Universidad de Granada

SESGOS INDUCIDOS POR EL SENTIDO DE LECTO-ESCRITURA EN LA COMPRENSIÓN DEL LENGUAJE HABLADO. ESTUDIOS INTRA E INTERCULTURALES.

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SESGOS DEL SENTIDO DE LECTO-ESCRITURA EN LA FORMACIÓN DE MODELOS MENTALES PROVENIENTES DEL LENGUAJE ORAL. ESTUDIOS INTRA E INTERCULTURALES.

Tesis doctoral presentada por Antonio Román Reche en el *Departamento de Psicología Experimental* para aspirar al grado de Doctor en Psicología en el programa de doctorado de Psicología Experimental y Aplicada de la Universidad de Granada.

Esta tesis ha sido dirigida por el profesor Julio Santiago de Torres, quien avala la calidad de la misma, así como la formación del doctorando para aspirar al grado de doctor.

Firmado en Granada, a 12 de noviembre de 2015

El doctorando El director de la tesis

Antonio Román Reche Julio Santiago de Torres

Universidad de Granada (2015)

“I often start my undergraduate lectures by asking students the following question: which cognitive faculty would you most hate to lose? Most of them pick the sense of sight; a few pick hearing. Once in a while, a wisecracking student might pick her sense of humor or her fashion sense. Almost never do any of them spontaneously say that the faculty they'd most hate to lose is language. Yet if you lose (or are born without) your sight or hearing, you can still have a wonderfully rich social existence. You can have friends, you can get an education, you can hold a job, you can start a family. But what would your life be like if you had never learned a language? Could you still have friends, get an education, hold a job, start a family? Language is so fundamental to our experience, so deeply a part of being human, that it's hard to imagine life without it. But are languages merely tools for expressing our thoughts, or do they actually shape our thoughts?”

Lera Boroditsky

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Este documento esta formado por una introducción en castellano, donde se establece un resumen del contexto teórico y metodológico. Le siguen las publicaciones en inglés que constituyen el núcleo de la investigación con todos los detalles y finalmente unas conclusiones finales en español donde se hace un resumen de los resultados y se discuten los mismos. El contenido en español constituye tan solo un resumen. El texto en inglés, ver capítulo 3, contiene todos los detalles de la investigación.

This document consists of an introduction in Spanish, where a summary of the theoretical and methodological context is provided. This is followed by three articles (one already published, a second currently under review, and a third still in preparation) in English that form the core of the research with all the details. The thesis is closed by a general discussion in Spanish. The content in Spanish is mainly a summary. The text in English contains all the details of the investigations.

Índice de contenido

CAPÍTULO 1: INTRODUCCIÓN

1.1 Breve introducción histórica

1.1.1 El origen del lenguaje

Pocas cosas hay en la literatura científica que hayan suscitado tanta controversia como el origen del lenguaje. El debate que se ha extendido a lo largo de los últimos siglos, no ha logrado aun hoy día un consenso generalizado. El principal problema del estudio de su aparición es la falta de un correlato material o fósil que nos dé información directa sobre cómo, cuando y porqué surgió en el ser humano esta revolucionaria capacidad. Ni siquiera hay consenso sobre si fue la aparición del lenguaje la que hizo al ser humano social o por el contrario fue la socialización de este la que desembocó en la creación del lenguaje como una herramienta necesaria. El resultado es que para cualquier aspecto que tratemos del lenguaje, hay un amplio abanico de teorías opuestas e irreconciliables (Tallerman, Gibson, 2012). Respecto a la temporalidad de su aparición, las teorías continuistas (Pinker, Bloom, 1990), sostienen que el lenguaje no puede aparecer de la nada, sino que es el resultado de una lenta evolución de formas psicolingüísticas heredadas de los primates próximos a nuestra filogenia. Por el contrario, las teorías discontinuas (Lenneberg, 1967) sostienen que el lenguaje (entiéndase articulado), como rasgo distintivo y único del ser humano, no puede derivarse de nada encontrado en animales. Por ello debe haber aparecido de forma bastante repentina en algún momento de la evolución humana. Otra distinción que divide a los académicos es si el lenguaje tiene un origen innato en el ser humano (Chomsky, 1996) o por el contrario es el resultado de la interacción y la cultura o, como sostiene Tomasello (2003), del propio uso que hacemos del lenguaje.

Dada la gran diversidad de lenguas que conocemos en la actualidad, los investigadores se han preguntado si todas ellas provienen de una sola lengua madre que se expandió al resto del mundo. Según esta propuesta llamada monogénesis (Trombetti, A., 1905), el lenguaje apareció por primera vez en un único lugar y a partir de ese momento fue evolucionando y diferenciándose en el resto de lenguas actuales. Por el contrario la hipótesis de la poligénesis, sostienen que el lenguaje emergió de forma independiente y en diferentes lugares (Hall, 1944).

A pesar de que el estudio del lenguaje, como hemos visto, se caracteriza por la escasez de consenso y un enorme abanico de propuestas teóricas, en la actualidad se tiene muy asentada la idea de que su estudio debe ser necesariamente interdisciplinar. La psicología, la sociología y lingüística pasando por la biología y la antropología, por nombrar unas pocas disciplinas, deben aunar esfuerzos para abordar un fenómeno sin duda muy complejo y formado por múltiples factores.

1.1.2 El origen de la escritura

Si bien el lenguaje en el ser humano es una adquisición que ha suscitado, como acabamos de ver, todo tipo de hipótesis sobre su origen, no podemos decir lo mismo de la escritura. Esta capacidad de plasmar en un soporte físico el contenido lingüístico es un invento muy reciente en la escala de la evolución humana. Y es precisamente esta capacidad de perdurar en el tiempo lo que ha permitido a través de ella misma estudiar su origen y evolución La aparición de la escritura marca por definición el comienzo de la historia, considerándose prehistoria todo lo ocurrido antes de ese periodo.

La escritura tiene su antecesor más temprano en la representación de pictogramas simples en la prehistoria. Estas manifestaciones, aunque no son consideradas una escritura per se, sí comparten con esta la intención del autor por reflejar sus creencias, pensamientos, temores, en definitiva en hacer perdurable en el tiempo su microcosmos. Un pictograma es pues una representación de un objeto, un lugar o una actividad por medio de una ilustración más o menos fiel a la realidad. Posteriormente, aparecieron los ideogramas, en los que un signo no lingüístico representa una idea o concepto sin necesidad de que haya una representación fiel del objeto o concepto que representa.

La siguiente revolución que nos acercó hacia la escritura, tal y como la conocemos en la actualidad, es la creación de signos fonéticos. En las escrituras fonéticas y, más concretamente, en las alfabéticas, cada signo (grafema) corresponde con un sonido simple de la lengua hablada (fonema). Esto supone un considerable ahorro cognitivo y permite la posibilidad de expresar infinitas ideas con un número muy limitado de signos. Existen, no obstante, lenguas que hacen uso de más de una variante como el Chino, que es parcialmente ideográfico y presenta también signos fonéticos. (ver Haarmann, H., 2001 para una completa revisión).

Permítame el lector en esta introducción una reflexión personal, ciertamente especulativa, sobre cómo pudo ser el origen de la escritura, pero conectada con la base de esta investigación. Todas los tipos de escritura expuestos hasta ahora, a pesar de su aparente diversidad, tienen una característica común inalienable para cualquier código escrito. Desde los primeros pictogramas e ideogramas, la escritura cuneiforme y la amplia variedad de alfabetos que han existido en los últimos milenios hasta la actualidad, todos, están representados en el espacio. La escritura necesariamente se lleva a cabo sobre un soporte que posee unas características espaciales. Generalmente esta manifestación se lleva a cabo en un plano bidimensional, tanto si se trata de la pared de una cueva, tabla de arcilla, papiro o la pantalla de nuestra computadora. Partiendo de aquí, la condición necesaria y suficiente para representar un pictograma es tener un espacio sin más. Solo tenemos que atender a ese punto y, si poseemos el significado, entenderemos el mensaje asociado a él. Pero se nos presenta un dilema, interesante por lo que implica, si a ese primer pictograma le queremos añadir un segundo. Seguimos haciendo uso del espacio, pero necesariamente nos vemos en la tesitura de tener que movernos y decidir en qué parte libre lo plasmamos. Cuando posteriormente decodificamos esos dos símbolos, también necesariamente tenemos que hacerlos en un orden, atendiendo y comprendiendo el significado del primero para pasar posteriormente al segundo. Acaba de aparecer la segunda característica fundamental de cualquier sistema de escritura, el movimiento. La escritura, simplificando enormemente el concepto, podríamos decir que es “movimiento en un espacio”. Es el resultado obligado de tener que plasmar dos o más signos en un espacio sin reemplazo. Posteriormente, si estos signos estaban relacionados, surgió la necesidad de colocarlos en un orden convencional que permitiera al resto de personas su correcta decodificación. El resto sólo fue cuestión de añadir un tercero, un cuarto... y de reforzar a base de práctica y consenso social el sentido en el que se hacía su escritura y posterior lectura.

Si espacio y movimiento caracterizan a todos los sistemas de escritura, no ocurre lo mismo con la dirección en la que se lleva a cabo dicho movimiento. Es en este punto donde los distintos sistemas de escritura que ha habido a lo largo de la historia divergen en su direccionalidad espacial. La gran mayoría de lenguas se representan en dos ejes principales con sus correspondientes sentidos opuestos. Así, numerosas lenguas usan el eje horizontal de izquierda a derecha (alfabeto latino, cirílico, griego) o de derecha a izquierda (árabe, farsi, hebreo, urdu). Otras, como el chino, en su versión clásica se escribían de arriba hacia abajo y de derecha a izquierda, aunque en la actualidad también se escribe de izquierda a derecha (con la excepción de Taiwan). También es necesario hacer notar que incluso aquellas lenguas con sentido de lecto-escritura horizontal se pueden escribir en otros ejes. Por ejemplo, un cartel publicitario vertical en inglés que se pueda leer de arriba hacia abajo o, aunque menos frecuentemente, de abajo a arriba.

1.2 La influencia del lenguaje sobre nuestras cogniciones

Tras esta breve exposición sobre los orígenes del lenguaje y su expresión escrita, definimos el marco teórico en el que situamos este trabajo. En primer lugar, expondremos la hipótesis de Sapir-Whorf o también llamada “relativismo lingüístico”. Seguidamente se exponen estudios relevantes que demuestran empíricamente la influencia del lenguaje en diversos procesos cognitivos, apoyando la existencia de un relativismo lingüístico en su versión débil. En segundo lugar, expondremos algunos estudios destacables limitándonos a la influencia de la escritura, como parte del lenguaje. Más concretamente a cómo el sentido en el que escribimos y leemos sesga múltiples procesos cognitivos. Finalmente, dentro de los sesgos debidos a la lecto-escritura y como tema central de esta tesis nos circunscribimos a su influencia sobre los modelos mentales que originamos a partir de la comprensión lingüística.

1.2.1 La hipótesis de Sapir- Whorf

La hipótesis de Sapir-Whorf o también llamada “relativismo lingüístico”, sostiene que la lengua materna que tiene cada persona determina la forma que tiene esta de conceptualizar y estructurar el mundo (Whorf, 1956). La hipótesis se puede definir según su extremismo en dos niveles. Por un lado, la versión fuerte sostiene que la percepción del mundo y nuestra conducta en él se ve completamente determinada por la estructura gramatical y sistemas categoriales de la lengua materna. Esta versión no da mucho espacio a procesos de flexibilidad o reversibilidad y, debido a su determinismo, ha recibido poco apoyo en la literatura científica. La versión débil, que es la más apoyada por los datos experimentales, sostiene también que la lengua que hablamos tiene efecto sobre nuestra percepción y categorización del mundo, pero de una forma más sutil. De modo que estadísticamente hablando, grupos de personas que hablan distintas lenguas, presentan ligeros cambios en sus procesos cognitivos. Esta versión sí deja la puerta abierta a procesos de flexibilidad y reversibilidad que nos permitan cambiar nuestras percepciones o estructuras mentales si aprendemos una nueva lengua. En los siguientes apartados se exponen una serie de estudios que dan un fuerte apoyo experimental a la versión débil de esta hipótesis, incluyendo los resultados obtenidos en la presente tesis.

1.2.2 La influencia del lenguaje sobre los procesos mentales

La literatura científica mantiene encendido el debate sobre la relación entre el lenguaje y distintos procesos mentales. Repasaremos aquí algunos de los campos de estudio en los cuales se ha centrado este debate. Comenzando con la percepción, concretamente del color, todos los seres humanos con visión normal tricromática tenemos la misma base fisiológica que nos permite su percepción (Jordan & Mollon, 1997). Sin embargo, existen estudios que apoyan la idea de que la categorización semántica del color, diferente en cada lengua, sesga la forma que tenemos de percibirlos. En este sentido, Winawer, Witthoft, Frank, Wu, Wade y Boroditsky (2007) demostraron que los hablantes de ruso que tienen dos nombres para dos tonos distintos de azul, un tono claro (“goluboy”) y un tono oscuro (“siniy”), discriminaban más rápidamente entre estos dos tonos que el grupo de participantes ingleses en cuyo idioma no se tiene esa distinción. Además, si la discriminación se debía de hacer entre dos azules que caían en la misma categoría por ejemplo, discriminar entre dos tonos que estaba dentro de la categoría goluboy, en este caso el grupo de rusos perdían su ventaja y eran igual de rápidos que los ingleses, demostrándose así que discriminar verbalmente supone una mayor discriminación perceptual. No menos interesante es el hecho de que, cuando añadían al diseño experimental una tarea verbal distractora, el efecto desaparecía aún cuando los dos tonos cayeran en categorías diferentes. Esto reforzaba la idea de que la influencia era netamente lingüística y además que se aplicaba en el momento. En este mismo campo, Gilbert (2006) demostró que esta facilitación discriminativa del color se producía en mayor cuantía cuando el estimulo se proyectaba en el hemicampo visual derecho, que proyecta toda la información visual al hemisferio izquierdo marcadamente lingüístico. También hay evidencias de que el lugar donde colocamos el borde entre un color y otro está mediado por el lenguaje. En esta línea, Roberson, Davidoff, Davies y Shapiro (2006) mostraron que dos lenguas (berinmo e himba), que eran iguales en los colores fundamentales que categoriza (negro, blanco, verde, rojo y amarillo), eran sin embargo diferentes en dónde consideraban que terminaba un color y comenzaba otro.

La percepción que tenemos del tiempo también se ve afectada por la lengua a la que pertenecemos. Concretamente, el tiempo es un concepto abstracto que entendemos en términos metafóricos a través del espacio. Por ejemplo, las personas de habla inglesa o indonesia se refieren al tiempo en términos de longitud y así se ve reflejado en frases como “it was a long talk”, mientras los hablantes de español o griego lo hacen más en términos de cantidad o tamaño (“esta tarea se ha llevado mucho tiempo”). Esta diferenciación en las metáforas temporales les llevó a los hablantes de inglés e indonesio a sobreestimar el tiempo que permanecía una línea en pantalla cuando esta era más larga, mientras los españoles y griegos tenían el sesgo de sobrestimar el tiempo cuando en vez de líneas su usaba un contenedor y este estaba más lleno (Casasanto, Fotakopoulu, Pita, & Boroditsky, en revisión).

Otro caso interesante es el de sesgos producidos por el género gramatical (Boroditsky, 2003). Se les pedía a hablantes de alemán y español, que clasificaran listas de palabras. Todas ellas cumplían la condición de tener el género gramatical distinto en cada uno de los dos idiomas. Por ejemplo, “llave” en alemán es masculino y en español es femenino. Lo contrario ocurre con “sol”, que es masculino en español y femenino en alemán. El resultado de este estudio demostró que los objetos masculinos se calificaban con adjetivos más “masculinos” (duro, grande, áspero, etc.) mientras esos mismos objetos con género femenino eran clasificados en la otra lengua con adjetivos femeninos (pequeño, suave, elegante, etc). Se pone de manifiesto así que incluso aspectos totalmente convencionales de un idioma, como el género gramatical, producen sesgos en cómo percibimos el mundo.

1.3 La influencia del sentido de lecto-escritura sobre los procesos mentales

Si en el apartado anterior vimos algunos de los estudios que relacionan lenguaje y su influencia o sesgo en diversos procesos cognitivos, en este nos centramos en un aspecto muy concreto del lenguaje, su escritura. Hay numerosa evidencia empírica que confirma que el sentido de lecto-escritura (en adelante SLE, o en los artículos en inglés RWD - reading and writing direction) tiene efectos sutiles, pero muy consistentes, en un amplio abanico de procesos cognitivos.

Por ejemplo, se ha demostrado que el SLE es capaz de afectar habilidades cognitivas de bajo nivel, como la lectura de palabras. Mishkin y Forgays (1952) observaron que usuarios del inglés eran capaces de detectar más fácilmente las palabras que se presentaban en la derecha de la pantalla que cuando se presentaban a la izquierda, mientras que esto no sucedía en los usuarios del hebreo. Por otro lado, Pollatsek, Bolozky, Well y Rayner (1981) examinaron la lectura de frases en inglés y hebreo y comprobaron que la amplitud de las ventanas perceptivas hacia cada lado del punto de fijación ocular no era simétrica y estaba sesgada hacia uno de los lados. Los participantes hebreos percibían más caracteres hacia la izquierda del punto de fijación que a la derecha cuando las frases estaban en hebreo, y su ventana perceptiva se desplazaba hacia la derecha cuando las mismas frases las leían en ingles. También la percepción de las conductas de otros (Maass, Pagani, & Berta, 2007) esta afectada por el SLE. En este experimento, las personas categorizaban acciones deportivas (p.ej., marcar un gol) como más agresivas, potentes y rápidas cuando se les mostraba la acción de izquierda a derecha que a la inversa. Por el contrario, el grupo de árabes mostraba el patrón opuesto. Spalek y Hammad (2005) estudiaron el sesgo del SLE sobre la inhibición de retorno (Posner & Cohen, 1984) y comprobaron una vez más que angloparlantes y árabes ejecutaban la tarea de forma opuesta: el retorno atencional era más lento cuando debía realizarse en contra del SLE habitual. La exploración del espacio en bisección de líneas (Chokron & Imbert, 1993), tarea donde se pide dividir una línea justo por la mitad, indicó que los participantes franceses marcaban a la izquierda del punto medio real, mientras que los israelíes lo hacían hacia la derecha.

También se han observado efectos del SLE en la representación mental de conceptos muy abstractos, como la magnitud numérica. Dehaene, Bossini y Giraux (1993) usaron una tarea que consistía en responder con una mano si el número presentado en pantalla era par y con la otra si era impar. El resultado mostró que las personas eran más rápidas en responder a los números pequeños con la mano izquierda y a los números grandes con la derecha, lo que puso de manifiesto que la representación mental de los números recurre a una línea mental que va de izquierda a derecha. De forma importante, participantes iraníes no mostraron este efecto cuando valoraban números escritos en notación árabe. Posteriormente, Shaki (2009) aplicó el mismo procedimiento para comparar diferentes culturas con diferentes SLE, replicando el patrón de izquierda a derecha en un grupo de canadienses, pero encontró un efecto inverso en árabes, que respondían más rápido a los números pequeños con la mano la derecha. Por su parte, los israelíes se localizaban entre los dos grupos anteriores debido, sugieren los autores, a que leen texto de derecha a izquierda, pero lo hacen de izquierda a derecha con los números. También es importante destacar que este efecto es altamente flexible, según pusieron de manifiesto Fischer, Mills y Shaki (2010). La concepción del tiempo, que en el apartado anterior vimos que también se veía afectado por la lengua que hablamos, también se ve afectado por el SLE. En un estudio de Fuhrman y Boroditsky (2010), un grupo de ingleses tendieron a organizar de izquierda a derecha unas tarjetas que formaban una historia, mientras un grupo de hebreos lo hicieron a la inversa. Esto lleva a pensar que el tiempo está representado en una línea mental cuyo sentido es congruente con el SLE. Santiago, Lupiáñez, Pérez y Funes (2007) investigaron cómo el tiempo no sólo se proyecta en el eje sagital, con el futuro delante y el pasado detrás, sino que también está representado en un mapa horizontal con el pasado a la izquierda y el futuro a al derecha, de forma congruente con el SLE de su muestra de participantes españoles. Ouellet, Santiago, Israelí y Gabay (2010) mostraron poco después que participantes hebreos representan el tiempo, en cambio, de derecha a izquierda. Otro aspecto conceptual de alto nivel que se ha demostrado relacionado con el SLE es la representación mental de la estructura causal dentro de un evento, con los agentes siendo situados a la izquierda y los pacientes a la derecha, y la acción fluyendo de izquierda a derecha en participantes italianos, mientras que los iraníes mostraban la direccionalidad contraria (Maass & Russo, 2003). Incluso cuando se representa grupos sociales que difieren en agentividad, su localización en el espacio se ve afectada por el SLE (Maass, Suitner, Favaretto, & Cignacchi, 2009). Más concretamente, los participantes italianos colocaban los elementos percibidos socialmente como más fuertes y de mayor agentividad (hombres y jóvenes) a la izquierda, y las mujeres y ancianos a la derecha. Sin embargo, los participantes árabes tenían el patrón contrario. El SLE también es capaz de sesgar la elección de alternativas de comportamiento de una lista (como, por ejemplo, temas de estudio; Ariel, Al-Harthy, Was, & Dunlosky, 2011). Incluso procesos más sutiles, como las preferencias estéticas de artistas, así como los sentimientos evocados por obras de arte visual, pueden verse afectados por la SLE (Chokron y De Agostini, 2000; Nachshon, Argaman, & Luria, 1999; Pérez González, 2012).

Resumiendo, un aspecto tan extrínseco, culturalmente variable, y de adquisición tan reciente en la evolución del lenguaje como es el SLE es capaz de inducir una variedad de sesgos en la actividad cognitiva, tanto de bajo nivel (perceptual, atencional, motor) como de alto nivel (representación mental de conceptos abstractos).

1.4 Influencia del sentido de lecto-escritura sobre nuestros modelos mentales

1.4.1 Qué es un modelo mental

Tras la bibliografía expuesta en los apartados anteriores, nos centramos finalmente en el tema central de esta tesis: la influencia del SLE en los modelos mentales que creamos cuando tenemos que representar un contenido lingüístico oral. Pero antes de pasar a los objetivos y metodología es necesario definir qué entendemos por un modelo mental y exponer sucintamente la teoría de los modelos mentales de Johnson-Laird (1983).

Aunque el concepto de modelo mental está presente en otros autores con otras aproximaciones teóricas, Johnson-Laird (1983) propuso una teoría donde se unifican fenómenos cognitivos tan diversos como el razonamiento deductivo o la comprensión del input lingüístico. La principal característica de la concepción teórica de Johnson-Laird es el postulado de un cierto tipo de representación mental, los modelos mentales, que son representaciones de la realidad que nos sirven para interpretar y manipular las relaciones existentes entre sus diferentes elementos. Para este autor, existen al menos tres clases de representaciones mentales: las representaciones puramente *proposicionales* formadas por cadenas de símbolos combinados según un conjunto de reglas. Los *modelos mentales,* que son análogos estructurales de nuestro entorno, y las *imágenes* como el componente visual de los modelos. Un modelo mental, de una forma muy resumida, podría definirse como una representación mental de una realidad no necesariamente presente en ese momento, que incluye tanto aspectos proposicionales (como etiquetas lingüísticas) como analógicos, y que se construye con un fin, por ejemplo, resolver un problema.

Cualquiera de nosotros es capaz de cerrar los ojos e imaginarse un lugar que le sea muy familiar, construyendo lo que se denomina un *modelo físico.* Por ejemplo, la habitación donde pasamos nuestra infancia. Podemos imaginarnos la disposición de cada uno de sus muebles, la orientación de la ventana, si era un lugar luminoso u oscuro, si el techo era liso o tipo buhardilla, color de las paredes y un largo etcétera. En este caso se trataría de un modelo tridimensional, aunque no es esta característica una condición necesaria para considerarse un modelo mental. Esta representación es extremadamente flexible, y nos permite operar con sus elementos, p.ej., cambiando de sitio algunos de ellos. De hecho, ¿quién no ha tratado alguna vez de imaginar como quedarían los muebles de otra manera antes de mover ninguno de ellos? También podemos representar relaciones dinámicas entre los objetos de nuestro modelo, p.ej., cómo el viento nos mueve la ventana entreabierta. Toda esta escena la vemos desde un punto de origen deíctico, que es un elemento imprescindible de un modelo mental, pero que puede moverse a voluntad, imaginándonos, p.ej., que en vez de ver la habitación desde la puerta, la vemos desde la cama u otra posición cualquiera. Así, podemos elegir libremente qué elementos son los que representamos dentro de nuestro modelo y desde qué punto de vista lo contemplamos, y de esto va a depender la otra característica importante de cualquier modelo, su naturaleza instrumental.

Creamos modelos de la realidad para conseguir un fin, como puede ser la resolución de un problema. Dependiendo de qué elementos sean importantes para ese objetivo, representaremos los elementos relevantes. Si queremos meter un nuevo mueble en la habitación, nuestro modelo mental estará muy orientado a representar las dimensiones de la puerta o la altura de la ventana, y no tanto el olor del ramo de flores en el alféizar de la misma o el color de las paredes. Es importante notar también que estos modelos físicos no sólo representan el espacio cartesiano en el que nos movemos, sino también contemplan y contienen al tiempo. La habitación del ejemplo nos la podemos imaginar cambiando del mediodía a la noche.

Los modelos mentales pueden incluir otros modelos en su interior, es decir, son recursivos. Por ejemplo, cuando tengo un modelo mental de mi entorno inmediato y dentro de ese modelo tengo incluido otro modelo contemplado desde el punto de origen deíctico de otra persona, tendremos representada información sobre qué puede o no puede ver esa persona.

Además de modelos físicos como los descritos, existen otros denominados *modelos conceptuales,* en los que el tiempo y el espacio no son elementos centrales y cobran protagonismo más bien relaciones abstractas. Sirvan como ejemplo los modelos creados ante deducciones silogísticas. En estos casos la relación entre la imagen mental y lo que representan los diferentes elementos del modelo es más arbitraria.

Podemos distinguir tres grandes fuentes de información a partir de las cuales creamos los modelos mentales: nuestra percepción directa, los contenidos de la memoria a largo plazo (MLP), y el input lingüístico. Estas tres fuentes actúan en estrecha interacción para generar modelos mentales que nos permitan movernos y pensar de forma eficaz.

1.4.2 Aplicación de la teoría de los modelos mentales de Johnson-Laird a la comprensión de descripciones de escenas estáticas

En esta tesis examinamos cómo el SLE afecta al modo en que las personas construyen modelos mentales a partir de descripciones lingüísticas de escenas estáticas. En concreto, nos centramos en frases relacionales del tipo “el cuadrado está entre el triangulo y el círculo”. Desde la teoría de los modelos mentales de Johnson-Laird (1983), la comprensión de estas frases requiere la creación de un modelo mental donde queden correctamente posicionados todos los elementos que aparecen en ellas. La realización de esta tarea desde un punto de vista estrictamente proposicional resulta un tanto farragosa. Tendríamos que empezar por definir los objetos por separado. Por ejemplo, el cuadrado como figura que está formada por dos líneas paralelas verticales unidas por ambos extremos por otras dos líneas horizontales de igual longitud de forma que sus cuatro ángulos formen 90 grados. Después, definir proposicionalmente que el cuadrado puede y debe tener un objeto a cada lado, el segundo objeto sólo puede tener el cuadrado a un lado y, finalmente, el último objeto sólo puede tener al cuadrado en el lado contrario a donde lo tiene el segundo. Como alternativa a esta forma proposicional de descripción, Johnson-Laird (1983) aboga por una representación de los objetos como una realidad paralela en la que podemos fácilmente manipular los elementos para buscar la solución al problema. En este caso, se trata de crear un modelo mental que represente una situación donde se cumplan todas las premisas expresadas en el contenido lingüístico.

Jahn, Knauff y Johnson-Laird (2007) estudiaron cómo las personas usan modelos mentales para razonar sobre este tipo de configuraciones espaciales. Concretamente, presentaban a sus participantes un conjunto de diferentes descripciones de escenas y estos debían decidir si tales afirmaciones eran consistentes entre sí. Por ejemplo:

La mesa está entre la televisión y la silla.

La lámpara está a la izquierda de la televisión.

La mesa está al lado de la lámpara.

Estos autores predijeron que los sujetos se lanzarían a hacer un modelo de la primera situación y después contrastarían o tratarían de integrar el resto de afirmaciones con ese primer modelo. La primera proposición no es unívoca ya que, aunque nos obliga a colocar la mesa en el centro de los otros dos objetos, nos permite la libertad de colocarlos en dos posibles combinaciones, con la TV a la izquierda y la silla a la derecha o a la inversa. Ambos modelos son una representación válida de la frase. Pero de cuál sea nuestra elección inicial dependerá que también permita incluir o no las dos proposiciones restantes. Es decir, solamente si hemos elegido el modelo donde la silla está a la izquierda, es posible integrar en él las dos afirmaciones restantes.

Los resultados de este estudio sugerían que los participantes preferían poner los elementos en la horizontal y representar el segundo elemento de la frase (TV) a la izquierda del objeto de referencia (mesa). Jahn et al. (2007) sugirieron que esta preferencia podría estar relacionada con el SLE habitual de los participantes. En nuestro trabajo usaremos una versión simplificada de esta tarea para evaluar los efectos del SLE habitual sobre los sesgos espaciales que tienen lugar en la construcción de modelos mentales.

CAPÍTULO 2: OBJETIVOS Y METODOLOGÍA

El objetivo principal de todos los estudios presentados bajo esta tesis es explorar los sesgos producidos por el sentido de lecto-escritura (SLE) habitual en la representación mental que hacemos de descripciones espaciales a partir del lenguaje oral. Estas son las diez preguntas que nos hemos hecho secuencialmente a lo largo de todo el proceso y que se han ido contestando en los sucesivos experimentos:

2.1 OBJETIVOS

2.1.1 Objetivos del estudio 1

1. ¿Es capaz el SLE de afectar a la forma en que representamos los modelos mentales provenientes del lenguaje oral? Aquí nos interesa tan sólo saber si existe el efecto: si el hecho de ser una persona alfabetizada y expuesta durante años a un cierto SLE es capaz de sesgar cómo representamos mentalmente la información contenida en un mensaje oral.

2. Si el SLE es capaz de sesgar dicha representación, ¿pueden diferentes SLE producir diferentes sesgos en dicha representación? Como vimos en la introducción, todas las culturas despliegan su sistema de escritura en un plano, pero no todas coinciden en la dirección en que lo hacen. Nos preguntamos, por tanto, si estos sesgos son opuestos en lenguas que tengan diferentes SLE, en concreto español (en España) y árabe (en Marruecos).

3. ¿Es este sesgo inmutable una vez que se establece o es flexible? Nuestra lengua nativa y su escritura sin duda nos determina en gran medida en cómo percibimos nuestro entorno. Pero queremos saber si un cambio de cultura, p.ej., al ir a vivir a un país con diferente lengua y SLE, es capaz de cambiar la forma nativa que tenemos de representar la información. O si, por el contrario, nuestros sesgos ligados al SLE son un equipaje que va con nosotros allá donde vayamos. Para ello se hace necesario evaluar a un grupo de personas de una cultura que lleven un determinado tiempo inmersos en una nueva cultura. En nuestro caso se evaluaron en España a árabes que ya vivían aquí una media de 5.8 años, habiendo tenido

tiempo de adaptarse a nuestra lengua y cultura. Nos interesa, por tanto, con esta pregunta explorar la plasticidad a largo plazo de este sesgo en nuestro sistema cognitivo.

4. ¿Es estrictamente necesario estar expuesto durante mucho tiempo a un SLE diferente para sesgar nuestras representaciones mentales? Si en la pregunta anterior nos preguntábamos por la flexibilidad a largo plazo de personas aculturadas durante años en un SLE diferente al nativo, en este caso queremos comprobar si un breve entrenamiento en un SLE opuesto al nuestro es suficiente para producir cambios en el mismo sentido en nuestras representaciones mentales.

5. Si se demuestra que existe una flexibilidad a largo plazo y otra inmediata o de corto alcance, ¿cuál es más importante? o ¿cómo se relacionan o afectan entre ellas?

2.1.2 Objetivos del estudio 2

6. ¿Es el SLE una condición suficiente para generar estos sesgos espaciales si la aislamos de otros factores culturales? Dado que grupos provenientes de culturas diferentes como son la española y la marroquí no sólo difieren en el SLE de sus lenguas respectivas, es necesario profundizar en el tema. Hay multitud de matices inter-culturales a tener en cuenta, así como aspectos religiosos, geográficos, históricos, que dificultan aislar el SLE como causa genuina de estos sesgos. Se hace necesario, por tanto, comprobar, manteniendo todas esas variables culturales constantes, si al cambiar experimentalmente el SLE dentro de una misma lengua, se producen también cambios en cómo creamos la correspondiente representación. Así, expusimos a varios grupos de españoles a SLE diferentes, pero todos en su lengua nativa, y evaluamos sus sesgos espaciales.

7. ¿Cuál es el curso temporal de los sesgos espaciales inducidos por una breve exposición a un SLE diferente? ¿Se desvanecen rápidamente, o perduran en el tiempo?

8. Dado que los sistemas de escritura analizados en esta tesis, aunque con SLE opuesto, son

todos horizontales, cabe preguntarnos también sobre qué resultado arrojaría una exposición a un SLE en el eje vertical. Es decir ¿un texto en vertical, hacia arriba o hacia abajo, es capaz también de sesgar nuestra representación mental del mensaje en el mismo sentido? De ser así, ¿ocurre este sesgo con la misma fuerza que en el eje horizontal?

2.1.3 Objetivos del estudio 3

9. El sistema de escritura, con su SLE característico, es parte de un sistema mucho más amplio de convenciones direccionales que se manifiestan conjuntamente en una cultura. Estas incluyen la dirección en que se organizan las viñetas de los cómics, se pasan las páginas de los libros, se representan los números, se ordenan los libros en las estanterías de las bibliotecas, etc. ¿Es necesaria la exposición al sistema de escritura para inducir sesgos espaciales en la comprensión de oraciones? ¿O basta con ser expuesto a otras de esas convenciones direccionales covariantes? Dado que los niños pequeños y sus padres comparten muchas horas de "lectura" de libros para niños bastante antes de que se les empiece a enseñar a leer y escribir, este tipo de sesgos podrían empezar a adquirirse a edades muy tempranas.

2.2 METODOLOGIA

En este apartado hacemos una exposición sucinta de la metodología utilizada para llevar a cabo la fase experimental. Para más detalles, véase el capítulo 3 con los artículos en inglés.

2.2.1 Metodología del estudio 1

El estudio 1 consta de dos experimentos. El primero de ellos tiene como objetivo dar respuesta a las 3 primeras cuestiones planteadas en el apartado anterior: ¿existe un sesgo en nuestros modelos mentales dependiente del SLE?, ¿cambia el sesgo si cambiamos de SLE?, ¿es este sesgo inmutable una vez que se establece, o es flexible si hay una inmersión en una cultura y lengua diferente? Para responder a todas ellas, se compara a un grupo de españoles evaluados en España con un grupo de marroquíes evaluados en su país. Asimismo, se añaden en el análisis a un grupo de árabes bilingües y altamente integrados en la cultura española.

Todos los participantes se encontraban sentados frente a una mesa y 10 hojas en blanco. La tarea experimental era una versión simplificada de Jahn et al. (2007). Concretamente, escuchaban una frase del tipo "la mesa está entre la lámpara y la televisión" y la tarea consistía simplemente en dibujar el contenido de cada frase en una hoja diferente. Como hemos visto en el apartado anterior, ese tipo de descripción es ambigua en cuanto a que puede representarse en dos modelos mentales diferentes, los dos verdaderos. Teniendo la mesa en el centro, podemos colocar la lámpara a la izquierda o a la derecha. Esta ambigüedad es la que nos permite usar este procedimiento para detectar posibles sesgos en un sentido u otro, midiendo la cantidad de modelos mentales que los participantes generaban de un tipo u otro. Adicionalmente, se analizaron también el orden de dibujo de los objetos y el orden de relleno del espacio, pero es la variable de tipo de modelo mental el eje en torno al cual se han planteado todos los experimentos de esta tesis.

Nuestra hipótesis inicial era que los españoles influidos por un SLE de izquierda a derecha (en adelante I-D) dibujarían el segundo objeto escuchado (lámpara) a la izquierda, para acabar en la derecha (congruente con SLE) dibujando la TV. Por otra parte, los marroquíes evaluados en su país deberían mostrar una preferencia por dibujar la lámpara a la derecha y acabar dibujando la TV en la izquierda (congruente con el SLE del árabe). Por otro lado, el grupo de árabes altamente integrados en nuestra cultura nos dará información respecto a cuán flexible es el sesgo. Si este está muy determinado por nuestra cultura y lengua nativa, este grupo debería mostrar un patrón parecido al de los árabes en Marruecos. Si, por el contrario, encontráramos que su sesgo está más cerca del de los españoles y es distinto a los árabes en su país, demostraría que es flexible al menos tras un largo entrenamiento en un SLE distinto al nativo.

El experimento 2 trata de responder si es necesario un tiempo largo de inmersión cultural para adoptar el sesgo de la cultura/lengua huésped o es suficiente hacer la tarea en una lengua diferente a la nuestra para que respondamos con un sesgo acorde al nuevo SLE. Para ello se evaluaron dos grupos de árabes marroquíes bilingües en su país. Ambos grupos dibujaban un bloque de frases escuchadas en una lengua latina (español o francés) y un bloque en dariya (el dialecto local del árabe). Este diseño nos permitió comprobar si, para una misma cultura, el simple hecho de escuchar las frases en un idioma u otro era suficiente para determinar qué sesgo presentaban los participantes. Por otro lado, se contrabalanceó el orden del idioma que hacían primero. Un grupo comenzaba el primer bloque en dariya y el otro grupo lo hacía en una de las lenguas latinas. En este diseño interactúan factores a largo plazo (lengua nativa) con factores a corto plazo (idioma de la tarea), permitiéndonos ver si el idioma de inicio en el primer bloque determina el desempeño en el segundo bloque y si ambos efectos son simétricos o por el contrario uno de los dos ejerce más influencia.

2.2.2 Metodología del estudio 2

Los experimentos anteriores, si bien han arrojado resultados interesantes, presentan una relación correlacional entre el SLE junto a otros factores culturales, pero no nos permiten sostener una relación causal directa entre el SLE y la presencia del sesgo. Para desambigüar el efecto del SLE de otras causas posibles, este experimento se realizó sólo en participantes españoles evaluados en español y en España. Para saber si el SLE es el factor clave y, por otro lado, si son posibles sesgos en la dimensión vertical, se formaron 5 grupos de participantes. Antes de la tarea de dibujo, a cada uno se les pidió leer un texto breve en cada una de las direcciones del espacio (texto normal, texto en espejo, texto girado 90º hacia la izquierda para leer de abajo a arriba, y texto girado 90º hacia la derecha para leer de arriba hacia abajo). Un quinto grupo, de control, no fue expuesto a este entrenamiento y realizaron la fase de dibujo directamente. En este estudio se utilizaron figuras geométricas para evitar asociaciones con la horizontalidad de los objetos reales. En este caso nos preguntamos si la breve exposición previa a un texto con distintos SLE es suficiente para producir sesgos congruentes en la posterior creación de modelos mentales, tanto en la dimensión horizontal como en la vertical.

2.2.3 Metodología del estudio 3

En el tercer estudio intentamos responder a la cuestión de si es posible adquirir este tipo de sesgos espaciales en comprensión de oraciones mediante la exposición a estímulos direccionales como son las viñetas de los cómics, sin exposición a ningún sistema de escritura. Concretamente, en el experimento 1 se expuso a un grupo de 40 personas a la exploración de un cómic mudo en papel previamente a hacer la fase de dibujo. Este cómic tiene como línea argumental la supervivencia de un grupo de animales ante un desastre natural y no tiene ningún tipo de texto escrito, ni siquiera onomatopeyas ambientales o de los propios personajes. La mitad de los sujetos fueron expuestos a una versión estándar del cómic (que se explora de izquierda derecha) y la otra mitad de los participantes hicieron la tarea con el mismo cómic, pero en versión espejada (con lo que era necesario explorarlo de derecha a izquierda).

El tamaño y la distribución de las viñetas en este primer experimento no seguía un patrón completamente consistente, permitiendo la exploración en múltiples direcciones que podrían dificultar la creación del sesgo. Por esta razón se diseñó una tarea en el que el mismo material gráfico era presentado en tiras de cuatro viñetas en una pantalla de ordenador, haciendo más restrictivo el sentido de exploración. De este modo, aunque perdíamos algo de validez ecológica, ganamos más control experimental sobre la dirección de escaneo para cada condición (estándar versus espejada).

Hasta aquí, un breve resumen de los objetivos marcados para cada una de las 3 investigaciones, así como la metodología que nos permitió llevarlo a cabo. En el siguiente apartado se encuentran los 3 estudios (en inglés), que siguen el formato de articulo científico. Tras ellos, volvemos en castellano con el capítulo 4 para mostrar un resumen de los resultados y una discusión de los mismos.

CAPÍTULO/CHAPTER 3: SERIE EXPERIMENTAL

3.1 Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction

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3.1.1 Abstract

Prior studies on reasoning tasks have shown lateral spatial biases on mental model construction, which converge with known spatial biases in the mental representation of number, time and events. The latter have been shown to be related to habitual reading and writing direction. The present study bridges and extends both research strands by looking at the processes of mental model construction in language comprehension and examining how they are influenced by reading and writing direction. Sentences like "the table is between the lamp and the TV” were auditorily presented to groups of mono- and bi-directional readers in languages with left-to-right or right-to-left scripts, and participants were asked to draw the described scene. There was a clear preference for deploying the lateral objects in the direction marked by the script of the input language, and some hints of a much smaller effect of the degree of practice with the script. These lateral biases occurred in the context of universal strategies for working memory management.

Keywords: reading and writing direction; spatial bias; mental model; flexibility; working memory; bilingualism; language comprehension.

3.1.2 Introduction.

How is linguistic content represented such that people can reason about it? And how is it affected by habitual reading and writing direction (RWD)? One theory of language comprehension which has received strong support in the literature is the theory of mental models (Johnson-Laird, 1983; see Van Dijk & Kintsch, 1983, for a related proposal; see Zwaan & Radvansky, 1998, for a review). Mental models are working memory representations about situations and events in the world. They are analogical, spatial, and populated by concrete content, although they can also represent abstract or temporal content (Goodwin & Johnson-Laird, 2005; Santiago, Román, & Ouellet, 2011).

The most important feature of mental models is that they allow us to represent and manipulate reality in working memory in order to make decisions and deal with the situation. Working memory is characterized by limited capacity and effortful processing. Therefore, people tend to create only one such mental model, integrating in it all the information that is relevant to solving the problem at hand. The greater the amount of information that must be kept simultaneously in working memory, the more difficult the resolution of the problem (Goodwin & Johnson-Laird, 2005).

Under this view, language serves to provide instructions that guide mental model construction in the comprehender (Johnson-Laird, 1983). From a linguistic input such as “The table is between the lamp and the TV”, the listener can construct a mental model that represents the spatial position of those three objects. Although many different spatial arrangements are consistent with the statement, people tend to create a single model that captures only one spatial configuration. Many studies show that, in a task like this, the preferred mental model places the mentioned objects in a línear array, either a horizontal or vertical one (see Evans, Newstead, & Byrne, 1993, for a review).

Jahn, Knauff, and Johnson-Laird (2007) studied how mental models are used to reason about such static spatial configurations. They presented sets of descriptions of scenes, and asked participants to judge whether the set was consistent or not. To use their same example:

A table is between the TV and a chair

The light is on the left of the TV

The table is next to the light

They predicted that people tend to make a single mental model of the first statement, and then try to integrate the next two in it. Depending on the configuration of the initial model, the integration may be easy or difficult, as in the example above. In this example, the descriptions are consistent if in the initial model the chair is placed to the left of the table. Otherwise, participants will tend to claim that the premises are inconsistent, or take longer to find the correct answer.

Jahn et al. (2007) postulated that the preferred initial model should include the three mentioned objects in left-to-right (LR) order. For the example above, a schematic model of this kind would be:

TV table chair

This assumption was strongly supported by the data. Jahn et al (2007) suggested that this preference for L-R models was a bias induced by the habitual reading and writing direction (RWD). One central goal of the present paper is to directly assess the role of RWD in mental model construction from linguistic descriptions such as those used by Jahn et al (2007).

Available evidence suggests that habitual RWD exerts subtle but consistent effects on a wide variety of mental processes and representations, taking the form of lateral biases that follow the direction of the script (see Santiago & Román, submitted, for a review). For example, it has been shown that RWD is able to affect low level skills such as word reading (Mishkin & Forgays, 1952), perceptual span (Pollatsek, Bolozky, Well, & Rayner, 1981), lateral motion perception (Maass, Pagani, & Berta, 2007), attention (Spalek & Hammad, 2005), exploration (Chokron & Imbert, 1993; Kugelmass & Lieblich, 1970) and hand movements in copying and drawing tasks (Nachshon, 1985; Shanon, 1979). More interestingly for current concerns, RWD effects have been observed on the mental representation of highly abstract concepts, such as number magnitude (Dehaene, Bossini, & Giraux, 1993; Zebian, 2005), time (Fuhrman & Boroditsky, 2010; Ouellet, Santiago, Israeli, & Gabay, 2010; Tversky, Kugelmass, & Winter, 1991), events (Dobel, Diesendruck, & Bölte, 2007; Maass & Russo, 2003), letter sequences (Shaki & Gevers, 2011) and social groups differing in agentivity (Maass, Suitner, Favaretto, & Cignacchi, 2009). RWD is also able to bias the choice of behavioral alternatives (such as study items) from a list (Ariel, Al-Harthy, Was, & Dunlosky, 2011). Even the aesthetic choices of artists as well as the feelings that are aroused by pieces of visual art can be affected by RWD (Chokron & de Agostini, 2000; Nachshon, Argaman, & Luria, 1999; Pérez González, 2012).

The standard account of RWD effects suggests that practice in reading and writing a given script induces directional habits that grow slowly and become progressively entrenched (Nachshon, 1985). These habits induce lateral biases in those skills which are components of the tasks of reading and writing (such as exploring the page or programming precise hand and finger movements). Moreover, as the eyes or hands move along the text, the mind moves along the concepts which are referred to by the text, opening the door to specific directional biases in their mental representation. Take temporal order as an example. Following universal pragmatic principles (Grice, 1975), events are usually described in the same order as they occurred. Thus, the reader is exposed to a quite consistent correlation between word order along the horizontal axis and the temporal order of events. This correlation is hypothesized to cause the tendency to represent temporal sequences along a spatial horizontal axis in the mind, flowing in the same direction as the script (Santiago et al., 2011). A similar reasoning applies to numerical and other types of sequences. Because all languages studied in this context so far use a word order in which the syntactic Subject precedes the syntactic Object, and because Subjects and Objects canonically incorporate the thematic roles of agent and patient, the user of a script also experiences a correlation between thematic roles and left-right space, which is hypothesized to cause the tendency to represent agents preceding patients along the horizontal axis in the direction of the script (Maass & Russo, 2003; Maass et al., 2009).

Under the standard account, when people are exposed to conflicting directional experiences (e.g., bidirectional readers of French and Arabic), they will develop contradictory directional habits which will enter into competition. As a result, lateral biases should be weaker than in people with fully consistent directional habits. Many published studies support this view (see, e.g., Kugelmass & Lieblich, 1970, for exploration tasks; Nachshon, 1985, for reproduction tasks; Berch, Foley, Hill, & Ryan, 1999, for numerical sequences; and Dobel et al., 2007, for agent-patient representation).

Thus, the standard account of high-level RWD biases suggests that they originate from experiences that occur during text comprehension, but there is very little evidence looking directly at RWD effects on mental model construction processes from linguistic input. Following up on work by Chatterjee, Southwood, and Basilico (1999), Maass and Russo (2003) asked their participants to draw sentences such as “the girl gives a gift to the boy” and found that Italians prefer to place the girl on the left and the boy on the right whereas Arabs[1] showed the opposite preferences. However, these results have not always been replicated: Altmann, Saleem, Kendall, Heilman, and Rothi (2006) found that both English and Arabic readers tend to place the agent on the right, and Barrett, Kim, Crucian, and Heilman (2002) failed to observe any lateral bias in R-L versus L-R Korean readers. Moreover, all available evidence focuses on the representation of intrinsically sequential concepts (numbers, time, events), and it is unclear what will occur with static scenes. To our knowledge, the only relevant study is Geminiani, Bisiach, Berti, and Rusconi (1995). They presented descriptions of static and dynamic scenes to Italian students and found a strong tendency to place the first mentioned item on the left and the second item on the right.

[1] We herein use the term “Arabs” meaning “users of Arabic languages”.

However, no R-L group was included, so the effects of RWD in such a task remain to be dilucidated.

If the effects of RWD arise during mental model construction in language comprehension, they should also be present when understanding descriptions of static scenes, fully devoid of any intrinsic directionality, order or motion. Moreover, they should reverse in readers of scripts with opposite directionality. The present investigation aimed to provide a first exploration of the influence of RWD on mental model construction avoiding any potential confounding with intrinsic order, thus bridging the gap between the literature on language comprehension and high-level effects of RWD. We set to do so in a way that would allow both an examination of the detailed processes of working memory management during language comprehension, and to test for the effect of degree of conflicting habits due to practice with scripts of different directionality. We hypothesized that RWD will affect the directionality of mental model construction, and greater practice with a different RWD will lead to weaker, or even reversed, lateral biases. Independently of the effects of RWD, all groups will show a trend toward minimizing working memory load. In other words, all groups are expected to show a preference for minimizing the number of items and the time those items are kept in working memory before production. Thus, all groups are expected to show the same preference for producing items in the same order as they are mentioned in the input sentence.

In order to do so, we devised a simpler version of Jahn et al's (2007) task. Participants were asked to listen to sentences such as "The table is between the lamp and the TV" and then draw the scene described by the sentence. Both order of drawing the mentioned objects and order of filling the spatial locations in the paper were measured. These measures allowed us to study independently spatial biases in the construction of mental models and working memory management processes (see details below). In order to assess the effect of RWD, in Experiment 1 we compared native Spanish users who read and write from left to right, and native Arabic users from Morocco whose preferred script runs from right to left, but are also familiar with L-R scripts such as French or Spanish. In order to better evaluate the effect of conflicting RWD habits we also included a group of native users of Arabic languages who had been living in Spain for a number of years and were highly acculturated into Spanish culture and language. Experiment 2 searched for the effect of the input language using a sample of bilingual bidirectional participants who performed the same task listening to the sentences in either a L-R or R-L language.

3.1.3 Experiment 1

3.1.3.1 Method

Participants.

There were three groups of participants. The Spanish group was composed of 21 psychology students at the University of Granada (mean age 21 years, 5 males, 1 left-hander). All of them were native Spanish speakers, had never lived in an Arabic country for longer than an occasional stay and did not know any R-L language.

The Moroccan group was made of 18 Moroccan students from the Abdelmalek Esaadi University, Tetouan, Morocco (mean age 22 years, 12 males, no left-handers). Demographic information of three participants was lost due to a computer problem (which also affected information of three participants in the next group). All the remaining participants were born in Morocco and had never lived in a Western country. They all were native speakers of Moroccan Darija (the local Arabic dialect) and nine of them were also native speakers of Standard Arabic (starting before age 4). Fourteen of them were also highly fluent in French, and nine participants in this group also had some knowledge of Spanish (started in high school or university). All of them were highly proficient and habitual readers of Standard Arabic.[2] The Moroccan group did the task in Darija.

[2] Standard Arabic is the only written Arabic language. Local Arabic languages are only oral (Lewis, 2009).

The Arabs-in-Spain group was composed of 26 Arab students at the University of Granada (mean age 22 years, 12 males, 1 left-hander). As mentioned above, demographic information from three participants was lost. For the remaining sample, 18 were originally from Morocco, three from Jordan, one from Iraq and one from Mauritania. Their average number of years living in Spain was 5.8 (range 1-11). All of them were native speakers of at least one Arabic language (Standard Arabic, Moroccan Darija, Mauritanian Hassania, Jordanian Levantine, Iraqi Arabic). All of them were also native or highly fluent speakers of at least one European language (mostly French and/or Spanish). All of them were highly proficient readers of Standard Arabic, and only three of them reported not to read it on a daily basis. All of them were highly fluent in Spanish and had no problems in understanding the instructions or having a conversation in Spanish with the experimenter. As described in detail below, the Arabs-in-Spain group did the task in Spanish.

It is important to note that all participants in both Arab groups are bilingual (often multilingual), knowing at least one L-R language (modally French). The difference between them is not so much a difference of bilingualism, but of immersion in a particular language and writing system and extended experience with it.

The Spanish Group received course credit, and the two Arabic groups received a small gift or monetary compensation.

Materials.

Five sentences were constructed, all of which consisted of an assertion that referred to a between relation among three different entities.

1 - The table is between the lamp and the TV.

2 - The bike is between the lamppost and the car.

3 - The cup is between the bottle and the dish.

4 - The pencil is between the book and the eraser.

5 - The man is between the house and the tree.

We selected those entities because they are very common in both cultures, thereby avoiding comprehension problems or potential biases due to different degrees of familiarity. Importantly, all sentences refer to completely static scenes without any agentive structure. With the single exception of “the man” in the last sentence, all mentioned objects are inanimate entities and they are embedded in sentences using a copulative verb. In the last sentence, “the man” is located in the center of the scene carrying out no action, and thus, it is unlikely that its animacy or agentivity may bias the location of the surrounding objects in the mental model in any particular direction.

Procedure.

The participants were tested individually. They sat at a desk with a pile of five blank sheets and a pen. They were instructed that they would listen to five sentences describing scenes, and that their task was to draw each scene in a different sheet. There was no mention of using a particular spatial arrangement (say, e.g., horizontal). The sentences were read aloud by the experimenter always in the same order and coding was made *in situ* and out of the sight of participants. The Spanish and Arabs-in-Spain groups were tested at the University of Granada, Spain, and heard the instructions and sentences in Spanish. The Moroccan group was tested at the Abdelmalek Esaadi University, Morocco, and did the task in Darija. The order of mention of the objects in each sentence is the same in both languages.

Data coding.

For each sentence, we measured the order in which each of the three mentioned objects was drawn (hereafter this measure will be referred to as *mentioned object order*, or just *object order*) and the order in which the three positions (left, center, right) were filled (*spatial order*).

Each sentence presents auditorily the three objects in a temporal sequence or order of mention. In the sentence “The table is between the lamp and the TV”, table is the first object mentioned, followed by lamp and then TV. Participants can draw the three objects in one out of six possible combinations of object order (see Table 1). For example, combination 213 means that the first object to be drawn is the second object mentioned in the sentence (lamp), followed by the object mentioned first (table) and then by the object mentioned third (TV).

Regarding the order of location filling, or spatial order, there are also six possible combinations (see Table 1). For example, LCR means that the object on the left was drawn first, then the central object, and then the object on the right. Combinations LCR, CLR, and LRC were grouped as patterns from left to right (L-R); and combinations RCL, CRL, and RLC were grouped as patterns from right to left (R-L).

The combination of each object order with one out of two possible spatial orders produce only one possible *drawn model* with the lateral objects (e.g., lamp and TV) in different positions (see Table 1 for details). To carry on with the example sentence "The table is between the lamp and the TV", suppose that a participant shows a 213 (Lamp-Table-TV) object order and a RCL (Right-Center-Left) spatial order. The resulting drawn model has the lamp on the right side and the TV on the left (a R-L model). If the same object order is combined with a LCR spatial order, the resulting drawn model will have the lamp on the left side and the TV on the right side (a L-R model).

Hypotheses.

We expected that habitual RWD would exert clear effects on the spatial order in which objects are drawn. Because we did not expect effects of RWD on object order (see below), RWD should also affect the final spatial configuration of the drawn model: Spanish participants will tend to draw L-R models, with the lamp on the left and the TV on the right, whereas Moroccan participants will prefer R-L models, with the lamp on the right and the TV on the left. A second hypothesis concerns the group of Spanish-acculturated Arabs: we expected that their extended practice with a L-R language would make them show a weaker R-L bias, or even to switch to a L-R bias like Spanish participants.

Our third hypothesis follows from the fact that each object order imposes different costs on working memory resources. For example, the pattern 123 means that we draw the objects in the same order as they appear in the speech stream. This pattern imposes the lowest memory load, because the objects are produced in the same order as they are heard, thereby reducing the length of time they are held in memory. The pattern 231 imposes a greater memory load because it draws last the object presented first. Table 1 lists the combinations of object order from the one requiring less cognitive resources (123) to the one requiring most (321). We expected that all the groups would prefer to use object orders that require fewer memory resources. For each one, the L-R spatial order will be preferred by Spanish participants and the R-L spatial order will be preferred by Moroccans, with the Arabs-in-Spain group somewhere in between.

It should be emphasized that, although tempting, the directionality of the drawn model cannot be taken as an index of the directionality of referents in the underlying mental model without a careful assessment of working memory management that assures that all groups follow the same general principle of minimizing memory load. Once this is secured, drawn model directionality can be confidently used as an index of mental model directionality.

3.1.3.2 Results

If any central entity (e.g., the table) was drawn anywhere else than the center, the trial was considered invalid and was not included in the final analysis. We also excluded those items drawn vertically or however differently from the horizontal axis. In all groups there were participants who saw all their five trials rejected as invalid trials, what amounts to the rejection of the participant altogether. This occurred to two participants in the Spanish group, one in the Moroccan group, and one participant in the Arabs-in-Spain group. Therefore, effective sample sizes were 19, 17, and 25, respectively. In the remaining participants, the average number of items rejected was 6.1% (7.2%, 5.3%, and 5.9% in the Spanish, Moroccan and Arabs-in-Spain groups, respectively).

In the analysis of drawn models, there were significant differences among the groups in the proportion of valid L-R trials ($F(2,58) = 5.52$, $p = 0.006$, $\eta^2 = 0.16$; see Table 2 for cell means and standard errors). The Spanish and Moroccan groups were significantly different from each other (70.7% vs. 38.3%, respectively; $t(1,34) = 3.70$, $p < 0.001$). Consistent with the findings of Jahn et al (2007) with German participants, Spanish participants preferred to represent the mentioned objects from left to right (with the lamp on the left and the TV on the right). In contrast, Moroccan participants showed the opposite bias (see Figure 1). The Arabs-in-Spain group did not differ from the Spanish group (58.8% vs. 70.7%; $t(1,42) = -1.25$, $p = 0.21$), whereas they differed from the Moroccan group (58.8% vs. 38.3%; $t(1,40) = 2.17$, $p = 0.03$). Thus, the Spanish-acculturated Arabs behaved more like Spaniards than like the other Arabic group.[3]

The spatial order measure followed closely the drawn model index. A one-way ANOVA on the proportion of valid L-R trials showed a significant effect of Group ($F(2, 58) = 5.36$, $p = 0.007$, $\eta^2 = 0.16$). Spanish participants tended to fill up before the left than the right space (a 72.6% preference for combinations LCR, CLR, LRC). In contrast, the Moroccan group showed the opposite preference (35.9% of L-R combinations, that is, a preference for R-L combinations RCL, CRL, RLC). The difference between the two groups was significant ($t(1,34) = 3.33$, $p = 0.002$). Again, the comparison between the Spanish and the Arabs-in-Spain groups failed to be significant (72.6% vs. 64.7%, respectively; $t(1,42) = -0.69$, $p = 0.48$), whereas the Arabs-in-Spain differed from the Moroccan group (64.7% vs. 35.9%; $t(1,40) = 2.59$, $p = 0.01$).

We then turned to analyze the differences in preferred object orders. Here, we expected no cultural differences: in both cultures, participants should prefer the orders that impose a smaller working memory load. The results substantiated this prediction (see Figure 2): all groups preferred the 123 order, followed at a great distance by 132, from where the numeric value of proportions decreased progressively as memory load increases. Statistically, no significant differences were found between the three groups of participants on each of the possible orders (Kruskal Wallis test with group as a factor, $N = 65$. Order 123: $H = 2.22$, $p = 0.33$; Order 132: $H = 5.22$, $p = 0.07$; Order 213: $H = 1.40$, $p = 0.49$; Order 231: $H = 1.46$, $p = 0.48$; Order 312: $H = 0.44$, $p = 0.80$; Order 321: $H = 3.77$, $p = 0.15$). The analysis of the different orders shows that 123 is the preferred option. A contrast with the next most common (132) is highly significant (Mann-Whitney $U = 1640$, $p < 0.001$). The remaining orders are not significantly different from one another. Even comparing conditions 132 and 321, the difference is non-significant ($U = 335.5$, $p = 0.062$). These results suggest that participants are sensitive to the increase in memory load that occurs from order 123 to all other orders. The latter are all preferred to the same (low) extent. Present data and analyses do not support the existence of a gradation of preference, but this might be due to the very small proportions observed in those conditions.

3.1.3.3 Discussion

Readers of Spanish (a L-R language) and Standard Arabic (R-L), when tested in their native language and immersed in their own culture, differ in their preferred spatial choices when constructing mental models of static scenes from auditory linguistic input: Spanish readers prefer L-R models and Arabic readers prefer R-L models. Hence, effects of habitual RWD can be observed in static scenes, as well as in the intrinsically ordered events which have received attention so far in the literature (see the Introduction). Thus, it does not seem necessary that linguistic meaning has intrinsic order for it to be construed línearly into a spatial mental model in a systematic way. Present results also reveal that cultural differences in mental model construction due to RWD are confined to spatial preferences, but the management of working memory resources is similar in all groups. This check grants the use of the measure of directionality of the drawn model as an index of the directionality of the underlying mental model.

Present data are consistent with the proposal that lateral biases in mental model construction vary as a function of the degree of practice in a certain direction. The Moroccan participants, who were exposed to more inconsistent RWD habits than the Spanish participants, showed a weaker lateral bias (11.7% R-L versus 20.7% L-R, respectively). Moreover, the Arabs-in-Spain group, who had been immersed in a L-R culture and language for a long period of time, actually reversed their Arabic R-L bias and were statistically indistinguishable from the Spanish (although their L-R bias was also not as strong in magnitude: 8.8% versus 20.7%, both L-R). However, as the two Arabic groups differed both in their degree of practice with L-R scripts (greater in the Arabs-in-Spain group) and the language used in the experiment (Spanish versus Darija), there remains the possibility that any (or both) of these factors could be the main responsible for the observed differences in lateral preferences. To disentangle these possibilities, we conducted a second experiment where a group of bilingual Moroccans were tested in their country using two languages of different script directionality. By keeping constant the participants and the cultural environment, we aimed to measure the influence of the input language. As the task was repeated with a different language, we also aimed to see whether there are carry-over influences from the first to the second language, and whether they differ depending on whether the first language is the more or less practiced one.

3.1.4 Experiment 2

3.1.4.1 Method

<u>Participants.</u>

A new group of 48 Moroccan students from the Abdelmalek Esaadi University, Tetouan, Morocco, was recruited (mean age 23.5 years, 29 males, 1 left-hander and 1 ambidextrous). All the participants were born in Morocco and had never lived in a Western country. All of them were native speakers of Moroccan Darija (the local Arabic dialect) and seven of them were also native speakers of Standard Arabic (starting before age 4). Nineteen of them were also highly fluent in French, one in Spanish, and twenty-seven of them were quite fluent in both romance languages (started in high school or university). All but three were highly proficient and habitual readers of

Standard Arabic. The remaining three also read Standard Arabic comfortably, but they did not do it on a daily basis.

Procedure.

The procedure was essentially the same as in Experiment 1. The difference in this case was that each participant received two sets of five sentences each one. The first set was composed by the five sentences from Experiment 1 and the second set consisted of the following five new sentences.

6 - The triangle is between the circle and the square.

7 - The knife is between the fork and the spoon.

8 - The phone is between the chair and the bed.

9 - The wardrobe is between the door and the window.

10 - The star is between the Sun and the Moon.

For each participant, one block was presented in Standard Arabic and the other block in a Romance language (either French or Spanish, both L-R languages) according to the preference of the participant. Half the participants started with a Romance language and moved to the Arabic language, and the other followed the opposite order. The mapping of sentence sets and languages to blocks was counterbalanced over participants, such that both sets and languages were presented an equal number of times in each block. Within each block, the sentences were presented in a fixed order.

3.1.4.2 Results

Criteria for exclusion of invalid trials were the same as in the prior experiment. Three participants were discarded because all ten trials were invalid. There were no participants with all five trials invalid in one language but at least one valid trial in the other language. Out of the remaining 45 participants, the number of items rejected was 5.3% (6.2% in the L-R language condition and 4.4 % in the R-L language condition).

Experiment 1 showed that there is a strong relation between spatial order and drawn model order, and that object order (affected by working memory management processes) is independent of RWD. Hence, in this second experiment we focused only on the directionality of the drawn models. Table 3 shows cell means and standard errors. The analysis proceeded in two stages. Firstly, we focused only on the first block and compared the L-R Romance group with the R-L Arabic group. The difference in means was in the right direction (58.6% vs. 42.4%; see Figure 3), but the contrast failed short of significance ($t(43) = -1.60$, $p = 0.11$). This might be due to lack of statistical power. One way to increase power for this particular contrast is to pool together the Arabic group in Experiment 2 with the Darija group in Experiment 1. These two groups are equivalent in all respects because they did the task in the same location and culture (Morocco), and their input language is written from right to left (actually, the written language is literally the same, Standard Arabic, see footnote 1). The increased number of observations in one of the samples yielded the contrast between L-R Romance and R-L Arabic significant ($t(60) = -2.19$, $p = 0.03$), suggesting that the directionality of the script of the input language is able to bias the directionality of mental model construction. Finally, it is also possible to pool together the Arab groups who did the task in a L-R language in both experiments (the Arabs-in-Spain group in Experiment 1 and the Romance group in Experiment 2), although the groups are not so closely matched as the two Arabic groups who did the task in Arabic. When both pooled groups are compared, the effect of input language is highly significant ($t(85) = 2.64$, $p = 0.009$).

Is there also an effect of the amount of practice with a script besides the immediate effect of the input language? One way to test this possibility is to compare the L-R Romance group in Experiment 2 (Arabic readers who did the task in a L-R language) and the Arabs-in-Spain group in Experiment 1 (Arabic readers who also did the task in a L-R language, Spanish, after living immersed in Spanish culture for several years). These two groups yielded virtually identical L-R preferences (58.6% vs. 58.8%; $t(46) = 0.01$, $p = 0.99$). Moreover, when these two groups were pooled together and compared to Spanish monolinguals, although their L-R bias is smaller (58.7% vs. 70.7%), this difference still failed to be significant ($t(1,65) = -1.41$, $p = 0.16$). This all runs against an influence of degree of practice with the script on lateral spatial biases (at least in participants who are already highly proficient in both scripts). Perhaps when two scripts of different directionality are practiced enough, such strategies become so fluid that they can be automatically activated by the input language and flipped over without any inertia.

However, Experiment 2 allowed a test of the potential carry-over effects from one language to a subsequent language with different written directionality, as the task was repeated in a second block with different materials in their other language. Thus, we could compare the proportion of L-R models that were produced to a given input language when it is the first language in the experiment versus when it is preceded by a language of different directionality. Therefore, we could also assess whether the carry-over effects differ in magnitude depending on whether they go from the most practiced to the less practiced language and script or the other way around.

The results showed clear carry-over effects of different magnitude for each input language (see Figure 4). When the task was done in a Romance language, the proportion of L-R models dropped from 58.6% to 37.9% when there was a preceding block with the same task in Arabic ($t(43) = 2.13$, $p = 0.03$). In other words, Arabic had a clear carry-over effect on Romance. In contrast, when the task was done in Standard Arabic, the increase from 42.4% L-R models (when done as a first block) to 50.6% (when preceded by Romance) was not significant ($t(43) = 0.82$, $p = 0.41$). That is, Romance failed to have a carry-over effect over Arabic. The most likely reason for this difference is that the Moroccan participants were more highly practiced reading Standard Arabic than their preferred Romance language (either French or Spanish). Therefore, carry-over effects were stronger from the more practiced script to the less practiced script than in the opposite direction. Extended practice in forming mental models with a given directionality does induce a long-term bias toward keeping that favourite directionality, or going back to it more easily.

3.1.5 General Discussion

The present study assessed the influence of RWD habits on mental model construction from auditory linguistic input. In order to tap more directly into the spatial components of those models that relate to RWD, we used descriptions of static scenes as input. The spatial configuration of mental models was inferred from how the scenes were drawn. Experiment 1 showed that Spanish monolingual participants, who read and write from left to right, tend to produce L-R models, whereas Moroccan participants, who mainly read and write in Standard Arabic from right to left (but also know at least one L-R language), show a (smaller) tendency to produce R-L models. A group of Arabs who had been living in Spain for several years showed a L-R bias comparable to the Spanish group, though numerically smaller. Taken together, these results support an effect of RWD habits on mental model construction from language. This occurred in the context of identical strategies of working memory management in all three groups: a similar preference for the order of object production that minimized the number of items and time in memory.

However, because both the Spanish participants and the Arabs-in-Spain group heard the sentences in Spanish, whereas the Moroccan participants heard them in their local Arabic dialect, Experiment 1 was unable to disentangle two possible causes of the observed pattern of spatial biases: the long-term practice with a script versus the short-term influence of the language used as input in the task. In Experiment 2, Moroccan participants carried out the same task in either Standard Arabic or their preferred Romance language (either French or Spanish). When the input language was Standard Arabic, they behaved like the Moroccan group in the prior experiment. When the input language was French or Spanish, they behaved like the Arabs-in-Spain group in the prior experiment. Therefore, the results revealed a clear influence of the input language in spatial biases in mental model construction, suggesting a flexible deployment of spatial strategies depending on the language in use. The Arabic speakers' lateral bias when listening to a L-R language was smaller in size than the bias shown by monolingual L-R Spanish readers, what suggests that there are no graded effects of conflicting bidirectional habits. However, the second block in Experiment 2 revealed carry-over influences from the language used in the first block and, importantly, these influences varied depending on language. A previous block in Arabic had stronger carry-over effects on a subsequent Romance block than vice versa. Although all participants were highly fluent bidirectional bilinguals, their degree of practice with the R-L Arabic script was greater than with the L-R Roman script. Therefore, the pattern of carry-over effects suggests an effect of degree of practice with the script in the face of highly flexible spatial strategies in language comprehension.

All in all, present results both support and qualify the standard view of the origin of RWD effects on high-level skills. In visual language comprehension, as word meanings are accessed, their referents are integrated into a developing mental model of the situation. Maass et al (2009) and Chatterjee (2011) suggested that lateral biases at high levels of cognition arise because extended exposure to a given RWD leads to two effects, which may be causally linked between themselves or not. One is the development of lateral biases in perceptuo-motor habits such as scanning, exploration and hand movements, which can also be applied to internal representations. Either as a consequence of these low-level biases, or as an independent higher-level effect, there is also the establishment of a generalized schema for action that unfolds laterally in the same direction of the script. As a result, referents are placed in the mental model in a script-congruent way. This mental habit generalizes to situations where the linguistic input is not visual but auditory, like in the present study. It also generalizes more widely, reaching all kinds of concepts which are correlated with order of mention in language, such as causal relations in agent-patient interactions (Maass & Russo, 2003), or temporal (Ouellet et al, 2010), numerical (Zebian, 2005) and letter sequences (Shaki & Gevers, 2011). If the pleasantness aroused by visual artistic depictions depends at least partially on their perceived naturalness, this account should also be able to explain the observed effects of script direction on aesthetic preferences (Pérez González, 2012).

Under this view, practice with directionally inconsistent scripts leads to the development of inconsistent habits and thus to competing tendencies of lateral mental model construction. The lateralized schema for action should grow stronger as congruent experiences accumulate, but weaker as conflicting experiences accumulate. Therefore, bidirectional bilinguals should show smaller lateral biases than monolinguals. Many studies support this view (see Santiago & Román, submitted). Present results add to this line of evidence with the finding of a small effect of amount of practice with the script.

However, contrary to the standard view, the clearest finding in the present study supports a very flexible deployment of mental lateral habits in mental model construction during language comprehension as a function of the input language in the experimental task. This evidence comes to join a recent strand in the literature that suggests that bidirectional bilinguals can acquire two contrasting lateral biases and flexibly show either one depending on the characteristics of the situation (e.g., the input language). Such flexible switching has been shown both on low-level skills, such as saccadic eye movements or foveal letter perception (Nazir, Ben-boutayab, Decoppet, Deutsch & Frost, 2004), and high-level representations, such as number and letter sequences (Fischer, Shaki & Cruise, 2009; Shaki & Gevers, 2011; but not always, see Dehaene, Bossini & Giraux, 1993; see Santiago & Román, submitted, for a review). Even more problematic for the standard view are studies that show that just a very small amount of practice with text that provides the opposite directional experiences can lead to complete reversals in lateral biases (see Fisher, Mills & Shaki, 2010, for numbers; Shaki & Gevers, 2011, for letter sequences; and Casasanto & Bottini, 2010, for time; for an extended discussion, see Santiago & Román, submitted). Thus, people can sometimes switch flexibly and automatically from one spatial strategy to another, and an extended degree of practice with both strategies may not always be a requisite.

We suggest that, in order to account for this conflicting pattern of results, an alternative view may be helpful. The view we favour is an extension of the Coherent Working Models theory put forward by Santiago et al (2011). It rests on two assumptions. Firstly, as people become more practiced readers, they develop a strong habit of representing language visually, independently of whether it has been presented in the visual or auditory modality. Secondly, following universal working memory management strategies, the referred contents are accessed and introduced in the model in the order in which they are mentioned. Thirdly, the contents of the model are laid out in the same direction as the representation of the input words due to a characteristic of mental models that has often not been emphasized enough: their push for internal consistency. Perhaps because creating mental models is intrinsically effortful, mental models are constrained to be as internally coherent and simple as possible, given the requirements of the task at hand. We have proposed elsewhere that this characteristic of mental models is central to account for the flexibility of conceptual congruency effects in a wide variety of tasks (Santiago, Ouellet, Román, & Valenzuela, 2012; Santiago et al., 2011). If we assume that both the spatial representation of the input sentence and the mental model of its contents are part of a superordinate mental model of the whole situation, both entities will tend to unfold in the same direction because this will increase the internal coherence of the superordinate model. Because the directionality of the linguistic input is constrained by its entrenched association with written language (whose direction is fixed by the script), it is the directionality of the mental model which will adapt.

If this is so, the directionality of the mental model should depend strongly on the directionality of the language from which the model is being constructed. Changes in the spatial characteristics of the input language may induce very fast remappings of the mental model. Contextual priming, such as the language used for instructions, stimuli, or interaction with the experimenter, should also be able to affect the choice of spatial strategy in conceptual tasks with very little linguistic component, such as those that assess causal, number and time representations.

This account is not incompatible with the development of long-term preferencies for one or another lateral strategy. Bidirectional bilinguals will gain extended practice in constructing models in both directions, developing two contextually-dependent lateral schemas. Characteristics of the situation will control which of the two schemas will be activated and applied in a given occasion. Unbalanced bidirectional bilinguals may generate differential preferences for the use of one or another lateral strategy, and monolinguals are likely to generate a marked preference for the lateral strategy that matches their familiar script.

However, this view is in need of further development in order to provide an integrated account of available data. It will be necesary to specify in detail what are the factors that determine the predominance of short-term factors, such as input language, or long-term factors, such as degree of experience with a script, in a given task and context. So far, it is unclear why sometimes lateral habits are so flexible and require so little practice, whereas other times they develop slowly and are sensitive to the total amount of practice received in each direction throughout years of reading and writing experience. Given the number of different skills and representations that are affected by RWD, the complexity of the results reported so far, and the amount of lacunae that still remain to be filled (Santiago & Román, submitted), this goal seems still far ahead. Our main tenet here is that a more flexible view of the effects of RWD, such as the one just sketched, will probably prove to be a more adequate theoretical tool than prior views that emphasize integration of reading experiences in a single lateralized schema for action.

To sum up, RWD is able to induce directional lateral biases in mental model construction during language comprehension. These spatial biases can be automatically and quite flexibly activated by the current linguistic input, but they also show a small degree of inertia that suggest that they can slowly build up with practice. The challenge for the future is to integrate these two apparently conflicting characteristics into an integrated theoretical account.

3.1.6 Acknowledgments

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Table 1.- Mentioned object order and spatial order combinations, and the resulting drawn models.

Mentioned Object Order	In our example	Spatial Order	Pattern	Drawn Model
123	Table-Lamp-TV	CLR	L-R	Lamp-Table-TV
		CRL	R-L	TV-Table-Lamp
132	Table-TV-Lamp	CLR	R-L	TV-Table-Lamp
		CRL	L-R	Lamp-Table-TV
213	Lamp-Table-TV	RCL	R-L	TV-Table-Lamp
		LCR	L-R	Lamp-Table-TV
231	Lamp-TV-Table	LRC	L-R	Lamp-Table-TV
		RLC	R-L	TV-Table-Lamp
312	TV-Table-Lamp	RCL	L-R	Lamp-Table-TV
		LCR	R-L	TV-Table-Lamp
321	TV-Lamp-Table	LRC	R-L	TV-Table-Lamp
		RLC	L-R	Lamp-Table-TV

Table 2.- Mean percentage of valid trials and standard errors (in brackets) in Experiment 1.

L=Left; R=Right; C=Center	Spaniards (Spanish)	Moroccans (Darija)	Arabs-in-Spain (Spanish)
L-R Drawn Model	70.7 (6.5)	38.3 (5.7)	58.8 (6.7)
L-R Spatial Order	72.6 (8.1)	36 (7.2)	64.7 (7.7)
LRC	7.4 (4.4)	8.4 (3.6)	5.3 (2.6)
LCR	22.8 (7.4)	10.5 (4.1)	13.8 (5.1)
CLR	42.5 (8.4)	17.1 (4.3)	45.6 (8.5)
CRL	24.2 (8.3)	43.4 (7.5)	30.3 (6.6)
RLC	1.1 (1.1)	2.4 (1.6)	1.6 (1.1)
RCL	2.1 (1.4)	18.2 (6.8)	3.4 (1.6)
Object Order 123	58 (7.6)	45.2 (6.7)	56.8 (6.9)
132	8.7 (3.2)	15.3 (4)	19.1 (4)
213	18.6 (6.3)	19 (6)	12.2 (4)
231	6.3 (3.9)	9.7 (4.3)	5 (2.2)
312	4.2 (1.9)	7 (2.8)	6.1 (2.6)
321	4.2 (3.3)	3.8 (2.1)	0.8 (0.8)

Table 3.- Mean percentage of valid trials and standard errors (in brackets) with a L-R drawn model in Experiment 2.

	First block	Second block
Romance (French or Spanish)	58.6 (6.6)	37.9 (7.2)
Standard Arabic	42.4 (7.7)	50.6 (6.5)

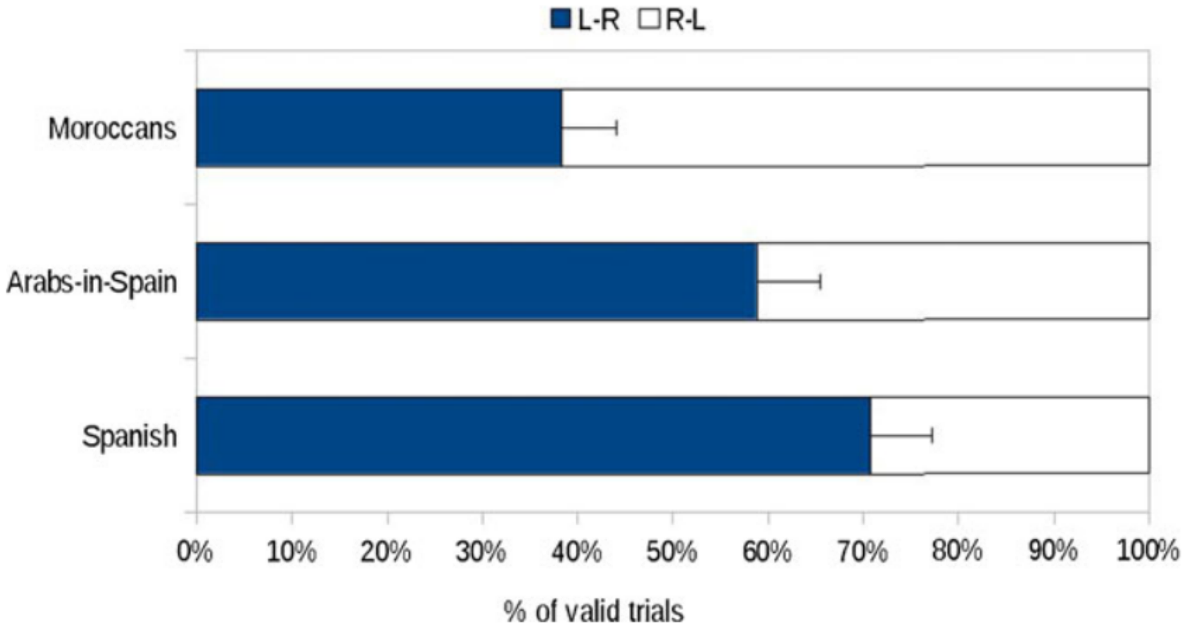

Figure 1.- Drawn model preference (percentage of valid trials) in each group. A value of 50% indicates no lateral bias. Error bars represent the standard error of the mean.

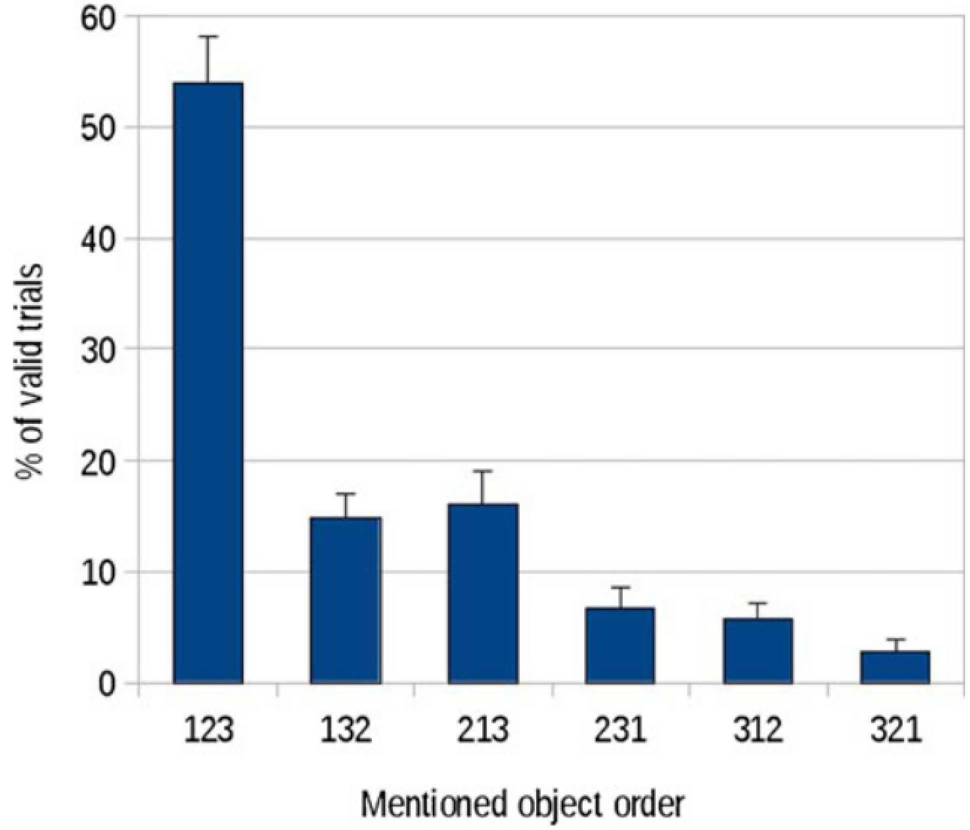

Figure 2.- Percentage of valid trials in each combination of object order. Error bars represent the standard error of the mean.

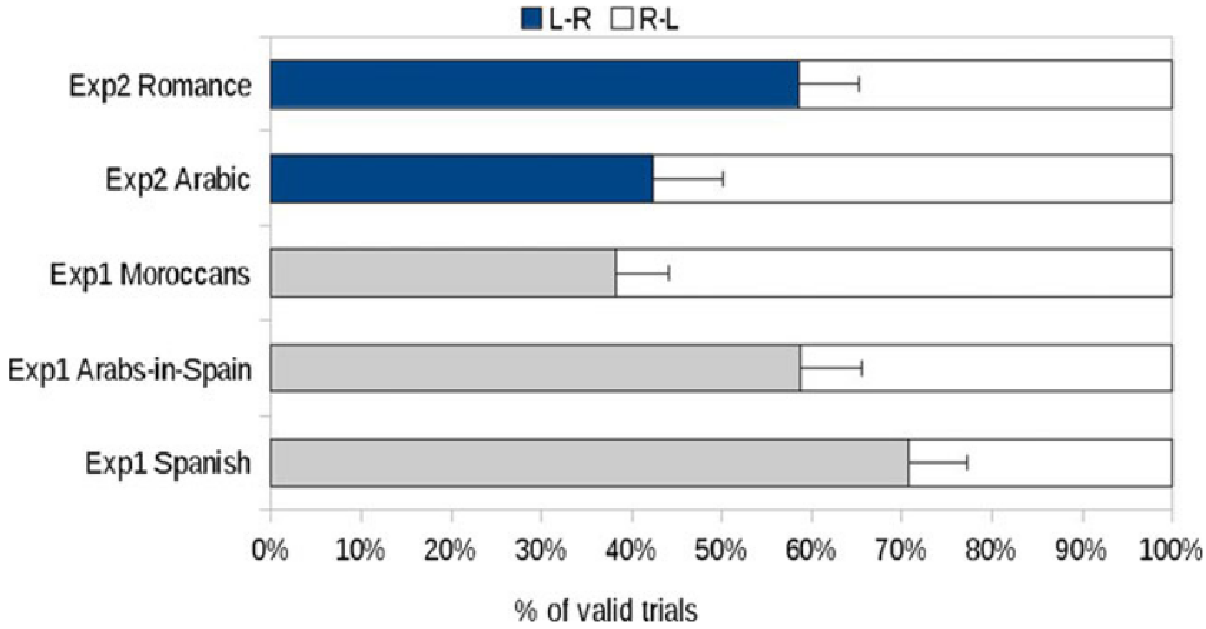

Figure 3.- The upper two bars (in dark grey) present the percentage of valid L-R and R-L models produced by Moroccan participants in the first experimental block, as a function of the input language: L-R Romance (either French or Spanish) or R-L Arabic. The lower three bars (in light gray) present the results of the single block in Experiment 1, reprinted here to ease cross-experiment comparisons. Error bars represent the standard error of the mean.

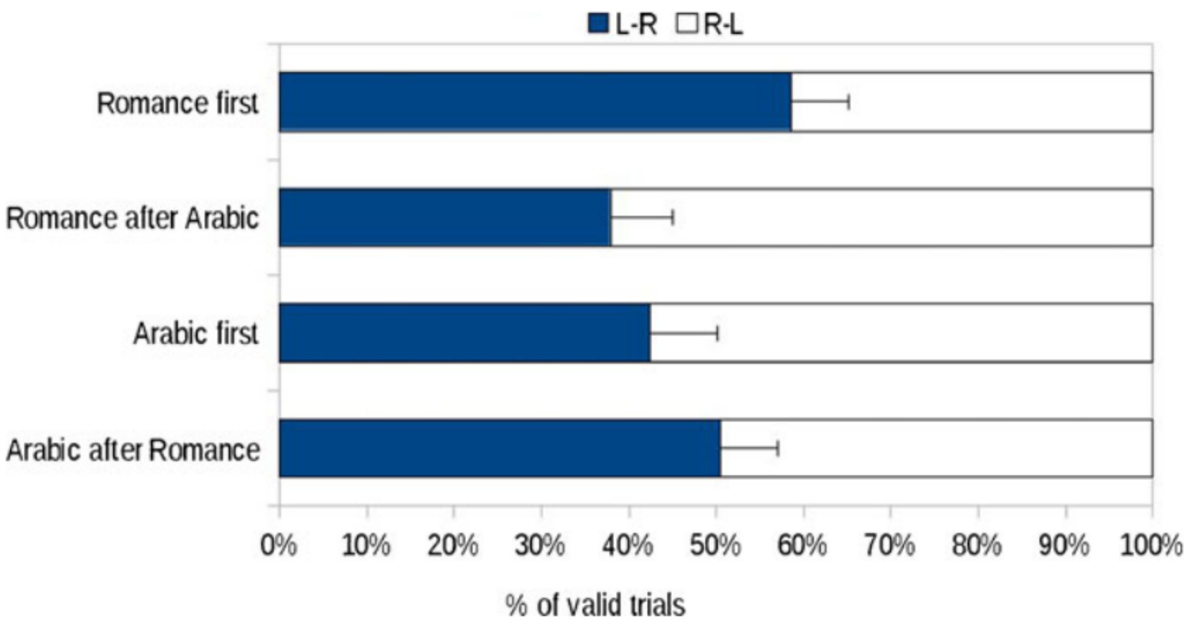

Figure 4.- Drawn model preference (percentage of valid trials) as a function of the input language (L-R Romance or R-L Arabic) when that language was presented in the first block versus when it was preceded by another block in a language of contrasting directionality. Error bars represent the standard error of the mean.

3.2 Reading direction causes spatial biases in mental model construction in language understanding

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3.2.1 Abstract

Correlational evidence suggests that the experience of reading and writing in a certain direction is able to induce spatial biases at both low-level perceptuo-motor skills and high-level conceptual representations. However, in order to support a causal relationship, experimental evidence is required. In this study, we asked whether the direction of the script is a sufficiente cause of spatial biases in the mental models that understanders build when listening to language. In order to establish causality, we manipulated the experience of reading a script with different directionalities. Spanish monolinguals read either normal (left-to-right), mirror reversed (right-to-left), rotated downward (up-down), or rotated upward (down-up) texts, and then drew the contents of auditory descriptions such as “the square is between the cross and the triangle”. The directionality of the drawings showed that a brief reading experience is enough to cause congruent and very specific spatial biases in mental model construction. However, there were also clear limits to this flexibility: there was a strong overall preference to arrange the models along the horizontal dimension. Spatial preferences when building mental models from language are the results of both short-term and long-term biases.

Keywords: Reading and writing direction; Spatial bias; Mental model; Cognitive flexibility; Working memory; Language comprehension.

3.2.2 Introduction

Can arbitrary and irrelevant aspects of the code that conveys a message, such as the directionality of its written script, modulate the mental representation of the contents of the message? In this paper we show that they do. It is now a standard assumption in the psychology of language comprehension that the final representation achieved by comprehenders is a mental model of the described situation (Johnson-Laird, 1983; see Van Dijk & Kintsch, 1983, for a related proposal; see Zwaan & Radvansky, 1998, for a review). Mental models are working memory representations about the world. They are analogical, spatial, and populated by concrete content, although they can also represent abstract content (Goodwin & Johnson-Laird, 2005; Santiago, Román, & Ouellet, 2011). Once set up, mental models can be run in working memory, allowing us to anticipate consequences, reason, solve problems, and plan and perform actions. Language provides instructions that guide mental model construction in the comprehender (Johnson-Laird, 1983). For example, from a verbal description such as "the table is between the lamp and the TV", the listener will construct a mental model that represents the spatial position of those three objects. However, the input leaves unspecified many aspects of the situation, which the comprehender must infer. In the present example, two different spatial arrangements of the three objects are consistent with the sentence: the lamp may be located to the left of the table or to its right (with the TV being situated at the opposite side). Jahn, Knauff, and Johnson-Laird (2007) observed that the preferred initial model for such a description aligns the three mentioned objects horizontally in left-to-right (L–R) order. They suggested that this preference for L–R models was a bias induced by the habitual reading and writing direction (RWD) of their German participants. As shown by Jahn et al. (2007) this bias is not inconsequential: the spatial arrangement of the objects in the mental model helps solving some kinds of problems and hinders others.

Román, El Fathi, and Santiago (2013) confirmed that such spatial biases correlate with habitual RWD as suggested by Jahn et al.(2007). They tested Spanish and Moroccan participants on a task that consisted in drawing the contents of auditorily presented sentences which described every-day elements arranged in static scenes (e.g., "The table is between the lamp and the TV”). Spanish participants showed a preference for drawing the lamp on the left and the TV on the right, whereas Moroccan participants (who read and write in Arabic, a language with a R-L script) tended to draw the lamp on the right and the TV on the left. These results add to a wide, though dispersed, literature, showing that habitual RWD correlates with lateral biases in a variety of mental processes and representations, including low level perceptual and attentional skills (Andrews, Aisenberg, D’Avossa, & Sapir, 2013; Maass, Pagani, & Berta, 2007; Mishkin, & Forgays, 1952; Pollatsek, Bolozky, Well, & Rayner, 1981; Smith, & Elias, 2013; Spalek & Hammad, 2005), visual exploration (Chokron, & Imbert, 1993; Kugelmass, & Lieblich, 1970), motion preferences in drawing (Kebbe, & Vinter, 2012; Nachshon, 1985; Shanon, 1979), item choice from a list (Ariel, Al-Harthy, Was, & Dunlosky, 2011), aesthetic preferences (Chokron, & De Agostini, 2000; Nachshon, Argaman, & Luria, 1999; Pérez González, 2012), product attitudes in advertising (Chae, (Grace) & Hoegg, 2013) and even kissing (Shaki, 2012). RWD also induces lateral biases in the mental representation of abstract concepts, such as number magnitude (Dehaene, Bossini, & Giraux, 1993; Zebian, 2005), time (Fuhrman, & Boroditsky, 2010; Ouellet, Santiago, Israeli, & Gabay, 2010; Tversky, Kugelmass, & Winter, 1991), events (Dobel, Diesendruck, & Bölte, 2007; Maass, & Russo, 2003), letter sequences (Shaki, & Gevers, 2011) and social groups differing in agentivity (Maass, Suitner, Favaretto, & Cignacchi, 2009). Studies conducted with illiterate participants (Dobel, Enriquez-Geppert, Zwitserlood & Bölte, 2014) show an absence of bias, consistently with the bias being caused by RWD.

How flexible are the lateral biases induced by RWD? Many studies in the literature have shown that preliterate children display either no lateral biases (Dobel et al., 2007) or L-R biases not linked to RWD (Kugelmass et al., 1970; Opfer, Thompson, & Furlong, 2010; Shaki, Fischer, & Göbel, 2012). As children learn to read, RWD-linked biases develop slowly and progressively

(Kugelmass et al., 1970; Kebbe et al., 2012; Tversky et al., 1991; Dobel et al., 2007; Shaki et al., 2012; Fagard, & Dahmen, 2003). Teaching children to read a second language with opposite directionality reduces those biases (Kugelmass et al., 1970; Nachshon, 1983) although they can be quite resistant to change when the new script is introduced at the adult age (De Sousa, 2012). This pattern of results suggests that RWD induces spatial habits with a limited degree of flexibility, which needs important amounts of time and practice to develop and change.

In contrast, other studies have shown that these biases are very flexible, and that the mere exposition to a script can make its associated lateral biases to appear instantly in bilinguals (Shaki et al., 2011; Fischer, Shaki, & Cruise, 2009). Román et al., (2013) also tested a group of Moroccan bilinguals in either Standard Arabic or their second L-R language (either French or Spanish). The input language had a clear effect on mental model directionality, supporting a flexible deployment of spatial habits depending on the language in use. There was also a smaller influence of long-term habits linked to the participants' higher practice in reading Arabic (favouring R-L biases). Thus, both short-term and long-term influences can be observed in the manifestation of lateral spatial biases, and it is still unclear what factors are responsible for the preponderance of one or another in a given situation (for a discussion see Román et al., 2013).

Unfortunately, most of the previous studies on RWD-related effects used correlational designs, comparing participants who read different scripts, which precludes random assignment of participants to groups. Therefore, extant studies do not allow us to establish a causal link between RWD and spatial biases, nor to isolate its time course during learning. The observed findings could be accounted for by a myriad of other factors that covary with script direction. For example, many cultural graphic manifestations, such as comic strips, calendars, and charts, covary in directionality with the script, and could account for the observed biases. The most solid conclusions can be drawn from studies that compare bidirectional bilinguals using each of their languages. However, this kind of participants constitute a special case, and the potential effects of modulating factors, such as the degree of bilingualism or the starting age, are still far from clear.

Training studies are better suited to reveal and explore causal effects. In such studies monolingual participants are randomly assigned to groups that practice scripts with different directionalities. This experimental design allows the establishment of causal relations between directional experience and spatial biases in target tasks, while all the other concurring factors are kept constant. To be clear, training studies can show that script directionality is a *sufficient* cause of changes in spatial biases. They cannot establish whether script directionality is a necessary cause, whether there are other causal factors in the spatial biases acquired by children during development in naturalistic situations, or how these other causes may interact with script directionality. However, establishing the status of script directionality as a sufficient cause of spatial biases is an important research goal. An additional advantage of training studies is that they also allow to measure the amount of training necessary for the development of the biases, as well as their course of decay.

To our knowledge, only two studies so far have followed this approach. Fischer, Mills, and Shaki (2010) showed that manipulating the associations of small and large numbers with the left and right sides of lines within a set of 20 cooking recipes (without changing script direction) was enough to change, and even revert, the SNARC effect. This study showed that some factors other than script direction may actually be able to induce spatial biases, and that their effects may develop quite fast. The only study which has directly manipulated script direction is Casasanto and Bottini, (2014). Dutch participants presented with phrases like “one day later” were asked to judge whether the stimuli referred to the past or the future by pressing either a left or right key, or an up or down key. Text could be presented either in L-R direction, mirror reversed (R-L), or 90º rotated downwards (up-down, U-D) or upwards (down-up, D-U). After a short practice, mirror reading was able to reverse the standard association between left and past, and right and future, showing faster latencies for right-past and left-future responses than with the opposite mapping. When both text and response keys were rotated onto the vertical axis, U-D text induced an up/past-down/future congruency effect, and D-U text induced the reversed one. These seminal results support that script direction is a sufficient cause of biases in the directionality of the spatial representation of time, suggesting again that these directional habits can be established after a very short practice.

One central aim of the present study was to extend Casasanto et al., (2014) results to a task that taps onto the processes of mental models construction from linguistic inputs. This task is a variant of the drawing task used by Román et al., (2013). First of all, participants had to read a short Spanish text in either standard (L-R), mirror reversed (R-L), or 90º rotated print, either upwards (D-U) or downwards (U-D). Then, descriptions of static scenes involving geometrical shapes, such as "the square is between the cross and the triangle", were presented auditorily. Finally, participants were asked to draw the three objects on a sheet of paper, in order to assess whether and how the directionality of their drawings was influenced by the prior reading experience. The drawing task used geometrical shapes instead of real world objects as in Román et al., (2013), so that participants would not feel necessarily compelled to arrange them along the horizontal axis.

3.2.3 Experiment

3.2.3.1 Methods

Participants. One hundred Spanish psychology students at the University of Granada (mean age 21.9 years; 14 males; 5 left-handed). All of them were native Spanish speakers and did not know any language with a different RWD. Informed consent was obtained from all participants. The procedure of the study was approved by the Ethics Committee of the University of Granada and it was carried out in accordance with the approved guidelines.

Materials. For the reading task, we prepared a 1195 words fiction narrative in Spanish. Words were printed in 15 points Arial font. The text occupied four pages; each one contained five to six paragraphs of four to six lines each one. For the drawing task we selected nine common geometrical shapes which could be drawn easily (square, rectangle, cross, rhombus, triangle, circle, trapezium, oval, pentagon). As a result of combining the names of those geometrical shapes, 441 sentences describing a between relation among three different shapes were constructed. For example, “The circle is between the cross and the rectangle” or “The oval is between the triangle and the rhombus.” All sentences referred to completely static scenes without any agentive structure. From this set of 441 sentences, 40 sentences were randomly selected to be used in the task (see Appendix). They were randomly divided into two lists of 20 sentences each one. Each participant was presented with only one list. The sentences were read aloud by a female experimenter and recorded in independent sound files.

Procedure. The participant sat in front of a computer screen at a desk with a pen and a stack of 20 blank square sheets. Stimulus presentation was controlled by Eprime 2.0. Participants were instructed that they should read aloud a 4-page text presented on the screen at their own pace. Reading aloud secured that the text was read. Instructions warned them to pay attention to the text because at the end of the experiment there would be five questions about the content of the story. Each group of 20 participants read the text with a different directionality (see Fig. 1): L-R (standard), R-L (mirror reversed), U-D (rotated 90º clockwise), and D-U (rotated 90º counterclockwise). There was also a control group with 20 participants that performed the drawing task without the prior reading phase. After finishing reading, they moved on to draw a set of auditorily presented sentences, each one on a different sheet. This task was presented as a filler task before the final comprehension questions. Care was exercised not to mention any particular spatial arrangement (e.g., horizontal) for the drawings. The program presented the sentences through loudspeakers. Participants controlled the rate of presentation by pressing a button to advance to the next one.

Data coding. During the drawing task, the experimenter stood behind the participant and coded in situ and out of the participant's sight the order in which each of the three mentioned objects was drawn (object order) and the order in which participants completed the different spaces in the sheet: right, left, center, up, down or any other (spatial order). Finally, model order was coded a posteriori from the drawings themselves, depending on the locations where the two side objects were placed with respect to the central object (for more detail, see the Data Coding section in Roman et al., 2013). As discussed in Román et al., (2013) the three measures (object order, spatial order, and model order) are linked, such that the use of a given object and spatial order determines a final model order. For example, when the three objects mentioned in the sentence "the square is between the triangle and the cross" are drawn in order 123 (the same order of mention, starting with the square, followed by the triangle, and then the cross) and in the spatial order CLR (filling up first the central position, then the left and then the right position), the resulting model is necessarily a L-R model ("triangle - square - cross"). Román et al., (2013) observed a strong tendency to draw objects in the same order as they are mentioned in the sentence (58% of trials in the Spanish readers group) with all the other orders being preferred to the same (low) extent (betwen 2.9 and 16.6%). Spanish (L-R) and Moroccan (R-L) readers showed the same pattern, suggesting that this preference is caused by a shared strategy devoted to minimize working memory load. Therefore, the differences in preferred mental model directionality arose from differences in the order in which the spatial slots were filled, with the order CLR being modal in the Spanish group (42.5%), and the order CRL being modal in the Moroccan group (43.4%). Román et al., (2013) thus showed that analyzing spatial order and object order independently did not qualify the results obtained in the measure of model order, so in the present study we focused our anlysis only on the latter. However, as a control check, we also report the analysis of object order in all five groups.

Design and Data Analysis. There were four experimental groups of 20 participants, depending on the directionality of the training: L-R (standard), R-L (mirror reversed), U-D (rotated 90º clockwise), and D-U (rotated 90º counterclockwise). Furthermore, we run a control group of 20 participants with no reading phase to serve as a baseline. In each condition, the number of drawings with a L-R, R-L, U-D and D-U directionality was counted. Because the four conditions are not independent, it was not possible to use ANOVA. Therefore, we took two approaches to the analysis. In the first one,we turned to 95% confidence intervals and t-tests in order to estimate whether the number of drawings of a given kind was significantly different from zero and from the other conditions. The percentage of responses of each kind was computed for each participant in each experimental group, and these percentages were compared by means of t-tests. In the second approach, we computed binomial logistic regressions. Due to the categorical and multinomial nature of our dependent variable, it would be appropriate to apply a mixed-effect multinomial regression, since participants can produce only four qualitatively different responses (horizontal left, horizontal right, vertical up or vertical down). However, to simplify the analysis and to have the freedom to focus on the contrasts in which we are interested, we carried out binomial logistic regressions in which the relevant response alternatives were pooled into only two contrasting kinds. This requires dummy coding our dependent variable (percentage of responses in each direction) into a dichotomous variable where, for each of the 4 possible responses, the direction chosen by the subject is set to “1” and the rest are assigned the value “0”. Thus, we could test, for example, whether the proportion of RL responses (dummy coded as 1) after reading mirror-reversed text is higher than after reading standard text. If these ratios differ it will be reflected in the odds ratio taking values away from “1”. For each relevant contrast we report Wald's χ^2 statistic, the odds ratio and its confidence intervals. Overall, the pattern of results is the same using t-tests and binomial logistic regressions. In a few cases where the t-test is not significant or approaches significance, regression shows greater sensitivity, reaching significance. We also report effect sizes using both Hedges' g and the Common Language (CL) effect size, which indicates the probability that, for any randomly selected pair of individuals, the score of the person from one group is higher than the score of the person from the other group (Lakens, 2013). We were also interested in analyzing the time course of the decay of the effect of prior reading experience. Thus, we analyzed the percentage of LR models for each of the 20 trials of the drawing phase. We expected the effect to be largest at the beginning of the drawing phase and to fade progressively away.

Open materials and data. All materials, programs and raw data can be obtained from Open Science Foundation at http://osf.io/v2n5x

3.2.3.2 Results

If the central object (e.g., the circle in the sentence "The circle is between the cross and the rectangle") was drawn anywhere else than at the center, the trial was considered invalid and was not included in the final analysis. Trials where it was not possible to ascertain the axis along which the objects were drawn (i.e., diagonal arrangements) were also discarded. The number of items rejected was less than 2%. Left-handers were few (five) and unequally distributed between groups, so the effect of handedness could not be assessed. The results did not change in any relevant way if left-handers were removed from the data. The average time (in seconds) of the previous reading phase for each condition was: Control = 0 s; L-R = 421 s; R-L = 1820 s; D-U = 433 s; U-D = 512 s. The average time of the final drawing phase for each condition was: Control = 321 s; L-R = 313 s; R-L = 282 s; D-U = 305 s; U-D = 265 s.

The control group (drawing task without prior reading of the text) showed 83.5% of L-R models. This percentage is similar to that found in the Spanish participants of Román et al., (2013) which amounted to 70.7%, and shows the default effect of native RWD. The results revealed clear effects of the prior reading phase (see Fig. 2). All the conclusions that can be drawn from visual inspection of confidence intervals in Fig. 2 were supported by t-tests and binomial logistic regressions.

In the group who read standard L-R Spanish, there were no vertically oriented drawings. Most drawings (98.2%) were arranged along the horizontal axis, flowing from left to right. The remaining drawings (1.8%) were horizontal from right to left, and did not differed significantly from zero (see Fig. 2; $t(19) = -1.95$, $p = .07$). The L-R group scored significantly higher in L-R models (M =

98.2%, *SD* = 4.15) than the control group (*M* = 83.5%, *SD* = 27.63; $t(38) = 2.35$, $p = .02$, *M1-M2* = 14.7, 95% *CI* = [2.04, 27.34]; Hedges's $g_s = 0.73$, *CL* = .70; Wald $\chi^2 = 31.4$, $p < .001$, *Odds ratio* = 9.79, 95% *CI* = [4.41, 21.74]).

By contrast, in the group who read mirror reversed R-L text, the percentage of L-R drawings decreased to 55.1% while R-L drawings increased to 44.9%. Again, there were no drawings with vertical directionality. The number of L-R models was lower in the R-L group (*M* = 55.1%, *SD* = 32.28) than in the control group (*M* = 83.5%, *SD* = 27.63; $t(38) = -3.0$, $p < .005$, *M1-M2* = 28.4, 95% *CI* = [9.21, 47.67]; Hedges's $g_s = 0.93$, *CL* = .75; Wald $\chi^2 = 76.4$, $p < .001$, *Odds ratio* = 4.6, 95% *CI* = [3.27, 6.48]). This number was also clearly smaller than in the L-R group (*M* = 98.2%, *SD* = 4.15; $t(38) = 5.93$, $p < .0001$, *M1-M2* = 43.1, 95% *CI* = [28.40, 57.86]; Hedges's $g_s = 1.84$, *CL* = .91; Wald $\chi^2 = 93.15$, $p < .001$, *Odds ratio* = 45.04, 95% *CI* = [20.79, 97.60]). Therefore, a brief experience of reading in the usual L-R or opposite R-L direction was able to affect the directionality of mental models built from auditorily presented sentences.

The two groups with previous exposure to horizontal reading (L-R and R-L) showed a very strong preference to locate the drawn models on the horizontal axis, as not a single vertical drawing was produced. Would previous experience with a vertical script change this preference? As shown in Fig. 2, the U-D group also showed a predominance of L-R models (*M* = 76.9%, *SD* = 22.4), which was not significantly different from the Control group by t-tests ($t(38) = 0.83$, $p = .41$), but significantly lower by logistic regression (Wald $\chi^2 = 7.9$, $p = .005$, *Odds ratio* = 1.68, 95% *CI* = [1.17, 2.42]). The number of L-R models in the U-D group was also below the level of the L-R group (*M* = 98.2%, *SD* = 4.15; $t(38) = 4.18$, $p = .0002$, *M1-M2* = 21.3, 95% *CI* = [10.98, 31.66]; Hedges's $g_s = 1.29$, *CL* = .82; Wald $\chi^2 = 49.2$, $p < .001$, Odds ratio = 16.49, 95% *CI* = [7.54, 36.09]), but above the level of the R-L group (*M* = 55.1%, *SD* = 32.28; $t(38) = -2.48$, $p < .02$, *M1-M2* = 21.8, 95% *CI* = [4.05, 39.6]; Hedges's $g_s = 0.77$, *CL* = .71; Wald $\chi^2 = 41.52$, $p < .001$, *Odds ratio* = 2.73, 95% *CI* = [2.01, 3.7]). The percentage of R-L models in the U-D group (*M* = 14.5%, *SD* = 23.9) was also at the same level as the control group (*M* = 16.2%, *SD* = 27.8; *t*(38) = -0.21, *p* = .83; Wald χ^2 = 0.015, *p* = .90, *Odds ratio* = 1.025, 95% *CI* = [0.69, 1.52]), below the level of the R-L group (*M* = 44.9%, *SD* = 32.28; *t*(38) = 3.38, *p* < .01, *M1-M2* = 30.4, 95% *CI* = [12.2, 48.6]; Hedges's g_s = 1.05, *CL* = .77; Wald χ^2 = 81.3, *p* < .001, Odds ratio = 4.81, 95% *CI* = [3.42, 6.77]) and above the level of the L-R group (*M* = 1.8%, *SD* = 4.15; *t*(38) = 2.34, *p* = .02, *M1-M2* = 12.7, 95% *CI* = [1.72, 23.7]; Hedges's g_s = .73, *CL* = .7; Wald χ^2 = 30.2, *p* < .001, Odds ratio = 9.36, *CI* = [4.21, 20.78]). Overall, the proportion of L-R and R-L models in the U-D group moves closer to the values of the control group. In the case of L-R models, understandably it is slightly below the control group because the fixed total number of responses must be shared among a greater number of alternatives. Thus, some practice with U-D reading did not change dramatically the proportion of L-R and R-L models as compared to a situation of no prior reading.

However, previous experience reading U-D text was indeed able to increase U-D models from 0% to 8.3%, a numerically small but significant change, as assessed by a t-test against zero (see Fig. 2; *t*(19) = 4.51, *p* = .0002). In contrast, the percentage of D-U models was not significantly different from zero in this group (*t*(19) = 1, *p* = .33). In short, reading U-D script selectively increases congruent U-D models.

In the group with prior experience reading D-U text, the number of L-R models (*M* = 64.53%, *SD* = 39.19) fell below the L-R group (*M* = 98.2%, *SD* = 4.15; *t*(38) = -3.82, *p* < .001, *M1-M2* = 33.67, 95% CI [15.83, 51.51]; Hedges's g_s = 1.18, *CL* = .80; Wald χ^2 = 72.2, *p* < .001, Odds ratio = 28.9, 95% *CI* = [13.3, 62.9]), and even below the control group (*t*(38) = 1.8, *p* = .08; Wald χ^2 = 37.1, *p* < .001, Odds ratio = 2.95, 95% *CI* = [2.08, 4.19]), and the U-D group (*t*(38) = 1.22, *p* = .23; Wald χ^2 = 12.4, *p* < .001, Odds ratio = 1.75, 95% *CI* =[1.28, 2.40]). Again, the decline in L-R responses can be due to increased numbers in other directions. In fact, the D-U group is the one with more kinds of different responses. The amount of R-L models (*M* = 17.1%, *SD* = 29.0) was similar to that in the control group (*M* = 16.2%, *SD* = 27.8; *t*(38) = 0.1, *p* = .92; Wald χ^2 = 0.22, *p* = .64; Odds ratio

= 1.1, 95% *CI* = [0.74, 1.62]) and U-D group (*M* = 14.5%, *SD* = 23.9; *t*(38) = 0.31, *p* = .76; Wald χ^2 = 0.36, *p* = .55, Odds ratio = 1.13, 95% *CI* = [0.76, 1.66]). In contrast, it was greater than in the L-R group (*M* = 1.8%, *SD* = 4.14, *t*(38) = -2.33, *p* = .02, *M1-M2* = 15.3, 95% *CI* = [2.04, 28.56], Hedges's g_s = 0.72, *CL* = .70; Wald χ^2 = 33.7, *p* < .001, Odds ratio = 10.54, 95% *CI* = [4.76, 23.32]) and smaller than in the R-L group (*M* = 44.9, *SD* = 32.28; *t*(38) = -2.86, *p* = .006, *M1-M2* = 27.83, 95% *CI* = [8.2, 47.47]; Hedges's g_s = 0.89, *CL* = .74; Wald χ^2 = 72.5, *p* < .001, Odds ratio = 4.27, 95% *CI* = [3.06, 5.97]).

Reading D-U text did increase D-U models significantly above zero (*t*(19) = 2.77, *p* = .01). Moreover, there was also a trend toward increasing the proportion of U-D models above zero (*t*(19) = 1.97, *p* = .06). Therefore, the data suggest that the effect of reading D-U text was somewhat less specific than the effect of reading U-D text, leading to a clear, though small, increment of D-U models but also to a slightly elevated proportion of U-D models.

The analysis of the effect throughout the drawing trials reveals a progressive decay. Figure 3 shows the percentage of L-R models in the L-R, R-L and control groups. A t-test of the slope of the regression line for each condition shows a slope different from zero in the R-L group (*t*(19) = 3.73, *p* = .001), but neither in the control group (*t*(19) = 1.65, *p* = .12) nor in the L-R group (*t*(19) = 0.06, *p* = .95).

As a final control check, we report the percentages of choice of each object order in each group in Table 1. All groups showed equally strong preference for object order 123 (i.e., drawing objects in the same order as they are mentioned in the sentence), thereby replicating prior findings by Román et al., (2013). Actually, the preference for object order 123 in the current study (*M* = 81.9%) seems to be greater than in the Spanish group of Román et al., (2013) (*M* = 58%). The reasons for this difference are at present unclear, but it may be related to the use of objects with more difficult names in the present study (geographical shapes versus common objects). The preference for object order 123 is likely due to a strategy that seeks to minimize working memory load. The use of this strategy in all groups and to the same extent therefore suggests that the observed differences in mental model directionality across the groups are due to the order in which the positions on the paper are filled, as also pointed out by Román et al., (2013).

3.2.4 Discussion

In the present study, a group of participants listened to spoken sentences of the kind “The triangle is between the square and the circle” and drew the described scenes. Four other groups carried out the same task after reading a short text with either L-R (standard), R-L (mirror reversed), U-D (downwards) or D-U (upwards) script. The directionality of their drawings revealed both long-term spatial biases, stable and difficult to change, as well as short-term, highly flexible biases. Firstly, there was a strong preference to construct mental models along the horizontal versus the vertical axis. This was observed in all groups, including those that read vertically oriented text, even though the geometrical figures could be drawn just as well along the vertical axis. This preference for horizontal models may have different and non-exclusive sources. It may be the result of long-term experience with a horizontal script, of universal preferences of mental model construction, or biomechanical factors like locomotion in the horizontal plane. In fact, people may have the tendency to place the objects in a mentally simulated scene as if they were resting on the ground instead of piled up in a stack, which is probably a less frequent arrangement in the everyday experience of the world. Future studies using readers of vertical scripts, such as Taiwanese Chinese, can help disentangle these possible causes.

Horizontal models also revealed a clear preference for arranging the elements from left to right, as it was also observed in the Spanish group of Roman et al., (2013). This supports previous evidence about a strong default L-R bias for Spanish readers, which may also result from two sources: the long-term experience with a L-R script, and the universal tendencies that favour L-R processing. This latter possibility is supported also by several prior studies showing that the L-R bias in L-R readers is stronger than the R-L bias in R-L readers (as reported by Román et al., (2013) in a task analogous to the present one; see the Introduction for references using other methodologies).

Can long-term biases be affected by a short reading experience? The present study provides a positive answer to this question. A short practice reading in each of the four directions was able to induce quite specific spatial biases on drawings, which followed the same direction of the prime text. Reading mirror reversed R-L text increased considerably the amount of R-L models, while reading U-D and D-U texts was also able to significantly increase (above zero) the amount of U-D and D-U models, respectively, although the size of this increase was numerically small. Given the absolute absence of vertical models in the control group, as well as in the two horizontal reading groups, this small increase is no doubt of theoretical relevance. Finally, even when the prime text was presented in the standard L-R fashion, it was able to intensify the default L-R bias, suggesting that even pre-established, life-long L-R tendencies can be strengthened by immediate practice.

The present results suggest that the amount of practice needed to substantially change previously established tendencies is very small: less than 10 minutes (except in the mirror R-L condition, which took about 30 minutes) of reading a text with a different directionality sufficed to affect spatial preferences in mental models construction. This is in agreement with the study by Casasanto & Bottini,[42] but contrasts sharply with many studies that document a slow and progressive development of spatial biases during the process of learning to read (e.g., see Kugelmass et al., 1970; see review in the Introduction section) and suggests the implication of different mechanisms underlying short-term and long-term biases. The present findings also showed that short-term biases are short-lived, and may vanish after a period of a few minutes. It is possible that repeated, consistent experiences will produce short-term biases that progressively return to lower asymptotes, leading to the modification of prior long-term biases, or to the establishment of different ones.

In our view, the two types of biases (short and long-term) are two sides of the same coin. Both have a great adaptive value and are necessary for a good performance in an environment which is both stable and constantly changing. We need, on one hand, an extremely flexible system that can adapt to sudden changes in our experience. On the other hand, we need a long-term memory system where adaptations to persistent changes can progressively crystalize, avoiding the need of relearning the new conditions. Future studies using training designs providing more extended practice should be able to trace the time course of the establishment of long-term biases in detail.

Present results, as well as those in Román et al., (2013), are consistent with the following process model of the implementation of spatial biases induced by reading direction. When understanding sentences like “the A is between the B and the C”, participants overwhelmingly use a strategy aimed at minimizing working memory load, such that objects are drawn in the same order as they were mentioned in the sentence. Thus, in most trials their performance can be explained by the use of a phonological buffer in which they maintain the just heard sentence in verbatim form by a process of repetitive rehearsal (akin to the phonological loop proposed by Baddeley and Hitch). As they rehearse the sentence, the mentioned objects are included in the mental model and drawn on paper in the same order as they appear in the sentence. The first-mentioned reference object is drawn first at the central location. It is when the second object is rehearsed and placed in the model and on the paper when a decision must be made about its location with respect to the central object. At this moment, prior reading experiences bias participants' choices, both regarding the spatial axis (horizontal or vertical) and the side on that axis. The location of the third object is then chosen by placing it at the opposite end of the axis on which the second object stands.

To conclude, the present findings provide clear support for a causal influence of RWD on the spatial inferences that are made during mental model construction from auditory linguistic input. It remains to be determined whether RWD is the one and only source of directional biases, as the same directional training can also be obtained from experiences with comic strips, book pages, number lines, charts, etc. The present study clearly establishes that exposure to text is a sufficient cause, in and by itself, of change in spatial biases, but does not discard other potential concurring causes.

3.2.5 Acknowledgments

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Table 1.- Percentage of choice of each object order in each group. Order 123 means that the object mentioned first is drawn first, the object mentioned second is drawn second, and the object third is drawn in third place. Order 312 means that the object mentioned third in the sentence is drawn first, followed by the object mentioned in first place and, finally, the object mentioned in second place.

Object order	Control	L-R	R-L	U-D	D-U
123	82.0	79.0	82.9	85.2	80.3
132	0	5.4	8.3	6.3	7.7
213	10.7	6.9	1	1.8	6.9
231	7.3	7.9	7.1	5.8	3.6
312	0	0	0	0.5	0.3
321	0	0.8	0.8	0.5	1.3

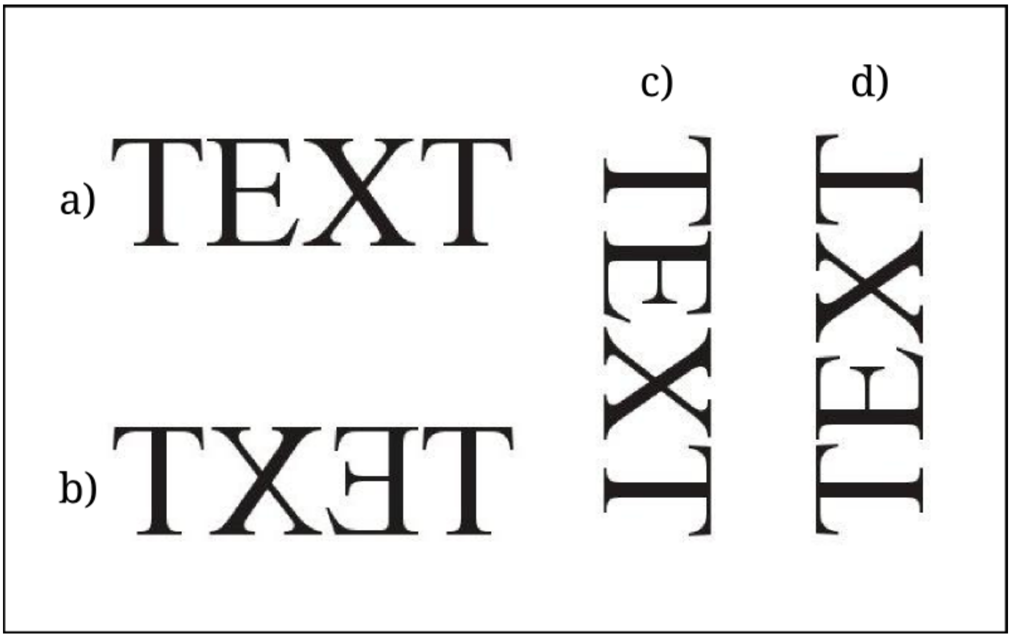

Figure 1: a) Standard L-R text; b) Mirror R-L text;c) Downwards U-D text; d) Upwards D-U text.

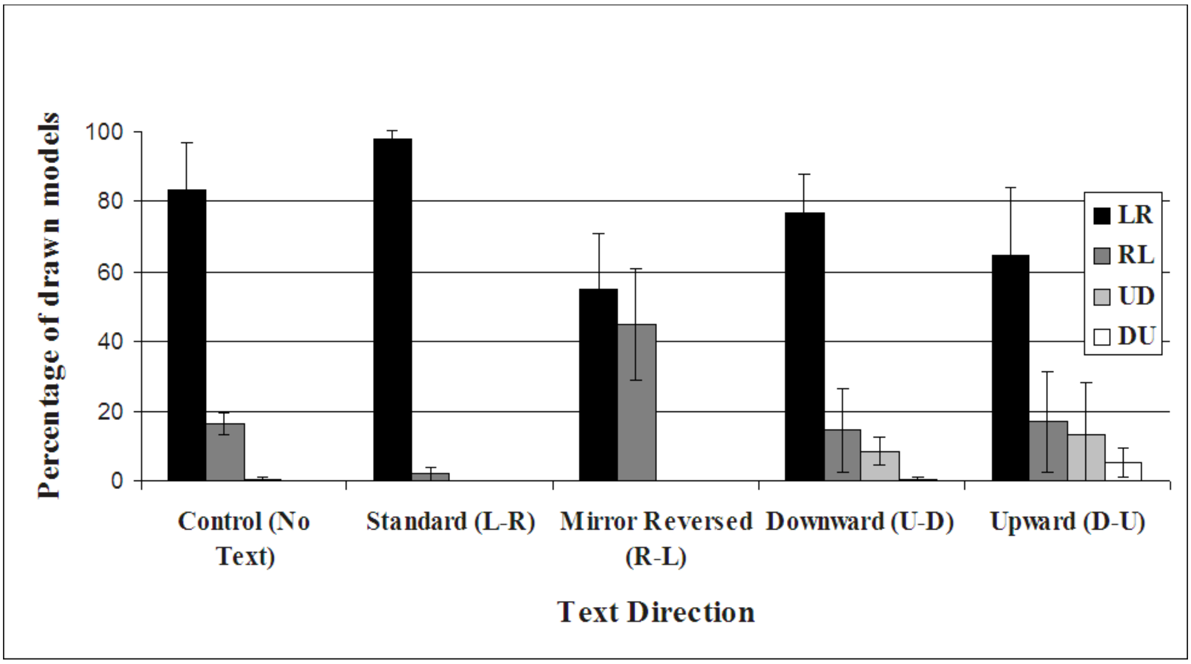

Figure 2: Proportion of drawn models of each directionality (L-R, R-L, U-D, and D-U) in each training group. Error bars show 95% confidence intervals.

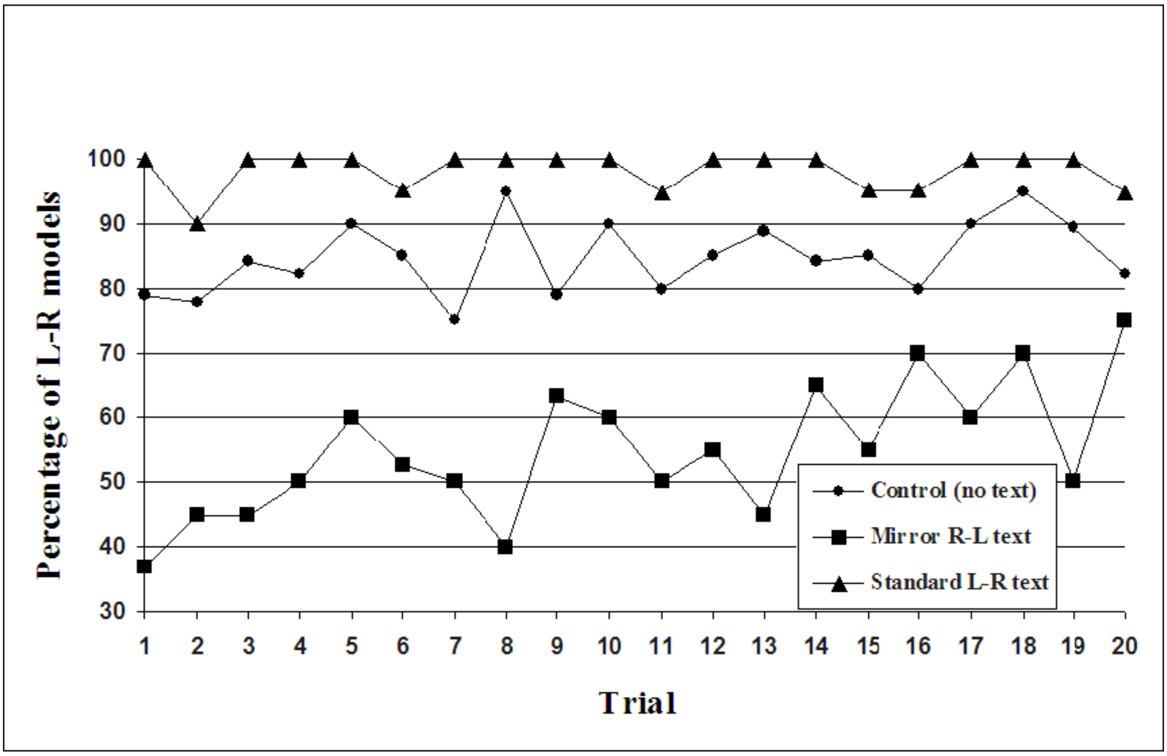

Figure 3: Percentage of L-R models over trials in the L-R, R-L and control groups.

3.3 When script is not essential: Effects of directional scanning of speechless comics on lateral spatial biases in language comprehension

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3.3.1 Abstract

Reading and writing direction is linked to a number of left-right spatial biases in cognition, including biases in mental model construction in language understanding, as well as the mental representation of number and time. However, number and time mental lines are in place before children begin to read. One potential alternative cause are the experiences of looking at picture books together with a caregiver, which occur well before the beginning of reading. In the present study, we tested whether the directional scanning of a speechless comic in either standard (left-to-right) or mirror reversed (right-to-left) form is a sufficient cause to produce lateral biases in mental model construction in adult Spanish participants. In Experiment 1, the unconstrained exploration of the comic did not change lateral biases. One possible reason is that the use of incongruent and internally inconsistent exploration movements may provide contradictory directional experiences. Experiment 2 presented the vignettes incrementally on screen in horizontal strips, thereby forcing a highly consistent and directionaly congruent scanning pattern. Now, the mirror comic was able to alter preexisting lateral biases. We conclude that consistent scanning patterns of picture sequences (without script) are a sufficient cause of lateral biases in mental model construction in language comprehension, and therefore, they constitute a potential cause for the generation of early lateral biases in pre-readers.

Keywords: Reading and writing direction; Spatial bias; Mental model; Cognitive flexibility; Working memory; Language comprehension; Comic; Visual scanning.

3.3.2 Introduction

The writing script is a cultural artefact with which literate people accumulate many hours of interaction during their lives, opening the possibility that irrelevant aspects of the script such as its left-right directionality affect perception and cognition. There is now a wide literature that suggests that habitual reading and writing direction (RWD) affects many levels of the cognitive system. At lower-levels, it induces RWD-consistent spatial biases in cognitive processes such as lateral motion perception (Maass, Pagani, & Berta, 2007), word reading (Mishkin & Forgays, 1952), perceptual span (Pollatsek, Bolozky, Well, & Rayner, 1981), visual exploration (Chokron & Imbert, 1993; Kugelmass & Lieblich, 1970), and spatial attention (Spalek & Hammad, 2005). At higher levels, it induces a preference to represent numbers along a left-right mental number line (Dehaene, Bossini, & Giraux, 1993), to represent time along a left-right mental time line (Ouellet, Santiago, Israeli, & Gabay, 2010; Tversky, Kugelmass, & Winter, 1991), to represent the agent-patient structure of events following a left-right schema of action (Maass & Russo, 2003; Maass, Suitner, & Nadhmi, 2014), and to construe the meaning of sentences describing spatial scenes proceeding along the left-right axis (Román, El Fathi, & Santiago, 2013). RWD affects also the aesthetic choices of artists (Pérez González, 2012), the aesthetic feelings induced by pieces of visual art (Chahboun, Flumini, Pérez-González, McManus, & Santiago, submitted; Chokron & De Agostini, 2000; Nachshon, Argaman, & Luria, 1999) or the attitudes aroused by advertisements (Chae & Hoegg, 2013). The effect of RWD on these spatial biases is consistent with some findings from illiterate participants and preliterate children. Neither illiterate people (Dobel, Enriquez-Geppert, Zwitserlood, & Bölte, 2014) nor preliterate children (Dobel, Diesendruck, & Bölte, 2007) show spatial biases regarding the representation of the agent-patient structure of events. Zebian (2005) reported that illiterates do not show spatial biases in the representation of numbers (see also Shaki, Fischer, & Göbel, 2012, exp.1), and Berch, Foley, Hill, and Ryan (1999) and White, Szűcs, and Soltész (2012) did not find spatial biases in number representation in children younger than 7 years of age (Grade 2).

Therefore, RWD seems to be a key factor in producing many kinds of spatial biases at both low and high levels of the cognitive system.

Most of the studies cited above compare preestablished groups (i.e., users of scripts with different directionality, illiterates, preliterate children...). Yet, these studies, by their very nature, can provide only correlational evidence. Evidence of a causal relation between RWD and this wide family of spatial biases has so far been reported by a very small number of studies that experimentally manipulated script directionality and assessed its effects, both of them at high cognitive levels. Casasanto and Bottini (2014) presented Dutch readers with standard left-to-right (L-R), mirror reversed (R-L), up-down or down-up text in a task designed to assess the directionality of the mental representation of time. All three non-standard reading conditions were able to induce congruent changes in the directionality of the mental timeline. Recently, Román, Flumini, Lizano, Escobar, and Santiago (submitted) used a similar rationale to test whether RWD can cause biases in the construction of mental models of descriptions of spatial scenes. After reading a short text presented in either standard, mirror, up-down, or down-up script, the participants heard sentences such as “the square is between the cross and the circle” and drew the described scenes. Their drawings revealed that non-standard script directionality was able to significantly change the spatial arrangements of the objects in their conceptualization of the scenes. These studies prove that the direction of the script is a sufficient condition, able by itself to cause changes in at least some members of this family of spatial biases.

Therefore, the case for an effect of habitual RWD on a number of spatial biases in cognition seems to be well established. However, recent studies have reported the presence of some of these biases in preliterate children, suggesting that learning to read and write cannot be the whole story. Most of these studies have focused on the development of the spatial representation of numbers, the mental number line. Using tasks adapted for young children, Opfer, Thompson, and Furlong (2010) and Opfer and Furlong (2011) found that English-speaking preschoolers (4 years old) expect numbers to appear ordered from left to right. Consistent results have been reported by Ebersbach, Luwel, and Verschaffel (2014), Ebersbach (2015), Patro and Haman (2011), and Patro, Nuerk, and Cress (2015). In the only cross-linguistic study, Shaki et al. (2012) assessed directional counting preferences in English-, Arabic-, and Hebrew-speaking preschoolers (4 years old), and observed that children at this age already show clear preferences to count in the same direction of the writing system of their language, a system which they have not yet started to use. Additionally, some studies have focused on the development of spatial preferences in the representation of time: Koerber and Sodian (2008) showed that the ability to represent temporal sequences as línear orderings horizontally with rightward directionality developes between the ages of 3 and 4 in German preschoolers, also before the beginning of reading.

If (at least some) of the spatial biases which have been linked to RWD appear before the acquisition of reading, what is driving their development? Three possibilities have been proposed. First, script directionality is linked to other graphic and material conventions such as the direction of vignettes in comic strips, page turning in books, the organization of calendars, the direction of event sequences in graphic compositions, and so on. As early as 4 months of age, children start accumulating many hours of picture book "reading" with their caregivers (Rossmanith, Costall, Reichelt, López, & Reddy, 2014). Usually the caregiver sits with the baby in the lap, pointing towards the drawings in the correct order, directing the baby's attention to them in turn, and turning the pages of the book. This kind of experience may provide a ground for the development of early lateral directional preferences in small children (Patro & Haman, 2011; Shaki et al., 2012; Tversky et al., 1991). A second possibility is the introduction of directional counting routines. Children are introduced to counting earlier than to reading, and they are often shown how to count objects. The caregivers and teachers usually count in the same direction of the habitual script, and therefore, provide a way to acquire directional preferences (Ebersbach et al., 2014; Ebersbach, 2015; Opfer & Furlong, 2011; Opfer et al., 2010; Patro & Haman, 2011). A third possibility, related to the prior one, is based on counting routines of a specific kind of objects: fingers. Finger counting constitutes an important grounding experience for learning the concepts of numbers and arithmetics (Di Luca & Pesenti, 2011), and children start to count on their fingers earlier than they start systematic training with written language (Noël, 2005). Although there are important cross-cultural differences in how people use their fingers to count that go further than just the left-right directionality of counting (Bender & Beller, 2012), Lindemann, Alipour, and Fischer, (2011) reported a preference to start counting on the left hand in speakers of Western languages, and on the right hand in speakers of Middle Eastern languages (which are written from right to left). Therefore, practice, training, and imitation of finger counting patterns could also provide an experiential basis for the establishment of early spatial directional biases (Ebersbach et al., 2014; Lindemann et al., 2011).

The present study focuses on the first of these possibilities and aims to test whether the mere exposure to speechless comics of different directionalities (L-R and R-L) can induce changes in spatial biases in one well-studied high-level conceptual task: the construction of mental models from oral descriptions of static scenes (used in Román et al., 2013, and Román et al., submitted). Establishing that the exploration and comprehension of sequences of pictures is casually sufficient to change pre-established directional habits in adults is important because it will support the case for this kind of experience being a cause of early biases observed in pre-literate children. For this purpose we asked adult Spanish participants to understand a speechless comic in either its original (L-R) version or in a mirror-reversed (R-L) version which included also a reversal in binding and page turning. We expected that the written script would not be necessary to induce changes in their established spatial biases (linked to habitual RWD). In order to assess the biases induced by this experience, participants were then asked to listen to sentences such as “the square is between the cross and the circle” and draw the described scenes, and we then compared the proportions of L-R and R-L arrangements of objects.

3.3.3 Experiment 1

3.3.3.1 Method

Participants. Forty Spanish psychology students at the University of Granada (mean age 20,2 years; 7 males; 3 left-handed). All of them were native Spanish speakers and only one knew a language with a different RWD (Arabic). This participant was fully fluent in Spanish and had lived for many years in Spain. As Román et al. (2013) showed that highly fluent Spanish-Arabic bilinguals living in Spain and carrying out the task in Spanish (as in the present experiment) tend to behave as Spanish monolinguals, we did not remove her from the sample.

Materials. For the practice task, we used a published commercial speechless comic (Brrémaud & Bertolucci, 2013). Using this kind of material increases ecological validity, and lightens concerns that might arise from the use of comics with text removed. Moreover, being a comic addressed to older kids and adults, we expected it to be of interest to our participants. The comic told the story of a fox to save her calf from a volcanic eruption on an island populated only by animals. It consists of a total of 36 double-sided pages and 373 vignettes. In this particular comic, the arrangement of vignettes is far from being completely regular (with vignettes arranged on a regular grid). The vignettes were of different sizes and shapes. For example, rectangular vignettes could be placed horizontally or vertically next to other vignettes of smaller or larger size and shape (see Fig.1 for an example). Nowhere in the comic appeared any written text, not even for onomatopoeias or ambient noises. A mirror version was devised by mirroring each page and binding them on the right side, such that the pages were turned from left to right. Otherwise, the two versions were identical.

For the drawing task we used the same materials and procedure as in Román et al. (submitted). Nine geometrical shapes which could be drawn easily (square, rectangle, cross, rhombus, triangle, circle, trapezium, oval, pentagon) were combined into 40 sentences divided into two lists of 20 sentences (see Appendix). The sentences described a between relation among three different shapes.

For example, “the square is between the cross and the circle”. All sentences referred to completely static scenes without any agentive structure. Each participant was presented with only one list. The sentences were read aloud by a female speaker and recorded into independent sound files.

Procedure. Participants were tested individually in a quiet room. They sat at a table where they were provided with written instructions and signed an informed consent form and a biographical information questionnaire. The study was presented as an investigation on the understanding of speechless comics. No mention was done regarding the directionality of the mirror-reversed comic. They were told that they were going to see first a speechless comic, then carry out a filler task consisting in making a number of drawings (thus, the drawing task was presented as unrelated to the experiment), and then they would answer three questions about the comic. The participants did not know the questions in advance, which were intended to motivate them to pay attention to the content of the story. The first was a content question (“who is the fox trying to save?”) and the two other questions could be answered by just paying attention to the drawings (“are there polar bears in the story?”, “are there lions?”).

They then carried out the two tasks (comic and drawing) in sequence. Their performance throughout the session was videotaped by an overhead camera which recorded a bird's-eye view of the participant's hands. Both the pattern of comic exploration as well as the drawing of the objects was later coded from the recorded videos. For the comic task, the comic (in either its standard or mirror version) was placed in from of them. They were instructed to explore the comic in silence at their own pace. At all times they had to point with a finger at the vignette they were watching at the moment. This allowed us to analyze their scanning pattern. After finishing the comic task, the comic was withdrawn from the table and a stack of 20 blank square sheets was placed on it centered in front of the participant. The sentences were then auditorily presented one by one in random order using E-prime software through one loudspeaker also centered in front of the participant. After listening to each sentence, the participant drew the described scene on a new sheet and, when ready, pressed the space bar on a computer keyboard to advance to the next one. After finishing, they answered the questions about the comic.

Design and Data Analysis. There were two experimental groups of 20 participants, depending on the directionality of the comic: L-R (standard), R-L (mirror reversed). Invalid trials occurred when the central object (e.g., the square in "the square is between the cross and the circle") was drawn anywhere else than at the center, and also when the three objects were not in a línear configuration (eg., forming a triangle). In valid trials, we coded the *model order,* our main measure of interest, depending on the locations of the two side objects with respect to the central object. In a sentence like "the square is between the cross and the circle", a drawing placing a cross to the left of a square and a circle to its right was coded as a L-R model. A circle-square-cross drawing was coded as a R-L model. As there were no drawings along axes other than the horizontal, there were only two possible kinds of models.

For the sake of completeness, we also coded the variable of *spatial order,* the order in which participants completed the left, central, and right spaces on the sheet. Finally, and working from model order and spatial order, we computed *object order,* the order in which each of the three mentioned objects was drawn. (For more detail, see the Data Coding section in Román et al, 2013). However, Román et al. (2013) and Román et al. (submitted) showed that these two additional variables do not provide data that qualify the conclusions obtained from model order (they show that participants have a strong tendency to draw the objects in the same order as they are mentioned and, therefore, that spatial order and model order are strongly correlated), and they were not analyzed in the present study.

In order to check whether the scanning directionality of the comic agreed with our expectations, we also coded the direction of the sequence of pointing movements from each of the vignettes as rightwards, leftwards, upwards, or downwards (when the movement was in an oblique direction, it was decomposed into its two spatial components).

Data were analyzed by means of binomial logistic regressions, using the experimental condition (standard versus mirror comic) as a categorical predictor of the presence of a L-R model or its absence (i.e., a R-L model). For each contrast, we show the Wald chi-square, the odds ratio, and its confidence interval.

3.3.3.2 Results and Discussion

The number of items rejected as invalid was 1.12 %. There were only three left-handers, so the effect of handedness could not be assessed. The results did not differ in any significant way if left-handers or the Arabic bilingual participant were removed from the dataset. The average time of the comic exploration phase for the Standard condition was 820.7 sec., and for the Mirror condition was 788.9 sec., which did not differ significantly ($t(38) = 0.254$, $p = .80$). The average time of the following drawing phase was 293 sec. for participants who previously saw a standard comic, and 310.5 sec. for those who saw a mirror-reversed comic. All participants, without exception, correctly answered the three comprehension questions.

The analysis of scanning patterns from videotaped finger pointing confirmed that they mostly adjusted to expectations (see Fig. 2). When only the horizontal axis is considered, both conditions are characterized by a majority of congruent movement. The Standard group scored significantly higher in rightward movements than the Mirror group ($t(38) = 21.1$, $p < .001$). Likewise, the Mirror group scored significantly higher in leftward movements than the Standard group ($t(38) = -24.14$, $p < .001$). Unexpectedly, upward and downward movements were also significantly different between groups, although the size of the difference was much smaller. The Standard group produced more upward movements ($t(38) = 3.23$, $p < .01$), as well as less downward movements ($t(38) = 2.1$, $p = .04$). So far, the causes of this difference in vertical movements is unclear.

Therefore, the two groups mostly performed movements in the direction congruent with the type of comic that they were scanning. However, in the analysis of the second phase (the drawing task) the Mirror group produced the same amount of L-R models (*M* = 73.7%, *SD* = 36) than the Standard group (*M* = 74.9%, *SD* = 35.3; *t*(38) = -0.1, *p* = .92; Wald χ^2 = 0.259, *p* = .61, *Odds ratio* = 1.087, 95% *CI* = [0.79, 1.50]). Thus, under the conditions of the present experiment, the exposure to a a standard or mirror-reversed versions of a speechless comic did not introduce any differential spatial bias in the creation of mental models in language comprehension.

One possible reason for this null result is that the comic task was too unconstrained. While comic exploration generated different proportions of lateral movements in the expected directions for the Standard and Mirror versions of the comic, there were also a high number of movements in other directions. The irregular distribution of vignettes and their variation in terms of shape and size in the present comic, together with the lack of written text, may have induced difficulties in comprehension which in turn may have generated a number of movement reversals, double exploration of some vignettes, and backtracking. As an example, Figure 3 shows the typical path (black arrows) for the Standard group while exploring two pages of the comic as well as some less common variants (gray arrows). In order to test this possibility, we calculated the canonical exploration pattern for each page in each version of the comic and counted the number of movements in each direction. We then compared the total number of movements performed by the participants in each direction with their canonical number by means of one-tailed t-tests. The Standard group differed significantly from the canonical values of exploration in the four directions (Down: *t*(19) = -3.9, *p* = .001; Left: *t*(19) = 3.32, *p* = .004; Right: *t*(19) = -15.5, *p* < .001; Up: *t*(19) = 12.3, *p* < .001). On the other hand, the Mirror group differed also significantly from the canonical values of exploration in three directions and marginally in the fourth (Down: *t*(19) = -1.9, *p* = .07; Left: *t*(19) = -7.8, *p* < .001; Right: *t*(19) = 2.5, *p* < .02; Up: *t*(19) = 6.87, *p* < .001).

The frequent change of movement direction may preclude the consolidation of any directional bias, at least in the short practice time that was provided in the present experiment. Because picture books for children probably use simpler arrangements than the present comic, and their attention is guided by their parents, it is likely that children who are exposed to picture books experience a more consistent directionality. Moreover, their directional experiences extend during far more hours of practice than participants in the current experiment, what leaves open the possibility that spatial biases may develop even under conditions of inconsistent practice, as long as there is a preponderance of script-congruent movements.

In the next experiment we submitted to a direct test the hypothesis that the variability in scanning patterns is diluting the influence of directional comic exploration on mental model construction, and that consistent practice is able to induce measurable spatial biases even after a very short practice. Experiment 2 showed the vignettes of the same comic, but instead of using the original arrangement, they were presented on a computer screen arranged in horizontal strips. Moreover, the vignettes in each strip appeared progressively, such that the participant was forced to pay attention to them in the correct order. This effectively limited the scanning pattern to either the L-R or R-L orders.

Experiment 2

3.3.3.3 Method

Participants. Fourty Spanish psychology students at the University of Granada took place in the experiment. A problem with two video files in the Standard group prevented coding the drawing phase, so we removed randomly other two participants in the Mirror group. The resulting 36 participants had a mean age of 20.1 years, and included 5 males and 6 left-handers. All of them were native Spanish speakers and only one had a high bilingualism with a language with a different RWD (Arabic).

Materials and Procedure. They were the same as in Experiment 1 with the exception that the exploration task did not use a printed and binded comic. The vignettes were scanned separately and presented by means of E-prime on a computer screen in strips of four vignettes which were presented progressively. In the Standard condition each trial began with a vignette being presented on the far left position of the screen. Two seconds later, a second vignette appeared to its right on the near left position. Then the third appeared on the near right and finally the fourth on the far right position. The prior vignettes of a strip remained on view until the whole strip was presented. Two seconds after the final vignette wass shown, the strip disappeared and a new one started. The Mirror condition differed from the Standard condition in that mirror-reversed vignettes were presented from right to left at the same four screen locations. Apart from equalling total presentation time (720 sec.) across conditions, this procedure forced participants to explore the comic using a highly consistent scanning pattern, removing vertical movements altogether, although still allowing some backtracking along the horizontal axis. After the comic task, participants performed the drawing task and finally answered comprehension questions about the comic.

3.3.3.4 Results

The number of items rejected as invalid in the drawing task was 2.8 %. There were only six left-handers and they were not balanced between groups, so the effect of handedness could not be assessed. The results did not differ significantly if left-handers were removed from the dataset. The average duration of the drawing task was 328.7 sec. in the Standard condition and 322.8 sec. in the Mirror condition. All participants correctly answered the three comprehension questions. Under the present conditions, the Standard group scored significantly higher in L-R models (*M* = 89.9%, *SD* = 21.9) than the Mirror group (*M* = 67.7%, *SD* = 34.1; Wald χ^2 = 48.6, *p* < .001, *Odds ratio* = 4.29, 95% *CI* = [2.85, 6.46]; See Fig. 4).

Because Experiment 1 revealed no effects of the prior directional practice and both conditions produced the same number of L-R models (74.9% on the Standard group and 73.75% on the Mirror group), we used it as a control group (with some reservations). The Standard group in Experiment 2 produced more L-R models (*M* = 89.9%, *SD* = 21.9) than the Standard group in Experiment 1 (*M* = 74.9%, *SD* = 35.3; Wald χ^2 = 25.6, *p* < .001, *Odds ratio* = 2.9, 95% *CI* = [1.92, 4.4]). Moreover, the

Mirror group in Experiment 2 produced less L-R models (*M* = 67.7%, *SD* = 34.1) than the Mirror group in Experiment 1 (*M* = 73.7%, *SD* = 36; Wald χ^2 = 3.59, *p* = .058, *Odds ratio* = 1.36, 95% *CI* = [0.99, 1.86]). This suggests that both kinds of directional experience (Standard and Mirror) affected pre-established biases, with the former condition exacerbating them, and the latter reducing them.

A better control group comes from Román et al. (submitted). There, there was a group which carried out exactly the same drawing task (same materials and procedure) as it was used here, but without any prior exposure to directional stimuli. Therefore, their data constitute the best estimation of the baseline of L-R models to be expected in the drawing task (*M* = 83.5%, *SD* = 27.6). Logistic regression analyses again showed that both conditions of Experiment 2 are not only different from each other, but also from this control group: the Standard group in Experiment 2 produced more L-R models (*M* = 89.9%, *SD* = 21.9; Wald χ^2 = 4.2, *p* = .04, *Odds ratio* = 1.6, 95% *CI* = [1.021, 2.48]), and the Mirror group produced less (*M* = 67.7%, *SD* = 34.1; *M* = 83.5%, *SD* = 27.6; Wald χ^2 = 29.75, *p* < .001, *Odds ratio* = 2.7, 95% *CI* = [1.88, 3.85]).

These results demonstrate that scanning direction is a sufficient cause of spatial bias in the construction of mental models in oral language comprehension. They also suggest that, in order to generate this effect under conditions of short directional practice, scanning direction needs be consistent. It is an open question how consistent it is in the assisted picture book reading that preliterate children experience, and whether spatial biases can still develop under relatively inconsistent but very extended practice.

3.3.4 General Discussion

In the present study, we tested the causal efficacy of the exploration of a speechless comic of different directionalities (L-R or R-L) to induce congruent spatial biases in the construction of mental models from auditory linguistic descriptions such as “the square is between the cross and the circle”. We expected that the mere experience of scanning a series of vignettes with a consistent directionality, without the presence of any written input, would be sufficient by itself to bias spatial preferences in mental models. The first experiment used a comercial speechless comic and presented it in either its published form or a mirror-reversed form, including a reversal in page binding. After exploring it for comprehension, participants in both groups drew auditorily presented descriptions, and their drawings showed an overall L-R bias which was not affected by the prior comic experience. We reasoned that this might be due to the unconstrained nature of the task, that allowed exploring the comic through alternative paths and carrying out movements in many different directions. Thus, in the second experiment the same materials were presented using a procedure that induced highly consistent scanning movements from vignette to vignette. Under these conditions, the mirror group significantly increased the proportion of R-L mental models in the drawing task, while the standard (L-R) condition induced even stronger L-R biases.

Present results do not contradict prior findings linking the directional experiences that occur while reading and writing as causes of spatial biases in cognition (e.g., Casasanto & Bottini, 2014; Román et al., submitted; see review in the Introduction). Instead, they support the idea that exposure to picture books is one factor that can provide the kind of experience that induces the early start of those biases (Patro & Haman, 2011; Shaki et al., 2012; Tversky et al., 1991). Parents often spend a considerable amount of time watching at picture books with their children from a very early age (Rossmanith et al., 2014), showing them the pictures, pointing at them and pronouncing their names aloud and talking about them, all activities which direct the attention of the baby in a very clear and consistent manner. Because pictures in the pages and pages in the book are arranged in a way that agrees with the directionality of the script in use in their culture, these early experiences can generate initial spatial biases that will be later reinforced by the interaction with the written script, as well as by other consistent experiences such as the learning and use of counting routines, both of fingers (Lindemann et al., 2011) and objects (Opfer et al., 2010; Shaki et al., 2012). Moreover, the present studies suggest that the degree of consistency of the directional experiences is important (see also Shaki et al., 2012), as we failed to find effects of directional scanning under conditions of low consistency in Experiment 1. Nevertheless, because the present experiments provided a very short experience with the comic, it is still an open question whether inconsistent practice can induce spatial biases after long-term extended practice.

Present results, together with prior literature, tell us much about the flexibility of the cognitive system and its adaptivity to both fast- and slow-changing conditions. As shown by Román et al. (2013, exp. 2), life-long directional training creates solid biases. When asked to carry out the drawing task in their native Arabic language versus in a second language with a script of opposing directionality, the native language induced stronger spatial biases than the non-native. However, the magnitude of the bias induced by the language in use at the moment of the task was greater than the bias induced by the native language. In other words, people can flexibly deploy contrasting spatial habits acquired from different directional experiences. Moreover, even if a person has a well-established spatial bias due to life-long experiences, it can be changed by a very short exposure to a contrasting directionality (Casasanto & Bottini, 2014; Román et al., submitted; and Experiment 2 in the present study). As shown by Román et al. (submitted), the short-term bias decays quickly, but it is likely that repeated short-term experiences induce bias faster, and recover from bias more slowly and to a lower asymptote. The results of this research line are consistent with a view that emphasizes the extreme flexibility of the cognitive system, which both adapts quickly to short-term changes and slowly to long-term changes. A flexible system that works at these different levels is a highly adaptive system.

To conclude, the present study shows that the mere exploration of a speechless comic is a sufficient cause of changes in pre-established life-long spatial biases in the construction of mental models in language comprehension. This supports the idea that this kind of experience may underlie early spatial biases of analogous nature which have been observed in preliterate children. Consistency of the directionality of scanning movements from vignette to vignette seems to be an important moderating factor.

3.3.5 Acknowledgments

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3.3.6 Appendix

Materials used in the drawing task.

Nº	List A	List B
1	The circle is between the cross and the rectangle	The square is between the rhombus and the cross
2	The oval is between the triangle and the rhombus	The triangle is between the pentagon and the oval
3	The Pentagon is between the trapezium and the square	The oval is between the trapezium and rhombus
4	The trapezium is between the circle and the square	The rectangle is between the square and the circle
5	The pentagon is between the triangle and the oval	The pentagon is between the rhombus and the trapezium
6	The cross is between the rhombus and the rectangle	The oval is between the pentagon and the circle
7	The rhombus is between the pentagon and the trapezium	The pentagon is between the oval and the rectangle
8	The cross is between the rectangle and the oval	The cross is between the rectangle and the square
9	The triangle is between the circle and the square	The circle is between the trapezium and triangle
10	The trapezium is between the rhombus and oval	The trapezium is between the square and the pentagon
11	The pentagon is between the triangle and the cross	The cross is between the circle and the rectangle
12	The circle is between the rectangle and the square	The trapezium is between the oval and the square
13	The pentagon is between the oval and the circle	The square is between the trapezium and circle
14	The trapezium is between the triangle and the rhombus	The rhombus is between the rectangle and the cross
15	The rectangle is between the square and	The triangle is between the rhombus and oval

	the cross	
16	The oval is between the rectangle and the pentagon	The triangle is between the Pentagon and the cross
17	The triangle is between the circle and the trapezium	The rectangle is between the cross and the oval
18	The cross is between the square and the rhombus	The rhombus is between the rectangle and the pentagon
19	The square is between the trapezium and the oval	The trapezium is between the rhombus and triangle
20	The pentagon is between the rhombus and the rectangle	The square is between the triangle and the circle

Figure 1: Distribution of vignettes of different size in a typical page of the comic.

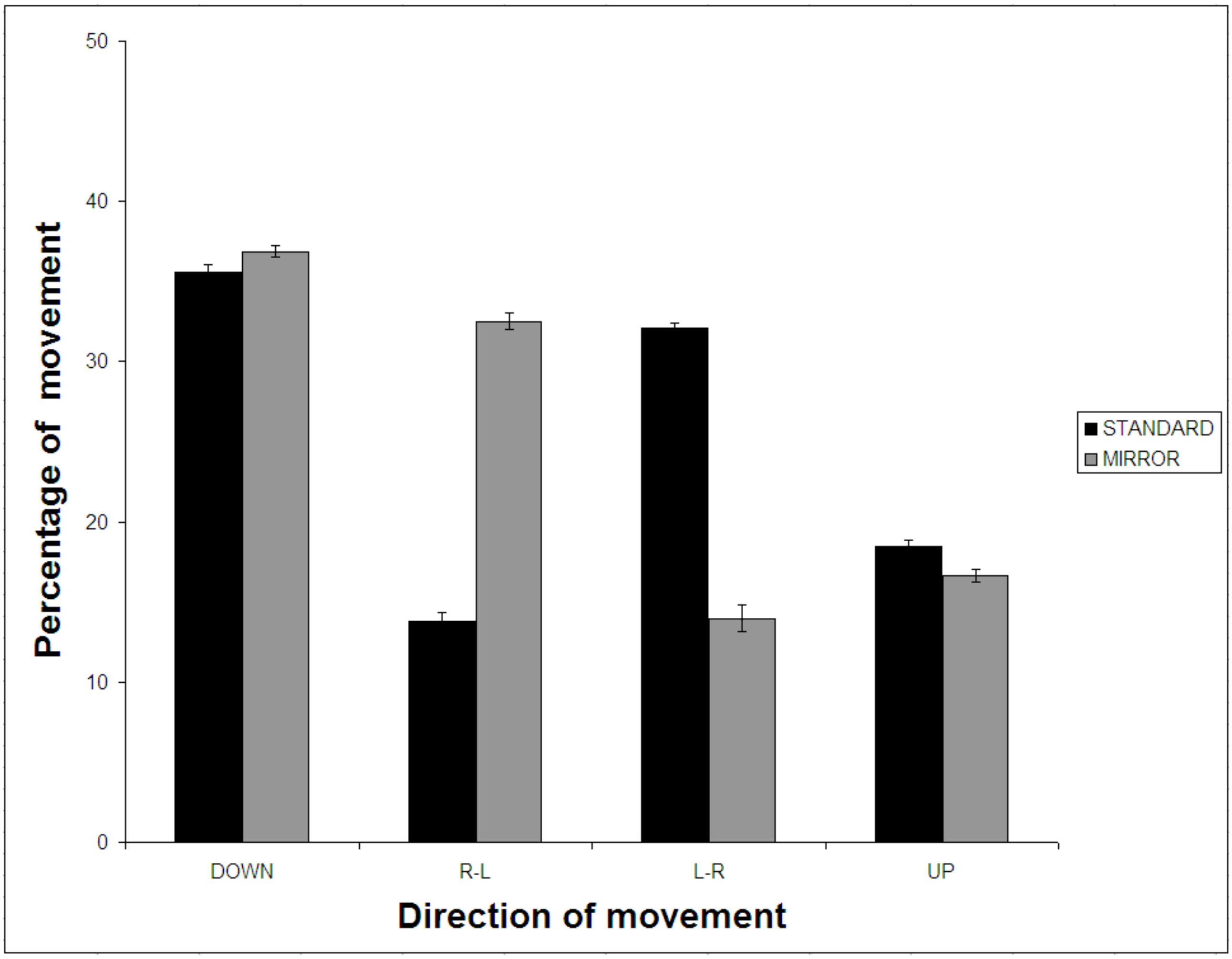

Figure 2: Percentage of scanning movements in each direction (DOWN: downward; R-L: leftward; L-R: rightward; UP: upward). Error bars represent Standard Error of the Mean (SEM).

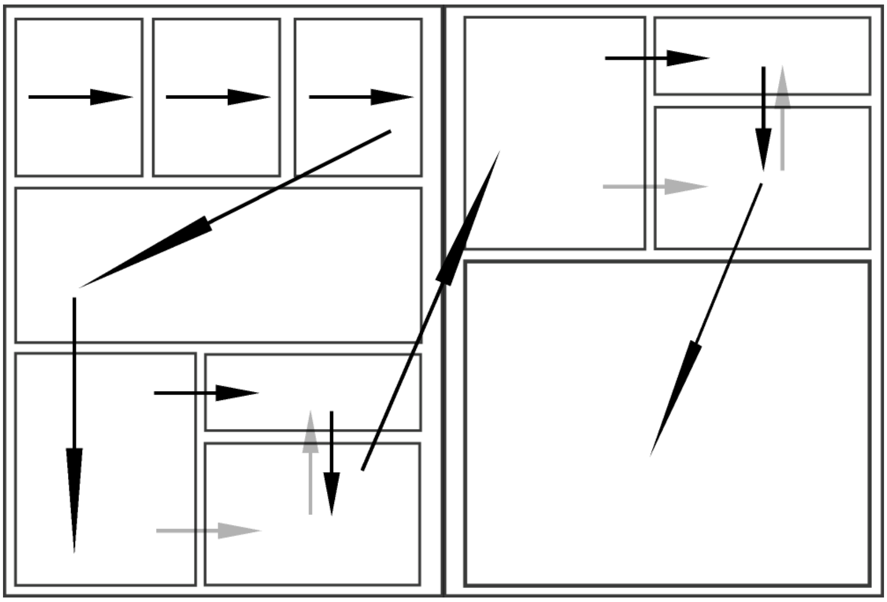

Figure 3: Scanning patterns of two pages in Experiment 1 for the Standard group. The most common pattern is shown in black arrows, and some less common variants are shown in grey arrows.

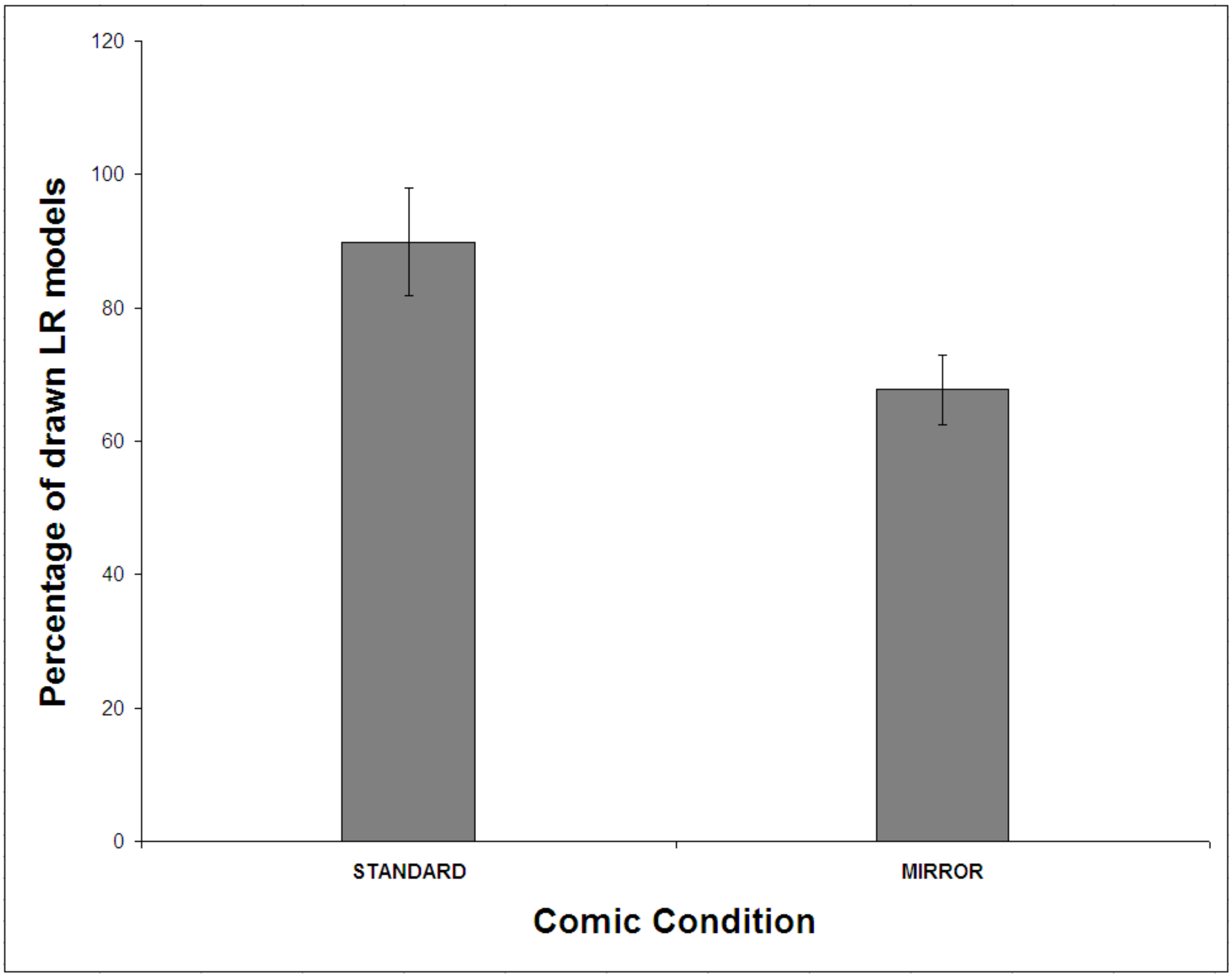

Figure 4: Percentage of left-to-right (L-R) models in the drawing task in the Standard and Mirror groups. Error bars represent Standard Error of the Mean (SEM).

CAPÍTULO 4: RESULTADOS Y DISCUSION

4.1 Resultados y discusión del estudio 1

El estudio 1 muestra que dos grupos que difieren en cultura y en SLE de sus lenguas, difieren también en cómo representan los modelos mentales provenientes de mensajes orales. Los españoles tienden a presentar más modelos de izquierda a derecha (I-D), concretamente el 70.7 %, mientras que los árabes tienden a mostrar menos modelos I-D tan sólo en el 38.3% de los casos. Estos resultados replican los encontrados por Jahn et al. (2007) y confirman que el sesgo existe, contestando a la primera de nuestras preguntas iniciales, y además se invierte en culturas con lenguas de diferente SLE, lo que contesta a la segunda cuestión. Por otra parte, el grupo de árabes fuertemente integrados en la cultura española mostró un 58.8% de modelos I-D, haciéndolos estadísticamente indistinguibles del grupo de españoles y diferentes del grupo de marroquíes evaluados en Marruecos. Esto responde a la tercera cuestión y refuerza la idea de que estos sesgos poseen cierta flexibilidad y, tras un tiempo de aculturación, la capacidad de instalarse de forma más definitiva como un nuevo esquema mental.

La cuarta y quinta preguntas encuentran su respuesta en el segundo experimento, donde al mismo grupo de marroquíes bilingües se les exponía a dos bloques usando idiomas con SLE opuestos. Los resultados demuestran que no sólo está teniendo efecto una flexibilidad a largo plazo, que necesita de años de integración, sino que simplemente hacer la tarea en otro idioma nos sesga congruentemente según el SLE de dicho idioma. Este efecto de la lengua de entrada usada en la tarea es significativa si unimos en el mismo grupo a los árabes del experimento 1 con el primer bloque en árabe del experimento 2. Además, se pudo observar que el árabe en el primer bloque reducía el número de modelos I-D de la lengua latina a 37.9% respecto a cuando esta se usaba en el primer bloque, 58.6%. Sin embargo, la lengua latina no tenía ese efecto de arrastre sobre el árabe cuando este último se presentaba en el segundo bloque. De ahí que podamos afirmar que esta relación es asimétrica y a favor de la lengua nativa. La simetría de la relación entre la lengua nativa y el segundo idioma podría depender en gran medida del grado de bilingüismo. Podemos así concluir que el idioma de entrada en el que se hace la tarea tiene un efecto importante en qué tipo de sesgos espaciales activamos, pero sin olvidar que todo ello está modulado por efectos más a largo plazo de nuestra lengua nativa.

4.2 Resultados y discusión del estudio 2

El estudio 2 responde a otras tres de las preguntas planteadas. La primera cuestión a responder es si el SLE es causa suficiente de este tipo de sesgos espaciales en comprensión del lenguaje (pregunta 6). Dado que los participantes del estudio 1 eran de culturas diferentes, este no permitía una relación causal directa entre el SLE y el sesgo, ya que ambas comunidades diferían en multitud de aspectos, no solo lingüísticos. Por esta razón, en esta ocasión se compararon cinco grupos de participantes pertenecientes a la misma cultura y ejecutando la tarea en el mismo idioma castellano. Concretamente, un grupo control y cuatro grupos expuestos a un texto en cada una de las cuatro direcciones principales (derecha, izquierda, abajo y arriba). Los resultados mostraron que en el grupo con texto estandar (I-D) aumentaron los modelos I-D hasta un 98.2%, siendo estadísticamente superior al 83,5% del grupo control, lo cual demuestra que es posible exacerbar los sesgos preestablecidos por años de exposición al sistema de lectoescritura habitual. Estos sesgos pueden también revertirse, como indicó el grupo con texto invertido en espejo (D-I), el cual mostró un decremento de los modelos I-D hasta el 55.1%, estadísticamente diferente también al grupo control. Esto contesta claramente a la pregunta 7 sobre si un entrenamiento congruente o incongruente sería capaz de elevar o bajar los niveles del sesgo por encima o por debajo de esos niveles basales, y demuestra que el SLE es causa suficiente de sesgo en la construcción de modelos mentales.

Con respecto a la cuestión de si sería posible crear el sesgo en el eje vertical, los tres grupos comparados hasta ahora presentaron una fuerte tendencia a dibujar sólo en la horizontal, y no mostraron ningún modelo vertical. Nos preguntábamos en la pregunta 8 si una experiencia previa en el eje vertical sería también capaz de sesgar nuestros modelos mentales hacia ese mismo eje espacial. Para ello analizamos los grupos con texto en vertical. El grupo con texto hacia abajo mostró un 76.9% de modelos I-D, siendo significativamente menor que el 83.5% de grupo control. Sin embargo, no podemos decir que este efecto se deba a que el SLE hacia abajo produzca un sesgo a favor de modelos de D-I. Más bien la bajada ha sido consecuencia de tener que repartir el total de respuestas entre un abanico más amplio de respuestas al entrar en escena las verticales. Estos valores verticales del grupo de texto hacia abajo, aunque no muy grandes, sí son teóricamente importantes, máxime cuando de ellos no hay ni rastro en los grupos horizontales. Esto pone de manifiesto, por un lado, que es posible sesgar también nuestros modelos mentales en un eje no muy común de una forma rápida y, al mismo tiempo, delata la fuerte tendencia a organizar nuestros modelos en la horizontal debido a esquemas más establecidos y de largo plazo.

Finalmente, los datos también apuntan a que el efecto tiene una vida limitada en el tiempo y apenas dura todo el experimento. Si representamos el numero de modelos I-D a lo largo de los distintos ensayos, se puede comprobar en la figura 3 del estudio 2 que la condición de texto espejado empieza con pocos modelos al comienzo del experimento, pero se va recuperando y tiende a ir en la dirección basal o de valores más cercanos a control. Queda, pues, patente que el efecto a corto plazo se forma rápidamente tras un breve entrenamiento, pero que de no seguirle un entrenamiento a largo plazo, se extingue igual de rápido, volviendo el sistema a mostrar de nuevo esquemas más nativos o de largo plazo.

4.3 Resultados y discusión del estudio 3

Hasta ahora hemos explorado el papel que juega el SLE en la formación de sesgos en modelos mentales en comprensión del lenguaje. Se ha afianzado el papel causal del SLE al separarlo de otros factores culturales y se han explorado sus características dinámicas al establecer hasta qué punto es un proceso flexible y qué tipos de flexibilidad confluyen e interaccionan. Seguidamente nos preguntábamos con la pregunta 9 si sería posible establecer este tipo de sesgos a partir de experiencias direccionales que covarían con el SLE, como son la dirección de las viñetas de los cómics, entre otras. La respuesta a esta cuestión no pudo ser contestada en el experimento 1 del estudio 3, debido posiblemente a que el prime no era lo suficientemente directivo en el sentido de exploración. La total libertad de los participantes para explorarlo y la utilización de movimientos en todas direcciones para hacerlo posiblemente no permitió la consolidación de sesgos claros en una dirección, dando como resultado un 74.9% y un 73.7% de modelos I-D en las condiciones estándar y espejada, respectivamente.

Pero cuando el patrón de exploración se hizo más consistente en el experimento 2, el grupo expuesto previamente a las tiras de cómic I-D presentó un mayor número de modelos I-D (89.9%), frente al grupo espejado, que sólo mostró un 67.7% de modelos I-D. Estas dos condiciones no sólo difirieron entre sí, sino que fueron significativamente diferentes de los valores mostrados por dos grupos control: los dos grupos del experimento 1 tomados conjuntamente, y el grupo control del estudio 2, que recibió exactamente las mismas frases sin ninguna experiencia direccional previa. En resumen, podemos concluir que la simple exploración de viñetas, sin mediación del lenguaje escrito, de un cómic mudo es una causa suficiente de sesgos en la construcción de modelos mentales. Estos resultados apoyan la idea de que las experiencias de “lectura” compartida entre padres y niños pequeños pueden ser causa de la presencia de este tipo de sesgos espaciales en niños preletrados (Patro & Haman, 2011; Shaki et al., 2012; Tversky et al., 1991). Los padres dedican mucho tiempo a este tipo de interacción con sus hijos, mostrándoles libros muy sencillos en los que el adulto refleja sus propios sesgos espaciales al apuntar y señalar la historia con sus dedos. Así, aunque aún no esta presente la escritura, los niños ya están expuestos a un escaneo I-D temprano.

4.4 Discusión General

A tenor de los resultados mostrados en esta tesis, no cabe duda de que el sentido en el que leemos y escribimos tiene un fuerte papel en cómo representamos, mediante modelos mentales, el contenido lingüístico. Conforme oímos una descripción de una escena, el sistema va construyendo un modelo mental que es coherente con las proposiciones expresadas en el lenguaje. Buscamos que este modelo sea lo más simple posible, dado que se forma y se manipula en la memoria de trabajo, de capacidad limitada.

Los resultados de esta tesis muestran que hay dos tipos de flexibilidad presentes y que interactúan según las circunstancias de la tarea. Por una parte, la repetida exposición a un patrón consistente acaba por convertirse en un esquema de acción que se encuentra activo por defecto. Este tipo de esquemas almacenados y recuperados de la memoria a largo plazo son muy útiles para responder de la misma forma a situaciones que ya hemos vivido anteriormente y en condiciones parecidas. Esto supone el ahorro de tener que aprender de nuevo la misma estrategia de acción ante situaciones que no han cambiado. Pero un sistema altamente adaptativo como es el cerebro necesita también tener una estrategia a corto plazo, la capacidad de sustituir ese esquema consolidado por otro de creación inmediata para responder a situaciones donde las condiciones normales han cambiado. Estas dos flexibilidades interaccionan entre ellas, ya que el esquema a largo plazo tarde o temprano volverá a ocupar su lugar una vez hayan pasado las circunstancias novedosas que lo relegaron en favor de nuevos y provisionales esquemas de acción.

El cerebro es en última instancia un sistema cuyo principal fin es la supervivencia de su portador. Sus procesos mentales, en base a esto, están dirigidos a solucionar los problemas que de forma continua les presenta el ambiente. Una forma de hacerlo es integrando la información externa y las respuestas que devolvemos al ambiente de forma coherente. La búsqueda de coherencia en todo lo que se percibe y responder en consecuencia ha sido después de todo un acierto para sobrevivir en un ambiente a priori con demasiada información y además desorganizada. La coherencia no implica estar en lo cierto. Podemos estar coherentemente equivocados pero en términos evolutivos nos ha permitido llegar hasta aquí. En esta dirección apunta la teoría de los modelos de trabajo coherentes propuesta por Santiago, Román y Ouellet (2011). La información que ya tenemos activa en nuestra MT sesga a representar el resto del input de forma coherente con ella. Así, hablar en un idioma determinado activa en la MT el sentido en el que se escribe y lee dicha lengua, aunque no esté explícitamente presente si el canal de entrada es el auditivo.

Finalmente, los resultados de esta tesis muestran también indicios de la existencia de procesos cognitivos comunes a todos los grupos experimentales sobre cómo se procesa la información entrante y se acomoda en la MT para elaborar modelos mentales y, en última instancia, la conducta. Todos los participantes de los estudios de esta tesis, independientemente de su cultura, tienen una tendencia muy clara a dibujar los objetos en el mismo orden en el que van apareciendo en el mensaje oral. Por ejemplo, la frase “la mesa está entre la lámpara y la televisión” puede ser dibujada en seis combinaciones diferentes. De forma sistemática, las personas dibujan primero el primer objeto mencionado en la frase, luego el segundo y finalmente el tercero. Con ello se consigue bajar la carga de memoria de nuestra MT al no tener que recordar elementos que han salido temprano en la secuencia pero que se dibujan después. La existencia de esta constante al margen de culturas o lenguas es importante en cuanto que delata a los elementos comunes sobre los que operan y cobran existencia esos otros que nos diferencian.

En otras palabras, y como conclusión, la estructura básica del sistema de construcción de modelos mentales a partir del lenguaje es común y universal, y está caracterizada por la búsqueda de la coherencia y una importante limitación de capacidad. Este sistema común comienza desde el nacimiento a acumular sesgos espaciales en función del tipo de experiencias direccionales a las que somos expuestos. Se necesita más investigación para profundizar sobre cuáles son las características de más bajo nivel del SLE y otras experiencias covariantes que son suficientes para provocar estos sesgos, así como para extrapolar los hallazgos de esta tesis a una variedad de otras habilidades y representaciones cognitivas, desde los niveles perceptivos y atencionales, a la representación de conceptos abstractos como el tiempo y los números.

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La afinidad que tienen las neuronas para comunicarse con otras es enorme. Las mismas neuronas que usan los neurotransmisores para comunicarse con sus vecinas más próximas, cuando la distancia se hace demasiado grande, utilizan el lenguaje. Cuando las separa el tiempo, utilizan la escritura.

The affinity of neurons to communicate with others is enormous. The same neurons that use neurotransmitters to communicate with their closest neighbors, when the distance is too large, they use language. When they are separated by time, they use writing.

Román, (2015)