 (14.20)	24 - 102	*r* = .88 (**) [b]
Grade 5 LFS Non-Word Reading	60.7 (16.16)	38 - 132	*r* = .80 (**) [b]
Grade 1 Word Reading	48.4 (13.99)	7 - 91	*r* = .88 (**) [b]
Grade 2 Word Reading	71.8 (15.97)	18 - 109	
Grade 3 Word Reading	84.1 (15.57)	35 - 117	
Grade 4 Word Reading	93.2 (13.86)	41 - 115	
Grade 1 Non-Word Reading	35.1 (9.44)	5 - 64	*r* = .79 (**) [b]
Grade 2 Non-Word Reading	46.9 (10.40)	13 - 79	
Grade 3 Non-Word Reading	53.1 (10.20)	25 - 86	
Grade 4 Non-Word Reading	59.6 (10.08)	31 - 92	

Note. Except for the time-based tasks, the maximum score for each test is presented in parentheses following its name. HF = High-Frequency; LF = Low-Frequency; HFS = High-Frequency Syllables; LFS = Low-Frequency Syllables. std = standardized test.

[a] Cronbach's Alpha. [b] Correlations from test/re-test using the whole sample.

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

Table 7 provides results of the correlation analyses between all cognitive variables measured in kindergarten (RAN, phonological skills, visual processing skills, verbal-IQ and non-verbal IQ) and all the literacy variables measured in Grade 5 (reading fluency for HF words, LF words, HFS non-words and LFS non-words, plus orthographic knowledge). Chronological age was partialed out. With the exception of non-verbal IQ, RAN was not significantly correlated to any of the other kindergarten cognitive abilities, suggesting RAN is independent from all of them.

Table 7

Correlations between cognitive ability variables measured in kindergarten and literacy variables of interest (reading speed variables plus orthographic knowledge) measured in Grade 5.

	PA	VPS	VIQ	NVIQ	HF-Ws	LF-Ws	HFS-NWs	LFS-NWs	OK
RAN	-.02	-0.10	0.01	-0.22*	0.29**	0.29**	0.28**	0.33**	-0.33**
PA		0.20*	0.32***	0.14	0.04	-0.03	0.03	-0.04	0.15
VPS			0.11	0.29**	-0.08	-0.13	-0.11	-0.14	0.10
VIQ				0.18*	-0.03	-0.15	-0.10	-0.14	0.02
NVIQ					0.11	0.00	0.00	-0.04	0.20
HF-Ws						0.86***	0.70***	0.73***	-0.52***
LF-Ws							0.83***	0.78***	-0.60***
HFS-NWs								0.85***	-0.53***
LFS-NWs									-0.49***

PA = Phonemic Awareness; VPS = Visual Processing Skills; VIQ = Verbal IQ; NVIQ = Non-Verbal IQ; HF-Ws = High-Frequency Words; LF-Ws = Low-Frequency Words; HFS-NWs = High-Frequency Syllable Non-words; LFS-NWs= Low-Frequency Syllable Non-words; OK = Orthographic Knowledge.

*$p < .05$; **$p < .01$; ***$p < .001$;

In order to examine the unique contribution made by kindergarten-RAN to Grade 5 reading and orthographic knowledge, a series of multiple regression analyses were conducted. For all regressions the control variables were entered into the model in a fixed order with RAN always included last. These regressions examined the contribution made by the controls and RAN to reading fluency of real-words (high frequency and low frequency), reading fluency on non-words (HFS and LFS) and orthographic knowledge. As can be observed in Table 8 kindergarten-RAN explained a significant amount of variability for all of the Grade 5 literacy measures beyond the verbal-IQ, non-verbal IQ, phonological and visual skills. Thus, these results show that pre-reading RAN predicts future lexical reading (HF words), advanced decoding (HFS non-words) and simple decoding (LFS non-words) fluency.

There was an interest in assessing whether the contribution made by RAN differed for each reading list. From Table 8 it can be seen that the contribution made by RAN to reading fluency of HFS non-words and LFS non-words (10.7% p = .003 and 13.1%; p = .001, respectively) was as strong as RAN's contribution to reading fluency of HF real-words and LF real-words (10.9% p = .003 and 10.9%; p = .002, respectively). To formally test these observations, Z-test analyses for dependent correlations (Steiger, 1980) were performed to determine whether the magnitude of the relationship between RAN and reading varied as a function of reading list. These analyses confirmed the initial impression that the correlations between RAN and the literacy variables were not significantly different from one another (all ps > .05). The relationship between RAN and orthographic knowledge was also of interest. RAN accounted for a unique amount of the variability in orthographic knowledge beyond the kindergarten cognitive controls (9.3%, p = .005).

Table 8

Results of separate regression analyses showing the percentage of unique variance explained by kindergarten cognitive abilities when predicting Grade 5 reading of High Frequency Words (HF-Ws), Low Frequency Words (LF-Ws), High-Frequency Syllable Non-words (HFS-NWs), Low-Frequency Syllable Non-words (LFS-NWs) and Orthographic Knowledge (Ortho K)

		HF-Ws		LF-Ws		HFS-NWs		LFS-NWs		Ortho K.	
Step	Predictor	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta
1	Age	1.3	-.115	2.8	-.168	1.0	-.102	1.2	-.109	0.2	.045
2	Non-Verbal IQ	2.0	.144	0.1	.032	0.2	.043	0.1	-.029	3.9	.198
3	Verbal IQ	0.0	-.018	1.7	-.136	2.1	-.151	2.4	-.159	0.0	-.002
4	PA	0.0	.003	0.1	-.030	0.1	.039	0.2	-.058	1.9	.144
5	VPS	1.6	-.137	2.0	-.156	1.5	-.135	1.7	-.141	0.0	.008
6	RAN	10.9**	.351	10.9**	.350	10.7**	.348	13.1***	.385	9.3**	-.325
	Total R^2	15.9		17.6		15.7		18.7		15.3	

PA = Phonemic Awareness; VPS = Visual Processing Skills; RAN = Rapid Automatized Naming

*p < .05; **p < .01; ***p < .001;

Table 9

Percentage of unique variance explained by kindergarten-RAN for each of the Grade 5 literacy variables over and above previous reading level from Grade 1 to Grade 4

		HF-Ws		LF-Ws		HFS-NWs		LFS-NWs		Ortho K	
Step	Predictor	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta	R^2 Change	Beta
1	Kindergarten Controls	5.0		6.8		5.0		5.6		6.0	
2	Grade 1 W & NW Reading	39.1***		49.7***		36.6***		32.6***		29.2***	
3	Kindergarten RAN	2.5	.176	2.0	.159	3.0*	.196	5.1*	.253	2.2	-.165
	Total R^2	46.5		58.4		44.7		43.3		37.4	
2	Grade 2 W & NW Reading	51.8***		65.9***		57.3***		45.4***		36.5***	
3	Kindergarten RAN	1.3	.131	1.0	.110	2.6*	.182	4.3*	.235	2.5	-.188
	Total R^2	58.2		73.6		64.9		55.3		45.0	
2	Grade 3 W & NW Reading	28.2***		36.6***		46.8***		28.8***		24.6***	
3	Kindergarten RAN	3.1	.199	2.0	.159	1.0	.113	3.6*	.216	2.9	.192
	Total R^2	36.2		45.5		52.8		38.0		33.5	
2	Grade 4 W & NW Reading	49.9***		54.3***		44.8***		43.6***		39.1***	
3	Kindergarten RAN	1.0	.113	0.8	.100	1.3	.129	2.3	.171	1.0	-.115
	Total R^2	55.9		61.8		51.1		51.5		46.1	

W = Words; NW = Non-Words; HF = High-Frequency; LF = Low-Frequency; HFS = High-Frequency Syllable; LFS = Low-Frequency Syllable; Ortho K = Orthographic Knowledge; Kindergarten Controls = Age, Verbal and Non-Verbal IQ, Phonemic Awareness and Visual Processing Skills.

*p < .05; **p < .01; ***p < .001;

In order to examine whether the independent influence by naming speed on each of the different type of words was direct or indirect, a second series of regression analyses were conducted. These models were exactly the same as those presented in Table 8 with the exception that previous reading level was controlled. Table 9 provides the regression results indicating the unique contribution (% of unique variance explained) made by each kindergarten cognitive variable to the four reading variables measured in Grade 5, after accounting for reading performance at each previous grade. Four regressions were carried out for each Grade 5 reading list; each regression accounting for the contribution made by word and non-word reading speed during Grades 1, 2, 3 or 4. As in the previous set of regressions, RAN was again introduced last into the model.

RAN remained an independent predictor of reading fluency of HFS non-words beyond the contribution of Grade 1 (3.0%, $p < .05$) and Grade 2 (2.6%, $p < .05$) reading performance, but not Grade 3 (1.0%, $p < .05$) nor Grade 4 (1.3%, $p > .05$) reading performance. Interestingly, RAN also made a significant contribution to the reading fluency of LFS non-words over and above differences in Grade 1 (4.6%, $p < .05$), Grade 2 (3.7%, $p < .05$), and Grade 3 (3.8%, $p < .05$) reading performance, but not Grade 4 (1.1%, $p > .05$) reading performance. LFS non-words are the type of reading item which is least reliant on accumulated orthographic knowledge and most reliant on decoding. Therefore, the result indicating that RAN's contribution to reading of LFS non-words was significant beyond the variance explained by previous reading level (with the exception of Grade 4 reading) suggests that naming speed is directly involved in decoding. Furthermore, the results revealed that RAN made no significant contribution to the reading fluency of HF and LF words when differences in reading performance at any previous grades were accounted for. HF- and LF-words are dependent to some degree on previously accumulated whole-word orthographic knowledge. Therefore, this result opens up the possibility that naming speed's influence on word reading fluency is partly indirect. This would mean that naming speed's influence on reading is mediated by its influence on previous decoding and the accumulation of orthographic knowledge which results from it.

Moreover, RAN's contribution to orthographic knowledge ceased to be significant once individual differences in reading performance at any previous grade were controlled for. This result lends further support to the notion that naming speed's contribution to orthographic knowledge is indirect, suggesting it is mediated by its influence on previous reading performance.

Discussion

The main aim of this study was to examine the relationship between RAN and orthographic familiarity. This was done by assessing the contribution of RAN to orthographically familiar novel items (high-frequency syllable non-words) and to orthographically unfamiliar novel items (low-frequency syllable non-words), as well as to real words (HF and LF words). There were three main findings from the analysis. Firstly, HFS non-words were read faster than LFS non-words, a result which reflects the important role of syllable frequency in Spanish (Carreiras et al., 1993; Carreiras & Perea, 2004; Luque et al., 2013). This is evidence that children automatize frequent sublexical spelling patterns (e.g., commonly occurring syllables) more than infrequent sublexical spelling patterns. This ability to automatize frequent patterns might be related to the tendency that good readers, in comparison to readers with dyslexia, have for implicit sequence learning (Jiménez-Fernández, Vaquero, Jiménez, & Defior, 2011; Nigro, Jiménez-Fernández, Simpson, & Defior, 2015).

Secondly, and central to the main question of this study, RAN predicted reading speed of the four types of items beyond all the other cognitive and linguistic measures. Most revealingly, RAN's contribution to the reading of real words was not larger than its contribution to the reading of either type of non-word. Furthermore, RAN made a similar contribution to both types of non-words, suggesting that naming speed relates to letter-by-letter reading as much as it does to orthographic processing of familiar spelling patterns (HF syllables or letter-clusters). RAN also made a significant contribution to orthographic knowledge beyond the influence of all other cognitive variables. Thirdly, RAN's contribution to orthographic knowledge, as well as to high- and low- frequency word reading, but not to HFS and LFS non-word reading, disappeared if previous reading performance was controlled. This result suggests that RAN's contribution to decoding (LFS and HFS non-words) may be direct, whereas RAN's contribution to orthographic knowledge and to real-word reading (HF and LF words) may be partly mediated by previous reading performance.

RAN Is Not a Measure of Orthographic Processing

The result indicating that HFS non-words were read significantly faster than LFS non-words replicates the syllable frequency effect, confirming that, under certain conditions, high syllable frequency enhances reading speed (Carreiras et al., 1993;

Carreiras & Perea, 2004; Conrad et al., 2009). RAN was the best predictor of word reading speed, in agreement with the extensive literature reporting this relationship, but it also made a contribution to unfamiliar word reading speed, concurring with other published results (Moll et al., 2009; Poulsen & Elbro, 2013; van den Boer et al,. 2013). The findings presented in the current study cannot be explained by the ideas proposed by Wolf and Bowers (1999) or by Manis et al. (1999) which contemplate RAN as a measure of orthographic processing skill. Firstly, RAN's contribution to non-word (HFS and LFS) reading speed was comparable to its contribution to HF word reading speed (βs .305, .363 and .319, respectively), suggesting RAN's influence on decoding is as strong as its influence on sight-word reading. Importantly, RAN's contribution to orthographically unfamiliar LFS non-word reading speed was equivalent to its contribution to orthographically familiar HFS non-word reading speed (βs .305 and .363, respectively). This result can only be conceived under the assumption that the cognitive ability tapped on by RAN is as relevant to grapho-phonemic decoding, which requires little or no orthographic processing, as it is to grapho-syllabic decoding, which is dependent on sublexical orthographic processing.

Furthermore, of note is that RAN does not account for any variance in real word reading speed or orthographic knowledge after controlling for differences in previous reading performance. This result might indicate that the core cognitive ability measured by the RAN task does not exert a direct influence on word reading speed nor orthographic knowledge, or else RAN would have continued to contribute to these to literacy skills beyond previous reading level. Therefore, this result cannot be accommodated by Manis et al.'s (1999) view, who proposed that the reading-related ability measured by the RAN task is specifically involved in whole-word orthographic processing. Furthermore, RAN accounted for a significant amount of variance of reading speed of HFS and LFS non-words beyond the variance explained by reading performance during grades 1 and 2 (as well as Grade 3 for LFS non-words), suggesting that the cognitive ability which is captured by RAN plays a more direct role in decoding than in sight-word reading.

The current results are compatible with the notion that naming speed's involvement in whole-word processing is not a direct one. Therefore, we cannot rule out the possibility that kindergarten-RAN's prediction of real-word reading during Grade 5 may be an indirect product of its contribution to earlier decoding. In this sense, if the cognitive ability measured by RAN were essential for fluent grapho-phonemic and grapho-syllabic decoding, fast-RAN children would benefit from more self-teaching opportunities. This is due to the fact that fast decoders will benefit from additional exposures to words than slow decoders in an equal time frame devoted to reading (Moll et al., 2009). A larger exposure to print increases the size of the orthographic lexicon (Share. 1999), which in turn allows for faster sight-word or lexical reading (Bergmann & Wimmer, 2008). Therefore, naming speed's role in sublexical decoding speed would partly contribute to growth in the size of the orthographic lexicon. This would misleadingly appear as a direct role by naming speed in lexical reading, irregular word reading and whole-word orthographic processing, even if RAN's contribution to these forms of reading is mediated through decoding speed. The results of the current study are compatible with this suggestion.

RAN as a Measure of Visual-to-Verbal Processing

The finding that RAN predicts reading speed of all non-words (whether orthographically familiar or unfamiliar) beyond all other cognitive measures, indicates that the RAN task shares an underlying mechanism with sublexical decoding speed at a grapho-syllabic and a grapho-phonemic level. In both cases, as well as in lexical reading, which naming speed might also be involved in, the reader is converting symbols into speech. When completing the RAN task the child is converting one single symbol (i.e., a picture) into its spoken counterpart. Similarly, when reading lexically the child is converting a unitized set of symbols (i.e., a sight-word) into its spoken counterpart. When reading LFS non-words and HFS non-words the reader is converting a sequence of individual letters or letter-clusters into their phonological counterparts. Apart from visual processing and phonological processing, in order to perform these four tasks (RAN performance, sight-word reading, LFS non-word reading and HFS non-word reading) the following functions must be completed: 1) at some previous point, the link between the visual and the verbal stimulus must be established (formation of visual/verbal mappings); 2) when encountered in the naming task, the visual stimulus must be fluently converted into its phonological counterpart (visual-to-verbal conversion speed).

The findings of the present study do not support the first option – the perspective that naming speed, as measured by the RAN task, measures the ability to establish visual-verbal mappings. Because of their markedly low level of orthographic familiarity, in order to read LFS non-words the reader must engage in simple (grapho-phonemic) decoding. The visual-verbal associations between the individual graphemes and their phonemic counterparts were established back when the letters of the alphabet were first learned, that is, during the early stages of reading skill acquisition (i.e., Grade 1). If the RAN task measured the ability to establish visual-verbal mappings, RAN's contribution to LFS non-words should have been cancelled by RAN's contribution to reading during Grade 1, the period when visual-verbal mappings between the letters and their sounds were being established. The results of Table 9 show that RAN made a significant contribution to LFS non-word reading beyond the contribution of reading performance during grades 1, 2 and 3. Consequently, RAN's contribution to LFS non-words appears to be rather direct.

The second option, which understands RAN as an indicator of the speed or automaticity of visual-to-verbal conversion, seems more likely. The finding that RAN made a similar contribution to both types of non-words supports the view put forward by Moll et al. (2009) that the association between RAN and reading reflects the automaticity of orthography to phonology associations at the letter and letter cluster level. This interpretation of RAN would explain its relationship with reading fluency of HFS and LFS non-words, given that these tasks, as well as the RAN task, rely to some extent on the speed with which phonological representations can be accessed from visual representations.

Phonological Retrieval

It is also possible that the visual component is fully irrelevant to the RAN-reading relationship. In this sense, RAN, rather than measuring visual-to-verbal cross-modal conversion speed, might instead measure the rate at which a phonological label can be elicited – that is, phonological retrieval speed – as initially proposed several decades ago (Torgesen et al., 1994; Wagner & Torgesen, 1987). Such a suggestion does not necessarily mean that phonological retrieval speed must correlate with another aspect of phonological processing such as phonemic manipulation (when measured through accuracy rather than speed), just as reading fluency and reading accuracy often only correlate moderately. This view argues that naming speed tasks primarily assess the fluency or automaticity of access to and retrieval of stored phonological information in long-term memory. Therefore, RAN could simply measure phonological elicitation speed. In order to clarify whether the RAN-reading relationship is predominantly due to visual-verbal conversions speed or by phonological retrieval speed, future research should aim to separate the visual and verbal components of RAN and assess their individual relationship to decoding and sight-word reading. Observing the contribution of visual scanning skill, phonological retrieval skill and visual-verbal cross-modal skill to both forms of reading would substantially assist in clarifying the nature of the RAN-reading relationship.

Conclusions

This study has shown that RAN, measured at the onset of literacy instruction, predicts lexical reading fluency, advanced decoding fluency and simple decoding fluency, 5 years later. This result corroborates that naming speed ability is a crucial precursor to reading acquisition and highlights the fact that, due to its long-term capacity to predict later reading fluency, RAN holds major potential as an effective early diagnostic measure of later reading difficulties (Georgiou, Parrila & Kirby, 2006; Lervåg & Hulme, 2009). The current findings clearly indicate that the ability measured by RAN directly operates at a grapho-phonemic level as much as it does at a grapho- syllabic level, while part of RAN's contribution to lexical reading could possibly be an indirect consequence of its previous involvement in decoding performance. This outcome allows us to confidently submit that RAN is not exclusively a measure of orthographic processing, when defined as the ability to process the orthography of groups of letters or entire words as single units. Furthermore, naming speed's strong involvement in sublexical processing of familiar and unfamiliar orthographic patterns, distinctly categorizes RAN as an early predictor of sublexical decoding fluency. Therefore, the current results suggest that visual-to-verbal conversion speed could be the common ability which drives to the RAN-decoding relationship. The theoretical implications of these findings will be further discussed in the following chapter.

General Discussion

In the first three paragraphs of the current section the main findings of the thesis will be summarized before elaborating on the implications of these outcomes. This thesis set out to explore reading skill development and, more importantly, the role played by three cognitive abilities which are known to be involved in the acquisition of reading skills in different alphabetic orthographies – RAN, VPS and PA. For this purpose, we used as a base the framework of the developmental and skilled reading models which have been elaborated in an effort to interpret the different reading strategies and the timeline in which they are acquired. The idea was that, in order to obtain further insight into the underlying mechanisms that allow for appropriate literacy acquisition, it would be very beneficial to couple the knowledge gathered about reading skill development with the understanding about reading-related cognitive abilities. Therefore, on the one side, there was an interest in assessing whether these cognitive abilities are predominantly involved in reading during particular periods of reading development. On the other side, there was an interest in using the knowledge that unfamiliar words must be serially decoded, while familiar words are recognized as a whole, to examine whether the relevant cognitive abilities are predominantly involved in decoding or sight-word reading.

The first major finding of this thesis is that the developmental trajectory of early reading skills in Spanish fits the description presented by developmental reading models. The data from study 1 shows that in the evolution towards mastery of reading skill, lexical reading appears to develop progressively from the early stages of learning. However, the transition from the alphabetic phase (the period during which the child learns the GtP correspondences) to the orthographic phase (the period during which advanced decoding develops) seems to be more pronounced. This transition takes place at the end of Grade 1. Furthermore, PA, RAN and VPS were all significant predictors of future reading skill. Noting that these predictors were measured before the onset of formal literacy instruction and at pre-reading levels, these results suggest that individual differences in these cognitive skills are causally linked to the process of reading skill acquisition. However, the evolving profile described by each of these cognitive abilities outlined a different developmental pattern. Pre-reading levels of PA proved to have a strong influence on reading which nonetheless was strictly limited to the period during which the children were learning the letters, suggesting a specific role by PA in GtP correspondence knowledge acquisition. In contrast, the time of maximum influence for RAN and visual skills, on reading began after most GtP correspondences had been learned.

In the following two studies, word length and word familiarity, the latter being regulated by means of lexical frequency and syllable frequency, were manipulated with the intention to further understand whether VPS and RAN are primarily related to decoding or sight-word reading. Visual processing skills were measured by means of a visual multi-element processing task which required the children to encode the positions of non-namable symbols within a string. In study 2, pre-reading VPS significantly predicted the future reading of words but only when these were both unfamiliar and long, suggesting that sublexical decoding partly relies on VPS. In order to examine the relationship between RAN and orthographic familiarity, the syllable frequency of non-words was manipulated in study 3. Results revealed that pre-reading RAN equally predicted Grade 5 reading for both orthographically familiar and orthographically unfamiliar non-words, contradicting the view that RAN measures orthographic processing. Furthermore, while RAN's contribution to real-word reading and to orthographic knowledge scores disappeared when previous reading performance was controlled, RAN's contribution to non-word reading remained significant beyond the contribution of previous reading performance. These results support the understanding that RAN measures visual-to-verbal conversion speed, a process needed both for sight-word reading, and in particular decoding, which requires more visual-to-verbal processing resources.

Different Developmental Periods and Reading Strategies

Rather than accepting the theoretical representations described by developmental reading models a priori, it was imperative to establish to what extent these models are relevant within the context of the Spanish orthography. It was also important to clearly distinguish the specific time-frame during which the different periods of development take place. As reviewed in earlier sections, stage-based developmental reading models (Ehri, 2005; Frith, 1986; Høien & Lundberg, 2000; Seymour & Duncan, 2001) describe a transition from an alphabetic phase to an orthographic phase, while Share's (1995) item-based developmental reading model describes a progressive evolution towards lexical reading. Results of this study indicated that the speed and accuracy measures assessing reading performance from kindergarten to Grade 4 revealed a developmental pattern compatible with the developmental periods portrayed by both, stage- and item-based reading models.

Stage-based developmental reading models (e.g., Ehri, 2005; Frith, 1986) submit that one initial and crucial step towards learning to read is the familiarization with, and assimilation of, the alphabetic code, referring to the language-specific mapping between graphemes and phonemes. The results obtained in study 1 support the view that learning this alphabetic code, which will become the working material from thereafter, regulates reading development. Thus, during the initial alphabetic phase, children were still making a sizable proportion of incorrect reading pronunciations. However, as tuition in letter knowledge was completed and GtP correspondence knowledge was acquired, reading accuracy of both words and non-words approached ceiling. During the subsequent orthographic phase the focus moved from the accuracy of GtP conversions to speed of GtP conversions. At this point reading speed became the only discriminating factor of reading performance. In study 1, we observed a continued increase in non-word reading speed even after essentially perfect reading accuracy had been reached, suggesting a transition from the basic decoding, characteristic of the alphabetic phase, to the advanced decoding of unitized letter-clusters representative of the orthographic phase. This finding is in line with the descriptions made by stage-based models, indicating that during this period the child begins to recognize commonly occurring multi-letter patterns as single units through the process of unitization (Ehri, 2005; LaBerge & Samuels, 1974).

Very importantly, the highly regular and transparent letter/sound mapping which characterizes the Spanish orthography (Defior & Serrano, 2014) enables the alphabetic phase to be relatively short. The simple one-letter-one-phoneme principle which typifies the transparent reading systems, facilitates the teaching of the alphabetic code, allows the novice reader to assimilate the GtP correspondences with relative ease and enables a critical reduction of reading accuracy errors by the end of Grade 1. Only nine months after the onset of formal literacy instruction the children approach ceiling with regards to reading accuracy. Therefore, the end of Grade 1 appears to mark a crucial turning point in development of reading in Spanish, being the specific period when the understanding of GtP correspondences is completed, reading accuracy approaches ceiling and pre-reading PA ceases to significantly contribute to reading while RAN and VPS begin their period of influence on reading. Many authors have noted that the phases described by stage-based developmental models should not be considered to be rigid, but as a continuum in which the learner acquires competence by incorporating decoding strategies for accurately and rapidly reading all the words in their language (Ehri, 2002; 2005; Orsolini, Fanari, Tosi, De Nigris, & Carrieri, 2006; Share, 1995). However, this study's results revealed a clear delineation at the end of Grade 1 between the alphabetic and the orthographic phases. One main finding of this thesis is to have identified the clear-cut developmental transition which takes place at the end of Grade 1.

In contrast, the transition to sight-word or lexical reading appears to be better described by continuous models of reading development, rather than stage-based models. As shown in study 2, word familiarity will determine whether a word is decoded or read by sight. In essence, all written words in all orthographies are visually unfamiliar (functionally non-words) the first time they are encountered, and thus, must be decoded through the application of a set of GtP correspondence rules. Likewise, any printed combination of letters in any orthography along the transparency spectrum should eventually become a familiar sight-word, if encountered enough times (Share, 2008). For instance, even though decoding is always a viable option in transparent scripts (due to the lack of irregular/exception words), evidence suggests that familiar words are also read lexically (by sight) in these writing systems (Spanish: Defior et al., 2002; Valle-Arroyo, 1996; German: Wimmer & Goswami, 1994; Italian: Pagliuca, Arduino, Barca, & Burani, 2008). Furthermore, lexical reading for familiar words begins from the very onset of reading skill acquisition (Spanish: Cuetos & Suárez-Coalla, 2009; Italian: Orsolini et al., 2006; Zoccolotti et al., 2009; Turkish: Öney et al., 1997).

Accordingly, the results obtained in study 1 reveal a gradual development of sight-word reading which can be perceived by the progressively widening gap between word and non-word reading speed occurring throughout the developmental process. In this sense, it seems that Share's item-based Self-Teaching Hypothesis (e.g., 1995) is better conceptualized than stage-based models to describe the development of lexical reading. Therefore, the developmental timeline of the alphabetic and the orthographic phases described in stage-based models might be script-dependent, based on the level of GtP consistency and on how long it takes the children to learn those GtP correspondences. However, the transition from decoding to lexical reading seems to be a progressive development regardless of the script in which reading skill is being learned. Indeed, it has been suggested that the unfamiliar/familiar dualism (or familiarity spectrum) exists irrespective of cross-linguistic differences, emerging as a universal commonality in the functional architecture of all writing systems (Share, 2008; but see also Coltheart & Crain, 2012, for a contrarian perspective). In summary, our data fit the description presented by stage-based developmental reading models in some aspects, while matching the description presented by continuous developmental models in other aspects. According to our results, while the transition from decoding to the lexical reading is progressive, the shift from the alphabetic to the orthographic phase in Spanish is fairly distinct and takes place at the end of Grade 1.

Phonemic Awareness is Crucial for Learning the Alphabetic Code

In study 1, the periods of reading development in Spanish during which the learning phases described by developmental reading models transpire were established. Once this match was ascertained, the focus shifted to the reading-related cognitive abilities. One of the goals of this longitudinal study was to determine to what extent phonemic awareness, measured prior to the onset of formal instruction, matches the alphabetic phase in a sample of Spanish children. Whereas RAN and VPS made a significant contribution to reading speed at later grades, the strong influence of pre-reading PA on reading was limited to the period when children were still learning the letter-to-sound mappings, between the onset of the study in kindergarten and the end of Grade 1. There appeared to be an intimate relationship between the contribution made by PA to reading and the children's accuracy on GtP correspondence knowledge and reading accuracy. When the children's GtP correspondence knowledge and word reading accuracy were below 50%, the correlations between PA and the two reading measures (accuracy and speed) were at their strongest. However, once children's knowledge of the GtP correspondences approached ceiling levels, PA ceased to significantly correlate with word and non-word reading (accuracy and speed). In studies 2 and 3, pre-reading PA also failed to make a significant contribution to Grade 3 and Grade 5 word reading or non-word reading, and in particular, low syllable-frequency non-words which require additional decoding demand.

Thus, PA seems to be critical to reading during the alphabetic phase, when children's letter-sound mappings are for the most part still incomplete, and the alphabetic system is functionally opaque (Share, 2008). The novel finding of this study with regards to PA is that it has highlighted the fact that PA's period of maximum influence in Spanish coincides with the period during which children learn the letter-sound associations. The current results are very much aligned with the wealth of data in transparent orthographies which indicates that the influence of pre-reading PA severely wanes after Grade 1 (e.g., Norwegian: Lervåg et al., 2009; Dutch: de Jong & van der Leij, 1999; Finnish: Leppänen et al., 2006). Overall, the combination of results conveys that in orthographies with transparent and consistent GtP correspondences, pre-reading PA's influence to reading development has a limited time span.

Rather than playing a permanent role in decoding, it appears that PA is crucially involved in learning and assimilating the alphabetic code, as has been previously proposed by several prominent authors in the field of literacy acquisition (Byrne & Fielding-Barnsley, 1989; Goswami, 2002; de Jong & Olson, 2004; Share, 2008; Vellutino et al., 2004). In concurrence with Share's (2008) functional opacity hypothesis, PA exerts a strong influence in reading for as long as the orthography-to-phonology conversion system is perceived by the reader as opaque. In transparent orthographic systems like Spanish, this is the case only until the end of Grade 1 (Seymour et al., 2003), the period when the GtP correspondences are fully incorporated by the novice reader. However, in opaque orthographic systems like English it takes longer for the child to grasp the totality of the GtP correspondence possibilities. Therefore, studying the PA-reading relationship in English, which is functionally opaque for an extended period throughout reading development, may have been the source of confusion leading experts to consider PA to be permanently involved in GtP conversion. Regarding the English orthography, if PA's main period of influence is also confined to the alphabetic phase, then pre-reading PA should predict reading until the child's GtP correspondence knowledge and decoding accuracy for regular words approaches ceiling.

The lack of influence by early-PA on reading after Grade 1 does not necessarily imply that later levels of PA are not relevant in future reading. Even in transparent orthographies, when measured concurrently, PA remains correlated with reading in later grades (e.g., Spanish: Rodríguez et al., 2015; Dutch: Vaessen & Blomert, 2010). However, due to the strong reciprocal impact that reading itself exerts upon PA (Aguilar-Villagrán et al., 2011; Bentin & Leshem, 1993; Hogan et al., 2005), PA levels at later grades may be so strongly transformed by reading practice that kindergarten-PA levels are rendered irrelevant to future reading. Furthermore, in later grades it is difficult to determine whether the PA-reading correlation reflects PA's influence on reading or merely the influence that reading practice has exerted on PA. In any case, the current results clearly indicate that initial unaltered PA skill is strongly related to reading only during the earliest period of acquisition, from kindergarten to Grade 1. This is the period during which children are learning the alphabetic code of the Spanish orthographic system.

Visual Processing Skills Play a Significant Role in Reading

Another core objective of this thesis was to clarify what role visual skills play in reading skill acquisition. However, before meeting that goal, a more basic requirement was to determine whether visual skills significantly and independently influence reading performance, a question at the core of an ongoing debate (Goswami, 2015; Lobier & Valdois, 2015). There is a considerable amount of evidence indicating that reading practice exerts a transformative influence on VPS (e.g., Dehaene et al., 2010; Perfetti et al., 2013). Consequently, in order to confidently determine whether VPS does have an influence on reading skill, for this thesis VPS was measured during a period when the children did not have any reading experience. The findings of studies 1 and 2 of this thesis, where pre-reading VPS was found to make a significant contribution to future reading skill, are in line with the evidence presented by Franceschini et al. (2012) and suggest that pre-reading VPS is causally related to future reading skill. However, this was to our knowledge the first study to provide evidence indicating that visual multi-element processing skill is a pre-reading predictor of future reading performance. A further goal of this thesis was to elucidate the precise role played by VPS in reading. The results obtained in study 2 revealed that, after controlling for IQ, naming speed and phonemic awareness, VPS were significantly related to low-frequency word reading speed, suggesting a specific role by VPS in decoding.

The finding that VPS predicts unfamiliar-word reading is in line with the results of several other studies which indicate that VPS is involved in decoding of letter sequences (Auclair & Siéroff, 2002; Facoetti et al., 2006; Jones et al., 2008; Kinsey et al., 2004; Valdois et al., 2006). However, it contradicts the results obtained in other studies which found VPS not to contribute at all to reading (Shapiro et al., 2013) and other studies which found VPS to contribute to familiar word reading as much as to unfamiliar word reading (French: Bosse et al., 2007; English: Bosse & Valdois, 2009; Italian: Franceschini et al., 2012; Spanish: Lallier et al., 2014; Dutch: van den Boer et al., 2013). As reviewed in the discussion section of study 2, the wide variety of methods used when assessing the relevance of VPS to reading skill development makes direct comparisons of the findings problematic.

Methodological factors which might contribute to these contradicting results and to the difficulty to interpret them are: employing namable stimuli or tasks which require a verbal response when attempting to measure pure visual ability (e.g., Bosse & Valdois, 2009), studying the VPS-reading relationship in samples of children whose reading experience might have modified their visual skills (e.g., van den Boer et al., 2013) or measuring the VPS-reading relationship at a time when VPS is not yet relevant to reading (e.g., Shapiro et al., 2013). Such methodological features are of substantial importance and should not be neglected in future studies.

Does Multi-element Processing Measure Visual Attention?

Another source for the inconsistencies in the results obtained in different studies could be the type of task used to measure VPS. Different visual tasks may measure different visual skills (Rayner, 2009 for a review). Moreover, not all types of visual skills are necessarily relevant to reading. Furthermore, visual skills which are related to reading might be involved in different aspects of reading (e.g., speed vs. accuracy). Therefore, when investigating the VPS-reading relationship it is crucial to consider the type of test which has been used and the particular skill which might have been tapped. For the studies in the current thesis, VPS was measured by assessing the child's ability to encode symbol-positions within multi-element symbol strings. Previous studies which assessed the influence of pre-reading VPS, when using pure visual tasks, have measured VPS through visual search tasks (Shapiro et al., 2013) and visuo-spatial attention (Franceschini et al., 2012) – considered to be classical visual attention tasks. Shapiro et al. (2013) found VPS not to be an independent predictor of future reading performance, while Franceschini et al. (2012) did obtain positive results.

It is plausible that visual attention, as assessed in Franceschini's (2012) tasks, is needed for both sight-word reading and decoding, while symbol-position encoding is exclusively relevant to unfamiliar word decoding. However, the previous account does not explain why Franceschini et al. (2012) found pre-reading visual search ability to significantly contribute to word and non-word reading, yet Shapiro et al. (2013) found that pre-reading visual search ability did not significantly contribute to word and non-word reading. Alternatively, Jones et al. (2008) found a positive correlation between visual-search and multi-element processing scores, which they interpreted as an indication that both skills share a common mechanism which is applied when rapidly guiding serial attention across the word. Pammer et al. (2004) also hypothesized that individual differences in multi-element processing might reflect variations in visual attention, given that visual attention serves to filter and prioritize information within the visual field during reading (McCarthy & Nobre, 1993). Therefore, it is conceivable that sensitivity to the spatial sequence of word-like symbol strings and visual search ability both rely on visual attention.

Whether the fluency of advanced decoding requires efficient serial visual-attentional orienting (Facoetti et al., 2006; Jones et al., 2008) or whether it requires the visual attention span to be large enough to process amalgamated letter-clusters as individual orthographic units (Ans et al., 1998) remains undetermined. The finding that VPS is specifically related to decoding speed of long, but not short LF words, seems to suggest that the width of the reader's visual attention span limits the number of visual elements which can be processed at a glance (Ans et al., 1998; Lobier et al., 2013). In this way the reader's maximum size of the visuo-attentional window would determine reading speed (Häikiö et al., 2009; Lobier et al., 2013; Rayner et al., 2010). However, both accounts (visual-attentional orienting speed vs. visual attention span) would explain why in the present results visual ability is unimportant during the earliest period of acquisition (Shapiro et al., 2013) whilst the novice reader is still engaging in slow effortful letter-by-letter decoding of words.

In order to determine which role VPS play in reading it was crucial to take into account the developmental period during which reading skill is being measured. This longitudinal study was the first to assess the contribution made by pre-reading VPS to future reading at several developmental time-points. This approach has allowed us to provide solid evidence that pre-reading VPS, measured through multi-element processing, is a significant predictor of decoding speed in Spanish, but only after the GtP correspondences have been learnt and reading speed has reached 60 syllables per minute (Figure 1). However, precisely in what manner VPS determines decoding speed (e.g., visual attention span vs. visual-attentional orienting speed) is far from established. Future studies should compare the contributions by different types of VPS to reading, in order to assess whether they share the same underlying processes.

Is Visual Processing Skill Relevant to the Parallel Reading Procedure?

Another result which is not immediately obvious is why multi-element processing would be important to serially decode sublexical segments, but not to read whole-word forms in parallel. The MTM model (Ans et al., 1998) postulates that the global (parallel) and analytic (serial) reading procedures differ regarding the visual attention window size. In the global mode (roughly equivalent to the sight-word reading procedure), the window opens over the whole letter string whereas in analytic mode, it narrows down to focus attention on each orthographic sub-unit of the input word. The visual attentional window delineates the amount of orthographic information which is under the focus of attention during word reading (Lallier & Valdois, 2012). Therefore, according to this model, a reduced visual attention span would be particularly detrimental with regards to sight-word reading. However, the results of this thesis indicate that a reduced ability in VPS, when measured through a multi-element processing task similar to the visual attention span tasks used by Bosse and Valdois (2007; 2009) and Lallier et al. (2014), affects the serial reading procedure more than the parallel reading procedure. Therefore, if multi-element processing is involved in serial decoding more than parallel processing, the implication might be that sight-word reading does not rely on the size of the attentional window but on a different sort of visual processing.

Sight-word reading appears to be carried out by processing the entirety of the visual image of the word in parallel (Aaron, Joshi, Ayotollah, Ellsberry, Henderson, & Lindsey, 1999). According to the DRC (Coltheart et al., 2001), word identification is achieved in parallel by activation of the word's entry in the orthographic lexicon followed by activation of its entry in the phonological lexicon. Aaron et al. (1999) explain that all the constituent letters in the orthographic representation of a word are processed simultaneously in a parallel fashion, meaning that proficient readers can process all the letters in a known word as fast as a single isolated letter. In line with this notion, single word reading has been found to be more strongly correlated to discrete rather than serial digit naming (de Jong, 2011; van den Boer & de Jong, 2015). The process of reading a single word mirrors naming of single overlearned symbols. According to van den Boer and de Jong's (2015) results, words, like digits, are read through parallel retrieval of phonological codes. Furthermore, the focus that readers allocate to the first and last letter of known words (Johnson & Eisler, 2012) suggests that familiar words are approached in a parallel and holistic manner. Rather than processing the familiar words through a serial procedure, attention is distributed in a parallel manner, placing emphasis on the outer features of the word.

Evidence indicates that parallel processing involves processing of every letter in the word, all at the same time, and associating it with the word's stored phonological representation (Aaron et al., 1999). This view is supported from eye-movement studies showing that all the constituent letters of fixated words are processed (Aghababian & Nazir, 2000; Johnson & Eisler; 2012; Rayner, 2009). Even at very short presentation times, all letters in a word undergo at least partial processing (Aghababian & Nazir, 2000). However, it is unclear how visual parallel processing can be so fast yet not be heavily dependent on visual multi-element processing, when serial analytic decoding is. One possibility which explains the ability of skilled readers to process known words so much faster than unknown words is that word recognition operates in terms of guessing the identity of the known word from partial cues through short-cutting into the orthographic lexicon. However, this seems unlikely because evidence shows that even skilled readers cannot guess more than 25 percent of the words correctly (Gough & Walsh, 1991). Future research should focus on investigating the underlying cognitive mechanisms which govern the visual parallel processing required for sight-word reading and the visual tasks which capture the corresponding cognitive ability.

Rapid Automatized Naming as a Measure of Visual-to-Verbal Conversion

The results presented in this thesis extend on the extensive amount of research on the field of literacy acquisition corroborating the intricate connection between RAN and reading skills (e.g., Kirby et al., 2003; Landerl & Wimmer, 2008; Wolf & Bowers, 1999). One of the most debated perspectives accounting for RAN's relation to reading argues that RAN measures orthographic processing ability, when defined as the ability to process groups of letters or entire words as single units (Bowers & Wolf, 1993). Evidence in favor of this perspective is that, despite the fact that RAN has traditionally been linked to reading speed, it has also been reported to significantly correlate with accuracy measures of orthographic knowledge and irregular word reading (see Kirby et al., 2010 for a review). However, results obtained in studies 1 and 2 contradict this perspective, given that a similar contribution by RAN to familiar word reading and to unfamiliar word reading was found. Likewise, a comparable contribution by RAN to unfamiliar and familiar word reading has been reported in most studies which have made this comparison (e.g., Moll et al., 2009; Poulsen & Elbro, 2013; van den Boer et al., 2013).

In order to investigate whether the RAN-reading relationship operates at a whole-word orthography level, at a sublexical orthographic level, at an individual letter level or at a combination of these, in study 3 orthographic syllable frequency was manipulated. Results revealed that RAN made a contribution to reading speed of non-words comprised of high- and low- frequency syllables which was as strong as its contribution than to real word reading. This result suggests that the reading-related cognitive ability measured by RAN operates at grapho-syllabic and grapho-phonemic levels as much or more than it does at a whole-word level. Moreover, RAN made no significant contribution to orthographic knowledge and to real-word reading when differences in previous reading performance were accounted for. Therefore, the current results do not support the view of RAN as a measure of orthographic processing.

What Reading-Related Cognitive Ability Does the RAN Task Measure?

In light of the evidence that RAN is unlikely to measure orthographic processing, other possibilities must be considered which can provide a more satisfactory explanation accounting for the RAN-reading relationship. The results from study 3 indicate that pre-reading RAN significantly predicted HF and LF word reading, as well as high-frequency and low-frequency syllable non-words. This result suggests that RAN contributes to reading words across the whole familiarity spectrum. The question then, is what can the common cognitive skill shared by RAN and reading at a whole-word, grapho-syllabic and grapho-phonemic level be. The common cognitive tasks which are required by RAN and these 3 types of reading are (1) visual serial processing (Logan & Schatschneider, 2014), (2) phonological retrieval (Torgesen et al., 1994), (3) speed or automaticity of visual-to-verbal conversion (Moll et al., 2009) and (4) the previously implemented skill of establishing the link between a visual symbol (e.g., words, morphemes, syllables or letters) and a verbal label (Manis et al., 1999). Although the results of this thesis cannot categorically discard any of these four possibilities, they do allow us to make some evidence-based conjectures.

Regarding the possibility that RAN's contribution to reading reflects visual processing ability, as explained in the theoretical framework chapter of this thesis, several studies have obtained findings which clearly suggest that the RAN-reading relationship is at least partly driven by visual serial processing (de Jong, 2011; Jones et al., 2009; Jones, Branigan & Ashby, 2013; Georgiou, Parrila, Cui & Papadopoulos, 2013; Logan & Schatschneider, 2014; Rodríguez et al., 2015). However, it is also clear that visual processing alone does not explain the totality of RAN's relationship to reading (Di Filippo et al., 2006; Landerl, 2001). For instance, readers with a RAN deficit have been reported to perform worse than typically reading controls on visual string processing tasks only when a naming response was required, but not when the task simply required visually detecting a pre-defined target among distractors (Hawelka & Wimmer, 2005). Similarly, Brizzolara, Chilosi, Cipriani, Di Filippo, Gasperini, Mazzotti,... and Zoccolotti (2006) found that the majority of the dyslexic participants in their study performed at the same level as controls on a visual scanning task which did not require verbal response, leading them to conclude that visual search difficulties were not responsible for the RAN deficits.

The case is similar for RAN's phonological component. Phonological retrieval fluency is known to be one of the crucial components which determine RAN performance (Decker, Roberts, & Englund, 2013). Likewise, neuroimaging studies have found that object naming is linked to the same name-retrieval and speech-production brain areas as reading aloud (Moore & Price, 1999; Price, McCrory, Noppeney, Mechelli, Moore, & Biggio, 2006). These results are compatible with the view that the RAN task fundamentally measures phonological recoding or phonological retrieval speed (Torgesen et al., 1997; Wagner & Torgesen, 1987). Our results, which found that the cognitive ability tapped by the RAN task also operates when analytically decoding an unfamiliar word (grapho-phonemic processing) and when retrieving the phonological representation of a well-known sight-word, also appear to match the RAN-phonological retrieval explanation. The reported correlation between RAN scores and performance on phonological skill tasks also lends support to this view. For instance, meta-analyses conducted on studies which included naming speed tasks and reading tasks found that naming speed correlates moderately (*r* between .3 and .4) with phonological awareness scores (Swanson et al., 2003; Vukovic & Siegel, 2006).

Nevertheless, evidence from discrete vs. serial naming studies indicates that the phonological retrieval theory, which overlooks the visual processing aspect, does not account for the totality of the variability shared between reading and RAN. As a matter of fact, RAN's multi-componential structure is most probably the reason why RAN provides such an effective all-encompassing testing method, with such a degree of predictive power of reading skill. Nevertheless, this complex circuitry of components might also be the reason why the underlying mechanisms which drive the RAN–reading relationship remain poorly understood. According to the results of study 3, together with the finding reviewed in the previous two paragraphs, it appears that RAN is related to reading because both involve visual serial processing and oral production of the names of the stimuli (Georgiou et al., 2013). Regarding future studies, attempting to examine the nature of literacy's relation to RAN will be an arduous endeavor without dissecting the task into smaller components, much in the like of the research-line set out by Jones et al. (2009), Di Filippo and Zoccolotti (2012), Logan, Schatschneider and Wagner (2011) or Georgiou et al. (2013).

RAN as a Measure of Visual-to-Verbal Conversion Speed

There are two explanations for the RAN-reading relationship which contemplate that RAN measures visual-to-verbal processing skill. In this sense, RAN could either tap the ability to establish links between visual representations and their phonological counterparts (Manis et al., 1999) or the ability to fluently recode those visual representations back into their phonological labels (Moll et al., 2009). Regarding the first option, the ability to create associative links between abstract visual and verbal stimuli is necessary to learn picture-name associations, letter-sound associations, as well as the associations between the orthographic and phonological representations of whole-word forms and sublexical multi-letter spelling patterns. However, as noted in the introduction, the associative links between letters and sounds are formed early in the process of reading skill acquisition. Therefore, if RAN tapped on the ability to create these links, any contribution by RAN to non-word reading (which partly relies on the quality of these associations) should cease to be significant if previous reading performance is accounted for. The results obtained in study 3, where kindergarten RAN made a significant contribution to low-frequency-syllable non-word reading beyond the contribution by previous reading level, argues against this possibility.

The second option, which regards RAN as a measure of the speed of access from visual symbols to the phonological output system (Moll et al., 2009) is a better fit to the results obtained in this thesis. The ability to fluently translate visual stimuli into its corresponding phonological representation should manifest as the magnitude of the speed lag when eliciting the verbal labels of pictures (RAN task). Likewise, this visual-verbal conversion speed ability should also manifest in the rapidity of access to the phonological representation of written words (sight-word reading) and in the time needed to serially convert graphemes into phonemes (non-word reading). Supporting the notion that RAN measures visual–verbal conversion speed, the results of study 3 indicate that RAN was as related to reading speed of highly unfamiliar words as it was to reading speed of familiar words. Furthermore, the graphemes which comprise highly unfamiliar non-words must be decoded through attentive parsing and therefore should require higher visual-to-verbal conversion demand. This is in line with the results obtained in study 3 in which RAN's contribution to LFS and HFS non-words, but not to HF and LF words, remained significant beyond the contribution of previous reading level.

If RAN performance is a pre-cursor to decoding speed, slow-RAN children will become slow decoders, resulting in a slow build-up in the orthographic lexicon. It is precisely through the process of decoding a word from its orthographic into its phonological form (phonological recoding) that a child will progressively build up the orthographic lexicon which will enable fast sight word reading (Share, 1995, 1999). Therefore, it is plausible that the low orthographic knowledge reported in children with RAN deficits is a purely secondary effect caused by the fact that slow readers will cover a smaller amount of print than fast readers in a set time (Moll et al., 2009). Given that slow readers would benefit from less self-teaching opportunities to acquire word-specific orthographic information (Share, 1999), the low orthographic knowledge scores revealed by slow-RAN readers might simply stem from a lower exposure to print and a poorer orthographic lexicon. In line with this notion, Conrad and Levy (2007) found that fast-RAN children benefited more than slow-RAN children from longer-study-duration during orthographic learning. Such findings should prompt us to explore a more coherent account of naming speed's involvement in orthographic learning. Future research should investigate whether RAN's contribution to orthographic knowledge and sight-word reading speed is direct or mediated through exposure to print.

Limitations of the Study

Ideally, reading speed and reading accuracy should be assessed individually in study 1 when attempting to obtain a precise estimation of reading performance. This study used a single test to evaluate both. While the reading speed measure was unaffected by this procedure, using a timed measure meant the accuracy proportion was calculated using a different amount of items for every child, thus resulting in a less comparable measure of individual differences in reading accuracy. However, for this study the primary use of an accuracy measure was not to study individual differences, but to obtain an average of the proportion of reading errors made by the whole sample, for which the current task provided a representative estimation. Furthermore, due to the high transparency of the Spanish orthography, after Grade 1 reading accuracy measures are far less representative of individual differences in reading level than reading speed measures. Regarding the study of individual differences, in order to better examine the relationship between reading and the various cognitive abilities it would have been beneficial to assess these cognitive abilities at every time-point, rather than only at a pre-reading level. Future longitudinal studies should investigate the development of reading and its corresponding reading-related cognitive abilities in parallel.

Moreover, while we trust the reliability of the GPC task used in study 1, we suspect children's percentage scores underestimate their actual knowledge of letter-sound associations. Given the strong syllabic nature of the Spanish language, children are not used to pronouncing isolated graphemes in absence of a vowel. In some cases this might have resulted in children giving formally incorrect answers to known graphemes. A higher average score would have probably been more representative of the children's knowledge of GtP correspondences, as well as providing a closer match between the proportion of errors in GtP correspondence knowledge and reading accuracy (Figure 1). Another possible drawback of the study is the possibility that by excluding the early readers we may have removed the better readers, thus rendering the sample not to be truly representative of a normal sample, but a sample composed of average and poor readers. However, we do not believe this to be the case. Using a series of *t*-tests we compared the reading levels of the included and excluded children at each grade, finding no significant differences between the two groups from grade 1 onwards. Thus, the excluded children do not represent the best readers in the group.

Concluding Remarks

The findings from this longitudinal study help to shed light on a number of matters of concern regarding the underlying cognitive and linguistic mechanisms of reading skill development. In general, the results obtained in the current study reveal that phonemic awareness, visual processing skills and rapid automatized naming influence reading proficiency differently depending of the developmental period and the reading strategy being applied. This result cautions against over-generalizing findings obtained when focusing on any particular point in development and/or a particular type of reading item. Of note is the importance of the period which can be referred to as the alphabetic phase, which in Spanish takes place during the school grades in which the children are introduced to the letters (kindergarten and Grade 1). According to our results, the role of phonemic awareness appears to be related to assisting the novice reader in learning the letter-sound correspondences and attaining reading accuracy during this period.

Once the alphabetic code is learned and reading accuracy has been achieved, the focus turns to improving reading speed by automatizing a more advanced system of decoding and progressively developing lexical reading. Visual processing skills and naming speed become important to meet these objectives. The former appears to play a key role in decoding speed, possibly by processing letter-clusters as single units. In contrast, naming speed is related both to decoding and to sight word reading from kindergarten to far into primary school years and might be involved in the crucial function of fluently converting visual stimuli (from individual graphemes to whole words) into their corresponding phonological representations. According to the results of this study, non-alphanumeric rapid automatized naming, measured at a pre-reading stage, is a task which has the capacity to predict decoding speed and sight-word reading fluency as much as five years after the onset of reading skill acquisition. Therefore, it can be confidently stated that naming speed is a critical precursor to reading. Furthermore, this result emphasizes the vast potential which RAN holds as a valuable long-term early screening measure of future reading level (Georgiou et al., 2006; Lervåg & Hulme, 2009).

More generally, our enhanced understanding of how phonemic awareness, visual processing skill and naming speed are involved in reading supports the effort to start taking theory through to educational application, making it useful in real-world school settings. These findings will assist education professionals in developing the appropriate methods to identify those children who are most likely to manifest reading impairments. When aiming to foresee and potentially prevent future reading difficulties it is imperative to develop an evidence-based understanding of the cognitive and behavioral markers which can yield strong predictions of future reading level. Results like those from the current longitudinal study can enable us to develop reliable and valid diagnostic tools with which typical and at-risk children can be screened for literacy-related cognitive deficits, even before they have been taught how to read. Importantly, further detailed longitudinal studies are needed which can provide education professionals with the best means of understanding the cognitive developmental antecedents which can serve as early indicators of future reading level.

Furthermore, a child with low scores on predictive diagnostic tests can benefit from the great efficacy of early intervention. Apart from enabling us to identify reading difficulties at an early stage, this study's findings can, most importantly, allow us to develop teaching systems which can help children to overcome their specific weakness and to their reach their potential. One primary benefit of identifying these crucial cognitive constructs is to attain the capability of elaborating methods which can improve these cognitive abilities at an early age. There is a special interest in boosting the cognitive abilities which reading skill relies on at an age when cognition is most plastic and most prone to enhancement. Given that later difficulties can be due to diverse cognitive factors, information about pre-reading cognitive abilities can also be used to elaborate specific intervention materials for particular profiles of at-risk children. Brief and easy early-intervention programs can be developed and individually tailored to be administered to children as early as kindergarten or possibly before. In sum, there is an important need to continue striving to understand the relation between early predictors of reading and reading development so that we elucidate the processes of reading skill acquisition and advance our capability to develop theoretically motivated intervention programs.

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Appendix

Appendix Index

Appendix 1 - Parental Consent for Participation in the Study

JUNTA DE ANDALUCIA CONSEJERÍA DE EDUCACIÓN Y CIENCIA	C.E.I.P. SIERRA NEVADA Paseo Emperador Carlos V, 17 Telf: 958893350-51 Fax: 958893352 18008968.averroes@juntadeandalucia.es	

Mejorar el desarrollo del lenguaje escrito en las lenguas europeas

Investigadores: Sylvia Defior, Eduardo Onochie-Quintanilla y colaboradores
Facultad de Psicología
Universidad de Granada

CONSENTIMIENTO INFORMADO

Marque lo que corresponda

1. Confirmo que he leído y he comprendido la información que consta en el documento presentado con fecha…………. sobre el proyecto de investigación arriba mencionado. He tenido la oportunidad de considerar dicha información, realizar preguntas y obtener respuestas satisfactorias. ☐

2. Comprendo que la participación de mi hijo/a es voluntaria y que puedo retirarlo/a de la investigación en el momento que lo desee, sin tener que justificarlo. ☐

3. Autorizo a mi hijo/a a formar parte de este estudio. ☐

En caso de duda o queja por favor contacte con la profesora Sylvia Defior, Facultad de Psicología, Universidad de Granada (Tfno 958 249408, sdefior@ugr.es)

Nombre del niño/a:

……

Nombre del padre/madre o tutor:

……

Firma…………………………………………………………………. Fecha…………………………………….

Sus datos:

Dirección:

……

Número de teléfono:

……

Correo electrónico (E-mail):

……

Appendix 2 - Parental Consent for Child Recording of Audio

Mejorar el desarrollo del lenguaje escrito en las lenguas europeas

Investigadores: Sylvia Defior, Eduardo Onochie-Quintanilla y colaboradores
Facultad de Psicología
Universidad de Granada

GRABACIONES EN AUDIO

Marque lo que corresponda

1. Comprendo que los investigadores podrán grabar en audio las sesiones en que participa mi hijo/a. Comprendo que estas grabaciones serán archivadas de forma segura y serán desechadas 5 años después de finalizado el proyecto (2017). ☐

2. Comprendo que las grabaciones serán confidenciales y que ninguna persona sin autorización tendrá acceso a ellas. ☐

3. Estoy de acuerdo con que los investigadores puedan grabar en audio las sesiones en que participa mi hijo/a y que éstas puedan ser utilizadas con fines de análisis o de entrenamiento únicamente. ☐

En caso de duda o queja por favor contacte con la profesora Sylvia Defior, Facultad de Psicología, Universidad de Granada (Tfno 958 249408, sdefior@ugr.es)

Nombre del niño/a: ……………………………………………..………………………

Nombre del padre/madre o tutor: ……………………………………..……………

Firma…………………………………………….   Fecha ………………………..

SEVENTH FRAMEWORK PROGRAMME

eldel enhancing literacy development in european languages

Universidad de Granada

Appendix 3 - School Consent for Participation in the Study

Mejorar el desarrollo del lenguaje escrito en las lenguas europeas

Investigadores: Sylvia Defior, Eduardo Onochie-Quintanilla y colaboradores
Facultad de Psicología
Universidad de Granada

CONSENTIMIENTO INFORMADO DEL DIRECTOR DEL COLEGIO

Marque lo que corresponda

1. Confirmo que he leído y he comprendido la información que consta en el documento informando sobre el proyecto arriba mencionado. ☐
2. Estoy de acuerdo en que el/los niño/s de este colegio participen en el estudio indicado en dicho documento informativo. ☐
3. El investigador ha respondido todas mis preguntas relevantes sobre el estudio y sus propósitos. ☐
4. Comprendo que puedo retirarme del estudio en cualquier momento. Los niños no serán identificables en ninguna publicación. Sólo los investigadores autorizados tendrán acceso a la información inicial. ☐
5. Comprendo que, conforme al Acta de Protección de la Información, puedo solicitar acceso a los datos obtenidos. ☐

En caso de duda o queja por favor contacte con la profesora Sylvia Defior, Facultad de Psicología, Universidad de Granada (Tfno 958 249408, sdefior@ugr.es)

Nombre del Director/a: …………………………………………………………………………

Colegio: ……………………………………………………………………………………………..

Número de teléfono: ……………………………………………………………………………

Correo electrónico (E-mail): ………………………………………………………………….

Firma………………………………………….. Fecha ……………………………….

SEVENTH FRAMEWORK PROGRAMME

eldel enhancing literacy development in european languages

Universidad de Granada

Appendix 4 - Phoneme Isolation Instructions (task used in all studies)

INSTRUCCIONES - AISLAMIENTO DE FONEMAS (INICIAL)

Experimentador:

"Vamos a jugar a un juego con unas palabras de mentira que me he inventado. ¿Quieres que te enseñe como se juega? Te diré una palabra y quiero que te fijes y me digas el PRIMER trocito de esa palabra. Primero te enseño como se juega y luego haremos unas cuantas juntos."

ÍTEM DE DEMOSTRACIÓN 1:

Experimentador: ***"****Empezamos con una palabra de verdad, SOL. Repítela. El primer trocito de la palabra SOL es /sss/. /sss/ es el trocito al principio de la palabra SOL. ¿Lo oyes?*

SOL - /sss/ ¿Puedes decir /sss/?"

ÍTEM DE DEMOSTRACIÓN 2:

Experimentador: *"Ahora vamos a hacer lo mismo pero con una palabra de mentira. Escucha esta palabra: LEN. Repítela.* **(Asegúrate de que el niño la repite correctamente antes de seguir)** *El primer trocito de la palabra LEN es /lll/. /lll/ es el trocito al principio de la palabra LEN.¿Lo oyes?*

LEN - /lll/ ¿Puedes decir /lll/?"

Se prosigue con dos ítems de práctica (pueden ser un máximo de 4).

ÍTEM DE PRÁCTICA 1: – FLOS

Experimentador: *"Ahora hagamos algunos juntos tú y yo. Te voy a decir otra palabra de mentira: FLOS. Repítela.* **(Asegúrate de que el niño la repite correctamente antes de seguir).** *"Ahora dime, ¿Cuál es el primer trocito de FLOS?* **(exagera el sonido /fff/)**

Si el niño responde correctamente, dices: *"¡Muy bien! Lo has hecho bien. El primer trocito de FLOS es /fff/."* **Pasas al Ítem de Práctica 2***.*

> **Si el niño da una respuesta incorrecta, dices:** *"Buen intento, pero la palabra FLOS empieza con el trocito /fff/. Di /fff/.* **[el niño dice /fff/]** *Muy bien, ahora probemos con otra."*
>
> **Repite exactamente el mismo procedimiento con la pseudopalabra "CREL". Después de probar con esta, aunque el niño se equivoque de nuevo debes proseguir con el ítem de práctica 2.**

ÍTEM DE PRÁCTICA 2: – CIR

<u>Experimentador:</u> *"Te voy a decir otra palabra de mentira: CIR. Repítela.* **(Asegúrate de que el niño la repite correctamente antes de seguir).** *"Ahora dime, ¿Cuál es el primer trocito de CIR?"* **(exagera el sonido /zzz/)**

Si el niño responde correctamente dices: *"¡Muy bien! Lo has hecho bien. El primer trocito de CIR es /zzz/."*

Si el niño ha dado la respuesta correcta empiezas la prueba del <u>FONEMA INICIAL (Bloque 1).</u>

> **Si el niño da una respuesta incorrecta, dices:** *"Buen intento, pero la palabra CIR empieza con el trocito /zzz/. Di /zzz/.* **[el niño dice /zzz/]** *Muy bien, ahora probemos con otra."*
>
> **Repite exactamente el mismo procedimiento con la pseudopalabra "MEL". Después de probar con ésta, aunque el niño se equivoque de nuevo se comienza la prueba.**
>
> **Prueba del <u>FONEMA INICIAL (Bloque 1).</u>**

<u>MUY IMPORTANTE</u>: Se deben contrabalancear las dos partes de la tarea:

La mitad de los sujetos harán el <u>FONEMA INICIAL</u> primero y el <u>FONEMA FINAL</u> más tarde y la otra mitad al contrario. Entre las dos pruebas se hará algún otro test.

Se finalizará la prueba si el sujeto comete 4 errores seguidos en el mismo grupo de 8 ítems.

<u>MUY IMPORTANTE:</u> El sujeto debe repetir siempre la pseudopalabra después de ti, antes de intentar aislar el fonema. Sin embargo si olvida repetírtelo debes esperar a terminar con el ítem para recordarle que debe repetir la pseudopalabra después de ti: *"Recuerda que con cada palabra primero te la digo yo y luego la dices tú."*

Si repite la palabra mal, se la repites las veces que sea necesario hasta que la diga bien.

Si el niño se equivoca y aísla el fonema erróneo se lo marcas como incorrecto pero antes de decir el siguiente ítem le puedes recodar que fonema debe aislar (inicial o final)

Antes de empezar la prueba le dices al niño: *"Vamos a probar con otra palabra, pero recuerda que es muy importante que repitas siempre la palabra después de que yo la diga".*

<u>PROCEDIMIENTO PARA EL TEST:</u>

- Tú dices la palabra

- Esperas unos segundos por si se acuerda de repetirla

- Luego le preguntas: *"¿Cual es el primer trocito de la palabra ______?"*

Appendix 5 - Phoneme Isolation Items (task used in all studies)

Código: ________________________ **Experimentador: ______________________**

Fecha y Hora: ___________________ **Colegio y Clase: ______________________**

AISLAMIENTO DE FONEMAS

Bloque 1 – Aislamiento del Fonema **Inicial**:

Ítems de Demostración: Sol – Len

Items de Practica: FLOS (CREL) – CIR (MEL)

CVC

NER	(n)	___________________
RIS	(r)	___________________
CUL	(c)	___________________
BAL	(b)	___________________
MAZ	(m)	___________________
LOD	(l)	___________________
SEN	(s)	___________________
JOR	(j)	___________________

CCVC

CLUR	(c)	___________________
BRAS	(b)	___________________
FLEN	(f)	___________________
TRUD	(t)	___________________
PROL	(p)	___________________
BLIR	(b)	___________________
GLOZ	(g)	___________________
DRAS	(d)	___________________

Código: _________________________ **Experimentador:** ______________________

Fecha y Hora: ____________________ **Colegio y Clase:** ______________________

Bloque 2 – Aislamiento del Fonema **Final**:

Ítems de Demostración: PEZ – BLER

Items de Practica: RAL (TOZ) – PLAS (JEN)

CVC

CAN	(n)	_________________
RUS	(s)	_________________
FOR	(r)	_________________
MID	(d)	_________________
PIL	(l)	_________________
LLES	(s)	_________________
TAR	(r)	_________________
LEZ	(z)	_________________

CCVC

BLAR	(r)	__________________
FRUD	(d)	__________________
CREL	(l)	__________________
DRAZ	(z)	__________________
PLIR	(r)	__________________
FLUS	(s)	__________________
GROL	(l)	__________________
TRIN	(n)	__________________

Appendix 6 - Phoneme Blending Instructions (task used in all studies)

<u>SÍNTESIS DE FONEMAS - Instrucciones</u>

ÍTEMS DE DEMOSTRACIÓN:

<u>Experimentador:</u> *"Vamos a jugar a un juego de adivinar palabras. Te voy a decir los sonidos de una palabra secreta y tú tienes que juntar esos sonidos para adivinar cual es la palabra. ¿Hacemos un ejemplo?* **(le enseñas un dibujo de un RIO).** *¿Qué es esto?"*

Si el niño dice RIO le dices: *"Muy bien."*

Si dice otra cosa le dices: *"Bueno, esto es un rio, di RIO'."*

<u>Experimentador:</u> *"Los sonidos de la palabra RIO son R-I-O. Si dices los sonidos R-I-O más rápido* **(le haces la demostración)** *dices la palabra RIO."*

<u>Experimentador:</u> *"Intentemos con otra palabra* **(le enseñas un dibujo de un DOS)** *¿Qué es esto?"*

Si el niño dice DOS le dices: *"Muy bien."*

Si dice otra cosa le dices: *"Bueno, esto es un DOS, di DOS."*

<u>Experimentador:</u> *"Los sonidos de la palabra DOS son D-O-S. Si dices los sonidos D-O-S más rápido* (le haces la demostración) *dices la palabra DOS."*

ÍTEMS DE PRÁCTICA:

<u>Experimentador:</u> *"Vamos a intentar unos pocos más, pero esta vez sin la foto. Yo digo los sonidos de una palabra secreta y tú me dices qué palabra crees que es. Pon atención, S-E* **(di los fonemas a una velocidad de 1 por segundo)**.

<u>Experimentador:</u> **"***¿Cual crees que es la palabra?"*

Si el niño dice la palabra correcta dices: *"¡Muy bien, has adivinado la palabra secreta!"*

Si el niño no lo sabe o dice la palabra equivocada, repites los fonemas de la exacta misma manera.

Si aun así no sabe o dice una palabra equivocada, le dices los fonemas otra vez, pero esta vez un poco mas rápido (pero todavía con espacios claros entre los fonemas), y le pides al niño que intente adivinar de nuevo.

Si esta vez lo dice bien, dices: *"¡Muy bien, has adivinado la palabra correcta!"*

En caso contrario, pronuncias la palabra tú y dices: *"La palabra secreta es SE, ¿lo ves? Los sonidos S-E juntos hacen la palabra SE."*

__Experimentador:__ *"Vamos a probar con otra. Pon atención, A-J-O* **(di los fonemas a una velocidad de uno por segundo)**. *¿Cual crees que es la palabra?"*

Si el niño dice la palabra correcta dices: *"¡Muy bien, has adivinado la palabra secreta!"*

Si el niño no lo sabe o dice la palabra equivocada, repites los fonemas exactamente igual.

Si aun así no sabe o dice una palabra que no es le dices los fonemas otra vez, pero esta vez un poco mas rápido (pero todavía con espacios de silencio entre los fonemas), y le pides al niño que intente adivinar de nuevo.

Si esta vez lo dice bien, dices: "¡*Muy bien, has adivinado la palabra correcta!"*

En caso contrario, pronuncias la palabra tú y dices: *"La palabra secreta es AJO, ¿lo ves? Los sonidos A-J-O juntos hacen la palabra AJO."*

__Experimentador:__ *"Ahora vamos a empezar el juego. Tienes que escuchar muy bien los sonidos y usando esos sonidos tienes que adivinar cual es la palabra secreta.* ***¡PON MUCHA ATENCIÓN PORQUE SOLO VAS A ESCUCHAR LOS SONIDOS UNA VEZ!****"*

N.B. Deberás FINALIZAR la prueba si el sujeto hace 6 ERRORES CONSECUTIVOS. Transcribe las respuestas del sujeto con la máxima precisión.

Se le permitirá escuchar la repetición del estímulo de nuevo ÚNICAMENTE si claramente no lo ha oído la primera vez (bajo volumen, interrupción, algún otro sonido haya interferido,…). No se le permitirá escuchar la grabación solo porque el niño no sepa la respuesta.

Puntuación:

- Respuesta Correcta = 1,
- Respuesta Incorrecta = 0.

Para CADA RESPUESTA incorrecta, debes copiar la respuesta del sujeto.

Appendix 7 - Phoneme Blending Items (task used in all studies)

Código: ______________________Experimentador: _________________________

Fecha y Hora: _________________Colegio y Clase: _________________________

SINTESIS DE FONEMAS – Hoja de Resultados

Puntuación: - Respuesta Correcta = 1, Respuesta Incorrecta = 0.

Para CADA RESPUESTA incorrecta debes copiar la respuesta del sujeto.

Se deberá finalizar la prueba si el sujeto comete 4 errores consecutivos.

PRÁCTICA:

- R-I-O
- D-O-S
- C-A-L
- A-J-O

1)	Su	(S – U)	____________________
2)	Mi	(M – I)	____________________
3)	Al	(A – L)	____________________
4)	En	(E – N)	____________________
5)	Oso	(O – S – O)	____________________
6)	Ala	(A – L – A)	____________________
7)	Rey	(R – E – Y)	____________________
8)	Mar	(M – A – R)	____________________
9)	Sol	(S – O – L)	____________________
10)	Luz	(L – U – Z)	____________________

Puntuación: /10

Appendix 8 - Instructions for the Visual Processing Task (task used in all studies)

Experimentador: *"Vamos a jugar a un juego con el idioma de unos extraterrestres. Su idioma se parece un poco al nuestro porque también tiene palabras y letras, pero no sabemos lo que significan."*

Enséñale la 'tarjeta de ejemplo' con una palabra extraterrestre como ejemplo. Muéstrale las letras individualmente.

Experimentador: *"Vamos a jugar a un juego de memoria con las palabras de los extraterrestres. Yo te voy a enseñar una palabra extraterrestre* **(le enseñas la 'tarjeta de ejemplo' otra vez)** *y tú tienes que recordar las letras de la palabra y en que orden están."*

"Después de enseñarte la primera palabra te voy a enseñar dos palabras: la que habías visto antes y una nueva **(enséñale la 'tarjeta de elección – ejemplo')**. *Lo que tienes que hacer es señalar la palabra que habías visto en la primera tarjeta. Por ejemplo, en este caso, la palabra que has visto primero* **(le enseñas la 'tarjeta de ejemplo')** *es la misma que ésta* **(le enseñas la palabra correcta en 'tarjeta de elección – ejemplo')**. *¿Ves como las letras están en el mismo orden?"*

ITEMS DE PRÁTICA

Experimentador: *"Hagamos unas cuantas para que practiques. Recuerda que te voy a enseñar una palabra en un idioma extraterrestre y que tienes que recordarla lo mejor que puedas. ¿Vale?* **(le enseñas la 'tarjeta de práctica 1' durante 3-5 segundos).** *Mira esta palabra. Recuerdala bien. Y ahora aquí esta la otra tarjeta con dos palabras extraterrestres* **(le enseñas la tarjeta correspondiente).** *¿Recuerdas cual de estas dos palabras es la que has visto en la primera tarjeta?"*

Si después de 10 segundos el niño no ha dado una respuesta o si da una respuesta errónea le enseñas ambas tarjetas juntas y le muestras como la primera palabra es igual que la respuesta correcta en la segunda tarjeta.

Luego repites el mismo proceso con el segundo ítem de práctica.

Repite el procedimiento de las palabras de práctica durante la prueba pero a partir de ahora no le des feedback de ninguno de los ítems. Responda lo que responda le dices: "bien" o "vale".

Asegúrate de que mira bien ambas opciones antes de que responda.

Experimentador: *"¿Lo has entendido? Ahora vamos a ver más palabras extraterrestres. "*

Appendix 9 - Items for the Visual Processing Task (task used in all studies)

Código: ___________________________ **Experimentador:** _________________________

Fecha y Hora: _____________________ **Colegio y Clase:** _________________________

Ítem. PRACTICA	Elección	Comentarios
1	Ξ Д	
2	λ Ξ	
3	ΞД ДΞ	
4	ЮΨ ΨЮ	
TEST: 2 Símbolos		
1	ΨΩ ΩΨ	
2	ӨҖ ҖӨ	
3	Φλ λΦ	
4	ΠΞ ΞΠ	
TEST: 3 Símbolos		
5	ΨΩλ λΨΩ	
6	ҖЮЃ ЃҖЮ	
7	ΩЃД ДΩЃ	
8	ӨΨλ ΨλӨ	
TEST: 4 Símbolos		
9	λЃҖӨ ҖЃӨλ	
10	ΠΩΞΨ ΨΩΠΞ	
11	θλҖΠ λΠθҖ	
12	ΦЮЃΨ ЃЮΦΨ	

Appendix 10 - Instructions for the RAN Tasks (task used in all studies)

Dibujos - RAN 1 y RAN 2 - Instrucciones

Los sujetos harán el RAN 1 y RAN 2 como ensayos separados y se les cronometrará el tiempo para cada uno. Habrá un pequeño descanso entre ellos. Se debe contrabalancear el orden de estos ensayos. La mitad de los sujetos harán RAN 1 primero y la otra mitad RAN 2.

Empieza a registrar el tiempo desde que el niño comience a nombrar el primer dibujo y para el cronómetro cuando termine de nombrar el último. Graba la sesión con la grabadora, pero también marca todos los errores realizados en la hoja de resultados, según los vaya cometiendo. Si al cambiar de fila el niño se equivoca y pasa a la fila que no es, puedes corregirle.

Experimentador: *"Vamos a jugar a juego. Quiero que me digas los nombres de unos dibujos lo más rápido posible. ¿Sabes cuales son los nombres de estas cosas? Señálalos con el dedo y dime el nombre de cada uno."* **(Le enseñas los cinco dibujos de la prueba)**

Si el niño puede nombrar correctamente y sin ayuda los cinco dibujos puedes comenzar la tarea. Si no sabe algún nombre, se lo dices tú y le pides que lo repita. Luego le pides que diga los cinco nombres otra vez (sin ayuda). Puedes repetir este procedimiento hasta tres veces, si es necesario. Si después de tres veces todavía no se sabe los nombres de las cosas se cancela la prueba.

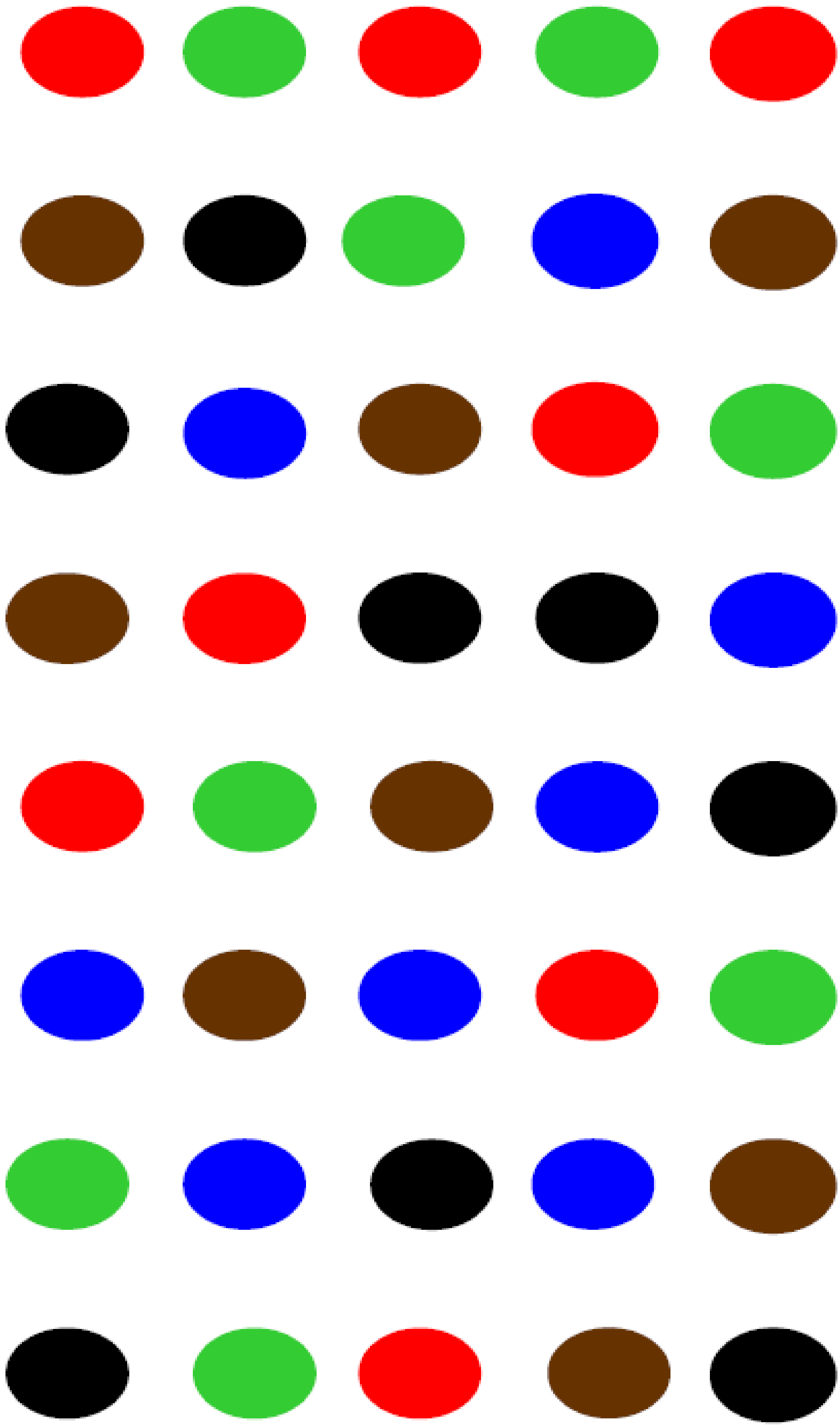
Luego dices: *"Ahora, cuando diga "ya", empiezas a señalar los dibujos y me vas diciendo los nombres lo más rápido que puedas. Solo hay dos reglas. La primera es que debes decir los nombres de los dibujos en el orden en que están* **(muéstrale la hoja de los estímulos e indícale la secuencia que debe seguir: de izq. a dcha.)** *y la segunda es que, si no sabes algún nombre, debes saltar al siguiente dibujo lo más rápido que puedas. Ahora empezamos el juego ¿vale? Prepara el dedo*… **(ten el cronómetro preparado)**

Preparad@, list@, ya!" **(Comienza la tarea)**

Si el niño da un nombre incorrecto pero se auto-corrige cuenta como correcto.

Appendix 11 - Example of the stimuli administered in the RAN Pictures task (task used in all studies)

Appendix 12 - Example of the stimuli administered in the RAN Pictures task (task used in all studies)



Appendix 13 – Grapheme-to-Phoneme Conversion Task Instructions (study 1)

CONOCIMIENTO DE LETRAS – INSTRUCCIONES

Empieza con las mayúsculas y después repite el procedimiento con las minúsculas

Experimentador:

- *"Vamos a jugar a un juego con letras…*
- *Primero te voy a enseñar una letra del alfabeto y quiero ver si me puedes decir el sonido de esa letra; luego quiero que me digas cual es el nombre de esa letra."*

N.B. Antes de comenzar la prueba, saca las letras correspondientes a las iniciales del niño, que son aquellas con las que comenzarás el test.

Ítem número 1:

Experimentador: *"Por ejemplo, si te enseño esta* letra **(levantas la cartulina con la letra MAYÚSCULA correspondiente a la inicial del nombre del niño).** *¿Sabes cual es esta letra?* (ex. Con José, le enseñas J mayúscula)

- o **Si el niño te dice el SONIDO o NOMBRE correctamente le dices:** *"Muy bien! Y sabes cual es el NOMBRE/ SONIDO?"*
- o **Si en niño dice una respuesta incorrecta, dices:** *"Buen intento. En esta cartulina pone…[por ej., J]…" (***Le dices la respuesta correcta). Luego le dices** *"Ahora dimela tú [J]"* **y te aseguras de que lo dice bien. Mismo proceso para el nombre y sonido de la letra.**

Experimentador: *"Vamos a intentar unas cuantas más…"*

- **N.B. Desde ahora en adelante, pídele siempre al niño que te diga el SONIDO primero y luego el NOMBRE de la letra.**

Ítem número 2:

Ahora se hace lo mismo pero con la inicial de su apellido (levantas la cartulina con la letra MAYÚSCULA correspondiente a la inicial del apellido del niño). (Ej. con Pérez, le enseñas P mayúscula)

Experimentador: *"¿Cómo suena esta letra?"*

- o **Si da una respuesta correcta, dices:** *"Muy bien, lo has hecho muy bien"* **y continuas con el siguiente ítem.**
- o **Si da una respuesta incorrecta, dices:** *"Muy bien, pero esta letra suena así …[ej. P]....; di …[P]…".* **Y haces que la repita.**

Experimentador: ¿Y cómo crees que se llama esta letra?

- o **Si da una respuesta correcta, dices:** *"Muy bien, "* **y continuas con el siguiente ítem.**
- o **Si da una respuesta incorrecta, dices:** *"Muy bien, pero esta letra se llama …[ej. P]....; di …[P]…".* **Y haces que la repita.**

- **Mismo procedimiento para todas las demás letras.**

- **Después de las iniciales del niño, se le mostrarán las 27 letras restantes del alfabeto en el mismo orden en el que están en la hoja de resultados (sin repetir las de sus iniciales).**

- **Si le pides el 'SONIDO' y te dice el 'NOMBRE' o viceversa, le das el punto y le pides el otro (NOMBRE o SONIDO).**

- **Hay 4 columnas. Si el niño hace 4 errores en cualquiera de las columnas dejas de evaluarle en esa columna (solo esa) y sigues con las demás.**

- **Cuando el niño dé la respuesta correcta lo marcas con un 1 y cuando dé la incorrecta escribes exactamente lo que haya dicho (incluyendo cuando el niño diga claramente una vocal tras una consonante oclusiva. Si la letra es 'P' y el niño dice que el sonido es /pe/). Si el niño no contesta escribes NC.**

- **Se te permite decirle una vez que a veces el nombre de una letra y su sonido son iguales.**

- **Al anotar las respuestas no utilicéis leguaje fonético.**

- **Las letras que tengan un * asterisco * le preguntas si esa letra tiene algún otro sonido.**

Appendix 14 – Grapheme-to-Phoneme Conversion Task Items (study 1)

Código: ____ **Fecha:** ______________
Colegio: _______________________________________ **Curso:** ______________

Hoja de Resultados

	MAYÚSCULAS Sonido	MAYÚSCULAS Nom	MINÚSCULAS Sonido	MINÚSCULAS Nom
Inicial Nombre	______	______	______	______
Inicial Apellido	______	______	______	______
O	______	______	______	______
I	______	______	______	______
A	______	______	______	______
U	______	______	______	______
E	______	______	______	______
R	______	______	______	______
S	______	______	______	______
F	______	______	______	______
CH	______	______	______	______
J	______	______	______	______
C *	______	______	______	______
Q	______	______	______	______
K	______	______	______	______
B	______	______	______	______
G *	______	______	______	______
L	______	______	______	______
T	______	______	______	______
P	______	______	______	______
M	______	______	______	______
Z	______	______	______	______
D	______	______	______	______
V	______	______	______	______
N	______	______	______	______
X	______	______	______	______
Ñ	______	______	______	______
Y *	______	______	______	______
LL	______	______	______	______
H	______	______	______	______
W	______	______	______	______

MAY - Sonido	MAY - Nombre	MIN - Sonido	MIN - Nombre
/29	/29	/29	/29

Appendix 15 – Instructions for the reading measures administered in study 1

PRUEBA DE 1 MINUTO DE LECTURA

Instrucciones

Experimentador:

"Te voy a enseñar unas palabras escritas y quiero que me las leas lo más rápido que puedas sin equivocarte.

- *Vete señalando con el dedo la palabra que estés leyendo.*
- *Quiero que las leas en este orden* **(le enseñas la cartulina por la segunda cara y le señalas el orden que debe seguir).**
- *Si te equivocas en alguna, la dices bien y sigues leyendo lo más rápido que puedas.*
- *Si te encuentras una palabra difícil inténtalo de todas formas. Y si no puedes, no importa, pasa a la siguiente palabra.*
- *No te olvides de señalar con el dedo*

¿Estas list@? Empieza"

Si el niño se estanca en una palabra le animas a que continúe. Pon una X al lado de las palabras en las que se equivoque o salte. Y escribe AC (auto corrección) en las palabras que diga bien la segunda vez.

Si el niño esta leyendo las LETRAS una a una lentamente (en vez de decodificar las palabras) lo debes anotar, ya que eso no es leer.

Aunque un niño este leyendo muy mal y muy lento dejas que llegue al minuto y luego le animas, recordándole que aun no le han enseñado a leer.

Si el niño erra en una palabra y lee otra cosa escribe lo que haya dicho.

No te olvides de cronometrar el tiempo. Mide el tiempo desde que el niño comience a leer la primera palabra y finaliza la tarea cuando hayan transcurrido 60 segundos.

Puntuación = número de palabras leídas – número de errores (no auto-corregidos)

Rodea la última palabra leída, ya que luego se deberá calcular el número de sílabas leídas.

Appendix 16 – Items for the word-reading task administered in study 1

Código: ______________________________ **Fecha:** __________

Colegio: ______________________________ **Curso:** __________

HOJA DE RESULTADOS 

Marca última palabra leída, ya que luego se deberá calcular el número de sílabas leídas.

Y___	Sobre___	Amigo___	Algunos___	Unidades__
Él___	Hacer___	Señora___	Delante___	Kilómetro__
Tu___	Entre___	Parece___	Primero___	Profesora__
Sí___	Madre___	Semana___	Tenemos___	Chocolate__
Dos___	Sigue___	Abajo___	Trabajo___	Oraciones__
Sin___	Mucho___	Camino___	Princesa___	Resultado__
Hay___	Gente___	Encima___	Ninguna___	Enseguida__
Son___	Padre___	Pájaro___	Corazón___	Realmente__
Vez___	Luego___	Comida___	Podemos___	Superficie__
Ser___	Cosas___	Pasado___	Persona___	Televisión__
Les___	Desde___	Abuela___	Llevaba___	Pantalones__
Nos___	Mismo___	Dinero___	Familia___	Compañero__
Ver___	Antes___	Manera___	Árboles___	Habitación__
Bien___	Mejor___	Equipo___	Ventana___	Demasiado__
Eso___	Ciudad___	Arriba___	Tampoco___	Movimiento__
Así___	Alguien___	Cocina___	Hermano___	Importante__
Día___	También___	Animal___	Alegría___	Comunidad__
Uno___	Después___	Escribe___	Escalera ___	Instrumentos__
Fue___	Siempre___	Momento___	Policía___	Naturaleza__
Todo___	Tiempo___	Estaban___	Aparato___	Fotografía__
Está___	Puerta___	Durante___	Gustaría___	Significado__
Cada___	Verdad___	Observa___	Todavía___	Actividades__
Como___	Hombre___	Aquella___	Apareció___	Seguramente__
Algo___	Ahora___	Pequeño___	Energía___	Temperatura__
Casa___	Cabeza___	Colegio___	Ocurrido___	Exactamente__
Nada___	Abuelo___	Palabra___	Teléfono___	Operaciones__
Magia___	Mañana___	Hubiera___	Alimento___	Vocabulario__
Hasta___	Nombre___	Ejemplo___	Diferente ___	Rápidamente__

PUNTUACIÓN = numero de palabras leídas – numero de errores (no auto-corregidos)

_______ / 60 segundos

Appendix 17 – Items for the non-word-reading task administered in study 1

Código: ______________________________ **Experimentador:** ______________________________
Fecha y Hora: ________________________ **Colegio y Clase:** ______________________________

<u>T4 - 1 MINUTO DE LECTURA DE PSEUDOPALABRAS - HOJA DE RESPUESTAS</u>

Marca con un círculo la última palabra leída.

- Respuesta Correcta = √
- Respuesta Incorrecta = Escribir la respuesta incorrecta

I___	Mobre___	Atigo___	Almunos___	Upitades___
Er___	Dacer___	Semora___	Melante___	Ripómetro___
Lu___	Estre___	Farece___	Crimero___	Crolesora___
Pí___	Sadre___	Bemana___	Renemos___	Llonolate___
Jos___	Jigue___	Azajo___	Tracajo___	Opationes___
Bin___	Pucho___	Tamino___	Prindesa___	Cevultado___
Har___	Pente___	Esdima___	Dinguna___	Espeguida___
Lon___	Cadre___	Pámaro___	Vorazón___	Teasmente___
Nez___	Zuego___	Cofida___	Godemos___	Pumerficie___
Cer___	Vosas___	Fasado___	Cersona___	Depenisión___
Tes___	Lesde___	Añuela___	Lletaba___	Zarcalones___
Bos___	Pismo___	Hinero___	Jamilia___	Fospañero___
Mer__	Altes___	Ganera___	Ármoles___	Valitación___
Dien__	Tejor___	Echipo___	Mentana___	Letasiado___
Eno___	Miudad___	Aquiba___	Tandoco___	Cotimiento___
Afí__	Alsien ___	Rocina___	Herfano___	Istortante___
Nía___	Lampién___	Atimal___	Apebría___	Volunidad___
Ujo___	Resnués___	Esdribe___	Esmacera___	Insprutentos___
Cue___	Riembre___	Pomento___	Rodicía___	Japuraleza___
Sodo___	Riempo___	Espaban___	Anafato___	Notoprafía___
Esmá___	Luerta___	Surante___	Tusgaría___	Tisnimicado___
Yada___	Serdad___	Obterva___	Lopavía___	ltimidades___
Zomo___	Rombre___	Achella___	Asateció___	Tepuramente___
Alpo___	Apora___	Requeño___	Ecelgía___	Jempesatura___
Sasa___	Nabeza___	Folegio___	Onuchido___	Epastamente___
Pada___	Atuelo___	Palacra___	Meséfono___	Ofemaciones___
Sagia___	Zañana___	Hufiera___	Añivento___	Mosabulario___
Dasta___	Tombre___	Eremplo___	Rimerente___	Dásidamente___

<u>PUNTUACIÓN</u> = número de palabras leídas – número de errores (no auto-corregidos)
________ / 60 segundos

Appendix 18 – Instructions for the reading measures administered in study 2

LISTAS DE PALABRAS

Instrucciones

En esta prueba se le pedirá al niño que lea 4 listas de palabras. Las listas se administrarán individualmente y para cada una se anotará el tiempo que tarda y los errores que comete.

Debes preparar el cronómetro y comenzar a registrar el tiempo según el niño empiece a leer la primera palabra.

- **Anotar el tiempo y no escribir nada al lado de las palabras bien leídas.**
- **Si el niño erra en una palabra la marcas con una ‘ X ’**
- **Si el niño lee una palabra (con o sin tilde) y asigna el acento incorrectamente, esta palabra será marcada con una ‘ T ’, de ‘tilde’.**
- **Si se salta alguna palabra se marcará con un**
- **Escribe AC (auto corrección) al lado de las palabras en las que se haya equivocado pero se haya autocorregido acto seguido.**

Mientras el niño lea una lista de palabras debes tapar la otra lista de palabras que se encuentre en esa página.

Evaluador:

“Te voy a enseñar unas listas de palabras y quiero que me las leas lo más rápido que puedas sin equivocarte.”

Appendix 19 – Items for the reading task administered in study 2

Sujeto: ______________________ **Experimentador:** ______________________

Fecha y Hora: ______________________ **Colegio y Clase:** ______________________

Listas de Palabras T7 - Hoja de Respuestas II

Lista 1	Lista 2	Lista 3	Lista 4
Sol ____	Fax ____	Círculo ____	Fósforo ____
Ojo ____	Eje ____	Montaña ____	Consumo ____
Luz ____	Bol ____	Ventana ____	Rotonda ____
Año ____	Osa ____	Palabra ____	Zancada ____
Suma ____	Fuga ____	Domingo ____	Trópico ____
Boca ____	Reto ____	Bolsillo ____	Mudanza ____
Isla ____	Orca ____	Príncipe ____	Culebra ____
Mamá ____	Paté ____	Castillo ____	Cartucho ____
Vida ____	Rizo ____	Problema ____	Tránsito ____
Diez ____	Leal ____	Momento ____	Progreso ____
Algo ____	Olmo ____	Planeta ____	Tornillo ____
Color ____	Letal ____	Teléfono ____	Cuchilla ____
Mundo ____	Himno ____	Muchacho ____	Teniente ____
Fácil ____	Fósil ____	Caliente ____	Dinamita ____
Libro ____	Rifle ____	Resultado ____	Caníbales ____
Nadie ____	Goteo ____	Comunidad ____	Totalidad ____
Jardín ____	Fértil ____	Personaje ____	Caligrafía ____
Medio ____	Mafia ____	Caramelos ____	Revoltoso ____
Reina ____	Ruina ____	Alimentos ____	Elemental ____
Tiempo ____	Pócima ____	Profesora ____	Manifiesto ____
Música ____	Huelga ____	Enseguida ____	Purpurina ____
Pueblo ____	Golosa ____	Fotografía ____	Maleficios ____
Dinero ____	Agenda ____	Movimiento ____	Granizado ____
Enorme ____	Masaje ____	Televisión ____	Espagueti ____
Comida ____	Buitre ____	Cumpleaños ____	Malcriados ____
Tiempo: ______	*Tiempo:* ______	*Tiempo:* ______	*Tiempo:* ______

Appendix 20 – Instructions for the Orthographic Knowledge task from study 3

CONOCIMIENTO ORTOGRÁFICO

Instrucciones

Evaluador: *"Ahora vamos a hacer un ejercicio de elegir palabras. Vais a ver cuatro palabras: Una está bien escrita y las otras tres están mal escritas. Vosotros tenéis que marcar la que está bien."*

Ítem de demostración:

Evaluador: *"Vamos a leer estas palabras. Aquí pone* 'biage'*, aquí pone* 'biaje', *aquí pone* 'viaje' *y aquí pone* 'viage' **[Señalas cada palabra según la dices].** *¿Cuál creéis que es la que está bien escrita?* **Después de la contestación de los niños les explicas porqué su respuesta es correcta o errónea y marcas la respuesta correcta con una raya en diagonal y les dices que hagan lo mismo en su hoja.** *"Marcad el cuadro correcto en vuestra hoja."*

Ítem de práctica 1:

Les enseñas a los niños el primer ítem de práctica y les dices: *"Vamos a hacer una más. ¿Cuál creéis que es la que está bien escrita?"* **Después de la contestación de los niños les explicas porqué su respuesta es correcta o errónea y dices** *"Entonces, marcad el cuadro correcto."*

Ítem de práctica 2:

Mismo procedimiento.

Evaluador: *"Muy bien, Ahora vais a hacer las demás vosotros solos. No digáis ninguna respuesta en alto. Cuando yo os diga quiero que miréis con mucha atención TODAS las palabras de cada línea antes de elegir cuál es la correcta. Luego debéis marcar con el lápiz la palabra que está bien escrita, tal como hemos estado haciendo, hasta el final. Y recordad, esto no es un examen, no os vamos a poner nota, así que mirad solo vuestra hoja y no copiéis."*

"Ahora, dadle la vuelta a la hoja y comenzad".

- **Cuando recojas las hojas de los niños asegúrate de que:**
    1) **Han escrito su nombre en la hoja.**
    2) **No se han saltado ningún ítem. Diles que completen cualquier ítem que se hayan saltado.**
- **Una vez que haya comenzado la prueba no les des ninguna información que les pueda ayudar, excepto motivarles para que sigan adelante.**

Appendix 21 – Items for the Orthographic Knowledge task from study 3

Nombre: ____________________________ Fecha: _____________________________
Código: _____________________________ Colegio y Clase: _______________________

CONOCIMIENTO ORTOGRÁFICO - HOJA DE RESPUESTAS

☐ llabe	☐ llave	☐ yabe	☐ yave
☐ berenjena	☐ verengena	☐ verenjena	☐ berengena
☐ behículo	☐ beículo	☐ veículo	☐ vehículo
☐ hárvol	☐ hárbol	☐ árbol	☐ árvol
☐ huevo	☐ huebo	☐ uevo	☐ uebo
☐ labavo	☐ lavavo	☐ lavabo	☐ lababo
☐ hijiene	☐ ijiene	☐ igiene	☐ higiene
☐ llubia	☐ lluvia	☐ yuvia	☐ yubia
☐ hollo	☐ oyo	☐ ollo	☐ hoyo
☐ jersey	☐ gersey	☐ jersei	☐ gersei
☐ himajen	☐ imagen	☐ imajen	☐ himagen
☐ búho	☐ vúho	☐ vúo	☐ búo
☐ salbaje	☐ salbage	☐ salvaje	☐ salvage

☐ abellana	☐ aveyana	☐ avellana	☐ abeyana
☐ hoxíjeno	☐ oxígeno	☐ oxíjeno	☐ hoxígeno
☐ torveyino	☐ torbeyino	☐ torbellino	☐ torvellino
☐ varandilla	☐ varandiya	☐ barandiya	☐ barandilla
☐ vendaje	☐ bendaje	☐ vendage	☐ bendage
☐ fugitibo	☐ fugitivo	☐ fujitibo	☐ fujitivo
☐ enbidia	☐ henbidia	☐ henvidia	☐ envidia
☐ cobaya	☐ coballa	☐ covalla	☐ covaya
☐ valleta	☐ bayeta	☐ vayeta	☐ balleta
☐ adhesibo	☐ adhesivo	☐ adesibo	☐ adesivo
☐ bigilar	☐ vijilar	☐ bijilar	☐ vigilar
☐ marabillas	☐ maraviyas	☐ maravillas	☐ marabiyas
☐ bívora	☐ bíbora	☐ víbora	☐ vívora
☐ privilejio	☐ pribilejio	☐ pribilegio	☐ privilegio
☐ ahuyentar	☐ auyentar	☐ ahullentar	☐ aullentar

Appendix 22 – Instructions for the reading measures administered in study 3

LISTAS DE PALABRAS

Instrucciones

En esta prueba se le pedirá al niño que lea 2 listas de pseudopalabras y 2 listas de palabras. Las listas se administrarán individualmente y para cada una se anotará el tiempo que tarda y los errores que comete.

En primer lugar se administrarán las 2 listas de pseudopalabras, seguidas de las 2 listas de palabras.

Debes preparar el cronómetro y comenzar a registrar el tiempo según el niño empiece a leer la primera palabra.

- **Anotar el tiempo y no escribir nada al lado de las palabras bien leídas.**
- **Si el niño erra en una palabra la marcas con una ' X '**
- **Escribe AC (auto corrección) al lado de las palabras en las que se haya equivocado pero se haya autocorregido acto seguido.**

Mientras el niño lea una lista de palabras debes tapar la otra lista de palabras que se encuentre en esa página.

Evaluador:

"Te voy a enseñar unas listas de palabras y quiero que me las leas lo más rápido que puedas sin equivocarte."

"Las dos primeras listas son de palabras inventadas. Léelas lo mejor que puedas"

Appendix 23 – Items for the reading task administered in study 3

Sujeto: ______________________ Experimentador: ______________________

Fecha y Hora: ______________________ Colegio y Clase: ______________________

Listas de Palabras - Hoja de Respuestas

Lista 1	Lista 2	Lista 3	Lista 4
vanjipe ____	carnite ____	círculo ____	fósforo ____
tasfoyo ____	tarsoto ____	montaña ____	consumo ____
gucasle ____	mutanche ____	ventana ____	rotonda ____
milzobo ____	pintoco ____	palabra ____	zancada ____
jillafro ____	tipabro ____	domingo ____	trópico ____
ñevufa ____	petuna ____	bolsillo ____	mudanza ____
lloziroi ____	comirio ____	príncipe ____	culebra ____
glangezo ____	granteno ____	castillo ____	cartucho ____
lligiva ____	nitila ____	problema ____	tránsito ____
dracloñe ____	clatrode ____	momento ____	progreso ____
fompasfa ____	portanca ____	planeta ____	tornillo ____
lesdoga ____	deslota ____	teléfono ____	cuchilla ____
nasgocro ____	tancodro ____	muchacho ____	teniente ____
gifiesvo ____	dipiendo ____	caliente ____	dinamita ____
yaselbebo ____	patenledo ____	resultado ____	caníbales ____
dojufacoz ____	bocenatos ____	comunidad ____	totalidad ____
jefobefal ____	tebotenas ____	personaje ____	caligrafía ____
varfugirra ____	pastulita ____	caramelos ____	revoltoso ____
imucurmil ____	abupunpiz ____	alimentos ____	elemental ____
gefapice ____	letavise ____	profesora ____	manifiesto ____
erfillabe ____	espitane ____	enseguida ____	purpurina ____
ondursembo ____	invermenso ____	fotografía ____	maleficios ____
fopusiencha ____	tocumienca ____	movimiento ____	granizado ____
dañivapies ____	malimabien ____	televisión ____	espagueti ____
ramplaupez ____	cantruanes ____	cumpleaños ____	malcriados ____
Tiempo: ________	*Tiempo:* ________	*Tiempo:* ________	*Tiempo:* ________